THE ENERGY EFFICIENCY GAP IN SHIPPING – BARRIERS TO IMPROVEMENT

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Abstract

The potential for increased energy efficiency in shipping is evident. Still, ship owners appear reluctant to act on these seemingly cost-efficient measures. This situation is seen in many sectors and is commonly called an "energy-efficiency gap". Decades of research in other sectors have focused on developing taxonomy of barriers using a multitude of research frameworks; from mainstream neo-- classical economics, to organizational theory and social psychology. Research has been directed to informing policy makers as well as managers of firms. In this article, this research tradition will be put into the shipping context through interviews and a review of existing literature. Some examples of barriers are discussed in shipping, related to imperfect and asymmetric information as well as to power structures in organizations. Implications for policy makers include the broadening of the role of governments into being a provider of information. Managers of shipping firms are encouraged to look through their organizations in search of principal agent problems and power structures and possibly strive towards organizational change.

Keywords

energy-efficiency gap, energy management, energy policy, shipping

Introduction

"Shipping companies reluctant to embrace energy efficiency" was the title of a recent article in Lloyds' list (Lloyds' list, 2010). It seems paradoxical, as shipping is a very energy-intensive activity, while the potential for improvement is immense. The International Maritime Organization (IMO) demonstrated in 2009 that 25% to 75% of CO2 emissions could be reduced almost exclusively due to energy efficiency measures (IMO, 2009a), a statement which has later been verified by for example Eide et al (2011). However, this situation, in which a large potential for energy efficiency improvement with significant economic impact is not realized, can be seen in many sectors. It is commonly called an "energy-efficiency gap" (e.g. Jaffe and Stavins, 1994).

Increasing energy efficiency[1] is an urgent matter, as global anthropogenic emissions of CO2 need to be substantially reduced in the coming decades and as fossil fuels are a dominant energy carrier (IPCC, 2007). The shipping sector has been estimated to contribute to these emissions by 3.3%, and as the world economy becomes larger, they are further expected to grow with increased need for transportation work (IMO, 2009a). From the perspective of the legislator or policy-maker, this may call for more efficient policy intervention in order to correct potential failures or barriers in markets, to ensure that reductions are carried through. Within the IMO, work is carried out on market based instruments, indices to determine performance of shipping operations[2] and ship design[3], and management plans[4].

From the perspective of the top management of a firm, the question should be similar to that of the policy-maker's: what are the barriers to improvements in energy efficiency within our organization and how to overcome them? If not for environmental reasons, the economic rationale is becoming increasingly clear. Direct costs will rise with the price of crude oil. Indirect costs will increase as well. Besides CO2, other environmental externalities in shipping are slowly being accounted for, as SOx and possibly also NOx emission control areas (ECAs) are being introduced, the latest being an ECA in North America (IMO, 2011)

In this paper, previously developed frameworks, methods and results for research on energy efficiency will be compared with data drawn from a literature review on shipping as well as interviews with different actors in shipping. It will focus on barriers to energy efficiency from the perspective of these actors, and give implications for management as well as policy-makers. The goal is to understand to what extent research done on other sectors is applicable also to shipping, and to give suggestions for further research with this as a basis.

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[1] Energy efficiency is defined here as decreasing energy use (as opposed to energy cost) while maintaining (or increasing) the level of service provided. 'Efficiency' is thus contrasted with 'conservation, which implies only a reduction in energy use. Energy efficiency is not equivalent to economic efficiency, as it comes with a cost.
[2] Energy Efficiency Operational Index, EEOI (IMO, 2009b)
[3] Energy Efficiency Design Index, EEDI (IMO, 2009c)
[4] Ship Energy Efficiency Management Plan, SEEMP (IMO, 2009d)

Method and scope

The two main research questions guiding this article are: Given that a large technical and economic potential exists, why do shipping organizations not act on these seemingly cost-efficient opportunities? What insights can be gained from applying the frameworks developed from research on other sectors on the shipping sectors? Follow-up questions also arise: what are the implications for policy-makers? What are the implications for top management in a shipping organization?

In order to explore these questions, interviews were combined with a review of research. In total, 19 interviews were conducted during the period of spring 2009 to fall 2010. Interviewees were selected in the Nordic shipping sector based on a snow-balling method (Biernacki and Waldorf, 1981). The intention was to locate people in companies that had a reputation of being ambitious in terms of energy efficiency as well as in companies that did not. Also, interviewees were sought in different parts of the organizations, with the criteria being that they were likely to make decisions in their role that affected energy use. In addition to shipping companies, also classification societies, consultancies, energy efficiency gadget suppliers etc., were targeted.

