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The social organization of energy efficiency in shipping: a practice-based study

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Abstract

The central research question explored in this study is *how energy efficiency is organized onboard large merchant ships*. The dominant techno-economical approach within energy research and policy, in general, and shipping research and policy, in particular, is reviewed and criticized as being too limited for understanding the challenges and opportunities related to the organization and management of energy efficiency in shipping companies. The failure, it is suggested, of previous research and policy, is associated with the lack of analysis and attention to how the organization of energy efficiency onboard ships is enacted by crew members acting in particular socio-material contexts. The primary aim of this study was to initiate the development of a practice-theoretical understanding of the organization and management of energy onboard ships. An ethnographic study onboard five ships operated by one of the largest ferry companies in the world was conducted in order to explore the social practices of the work associated with ship operation. Three topics were identified and explored: (i) the non-use of energy performance monitoring technology as a result of misalignments in practice, (ii) the role of situated and embodied knowledge for energy efficient navigation and voyage execution, and (iii) the contradictory structure of energy practice leading to reduced energy efficiency. It is concluded that formal energy management systems are insufficient in developing crew members' know-how, skill and practice associated with energy efficient ship operation. The findings have implications for policy and energy management within shipping companies, as well as other industries, and for training and education of managers and employees. It is recommended that shipping companies should focus more on local capacity building and collaboration among crew members as a means of improving the energy efficiency of ship operation.

Keywords: *Energy efficiency, Shipping, Practice theory, Energy consumption, Work, Activity theory, Energy management, Knowing-in-practice, Practice based studies*

Appended papers

Paper I

Viktorelius, M., Lundh, M. (2016). The role of distributed cognition in ship energy optimization. Presented at the peer-reviewed conference Energy Efficient Ships, 23-24 November 2016, London, UK

Paper II

Viktorelius, M. (2017). The human and social dimension of energy efficient ship operation. Presented at The International Conference on Maritime Energy Management, 24-25 January 2017, World Maritime University (WMU), Malmö, Sweden. Accepted for publication in *WMU Series of Maritime Studies*. Springer.

Paper III

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1 Introduction

Energy efficiency is currently one of the most important topics in the shipping industry. Maritime transport is responsible for emitting around 1016 million tons of CO_2 annually which accounts for about 3.1 % of global greenhouse gas emissions (Smith et al., 2014). The emissions from shipping are estimated to increase between 50% and 250% by 2050, depending on future economic growth in the sector. This is not consistent with the internationally agreed goal of keeping global temperature increase to below 2°C compared to pre-industrial levels, which requires worldwide emissions to be at least halved from 1990 levels by 2050 (EU, 2017). EU has recommended that CO_2 emissions from maritime transport should be cut by at least 40% from 2005 levels by 2050, and if feasible by 50% (EU, 2011).

In 2013 new international regulation aiming at improving ship energy efficiency entered into force after having been adopted by the International Maritime Organization (IMO)[1]. This was the first legally binding climate change treaty targeting shipping to be adopted since the Kyoto Protocol and is "expected to significantly reduce the amount of CO_2 emissions from international shipping" (IMO, 2017). An energy efficiency design index (EEDI) was made mandatory for new ships with the adoption of amendments to MARPOL Annex VI (IMO's International Convention for the Prevention of Pollution from Ships) and requires a minimum energy efficiency level for different ship type and size segments. IMO also made it mandatory for each ship over 400 gross tonnage to keep on board a ship specific energy efficiency management plan (SEEMP). The purpose of the SEEMP is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship's operation[2]. Moreover, in October 2016 the Marine Environment Protection Committee of the IMO adopted mandatory MARPOL Annex VI requirements for ships to record and report their fuel oil consumption[3].

These regulations can be seen as being aimed at changing the current design and operational practices in the shipping industry through developed managerial and organizational practices. In addition to the environmental and regulatory pressure for

[1] Resolution MEPC.203(62)
[2] 2016 Guidelines for the development of a ship energy efficiency management plan (SEEMP), Resolution MEPC.282(70)
[3] Resolution MEPC.278(70)

improved energy efficiency several recent studies have shown that a cost-effective potential for improved energy efficiency exists in shipping (Buhaug et al. 2009; Eide et al. 2011; Faber et al. 2011). There is thus an economic pressure on shipping companies to reduce its emission as well. This adds further to the need for organization and management of energy within shipping companies to reduce fuel consumption.

The few existing studies investigating the organization and management of energy efficiency in shipping have mostly focused on the existence of various barriers, in particular, informational imperfections and asymmetries, inhibiting the implementation of technical and operational measures known to improve energy efficiency (e.g., Jafarzadeh and Utne, 2014). Improvement in energy efficiency in shipping companies is suggested, by researchers and policy-makers, to result from the implementation of 'best practice' or standards (such as ISO 50001) including energy consumption monitoring (Bazari and Longva, 2011; Johnson and Andersson, 2014).

Notwithstanding the identified barriers and the recommended energy management systems, few studies have investigated *how* energy efficiency is organized onboard ships. Understanding the actual work performed in organizations when trying to reduce the fuel consumption is an important step in changing current practices throughout the shipping industry. This research gap is particularly pertinent when it comes to understanding the onboard everyday practices and how they contribute to the continual organization of energy efficient ship operation. The lack of research on work practices onboard ships thus constitutes a blind spot in our understanding of how shipping can become a more sustainable (through e.g. increased energy efficiency) transportation mode.

This thesis aims at understanding the performed organization of energy efficiency onboard ships by examining the everyday practices of crew members (masters, officers and engineers). An ethnographic case study was conducted onboard five ferries operated by one of the largest ferry companies in the world. It is argued in this thesis that understanding the challenges and possibilities associated with energy efficiency requires analysis of the situated actions and social context in which technology is enacted in practice.

Several questions were addressed in this thesis:

- How is energy efficiency organized onboard ships?
    - What role does crew members' knowledge play in the organization of energy efficiency?
    - What is the relation between technology, practice and the organization of energy efficiency onboard ships?

This thesis aims at contributing theoretically, empirically and methodologically in understanding the challenges and opportunities faced by crew members in operating ships energy efficiently. *Theoretically*, this thesis takes an alternative approach to the study of energy efficiency in shipping. Inspired by recent developments in the social science of energy consumption (Shove et al. 2012; Thollander and Palm, 2013) and organizational theory (Gherardi, 2012; Nicolini, 2012) this study takes socio-materially situated practices as the fundamental unit of analysis. The focus on practices aims at overcoming the theoretical problems associated with previous research on energy efficiency reviewed in the next chapter. Instead, it introduces a new framework for understanding the reproduction of practices within shipping companies. *Empirically* this thesis aims at bringing studies of work (Barley and Kunda, 2001) in to ship energy research. It investigates the work of a neglected, although crucial, actor in the global quest for improved maritime energy efficiency; the ship crew. Finally, the thesis also adds to the predominately quantitative methodological toolkit used in research about maritime energy efficiency and energy systems by suggesting and illustrating the value of ethnography and interpretative data analysis.

2 Background

This chapter will provide a literature review of the research on the organization and management of energy efficiency in shipping companies. It uncovers the theoretical underpinnings of the current approach in both research and policy on energy efficiency in shipping. The purpose is not the represent every detail in the literature but rather to sketch out the general approach and paradigms used in previous studies. The approach is argued to be based in a narrow techno-economic perspective on organization, management and behavior. Section 2.4 then reviews the critique that has been directed at the techno-economic approach in general and an alternative perspective, emphasizing the role of the social context for energy-relevant practice is suggested.