The interviews were carried out in a semi-structured or "focused" (Mertin and Kendall, 1946) manner, that is, with a number of open-ended questions prepared beforehand, developed on the basis of the below discussed theoretical framework. Focus was put on short-comings and barriers in energy management practices. Data from the interviews were compared to findings in other sectors and to energy efficiency research in general. As no little research of this kind was found related to shipping, the article has an exploratory nature.

The techno-economical potential for energy efficiency

The shipping industry is a very energy intense industry in the sense that energy costs comprise a large part of costs. For a typical tanker company, 50% of total costs could be energy costs. Compared to other sectors, this is a very large ratio. Thollander and Ottosson (2010), for example, in their paper on energy intense production industry in Sweden, discuss companies with energy costs from 5% to "beyond 20%".

Compared to some transportation modes, shipping has a head start when it comes to energy efficiency (e.g. IMO, 2009a). In other areas, such as short sea shipping, the efficiency of shipping vs. land-based transportation has been questioned, in particular with respect to SOx and NOx efficiency[5], but also when it comes to CO2 and energy efficiency (Hjelle, 2010; Hjelle and Fridell, 2010).

Luckily, the techno-economic potential for further improvement seems to be substantial. Table 1 shows the breakdown of estimates made by the IMO (2009). Typically, measures are found in various parts of the shipping organization, and each potentially improves energy efficiency by a fraction of a percent up to few percent. Also, measures may be on a daily operational basis (e.g.

[5] That is, emissions of SOx or NOx per transportation work

planning and executing a voyage efficiently), on a tactical basis (e.g. planning overhauls) or on a more strategic level (e.g. new buildings).

Table 1: Measures for CO_2 reductions, adapted from IMO(2009)

DESIGN (New ships)	Saving (%) of CO_2 per tonne-mile	Combined	Total
Concept, speed and capability	2-50		
Hull and superstructure	2-20		
Power and propulsion systems	5-15	10-50%	
Low-carbon fuels	5-15		
Renewable energy	1-10		
Exhaust gas CO_2 reduction	0		25-75%
OPERATIONS (all ships)			
Fleet management, logistics and incentives	5-50		
Voyage optimization	1-10	10-50%	
Energy management	1-10		

These estimates have later been discussed and confirmed by other researchers. Lindstad et al (2011) demonstrated that 18% reduction in CO_2 emissions could be achieved by reduction of speed alone, at a negative net cost for society. Eide et al (2011) asses cost and reduction potential of various abatement measures in a model which includes fleet growth projections, and conclude that 33% of CO_2 could be reduced by 2030 at a zero marginal cost to society.

Even though these potentials may appear large, they may not be enough to reduce emissions, and far from reducing emissions by the lengths necessary to reach the 2 degree goal. CE Delft (2009) demonstrate that the gains in efficiency will be more than compensated through increased transportation work.

Frameworks and results in previous energy efficiency research

Thus, a large potential for increased energy efficiency in shipping exists. In many sectors, the situation is similar. This has been the interest of researchers, managers and policy-makers for decades: if the potential is great, why so little action? As an example, a recent review showed a large gap between potential improvements and "reality" in different Swedish sectors (Jagemar and Pettersson, 2009). By 2020, the Swedish building sector could technically and economically implement improvements totaling 40 TWh of energy per year, though only 6 TWh were deemed “acceptable”. Some performance indicators in the Swedish building sector have actually stagnated; the average specific energy use for heating new buildings was shown in 2007 to be twice as high as the best performing buildings 20 years earlier (Nässén et al, 2007).

This "gap" has been explored and to some extent quantified and explained in other sectors, like the foundry industry (Rohdin et al., 2008) the paper and pulp industry (Thollander and Ottosson, 2010) and the building sector (Ryghaug and Sorensen, 2008), but has not yet been discussed to the same extent in shipping. Before the shipping sector is treated specifically, a general overview of energy efficiency research will be given. The outline draws heavily from research produced in the BARRIER project (Sorrell, 2000; Sorrell, 2004). In the next section, this material will be used to analyze data gathered on shipping. As will be evident, the topic of energy efficiency crosses disciplines. A range of frameworks will be involved, as focus is moved from markets to organizations to individual behavior.

Taking the market perspective as a starting point: by neo-classical economic theory, rational actors like private firms would be expected to systematically adopt available measures for increasing energy efficiency in order to maximize profits. According this view, if the market is unable to respond to the potential, there must exist market failures and/or barriers that hinder such a development[6]. Why is this so?

Part of the explanation could be that new, superior, technologies typically diffuse gradually, requiring communicational channels and a supporting social system (Rogers, 1962). It could still be worthwhile to question whether the present level of diffusion is the optimal, as the difference between techno-economically optimal situation and reality in many cases is substantial.

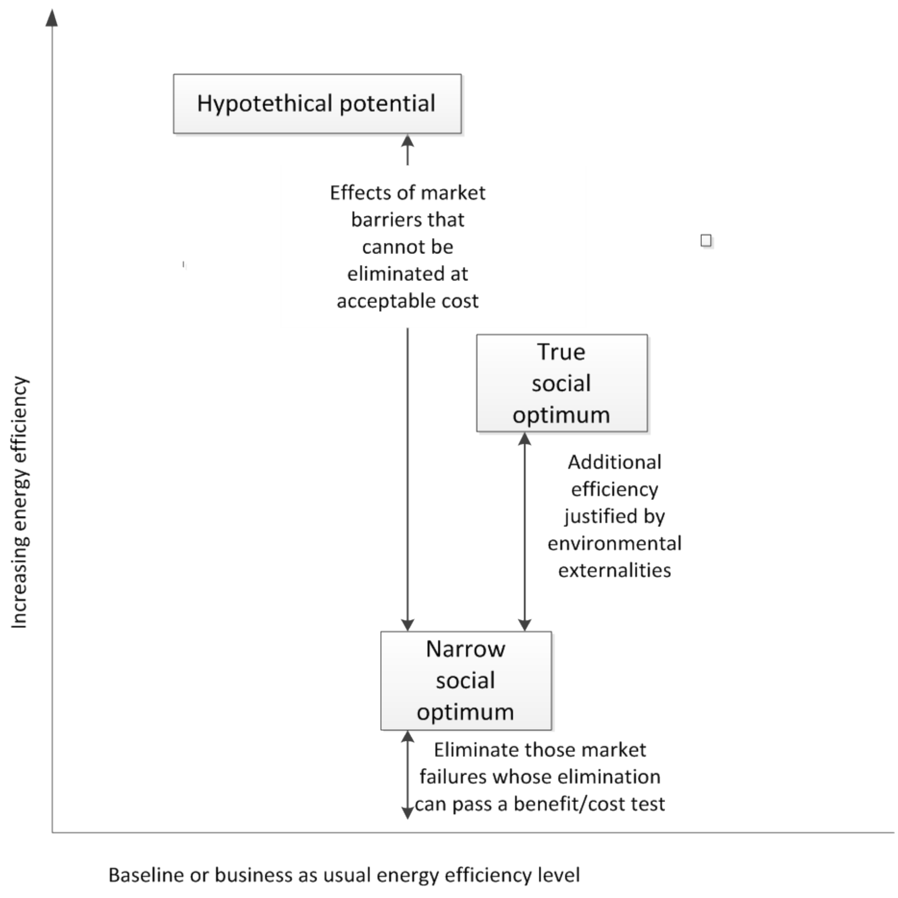
A common approach has been to explain this gap in terms of "barriers", here defined as an obstacle to an actor in reaching a certain goal in terms of energy efficiency (Weber, 1997). Different types of barriers have been developed and discussed in relation to markets, institutions, organizations or individual behavior (Sorrel et al, 2000), thus drawing upon research from different fields. A barrier model, as defined by Weber (1997), has the following general structure: "*what* is an obstacle to *whom* reaching *what* in energy conservation". An aim in using the model is to place energy use in a social context and thus to broaden the view from a more pure technical or economical potential perspective. For example, it can be argued that a person in one social setting may look for and implement many energy-saving measures while he or she may not in another, independent of actual techno-economical potential. The model explains this through barriers - in this case perhaps on a behavioral or organizational level - that hinder this person from achieving higher energy efficiency. In this article, three sets of barriers will be discussed; barriers related to markets, to behavior and to organizations.

[6] A distinction is made between failures and barriers, such that a market barrier is any barrier that hinders a cost-efficient energy efficiency measure to be implemented, and a market failure is a barrier that justifies public intervention from a cost-benefit perspective (Jaffe and Stavins, 1994). This distinction has later been questioned, and it can also be noted that the terms are used somewhat ambiguously between different energy efficiency researchers (Sorrell et al, 2004).