2.1 Energy efficiency measures

Both technical and operational measures for improving energy efficiency have been identified in previous research. This section focuses on the operational measures over which crew members have a significant influence. Voyage optimization refers to "the optimization of ship operation that the master can achieve within the constraints that are imposed by logistics, scheduling, contractual arrangements and other constraints" (Buhaug et al., 2009, p. 47). Energy efficient voyage execution depends, for example, on (a) the *speed choices* made by the navigating crew during each stage of a voyage, (b) *early departures* and *just-in-time arrivals* (minimized time in port to prolong the voyage and reduce the speed), (c) *routing* (selection of optimal routes with respect to weather, currents and water depth), (d) *autopilot use* (minimizing the number of times the rudder is used and the amount of rudder angle that is applied to maintain course or execute a change of course), (e) *ballast water use* (avoiding unnecessary ballast), (f) *trim* (distributing cargo and selecting the proper amount and location of ballast in order to achieve an optimum trim, i.e. the difference between the aft draft and the forward draft), (g) *optimal main and auxiliary engine load* (typically in the range of 70 to 90% of an engine's Maximum Continuous Rating (MCR)). In addition to the measures increasing the energy efficiency of the propulsion of the ship there are also measures reducing the power demand of energy consumers onboard the ship, such as shutting or slowing down non-essential pumps, fans, lights, equipment and machinery etc. as vessel operations allow (ABS, 2013). In all these measures the crew play a crucial role. The estimated reduction potential of improved voyage

performance and reduced onboard power demand is up to 20% CO2/tonne-mile[4] (Buhaug et al. 2009).

2.2 Recent studies on the organization and management of energy in shipping

As indicated in the introduction, research in shipping is currently emphasizing the existence of several different 'non-technical' barriers to the adoption of energy efficient technology and practice (e.g. Acciaro et al., 2013; Jafarzadeh and Utne, 2014; Johnson and Andersson, 2014; Rehmatulla and Smith, 2015a, 2015b). In proposing a framework for categorizing all of the likely barriers to energy efficiency in shipping, Jafarzadeh and Utne (2014) listed the following types; informational barriers, organizational barriers, economic barriers, technological barriers, policy barriers and geographical barriers. Most of the literature has focused on market and organizational failures, including imperfect information, adverse selection, principal-agent relationships and split incentives (Sorrell et al. 2004). This research draws on a broader discourse in energy research and policy about the existence of energy efficiency gaps in industry (Hirst and Brown 1990; Jaffe and Stavins 1994).

Johnson and Andersson (2014) argued, for example, that imperfect information is a significant barrier both within organizations and in the shipping industry as a whole, saying that, "since information is typically underprovided by ordinary market activity, actors lack proper basis for taking economically efficient decisions." (Ibid. 2014, p. 89). The authors argue that insufficient information to estimate savings, difficulties of assessing the energy performance of ships and uncertain future energy costs, makes it difficult to implement energy efficiency measures. According to the authors, "energy *in*-efficiency is a natural consequence of information asymmetries" (Ibid. 2014, p. 90), manifested in the form of split incentives, adverse selection, moral hazard, and principle-agent relationships, arising between different stakeholders (operators, ship owners, cargo owners, technical managers, commercial managers and crews). Johnson and Andersson (2014) also found 'structural organizational barriers' constraining the actions of ship crews and discouraging them to work on energy efficiency as well as inhibiting learning and innovation. Crews were seen to be "organizationally far from those responsible for implementing energy efficiency improvements and [were] rarely accounted for in the decision-making process" (Ibid.

[4] Amount of cargo shipped multiplied by the average distance that it is transported (Buhaug et al., 2009).

2014, p. 91). The authors conclude that "what seems to be required is a greater emphasis on monitoring and follow-up of performance, both internally within the company and with respect to external contracts" (Johnson and Andersson, 2014, p. 92).

In agreement with this, Rehmatulla and Smith (2015a) found that split incentives between charterers and ship owners was the most detrimental barrier for energy efficiency. Other barriers identified by the authors included the "lack of reliable information on cost and savings', 'difficultly in implementing under some types of charter', 'lack of direct control over operations' and that 'measures may be ignored by decision-makers due to their limited impact" (Rehmatulla and Smith 2015b). Jafarzadeh and Utne (2014) report that the barriers which were most emphasized by the participants in their study were "inaccuracy of information, incompatibility between technologies and operations, the lack of credibility and trust in the source of information, not using information, not maintaining information, split incentives, and immatureness." (Ibid. p. 608). Schøyen and Bråthen, (2015, p. 31) argue that "information sharing between ocean carriers, feeder operators, port agents and terminals is not adequate in supporting better logistics planning, e.g. in the form of improved voyage planning on board for more economical sailing speeds on legs.", and that, "staff on-board does not have the real time information nor the incentives to plan for operational fuel savings leading to more energy-efficient freight." (Schøyen and Bråthen, 2015, p. 32). In a report to the European Commission it was concluded that uncertainty regarding the information about future fuel prices, the effectiveness of different measures, future regulatory requirements, technological developments, investment returns, is the single most important issue underlying the barriers to implementing energy efficiency measures in shipping (Maddox Consulting, 2012).

Focusing more on organizational barriers Johnson et al. (2014) conducted an action research study in two short sea shipping companies where the authors contributed to the implementation of an energy management system. They identified a number of challenges during the implementation process associated with a lack of project management capabilities, lack of ship-shore communication, unclear division of responsibilities for energy use, lack of access to performance measurements and data analysis and lack of competence in energy auditing. These challenges were, however, interpreted as forms of imperfect and asymmetric information within the studied shipping companies. The division of responsibilities was, for example, seen to result

in a principal-agent problem; because "little follow up of the performance of ships was carried out", and since different agents are "assumed to rationally maximise utility, a difference in goals will arise naturally" (Johnson et al. 2014, p. 324). The authors also raised the possibility of subordinates' (crew members') opportunistic disclosure of information as an interpretation of why communication was lacking in the organization. Adhering to the demands in "best practice" standards, such as ISO 50001, was proposed as a remedy for some of the identified barriers, "by requiring management commitment to providing resources, procedures for monitoring performance, clear division of responsibilities as well as means of communicating performance." (Johnson et al. 2014, p. 326).

The implementation of performance monitoring systems and collection of valid and reliable data is seen by many researchers and policymakers as paramount in changing the behavior of organizational actors, arguing, for example, that "disaggregated data sets […] will allow onshore fleet managers and crews to immediately identify and realize cost-effective fuel saving initiatives." (Poulsen and Johnson 2016 p. 3790). The SEEMP, which builds on a similar method as ISO 50001 (although there are differences, see Johnson et al., 2013), is supposed to influence onboard practices and is assumed to "significantly boost the level of awareness and, if implemented properly, lead to a positive cultural change." (Bazari Longva 2011 p. 7).

However, Poulsen and Johnson (2016) found, by interviewing top executives and middle managers in mainly Danish shipping companies, that many shipping companies diverge from energy consumption monitoring best practice. They started their analysis by defining energy consumption monitoring best practice as comprising four stages (onboard data collection, data reporting to shore, onshore data analysis, feedback to ship). The analysis was focused on describing shortcomings in the realization of energy consumption monitoring best practice, due partly to current business models, in particular short-term charters. They highlighted, for example, the lack of real-time data and sub-metering; uncertainty in manual data collection; lack of crew engagement and training in data collection; the existence of incentives for misreporting of consumption; communication difficulties between ship and shore; lack of competence and resources for data analysis; insufficient feedback form shore to ship, etc.