The concept of barriers can be used to explain the difference between a hypothetical potential and what is actually observed, as seen in

Figure 1, adapted from Jaffe and Stavins (1994). A hypothetical potential changes in reality towards the narrow social optimum, as eliminating barriers come at a cost, and not all barriers are cost efficient to remove from a societal perspective. A true social optimum is reached only when environmental externalities are fully accounted for.

Figure 1. Potentials and barriers to energy efficiency



Source: Adapted and simplified from Jaffe and Stavins (1994)

Market failures can be divided into four main categories: incomplete markets, imperfect competition, imperfect information, and asymmetric information. Thollander (2008) argues that the two latter categories of imperfect and asymmetric information are more interesting to study in an energy efficiency context, which will also be the focus of this article.

On reason as to why information barriers are of importance in the field of energy efficiency, is that information related to energy use and efficiency can be said to have the qualities of a public good. As such, it is typically underprovided by ordinary market activity, giving rise to information barriers. For example, an adopter of a measure with unclear savings is taking a risk, the result (and information) of which other potential adopters receive the benefits. This leads to an under-supply of information regarding that particular measure (Sorrell et al, 2004).

With respect to information, different types of goods are also expected to affect market failure to different extents. Economists typically divide goods into three categories, namely search goods, experience goods and credence goods (Nelson, 1970; Stern, 1986). With the first type of good, it is possible for the customer to acquire information on quality, performance etc. of a good before purchase. Experience goods need to be used by the customer before it is possible to determine the same aspects. Lastly, credence goods are goods where it is difficult to gather information even after purchase and use. When information is distributed asymmetrically regarding a particular good, barriers become more severe in the same order: search, experience and credence goods (Sorrell et al, 2004).

Examples of asymmetric information barriers include split incentives, adverse selection and moral hazard; the first being perhaps the more well-known of energy efficiency barriers. In the building sector, these are known as landlord-tenant problems (e.g. Blumstein et al, 1979). A common example of a split incentive problem is where the party that would be the adopter of a particular energy efficiency measure could be aware of the possibilities, but does not realize these, as another party pays the fuel bill and would thus receive the benefits.

The distinction between adverse selection and moral hazard is that they are cases of asymmetric information applying before and after a contractual agreement, respectively (Sorrell et al, 2000). Before the agreement, there may be reasons for a vendor of a particular good to underprovide information of quality or performance. After the agreement, moral hazard problems may arise, especially if performance with respect to the contract is difficult to determine. These problems are often described as principal-agent (PA) relationships, where an agent is either acting on the behalf of or providing a service for a principal, but with partly differing sets of information and goals (Sharma, 1997). This would lead the agent to act opportunistically - to always optimize performance with respect to his or her own agenda - at a cost for the principal.

PA problems have been shown to have substantial impact. In a review of case studies in five countries by the International Energy Agency, principal agent problems alone affected energy use corresponding to 3,8 EJ, or 85% of the energy use in Spain in 2005 (IEA, 2007). Furthermore, from a policy perspective, these problems are said to be difficult to target through single policy interventions. The IEA (2007) notes that PA problems are "pervasive, disbursed and complex", and argue that sector and national specific sets of policies need to be designed.

Market barriers that are not market failures in the Jaffe and Stavins framework include a perception of higher risk for energy efficiency measures (thus imposing stricter pay-off criteria), low access to capital, hidden costs for implementation (production disruptions, staff training, etc.) and heterogeneity of actors (a measure that is cost-efficient on average may not be so in the case of a particular actor) (Sorrell, 2000).

Relying only on neo-classical economics for identifying energy efficiency barriers will not be sufficient to explain the full picture. One criticism is the proposition that firms always maximize profit and consumers always maximize utility (Hodgson, 1998). Therefore, a second set of barriers related to behavior, belonging to a range of scientific disciplines: psychology, transaction cost economics and decision theory, have been developed. They can be sub-divided into many categories, two of which are bounded rationality and inertia. An example of former is that an agent is assumed to have only limited rational behavior. Instead, an agent's decision making capacity is "bound" by constraints related to time, attention and the ability to process information. As a result, rules of thumb and routines replace rational optimization. The latter, the presumed existence of organizational "inertia", implies that all other things equal, actors favor status quo rather than maximization of utility (Sorrell et al, 2000).

When it comes to the third set of barriers, related to organizations and specifically organizational theory, not as much research has been produced in the context of energy efficiency. Sorrel et al (2000) describe it as being "the least developed". A decade later, Thollander et al (2010) point to a gap in research literature when it comes to understanding actual energy management practices and strategies in companies. Some examples found in literature are Selmer (1994), who studied management practices through longitudinal case studies of five companies in the building sector, and Cebon (1992), who studied behavioral aspects of energy management at two universities.

Sorrell et al (2000) describe two aspects of organizational theory as being especially interesting - power relationships between individuals, and organizational culture. In this context, power is seen as "a medium in which conflicts of interest get resolved. Power influences who gets what, when and how" (Sorrel et al., 2000).

Beyond barrier theory, there are also more interdisciplinary approaches to analyzing energy efficiency. Palm (2009) uses lifestyle categorization used in research on households adapted to explain attitudes to energy efficiency in industrial small-medium sized enterprises (SMEs). Nässén et al (2008) combine an econometric approach with interviews to explain stagnating energy efficiency in the Swedish building sector. Ryghaug and Sorenssen (2010) studied the Norwegian building industry and concluded that lack of public policy, a conservative industry and low government interest were main causes of why energy efficiency "fails".

Barriers to energy efficiency in shipping - an analysis

The above framework was used as an underlying guideline for the interviews carried out. The aim was to understand whether this framework was useful as a tool for discussing the shortcomings and barriers regarding energy efficiency as described by the interviewees, and as an implication, that the solutions put forward in other sectors would possibly have an impact also in shipping. In total, 19 interviewees were interviewed at least once. In terms of their professional roles, this group included chief engineers, master mariners, naval architects, environmental managers, ship operators, general managers, energy efficiency equipment vendors, energy efficiency consultants, shipping company CEOs, ship owners, and more. In the analysis, cases described by them will be discussed in terms of the above framework.

This discussion will be divided into the discussed barriers, focusing on market and organizational barriers. In some cases, this division may seem somewhat artificial as examples in practical terms may fall into more than one category. As the barriers are attempts to explain the energy efficiency gap with basis in different theoretical frameworks, this is perhaps not so surprising. Sorrel et al (2000) also notes that the barriers should be seen as perspectives to highlight interesting features rather than discrete variables. Especially the concepts of principal agent problems and split incentive problems overlap.

As will be shown, the data collected through interviews indicates that shipping does not divert significantly from other sectors. The framework seems well suited to discuss problems found also in shipping. In fact, some special characteristics of shipping may even make increasing energy efficiency even more difficult, despite relatively higher energy intensity.

Market barriers - imperfect information

From a shipping market perspective, imperfect information seems to be a significant barrier. The theoretical starting point is that since information is typically underprovided by ordinary market activity, actors lack proper basis for taking economically efficient decisions. An investment decision regarding an energy efficiency measure is from an economic perspective typically a trade-off between initial capital cost and potentially lower future energy costs (Gillingham et al, 2009). Therefore, increasing certainty in the prediction of future savings as well as future energy costs, expected lifetime of the measure, among other aspects, become critical. Throughout the interviews, at three main patterns concerning difficulties in realizing theses aspects could be seen.

Firstly, interviewees in the position of ship operators or owners explained that vendors of energy efficiency measures could approach them with a range of energy saving "devices" but without convincing measures or data available for proving actual savings. One ship owner explained that "if we add them all together, we can save more than 100%." Insufficient information regarding the estimated savings was in this case a barrier for them in investing in a measure.

Secondly, a number of company representatives elaborated on difficulties of assessing energy performance of ships - another form of imperfect information. Due to varying weather conditions, the quality of measuring equipment, efficiency of reporting systems etc., there could be so much “noise” in the information that it becomes very difficult to “prove” the results of measures. In one case, a shipping company had proven the efficiency of a measure in a testing environment, as well as on a trial run, but could not see the savings in day-to-day operational data. Consequently, they did not continue with the measure on a fleet-wide basis. Interviewees also stated that this noise reduced transparency of energy costs within their respective organization; making it difficult to set un-ambiguous benchmarks, focus on the right projects and set best practices.

Thirdly, lack of information regarding future energy costs could also be a barrier. A technical project manager in one shipping company explained that it was company policy to use the last month's bunker oil price to calculate pay-back times for projects. Even though oil prices were rising, they were also fluctuating, making it difficult to plan projects correctly with dockings and access to the right personnel. Furthermore, the use of payback time itself has been criticized (e.g. Narayanan, 1985), making application of the concept in energy efficiency questionable.