Poulsen and Sornn-Friese (2015) identified challenges related to energy efficient ship operation and stated that "especially behavioral aspects, including dimensions of bounded rationality and the human dimension, compose barriers to energy efficiency

in ship operations" (Ibid. 2015, p. 50). The authors had interviewed 56 top executives and middle managers in 33 shipping companies and found that practices related to voyage execution, onboard power demand and performance monitoring were generally inefficient. In particular, it was found that the information sent from shore to ship was often based on unspecified instructions to the crew (such as to proceed at "most economical speed"), which allowed "different views on what is the "most economical speed" in a given situation" (Ibid. 2015, p. 45). This causes, according to the interviewees in the study, crews to continue old operational practices of sailing at high and costly speeds at early stages of a voyage in order to avoid the risk of delays at later stages, instead of keeping a stable service speed throughout the voyage. Furthermore, and according to the top executives and middle managers interviewed in the study, the lack of 'clear instruction', 'lack of training', 'crew competence' and 'knowledge about the fuel saving potential' as well as the existence of "inexperienced crews… [that] don't understand the guidelines they receive from shore" (Ibid. 2015, p. 46), causes crews not to use the available weather routing systems, not to use the autopilot optimally, not to adjust the trim optimally and not to depart before schedule although they are finished unloading and reloading the cargo, which could reduce the required speed for the voyage and thereby save some energy. Crews were also accused, by respondents in the study, for purposely increasing the speed in order to "arrive in port early and get a sleep" (Ibid. 2015, p. 46) and to withhold information about the biofouling of the hull which could be used by the shore office to plan efficient hull cleaning. The authors interpret these findings as an illustration of how "important information on energy consumption and ship-shore communication regarding energy efficiency is for energy efficiency" Poulsen and Sornn-Friese (2015, p. 46). The authors state that their study "confirms the generally accepted role of imperfect information as a barrier to energy efficiency. Decision-makers, who work at sea or in shore organizations and influence voyage execution and power management, are limited by the information available to them. Often this information suffers from validity and credibility problems in shipping and this impedes energy efficiency enhancement in ship operations" (Ibid. 2015, p. 49).

2.2.1 Summarizing the research on the organization of energy efficiency in shipping

The reviewed studies describe a heterogeneous set of organizational and behavioral issues related to energy efficiency. However, the challenges are mainly understood in terms of a lack of data, performance monitoring, formal instructions, training and systematic procedures. The core of the explanation of the energy efficiency gap in

shipping companies is thus associated with the lack of or transparency of information. Researchers adopting this explanation of the energy efficiency gap argue that decision-makers (e.g. ship owners, charterers, crew members, ship managers) do not have enough of the right kind of information and incentives to make the right kind of rational economic choices (from a market perspective) regarding available energy efficiency measures. As stated by Acciaro and Wilmsmeier (2015): "Several reasons exist that could explain the gap between declarations and actions, but one of the biggest reasons is the lack of proper data to build proper performance indicators." (Ibid., p. 3) and that "an important issue is the limited availability of high quality data and the lack of information sharing between actors." (Ibid. p. 6). The underlying belief, throughout the current literature, that agency is determined by information is expressed, for example, when Poulsen and Johnson (2016) say that "when valid and reliable ECM [energy consumption monitoring] data are available in real time, crews will be able to detect this and adjust behavior accordingly", and when argued that energy consumption monitoring is "instrumental for raising energy efficiency awareness among crews and shore employees." (Ibid., p. 3790).
The above studies seem to assume that stakeholders (ship owners, charterers, ship managers, crews) who are properly informed about everything relevant for a utility maximizing calculation (e.g. fuel prices and savings from implementing energy efficient technology and operations), and have the financial incentives, will make choices that ultimately lead to a more rational and efficient use of energy.

If, for example, crew members were targeted with the right type and form of information (training, instructions, energy performance data, feedback from shore) they would be able and actually make the most optimal energy efficient decisions. All that is needed for the realization of optimal energy efficiency, this approach suggests, is for neutral and objective information to be clearly communicated to, absorbed by, and acted upon by rational and responsible individuals.

The next two sections (2.3 and 2.4) introduces some of the limitations of the 'informational view' on the organization and management of energy characterized above. It is argued that although many of the researchers referred to above have started to investigate organizational and behavioral issues related to energy efficiency in shipping they still base many of their assumptions on the traditional techno-economic theory, black-boxing social and organizational processes. An alternative approach to the study of energy efficiency is introduced which accounts for the social context of energy relevant decision making.

2.3 Uncovering the assumptions in policy and research on energy efficiency in shipping: The techno-economic perspective

The literature on energy efficiency in shipping, as well as other industrial domains, is dominated by a techno-economical perspective on organization, management and behavior. Barriers are conceived to be factors that inhibit the adoption of cost effective, energy efficient technologies and practices or delay their diffusion among organizations (Sorrell et al. 2004). The underlying neo-classical economic ontology of the barrier model is based on the idea of an idealized, perfectly rational, profit-maximizing, efficient, proactive and omniscient organization operating in an ideal market "defined as a system of transactions with well-informed unbound individuals and prices reflecting the unbiased balance of demand and supply." (Weber, 1997, p. 834). The techno-economic perspective is thus based on a conception characterizing organizations as rational systems, or at least that they should be. According to a rational systems definition organizations are "collectivities oriented to the pursuit of relatively specific goals and exhibiting relatively highly formalized structures" (Scott & Davis, 2003, p. 29). They are assumed to "possess well-developed rational-analytic capacities, goals of maximization, access to information and resources" (Woolsey Biggart and Lutzenhiser, 2007, p. 1073). Specific goals are explicit, clearly defined and provide unambiguous criteria for selecting among alternative activities. Roles and the relations between them are explicitly structured and the formalization determines behavior independent of the individuals occupying the position or the personal relations to other individuals in the structure. Moreover, human agency (intentional action) is conceived to be *determined* by organizational, informational, economic, regulative and technological structures, rules and plans. The role of community or any non-individual elements, such as social relations, power and norms, are rarely considered.

Guy and Shove (2000, p. 59) summarize the core assumptions of the techno-economic perspective:

- Decisions are made by relatively autonomous individuals - that is, people are free to make energy efficient decisions if they so choose.
- People do not make energy efficient decisions because they do not know how to, and/or because they are not aware of the benefits, and/or because there is a price distortion in the market, and/or a conflict of interests (for instance between landlord and tenant).

- Once individuals are personally convinced, have the necessary information and receive the correct pricing and/or regulatory signals they will adopt proven energy saving technologies.
- Technology transfer is more or less inevitable - it is part of scientific progress - but can be speeded up by accelerating the diffusion of knowledge and the correction of market imperfections by selective regulation and/or financial encouragement.

A central idea in the techno-economic explanation of the energy efficiency gap is that actors lack information on current energy consumption and on energy-specific opportunities regarding technologies and practices (Sorrell et al. 2004). The principle of well-functioning markets and organizations can be violated (thus causing the energy efficiency gap) in two associated ways;

Imperfect information involves the lack of information, the accuracy of information or the cost of collecting information. If decision makers are poorly informed about their current energy consumption and available energy efficiency measures (technical or operational) they are assumed to be inhibited in implementing the available measures and realizing the potential for energy efficiency (Sorrell et al. 2004).