Market barriers - asymmetric information

Problems of asymmetric information seem to appear in many forms in shipping, both in terms of markets and within organizations. A large numbers of actors can be involved in providing a shipping service, separated geographically and managerially, potentially opening up for many problems related to information.

Examples include freight contracts where the cargo owner pays bunker prices[7], when management of technical maintenance is separated from the commercial management with responsibilities for the fuel bill, or when a ship is procured. In the last example, adverse selection ensures that potential energy efficiency measures are not accounted for in the value of the ship, as the transaction costs involved for the procurer in using the discounted values of an energy efficiency investment is too large. Information exists, but is asymmetrically distributed, in this case at the shipyard.

Some of these situations in shipping can be easily described as principal agent problems, where there are few incentives for the agent to address energy efficiency to the benefit of the principal. One reason is simply that the actions taken by the agent are invisible to the principal, giving rise to a so called moral hazard problem. A technical management optimizing the financial performance of their department may wish to reduce expenses for maintenance, at a higher total cost for the company due to higher fuel consumption (IMO, 2009). This could also be described as a problem of split incentives as discussed below.

The solution model proposed by agency theory is that contracts are better formed. An example from shipping is the case where a ship operator may have financial incentives to go full speed, as he receives demurrage while the cargo owner pays costs of fuel. The "virtual arrival" process, where vessels upon receiving information of a delay at their upcoming port reduce speed in order to arrive in time for unloading, is an example of such a "better formed" contract. An external verification service would calculate what the fuel consumption and arrival time would have been should the ship have continued on its initial contract speed (IMO, 2010). This kind of process could then be used to share "savings" between cargo owner and ship operator, with the operator still receiving demurrage.

Split incentive problems also seem to be prevalent in shipping. As Sorrell et al (2000) put it: "It is necessary to ask, what are the personal incentives for investing in energy efficiency?". As many measures in shipping are operational, "investing" in this sense could be broadened to include also day-to-day decisions. A consultant working on improving energy efficiency in shipping companies explained in an interview that usually there is a paradox in that no one in the shipping organization is truly accountable for energy costs and cost reduction. Moreover, a master mariner explained that there could be large variations in the company between the performances of different crew when it comes to fuel efficient operation (vessel trim, speed profile, route planning etc.), but as they are not evaluated on or held accountable for this, little incentives exist for improvement.

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[7] CE Delft (2009) estimates that 70-90% of all costs for bunker fuel consumed are passed on to another party.

Also, in the terminology developed above, a ship could be argued to be a credence good, i.e. it can be difficult for the buyer to assess performance and characteristics of the good even after it has been purchased and used. This was a concerned raised by interviewees; that it could be difficult for them to assess performance of their ships compared to new condition. As discussed, credence goods are most susceptible to asymmetric information problems.

Organizational barriers - Power structures

Many previous studies on energy efficiency in other sectors highlight the importance of the energy efficiency "champion", or simply "people with real ambition" (Rohdin et al, 2007), who will work on energy efficiency despite lack of formal incentives.

Throughout this project, the author met interviewees of this sort, working in organizations where they were either encouraged or not to work on energy efficiency. A senior chief engineer specifically mentioned that he had been strongly discouraged from investing or improving the ship where he was working in many different shipping companies, save the one where he was working now. He had now been able to receive funding for several projects, all which had had short payback times for the company. The importance of the social or organization context in this story leads to the next set of barriers, those related to power structures in companies.

Studying an organization in terms of power structures means that the focus is on the actors affecting energy use and efficiency, and the power available to them. An organization in itself cannot be said to be a barrier to energy efficiency, but it can be argued that organizational structure affects and constrains what choices actors within an organization make (Cebon, 1992). Sorrell et al (2000) discusses a few key questions related to power, namely; What kind of position in the hierarchy do they hold? How much control do they have over key resources? Do they have the required information?

These kinds of questions proved interesting throughout the interviews. The first example has already been mentioned: the senior chief engineer in the previous example. He mentioned that the biggest barrier was the person a step up from him in the hierarchy, onshore, who was not willing to consider new ideas. Another example was a technical inspector coming to a halt because he was not able to convince the management of a set of ships that measures tried successfully on other ships should be implemented further. It was not something that his formal position within the hierarchy allowed. Literature on resistance in organizations gives some support to this: "If we look at how managers define their jobs, we see responsibility for initiating change as one of the major tasks. At any given level of hierarchy, a manager does not expect those who are subordinate to that level will initiate change, and when subordinates do, they generally have a hard time with it." (Nevis, 1987).