Asymmetric information arises when the information, about the energy efficiency of some product or service, possessed by two parties engaged in a transaction, is not symmetric, e.g., when the seller of a product knows more about its actual quality than does the buyer (adverse selection) or when an employer does not have access to information about the quality of the work carried out by the employee (moral hazard or principal-agent relationship). In the absence of strict monitoring (sub-metering) of the employee (e.g. the ship crew) and/or without an appropriate incentive structure, the employee is believed to act opportunistically (not work hard and be dishonest) instead of contributing to the energy efficiency of the enterprise. Another barrier, due to asymmetric information, is associated with split incentives and refers to situations where the party possibly investing in energy efficient measures is not the one paying for the consumed energy. It is considered an informational issues because if information would be shared than costs could also be shared and the split incentive would no longer ensue. On an organizational level, the lack of sub-metering of energy use creates an absence of personal incentives for employees to realize energy efficiency. Moreover, since the energy efficiency gap in shipping organizations is often thought to be a consequence of imperfect and asymmetric informational

structures, and since organizational behavior is thought to be determined by its structures (systems, technology, rules, instructions, plans, codified roles and procedures) the antidote for the barriers has been suggested to involve the implementation of energy management systems, particularly emphasizing performance monitoring (e.g. Johnson and Andersson, 2014).

Given the ideal of well-functioning markets and organizations, and the existence of cost-effective energy efficiency measures, the energy efficiency gap should not arise, but since it does in fact arise, economic, organizational and behavioral barriers are inferred (as was seen in section 2.2). Previous research and policy in ship energy efficiency can thus be seen to rest on many of the core assumptions of the techno-economic theory.

2.4 Some limitations of the techno-economic perspective

> "Unquestioning faith in rationality has rendered it into one of the myths most deeply rooted in the Western collective consciousness." (Gherardi, 2008, p. 517)

Information and incentives are, undeniably, important factors of human and organizational behavior, however, there is more to understanding social reality than this. Although the conventional techno-economic view is well established in both academia and the policy sphere, also outside the maritime domain, it has received criticism for being overly reductionist, rationalist and relying on a flawed characterization of technological diffusion and ignoring the social dynamics of organizational change. A major source of critique of the explanation invoking informational barriers is that it fails in accounting for the socio-technical network of energy practices (including energy management). The critique originated in the sociological writings of Shove (1998) and Lutzenhiser (1994) but has been developed by many other researchers since then. The conventional explanation of the energy efficiency gap is characterized as depicting an "abstract world, mostly without conflict and the messiness of ordinary affairs. It is a technical world of physical forces and economic verities. It is governed by rationality; so puzzlement abounds when reason fails to materialize." (Lutzenhiser 2014, p.142). Shove argued that "what is missing is an appreciation of the social contexts of energy saving action and of the socially situated character of technical knowledge." (1998, p. 1108). Barriers should not be seen "as simple evidence of intervention failure but as constitutive features of

social structure and social action." (Lutzenhiser 2014, p.149). As a consequence of the reductionist, rationalist and de-contextualized logic of the techno-economic model it "fails to recognize the routine complexities of energy-related decision-making." (Guy and Shove, 2000, p. 64). Furthermore, the sociological critique emphasizes the necessity of understanding "the ways in which the social organization of energy-related choices structures opportunities for energy-saving actions." (Guy and Shove, 2000, p. 66). Counteracting this deficit of the techno-economic framework is "an analysis which instead suggests that technical change is an unremittingly social, and thus contextual, localized and temporally specific, process." (Shove, 1998, p. 1109).

According to Sandberg and Tsoukas (2011) there are three basic problems with the conception of rationality expressed in conventional management studies, based on the techno-economic approach: "(1) it underestimates the meaningful totality into which practitioners are immersed, (2) it ignores the situational uniqueness that is characteristic of the tasks practitioners do, and (3) it abstracts away from time as experienced by practitioners. By doing so theories developed within the framework of scientific rationality fail to do justice to the logic underlying practice." (Ibid., p. 341).

The arguments made against the techno-economic view have been elaborated by many energy researchers outside of shipping. In a book and an article devoted to develop the barrier discourse Thollander and Palm (2010, 2013) argued that:

> "It is important to approach barriers from a new perspective, using non-traditional analytical tools that can contribute new understandings or questions as to why a particular barrier is perceived as important in a company. Analyzing a company's culture and existing networks, that is, understanding the context in which energy efficiency goals and measures are discussed, is important in order to take industrial energy efficiency a step further." (Palm and Thollander, 2010, p. 3260)

The adoption and implementation of energy efficiency measures is thus seen as the result of social, organizational, institutional and cultural context. This cannot, however, be reduced to incentives or informational structures as apparently conceived by the conventional view of technical and organizational change in shipping. Thollander and Palm (2013) argue instead for the importance of

considering the sociotechnical context of the potential of improving energy efficiency in industrial and organizational settings.

In an attempt to accommodate the above criticism and include the social context in the analysis of energy efficiency, energy researchers have started to explore energy consumption as the result of, i.e. as transpiring amidst, human social practices, treating these as fundamental units of analysis. From this perspective, barriers and structural organizational features are no longer merely studied as 'black boxes' standing in various general causal relations to the optimal and rational use of energy. Instead, practices are rather investigated from the inside, as holding objects and situated actions together (Hargreaves, 2011; Gram-Hanssen, 2011; Warde, 2005; Røpke, 2009; Sahakian and Wilthe, 2014; Spaargaren, 2011; Palm and Darby, 2014; Palm and Reindl, 2016). The next chapter gives an extensive characterization of the practice based approach to organization, management and behavior, suggested in this thesis as an alternative to the techno-economic approach.

3 Theoretical framework: organization as practice

Chapter 2 highlighted the importance of developing new analytical tools for understanding the challenges of energy efficiency in shipping. This section introduces the concept of social practice as an alternative theoretical framework for examining and understanding the organization of energy efficiency in shipping. The characterization of the concept is derived from recent developments in organizational theory and the emerging field of social science studies of energy consumption. The section situates this thesis in its ontological and epistemological setting.

3.1 What is work practice?

Practice theory, or the practice based approach, is a type of social theory with roots in such divergent thinkers as Bourdieu (1977), Garfinkel (1967), Giddens (1986), Heidegger (1927), Vygotski (1980) and Wittgenstein (1958). The practice approach is defined by treating human practices as the foundational unit of analysis in investigations of organization and social order. The turn to practice is a pronounced theme in social science in general (Schatzki et al., 2001) and the approach has been adopted and developed by several organizational theorists as an alternative to the conventional rationalist, cognitivist and individualist paradigms in organizational theory, in order to elucidate the concept and phenomena of organizing and work from a novel perspective (Corradi et al. 2010; Miettinen et al. 2009). This perspective rejects the "formal, static and rather reductionist analysis of organizations" (Geiger, 2009, p. 129), like those found in the techno-economic theory of energy efficiency. The practice approach is unified by focusing on "routinized, pre-reflective, and/or unconscious, embodied actions and dispositions to actions in contrast to individual rationality and reflection" (Miettinen et al. 2012, p. 348).

Work practices have practical consequences for organizations. In fact, from a practice based perspective organizing is nothing but practice. Organization, and social order in general, is achieved through a constant production and re-production of practices using technology, discourse and moving bodies. According to Schatzki (2005) organizations transpire through a nexus of practices and material arrangements. Practices (meshed with material arrangements) are the site of organizing and acting. By this he means that work practices in an organization are constitutive, that is inherently a part of, the actions of organizing carried out during work. As such practices become the locus of many phenomena relevant for the functioning of

organizations including, knowledge, learning, innovating, working, change, strategy, power, collaboration, routine, technology, and not least energy consumption.

The concept of practice has been used somewhat differently to refer to "the coordinated activities of individuals and groups in doing their 'real work' as it is informed by a particular organizational or group context" (Cook and Brown 1999, p. 387), or as "an organized, open-ended spatial-temporal manifold of actions" and as "materially mediated arrays of human activity centrally organized around shared practical understanding" (Schatzki et al., 2001, p. 11). Reckwitz defined 'practice' as "a routinized type of behavior which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (Reckwitz, 2002, p. 249), and as "a routinized way in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood" (Reckwitz, 2002, p. 250).

Practices have, moreover, been treated as *entities* and as *performances* (Schatzki, 1996). Although practices might be recognizable as coordinated entities (such as cooking or accounting), they essentially require performances for their continued existence. The practice approach is interested in examining how practices-as-entities are accomplished by practitioners and objects through their performances. Moreover, the importance of distinguishing between the actual performance or accomplishment of practice and idealized formalizations of practice, such as those found in work manuals or descriptions of 'best practice', is described by Brown and Duguid:

> "reliance on espoused practice (which we refer to as canonical practice) can blind an organization's core to the actual, and usually valuable practices of its members (including noncanonical practices, such as "work arounds"). It is the actual practices, however, that determine the success or failure of organizations." (1991, p. 41).

Most practice based theories of work also share an agreement about the relational nature of human activity, that is, "that subjects, social groups, networks, or even artifacts develop their properties only in relation to other subjects, social groups, or networks" (Østerlund and Carlile, 2005, p 92). The relational nature of practice means that differences, dependencies, changes, and boundaries are always the effects of relational enactments that are "intertwined in practice worlds" (Sandberg and Dall'Alba 2009, p. 1356). The relational nature has been captured clearly in

Engeströms (2014) version of practice theory, in which the relationship between actors and the object of activity is mediated by cultural means (tools and signs), a division of labor, communities, and by rules.

Feldman and Orlikowski argue that the relationship between specific instances of situated action and the social world in which the action takes place is critical to practice theory. They see practice theory as relying on three principles (2011, p. 1241):

- that situated actions are consequential in the production of social life,
- that dualisms are rejected as a way of theorizing, and
- that relations are mutually constitutive

Practice theory can be seen to differ from the techno-economic theory in a number of ways (see table 1). These differences include, but are not exhausted by, the ways in which knowledge, agency, rationality, and technology is conceived. The next section will focus on these themes and further describe the practice approach in order to contrast it to the techno-economic theory.

	Practice theory	**Techno-economic theory**
Knowledge	Embodied Situated Material Historical	Individual Rational Informational Propositional
Agency	Embedded in practice	Individualist Isolated Rational
Rationality	Socio-materially entwined	Objective Calculative
Technology	Enacted Constitutively entangled with practice	Pre-defined Determinative Predictive

Table 1. A comparison between practice theory and techno-economic theory

3.2 Knowing-in-practice

The intimate relationship between work practice (and thus organization) and knowledge has been emphasized and investigated by several organizational scholars. It has been suggested that understanding how work practices are accomplished and how they change necessarily involves examining the manifestations of practitioners' knowledge.

In delineating the association between practice and knowledge Gherardi (2008, p. 518) suggests three relations in which the phenomena stand:

- a relation of *containment*, in the sense that knowledge is a process that takes place within situated practices and in the relationships between practitioners belonging to communities of practices (Wenger, 1998).
- a relation of *mutual constitution*, in the sense that the activities of knowing and practising are not two separate phenomena but emerge in interaction between practitioners and their worlds (Cook and Brown, 1999).
- a relation of *equivalence*, in the sense that practising is knowing in practice, whether the subject is aware of it or not. Acting as a competent practitioner is synonymous with knowing how to connect successfully with the field of practices thus activated (Nicolini, 2011).

In further specifying the nature of knowledge as inextricably linked to professional work practice and organizing, two interrelated paradigms have been suggested in the literature. The first highlights the embodied nature of knowledge, the other its' socially and materially situated character. They are unified by a notion of knowing in practice that conceives of knowledge as "neither in the head nor as a commodity" (Gherardi 2006, p. 13). The following section explores these concepts and their relation to organizing.

3.2.1 Embodied knowledge in the organization of work

Practices can, as seen in section 3.1, be conceived of as routinized performances or enactments (Reckwitz 2002). As such, practices are constitutively dependent on the sayings and doings of the practitioners 'carrying' the practices (Schatzki 1996, 2002). When practitioners radically change the way they do things, that is, accomplish their work, the practices, as well as the knowledge with which practitioners perform their work, must be said to have changed. The performance of the actions comprising a

practice is thus guided by a knowing that is inseparable from practice (Orlikowski, 2002).

Knowledge is thus not conceived of as a fixed possession or mental structure in the heads of practitioners but rather as inherent *in* action (Schön 1983). This dimension of knowledge, or 'knowing' (to emphasize its active component) refers to "the epistemic work that is done as part of action or practice, like that done in the actual riding of a bicycle or the actual making of a medical diagnosis" (Cook and Brown 1999, p. 387). A medical student may, for example, remember the right answers to all exams but fail in the practice of diagnosing patients. Cook and Brown (1999) distinguishes between the possession of knowledge and knowing in practice and argue that:

> *To be accomplished in a profession, discipline, or craft, for example, is necessarily tied up with practicing it. This does not mean that its body of knowledge is useless to practice, only that it is not the same as the epistemic dimension of practice.* (Cook and Brown (1999, p. 387)

The relation between knowledge, action and practice described above is illustrated in figure 1. It should be noted, however, that the distinctions made between these concepts (as indicated by the partly overlapping graphic) are there merely for analytical purposes. Empirically and ontologically they are indistinguishable, i.e., they can only be studied together.

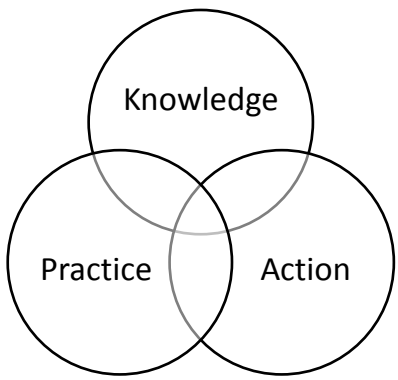

Figure 1. The relation between practice, knowledge and action according to practice theory

Ryle's (1949) distinction between know *that* and know *how* and Polanyi's (1957) emphasis on the tacit dimension of knowledge, have contributed enormously to the research on work practices. Both know-*how* and tacit knowledge can be understood

as dimensions of knowledge crucial in action but essentially irreducible to a codified, propositional or explicit form, that is, "knowing how to do something without being able to provide an adequate analytical description of it" (Gherardi 2006, p. 15). Know *that* and know *how* are interdependent but cannot be reduced to one another. Acquiring know *that* does not lead practitioners to being able to use it. Polanyi's distinction between tacit and explicit is exemplified in the practice of riding a bicycle. The knowing expressed in using a bicycle proficiently, could not be transferred to a novice merely by *describing* how to find the balance by moving the body in particular ways (although this could be a first step in learning how to ride a bike). The knowing in the practice of riding bikes, or any other practice, is thus more than can be translated into an instruction or made explicit in a rule or plan. Moreover, explicit knowledge is only meaningful when used "as a tool at the service of knowing", that is, as part of the actions carried out in practice (Cook and Brown 1999, p. 388). Following Ryle (1949), Brown and Duguid (2001, p. 204) argue that "to make know *that* useful requires appropriate know *how*, something thus very similar to Polanyi's tacit dimension". Practices are thus held together by knowledgeable actions while knowledge (both explicit and tacit) is dependent on and expressed in practice. This recursive relationship between knowledge and practice is an important assertion in practice theory. It implies that understanding or analyzing one of the concepts necessarily involves the other.