A general pattern described by interviewees, was the people in a shipping organization who may be closest to experiencing and affecting energy use - the ship crew - may be far from controlling the resources needed to implement improvement processes. On another end, ship charterers and operators also make decisions that clearly affect energy consumption, through e.g. charter speed and operational instruction, depending on organization. In more than one shipping company studied, interviewees explained that these parts of the organization might not have sufficient knowledge or information regarding energy performance of different ships in different loading conditions and speeds, effectively rendering it very difficult for them to decide on most energy efficient speeds for a given cargo and voyage. This is also a good example of a situation where more than one barrier can be used to describe the situation; it could also be argued to be a situation of asymmetric information.

Implications for management

It is clear from the interviews that market access to energy saving measures is not in itself a barrier. Indeed, the surveys mentioned above made by various organizations suggest that the possibilities for increased energy efficiency, through existing knowledge and technology, are very large. It is also clear from the interviews that for different reasons, many shipping companies seem to lack the ability to systematically address energy efficiency within their organizations. Thus it could be argued that a part of the problem could be placed in the way a shipping company is managed, and as such, many shipping companies may need to different extents scrutinize their organizations and perhaps pursue a process of organizational change.

With regard to organizational effects on performance, some support can be found in literature. A typical strategy for cost-cutting in shipping the last decades has been registration of ships in open registers, thus minimizing regulatory requirements and reducing operational costs due to cheaper labor. It has been argued that this has driven a trend towards substandard shipping (Bode et al, 2001). Another common practice has been to outsource day-to-day operations to third-party ship management (e.g. Mitroussi, 2003). The above theoretical discussion implies that such a development would open up for further principal-agent and split incentive problems, besides those that already exist between cargo owner and cargo carrier. Interviews with vendors of energy efficiency measures supported this picture, in the sense that their main customers were shipping companies with in-house technical management. This would imply that for many shipping organizations, energy efficiency is a contractual problem.

What kind of change process is needed? What are the competences needed in order to better harness the potential for energy efficiency? It has been argued that there exists no one solution that fits all companies when it comes to managing energy (Russel, 2006). Still, many best practices for use in organizations to manage work with energy efficiency were developed during the last decade. A Danish standard, DS2403, was produced in 2001. A Swedish standard, SS 62 77 50, was introduced in 2003 as part of a governmental energy efficiency program called "Program för energieffektivisering" (Program for energy efficiency, PFE). A European standard followed in 2009, and an international ISO standard, ISO 50 001, is to be released in 2011. A similar development has started in shipping: the IMO has developed a Ship Energy Efficiency Management Plan (IMO, 2009), OCIMF has revised its TMSA to include also energy efficiency (OCIMF, 2008), and Intertanko has produced a Guide for a Tanker Energy Efficiency Management Plan (Intertanko, 2009). No papers have been found by the authors that reviews experience drawn from the implementation of these standards in shipping, and would thus be an interesting topic for further research.

Most change processes in firms fail (Kotter, 1996). Therefore, further research into what the key success factors for shipping companies are in their endeavor to pursue organizational change for increased energy efficiency would be interesting. How do organizations learn to become more energy efficient? What are the effects of management style and organizational structure on performance in general and energy efficiency in particular? Some previous research exists for other sectors. Rohdin et al (2008) name "a long-term energy strategy" and "people with real ambition" in their study of the Swedish foundry industry.

Implications for policy-makers

Even if all cost-effective measures are implemented, it has been argued that it will not be enough to lower emissions from shipping (CE Delft, 2009). This is a situation far from a 90% reduction. The above discussion showed that inefficient behavior, in individuals as well as in firms, can be argued to arise as a natural consequence of principal agent relationships, power structures and other barriers. In reality, rational business-economic considerations on energy efficiency measures simply do not seem be taken. What would be the consequence for policy-making, if the situation is such that

A: even if all cost-effective measures are implemented, achieving emission reductions *at all* will be difficult;

B: far from all cost-effective measures will be implemented through ordinary market activity?