A concept related to tacit and embodied knowledge, proposed as an important dimension of work practice, is sensible knowledge (Strati 2003, 2007). Sensible knowledge is directly derived from and utilizes sensory faculties, such as hearing, vision, touch and smell. Strati illustrated the concept in empirical observations of the work of re-laying a steeply sloping roof. The men working on the roof were highly skilled and proficient in their footwork and manual dexterity. They performed several tasks at once, which required changing place and posture on the roof as the work progressed and moving across the roof in order to cooperate. They worked fast and rhythmically focusing their attention on the task at hand mostly using gesticulations and few words to communicate. Strati interviewed the workmen about their knowledge of re-laying roofs but received mostly vague and indeterminate answers referring to the importance of, for example, 'feeling the roof with your feet' or 'watch the others'. This was interpreted as indicating that an essential aspect of the workers expertise and knowledge was tacit, based in different forms of perception and that they only had subsidiary awareness of their methods and tools.

3.2.2 Socially, locally and materially situated knowledge

Tacit, sensible and embodied knowledge is not acquired or formed in isolation from the social context in which it is utilized but is shaped by interpersonal and material relationships in organizational settings and in society.

> *"knowledge is conceived largely as a form of mastery that is expressed in the capacity to carry out a social and material activity. Knowledge is thus always a way of knowing shared with others, a set of practical methods acquired through learning, inscribed in objects, embodied, and only partially articulated in discourse." (Nicolini, 2012, p. 5).*

Knowledge and learning are conceived of as social and cultural phenomena rather than as mental information processes residing in practitioners' heads. As argued by Nicolini et al. (2003, p. 3), "…knowing is situated in the system of ongoing practices of action in ways that are relational, mediated by artifacts, and always rooted in a context of interaction […] knowledge is thus acquired through some form of participation, and it is continually reproduced and negotiated".

Acquiring tacit knowledge, developing it in organizational settings, is, a social interactive process based on engagement in local communities of practice (Brown and Duguid 2001). When professionals gradually become members of a community of practice they simultaneously get access to and internalize the tacit knowledge required for participation. Novices gradually obtain access to the expertise of a community of practice by engaging in its activities. The participation is, however, only partial in the beginning but novices are given more responsibility for the common work product as they become more central members of the community. Learning to participate in a particular practice is thus a process involving the development of social membership and identity (Lave and Wenger 1991; Wenger 1998). When newcomers move from peripheral participation to fully legitimate membership in the community of practice they acquire tacit understanding of the patterns and implicit complex logic of the practice. This 'work-based curriculum' "allows newcomers to become competent members of the way defined by the specific organizational setting, connecting them with the results of the historical dynamics of the local setting of activities[…]the novice learns not only the specific skills of the profession or occupation, but also the local criteria of accountability, the specific set of values sustained by the community, and the local patterns of power relations, together with the proper strategies to cope with them." (Gherardi et al. 1998, p. 293)

Since learning is associated with social membership and identity, relations of power between practitioners become determinate for what is considered competent and expert participation. This notion of knowledge and learning thus brings light to the normativity of practice. Practitioners not only acquire knowledge but also a sense of what ends and projects ought to be performed, or what Schatzki has called a practice' teleoaffective structure. Practices are negotiated among practitioners as they participate and reify the meaning of their activities.

Tacit knowledge is thus simultaneously embodied in individuals of a practice and held together collectively through the enactments of a shared situated practice. This was illustrated by Cook and Yanow (1993) in their study of the production of handmade flutes, recognized, by musicians, as the best in the world. Several craftsmen worked on a flute for two weeks before it was done. During the construction of a flute workers, with different specialties, passed it back and forth between each other in order to adjust details on the flutes that they did not think had 'the right feeling' or 'did not look quit right'. With very little explicit guidelines (objective measurements and tolerances), the flute-makers work progressed by mutual judgements of hand and eye, that is, based on collective tacit knowledge. What the flute-makers knew collectively had been learned in that particular organizational context and could not easily be transferred to different settings (a flute-maker starting to work with another flute-making company had to re-learn many things). The ability to produce the flutes was clearly dependent on the know-how in the organization as a whole, not the individual members of the organization. Organizational learning is thus an activity performed by a group, which over time "creates a set of intersubjective meanings that are expressed in and through their artefacts (objects, language, and acts)" (Cook and Yanow 1993, p. 361).

The observation that most organizations require specialized knowledge pertaining to different problems imply that knowledge is locally developed in the practices of solving particular problems (Sole and Edmondson 2002). The localized knowledge is, furthermore, embedded in practitioners' accumulated collective experience, technologies, methods, and rules of thumb. Moreover, when the local embedded knowledge invested in practice proves successful "individuals are inclined to use that knowledge to solve problems in the future. In this way, individuals are less able and willing to change their knowledge to accommodate the knowledge developed by another group that they might be dependent on. Changing their knowledge means that

individuals will have to face the costs of altering what they do to develop new ways of dealing with the problems they face" (Carlile, 2002, p. 446).

One reason, thus, for the difficulties of sharing knowledge is that work practices are fundamentally dependent on practitioners' *local* knowledge, which "develops in interaction among people with the programs, operations or objects (physical artefacts) that are specific to a local context" (Yanow, 2004, p. 10). It is associated with the "very mundane, yet expert understanding of and practical reasoning about local conditions derived from lived experience." (Yanow, 2004, p. 11). This can be contrasted to abstracted and generalized models not referring to any situation in particular. Practice theory, however, opposes the possibility to isolate "a body of factual knowledge about the world" from "activity in and with the world" (Lave and Wenger, 1991, p. 33). Even so called general knowledge, i.e., abstract "scientific" representation, is only meaningful and has power when made specific in particular situations, that is, when judged to be relevantly applicable to the specific case at hand.

3.3 Agency and structure

A hallmark for practice theory is its rejection of dualisms such as sociality/technology, agency/structure, objective/subjective, actor/system, body/mind, stability/change and theory/action (Nicolini 2012). Practices are conceived of as spanning these dichotomies. Instead, the components of the dichotomies are recognized to *mutually constitute* each other, that is, to be inherently related in practice (Feldman and Worline 2016). The notion of mutual constitution implies "that social orders (structures, institutions, routines, etc.) cannot be conceived without understanding the role of agency in producing them, and similarly, agency cannot be understood "simply" as human action, but rather must be understood as always already configured by structural conditions." (Feldman and Orlikowski 2011, p. 1242). The social structure or system of an organization or workplace is thus recursively related to its practices, meaning that individual actions are as much enacting the structure as the structure is shaping the actions. Structure and agency is thus seen as a duality rather than a dualism of distinct phenomena (Giddens 1986).

Practice theory also emphasizes that human agency cannot be conceived without considering the things (artefacts, tool and materials) mobilized in activities (Svabo 2009). Things thus become what they are first when enacted through the very same activities shaped by the things (Fenwick, 2012). This implies that agency should not

be exclusively located in human agents but rather in the distributed assemblages, or seamless web, of human and technology.

3.4 Rationality and reflection

Another aspect of practice theory is the view on decision making, problem solving and rationality. The focus in practice theory is on *practical* rationality (Sandberg and Tsoukas 2011) or the "logic that is internal to specific recurrent activities, rather than viewing those activities from a detached outsider view." (Feldman and Worline, 2016, p. 306). Actions are made intelligible in practice, through a logic of practice and practical understanding structured by the embodied temporality of practitioners' entwinement with their world (Schatzki 1996; Sandberg and Tsoukas 2011). According to this view, intelligibility is embedded in the *life-world* of individuals. It is recognized that "we are always already intertwined with others and things as we engage in our activities and projects" Sandberg and Dall'Alba 2009, p. 1351). The concept of *life-world* refers to the phenomenological insight that "we are inevitably intertwined with our world through constant engagement in specific ways of being-in-the-world, such as cooking, driving, parenting, teaching, engineering and nursing. It is our ways of being-in-the-world that enable us to make sense of ourselves, others and things we use, deal with and encounter in our everyday activities." (ibid. p. 1354). Being-in-the-world, as fundamental for agency, is dependent on embodied know-how and shaped by the equipment used in practice. Moreover, "our relations with others structure the life-world, the social and contextual nature of knowledge into which we are socialized, and how our shared goals, motives and purposes guide our actions" (ibid. p. 1354). From a practice based approach, then, "agency is not seen primarily in terms of a person who acts in relation to a world but, rather, in terms of ways of being that are purposive and imbued with meaning for us." (ibid. p. 1357).

Drawing furthermore on phenomenological investigations of work practice it can be noted that reflection (or rational deliberation) on work that has already transpired normally only enters the scene when unhampered interaction is no longer possible due to some breakdown in the interaction (Dreyfus and Dreyfus 2005; Yanow and Tsoukas 2009; Sandberg and Dall'Alba 2009). In the normal flow of interactions practitioners' practical "understanding of situations is pre-reflexive…." (Nicolini et al. 2003, p. 9), an absorbed coping that is not mediated by mental representations (Dreyfus 1991) with only subsidiary awareness of the tools in use, disappeared from focus (Polanyi 1957).

However, practitioners do reflect-*in*-practice, that is, in the midst of action. In everyday recurrent work practice the professional practitioner encounters certain types of situations again and again. This repetitive and routine feature of practice might lead to a learned inattention to the things that do not fit with the knowing. Nevertheless, in situations where the interaction breaks down (e.g. the equipment stops working as usual) there lies a potential for reflection in action, where the practitioner can "criticize his initial understanding of the phenomena, construct new descriptions of it, and test the new description by an on-the-spot experiment" (Schön, 1983, p. 63), through a 'conversation' with the material situation at hand (Yanow and Tsoukas 2009). The fact that expert practitioners do not engage in explicit rational deliberation in normal operation should thus not be seen as a failure, as in techno-economic theory, but rather an essential characteristic of expertise.

3.5 On rules, plans and standards in practice

In most real-world situations, complex problems rarely appear as clearly defined, but rather as ill-structured, meaning that it is not clear for the actors in the situations what alternatives exist. The role of plans (as well as instructions, manuals and other formalized procedures) in organizational interaction and problem-solving has been problematized by researchers adopting the practice based approach (Brown and Duguid 1991; Feldman and Pentland 2003; Orr 1996; Lave 1988; Suchman 2007; Winograd and Flores 1986). Suchman, originally working on issues of human-machine-interaction, have argued that plans only play a role before and after action but only minimally during it.

> the [cognitivist] planning model confuse plans and situated actions, and [Suchman] recommend instead a view of plans as formulations of antecedent conditions and consequences of actions that account for action in a plausible way. As ways of talking about action, plans as such neither determine the actual course of situated action nor adequately reconstruct it. (Suchman, 1987, p. 3)

When it comes to actually solving ill-structured problems, plans do rarely help in guiding our situated actions. Plans, according to Suchman, merely express how we *reason about* action (before or after it has taken place), but does not constitute a generative mechanism of action.

Local interaction can thus not be fully described or understood in terms of rule-following or as plan-based and goal-oriented (Suchman, 2007). Accounts of

organization and work need also to consider "the contingencies which emerge during the execution of practical actions." (Heath and Luff, 2000, p. 11). Rules, plans and goals do not determine human, or organizational, conduct because they "depend for their accomplishment upon the ordinary abilities, practices and common-sense reasoning of individuals..." (Heath and Luff, 2000, p. 11).

The notion of practice, embedded in management standards (best practice), is in sharp contrast with the concept of practice recognizing the situated, embodied, collective and material nature of human action.

> "'Best practices' cannot simply be shared or transferred. Leaving aside the problematic notion of who decides what" best" means, practices are, by definition situationally constituted. They are not discrete objects to be exchanged or stable processes to be packaged and transported to other domains. Practices are generated through people's everyday action." (Orlikowski, 2002, p. 271.)

From a situated perspective, practices cannot be simply "spread around as if they were fixed and static objects" (Orlikowski 2002, p. 253). Real practices, have histories, are situated in particular social and cultural local contexts, they are embodied in the pre-reflexive know-how and shared understanding of practitioners and communities (Brown and Duguid 2001). Practices are inseparable from their carriers' (practitioners') situationally enacted capabilities.

Brown and Duguid (1991, p. 42) argue that espoused practices (or best practices, procedure, manuals, instructions and other prescriptive documentation) "inevitably smooths over the myriad decisions made with regard to changing conditions… [and] provide little insight into how ad hoc decisions presented by changing conditions can be resolved". Orr (1996) showed, in his influential study of service technicians, how these had to develop improvisational practices (shared narratives of how to fix broken photo copiers) for successfully executing their tasks that contradicted the manuals and instructions written by management, which simplified the task and assumed it to be a rote repair of identical machines that could easily be codified in instructions (Suchman et al. 1999; Brown and Duguid 1991). Conceived in this way, practices and organization cannot be reduced to formal system, instructions or plans.

3.6 Technology

The techno-economic view differs from the practice based approach also in its conceptualizations of technology. Assessments of the potential for increased energy efficiency in shipping routinely rest on analyses of purely techno-economical possibilities, referring to both technological as well as operational measures (e.g. Buhaug et al. 2009). The energy efficiency gap is then conceived of as the divergence between this technical potential and actual practice. It is assumed that once the intervening non-technical barriers (economic, organizational and behavioral) have been removed the technical potential can be achieved. As seen in the chapter 2, this conception of technical potential has been criticized because:

> "Technical potential which cannot be realised for a range of perfectly explicable sociotechnical reasons is not really technical potential, or at least it is not technical potential which is of any relevance in the race to reduce CO2 emissions" (Shove 1998, p. 1110).