The existence of barriers to energy efficiency is discussed to some extent by policy-makers in shipping. From the IMO:

"it is essential that [all parties have] the incentives and flexibility to join the energy-saving effort, and it is particularly important that they do not have incentives to contribute to inefficient behaviour" (IMO, 2009, section 5.25),

However, one conclusion drawn in the same report is still that

"[d]epending on fuel price, some measures are expected to be cost-effective for the operator. It is likely that these measures will be taken on the basis of business-economic considerations by actors in the shipping sector. Other measures will not be taken if business-economic considerations are the sole driver; they have to be incentivized by policy." (IMO, 2009, section 6.45)

An implication of the existence of barriers is that "cost-effectiveness" is an ambiguous term. When it comes to energy efficiency, assessments of technical potential may be too optimistic. In reality, the amount measures taken on the basis of business-economic considerations are likely to be fewer than expected. It should be noted again that this is the situation seen in most sectors. Another implication is that results from models and other estimations of technical and economic potential cannot be used by itself as a guideline as to where to direct policy measures. Not only the cost of technically implementing a measure will be relevant; an organization may have various internal barriers that need to be overcome, at a cost, before implementation is possible. Thus, what will be actually implemented by actors in shipping markets is likely to be different from model results.

In the review of CE Delft (2009, section 12.1-2), behavioral responses to financial incentives to reduce CO2 emissions are discussed. It is argued that transaction costs and the time lag of implementing technologies are the most important factors in explaining the slow diffusion of energy efficiency measures. It is also argued that policies that lead to an increase of the price of energy will lead to a reduced time lag and diminish the transaction costs.

Given the prominence of the problem as outlined in points A and B above, further research into how to improve policy-making in this field will be necessary. In the light of problems such as these DeCanio (1993) discusses a widening of governmental policy when it comes to energy efficiency: government could serve as a "clearing house of information" regarding energy efficiency measures. It could also provide "management consultancy services" and should serve as a "rallying point". Palm and Thollander (2010) also argue that "by realizing the social construction of technological development and the spread of energy efficient technologies, other policy instruments would become relevant, such as networks regarding energy services and energy efficiency." Continuing, they discuss possibilities to challenge existing norms and routines through the creation of workshops, clusters and open networks. Similarly, Rohdin et al (2008) highlight the importance of consultancy firms in providing knowledge in their review of barriers and drivers in the Swedish foundry industry. These arguments have theoretical backup in the sense that since information has the characteristics of a public good, it will be underprovided by private actors and thus need to be provided by public actors. The implications of these findings for policy in the shipping sector would be an interesting trajectory for further research.

Discussion and conclusions

It is evident that there is an energy efficiency gap in shipping, and that that many of the barriers developed through various theoretical frameworks are useful also in this sector . Given the geographically and organizationally fragmented nature of shipping, and that the main good in shipping - ships - could be argued to be a credence good, many barriers related to imperfect and asymmetric information may even be augmented compared to other sectors.

The intention of this research article was to give an overview of a couple of decades of research on energy efficiency policy and gaps, and to through interviews delve into what aspects of this research is applicable also to shipping. While the potential for shipping to increase its energy efficiency has been known at least equally long, the same discussion of barriers has not previously been taken into shipping context.

The scope of this article is shipping and its organization - despite the heterogeneous nature of the sector. It is thus also limited in the sense that it does not directly include cargo owners. This would have been relevant as choices made up or downstream very much affect choices available for shipping actors. Similar studies could be done that focused on barriers in a particular market, product supply chain or region. It is the intention of the author that more specific studies are carried out in the future. Moreover, the focus of the article was on barriers. Equally important is the study of drivers and key success factors, which is a topic of coming articles. Moreover, the focus was on policy-makers and management groups of shipping companies. Other important actors exist, for example classification societies. Their role could also be the focus in further research.

It is further evident that pressure on shipping to reduce its environmental impact will increase. It is also clear that the most cost-efficient route to CO_2 emission reduction will be through increased energy efficiency. Further research when it comes to increasing the diffusion and application of measures impacting energy efficiency could be done in the direction of policy-making as well as decision making in companies.

As for companies, many best practices exist to manage energy efficiency in a systematic way, the implementation of which would be interesting to study. These studies could include aspects such as critical success factors for organizational change related to energy efficiency, the role of different organizational structures, incentive structures and the formation of better contracts. Specific studies concerning the application of the IMO SEEMP or ISO 50001 could also be done.

For policy makers, it has been argued that while researchers focusing on other sectors have argued that no single policy bullet exists for "busting barriers" or "bridging gaps", a call for a broadening of the role of policy makers to be a strong provider of information can be seen. Further research could be carried out on how to better support policy-makers in this endeavor.

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