The separation between technology and practice leads, according to the reviewed criticism, to inadequate analysis of technical potential, and hence of the energy efficiency gap, because the practical implications and effects of technology cannot be understood without also examining how technology is used, appropriated and reconfigured in practice (Moezzi and Janda, 2014). Whereas the techno-economic theory separates technology, conceived of as discrete entities, and its 'designed effects', from practice, where it is adopted and used, practice theory recognizes that the consequences of technology (organizational performance) are fundamentally dependent on the practice in the setting in which the technology is implemented (Barley, 1986; Orr 1996; Hutchins 1995; Suchman 2007).

From a practice based perspective, "technology results from the ongoing interaction of human choices, actions, social histories and institutional contexts. Technology is here understood as material artifacts that are socially defined and socially produced, and thus as relevant only in relation to the people engaging with them." (Orlikowski 2010 p. 131). Similarly, Suchman et al. (1999) re-conceptualize technologies *as* social practice, treating technology, not as predefined and determined entities, but as artefacts-in-use, that is, in relation to the circumstances and the practices in which it is embedded. Schultze and Boland argue for the importance of "understanding how information technology, organizations and practices shape each other." (2000, p. 194).

Since the relationship between technology and practice is understood as "constitutively entangled" in the above sense, it is not only the case that technology cannot be understood without considering practice, but also that practices cannot be understood without examining how it shapes practice. It is argued that the social and the material are never separated in actual work practices and that it is appropriate to replace "the idea of materiality as 'pre-formed substances' with that of 'performed relations', in order to characterize the recursive intertwining of the social and material as these emerge in ongoing, situated practice." (Orlikowski, 2007, 1438).

Moreover, according to the techno-economic theory, once technology, such as sub-metering and monitoring of energy consumption, is invested in and implemented, it will exert an exogenous force and be an "autonomous driver of organizational change and, as such, [have] significant and predictable impacts on various human and organizational outcomes, such as governance structures, work routines, information flows, decision making, individual productivity and firm performance" (Orlikowski 2010, p. 129). This deterministic view of technology has been forcefully rejected by several studies emphasizing the importance of the social shaping of technology (MacKenzie and Wajcman, 1985), the social construction of technology (Bijker, Hughes and Pinch, 1987; Woolgar and Grint, 1991; Bijker and Law, 1992) and the enactment of technology (Orlikowski 2000). From a practice based perspective, technology should neither be seen as determined by the "human factor", nor by the design of the technology. The human, social and technological dimensions are ontologically fused and are equally determinative of the effects and outcomes of their entanglement and mutual constitution.

> Rather than attributing agency either to individual actors (designers, engineers, team members) or particular technologies (computers, algorithms, graphics engines, networks), capacities for action would be studied as relational, distributed and enacted through particular instantiations. (Orlikowski 2010, p. 136).

The effect of introducing new technology in workplaces in order to change human practices has been problematized within the research field known as workplace studies (Heath and Luff, 2000). Experience in many different environments proves that computer systems seldom influence practice in predictable ways (Barely 1986). They can assist in the process but "any attempt to force change through the

introduction of a system with the characteristics of an operational 'strait-jacket' would be potentially doomed to failure." (Heath and Luff, 2000, p. 3). Heath and Luff argue for the importance of understanding "the ways in which individuals, both alone and in concert with each other, use tools and technologies in the practical accomplishment of their daily work… [how] new technologies feature in practical organisational conduct…the ways in which these tools and technologies, even basic information systems, are embedded in and depend upon practical activities within the workplace and the practices, procedures and reasoning of personnel…" (Heath and Luff, 2000, p. 4).

Orlikowski (2000) has presented an account of technology that emphasizes how it emerges from the enactments by its users. The position is not merely that technology (for example an IT-system) embodies certain designed structures (for, e.g., learning, communication, analysis) that users then appropriate in different, and sometimes unintended, ways but rather that human action "enacts emergent structures through recurrent interaction with the technology at hand." (ibid. p. 405). These structures 'are not fixed or given, but constituted and reconstituted through the everyday, situated practice of particular users using particular technologies in particular circumstances' (ibid. p. 425). It is acknowledged that "while users can and do use technologies as they were designed, they also can and do circumvent inscribed ways of using the technologies-either ignoring certain properties of the technology, working around them, or inventing new ones that may go beyond or even contradict designers' expectations and inscriptions." (ibid. p. 407).

In their situated accomplishments of work and enactment of technological structures, users draw on their previously developed collective skills and knowing, their negotiated norms and meanings and the intended functionality and properties of their technology. Over time, the enacted technological structures become routinized and habitual, which then recursively influence the ongoing accomplishments and work practices. This routinization can however, when institutionalized, become resistant to change (Tyre and Orlikowski 1994). The enactment of technological structures is, nevertheless, open to transformation precisely because it is constituted and re-constituted in everyday activities underpinned by practitioners shared understandings and negotiated meanings. As practitioners' taken for granted beliefs and local knowledge changes, it is also likely that their situated enactments of technological structures change. It is in the possibilities to do otherwise that the potential for innovation, learning, and change lies.

> Every engagement with a technology is temporally and contextually provisional, and thus there is, in every use, always the possibility of a different structure being enacted. (Orlikowski 2000, p. 412)

From this perspective, energy monitoring systems, do not embody, in themselves, the structures sufficient for establishing structured energy monitoring in shipping companies (onboard and onshore). These structures only emerge when users (participants in the organization) realize them through their recurrent and situated practices.

3.7 Summarizing the practice based approach to organizing

Practice theory can now be seen to differ substantially from techno-economic theory by emphasizing the social, embodied, historical, collective and material nature of organizing and management. It endorses a radically different view on organizational action, and by implication also on energy consumption and energy efficiency. The concepts of information and rationality which are at the core of the techno-economic theory, can now be seen to miss relevant dimensions of organizational action. Moreover, explorations of the social practices of energy management and improvements in energy efficiency differ from studies analyzing barriers, whether they are deduced from theory or grounded in empirical data. Whereas the conventional techno-economic framework of energy efficiency is directed at management systems, practice theory examines performed activities and its elements; understandings, meanings, procedures, engagements, competences, embodied habits, knowledge and rules. The distinction is thus one between studying structures as such and studying structures as *emerging* from particular process of ordering activities (Reckwitz, 2002).

The difference is embedded in more foundational epistemological assumptions of individual and organizational knowledge and behavior. Where techno-economic theory conceives of knowledge as an objective representation of reality, practice theory sees knowledge as a socially embedded and embodied process in which reality is constructed. From this perspective, studying action in relation to energy efficiency needs to take such processes into account and explore how the "truths" of the actors are created through their interactions and practices. The researcher's task is not to come with the verdict proclaiming whether practitioners understand the world as it 'actually' is, but rather to examine how knowledge about the world is created by those inhabiting it. It is thus important to study energy consumption as socially

constructed practices rather than the barriers to some theoretical technical potential or 'best practice'. Such an analysis can still uncover challenges to improved energy efficiency, but does so by exploring the inherent logic and social perpetuation of current but contingent ways of organizing. It means studying the opportunities and difficulties for energy efficiency as the result of the reproduction of present socio-technical systems.

Studying energy practices thus involves examining organizations and institutions as effects rather than causes and, more importantly, *as produced by* people and objects *in practices*, rather than merely as abstract constraints of behavior (of improving energy efficiency). Barriers to energy efficiency are, from a practice based perspective, the result of activities, performances and work. Understanding barriers requires thus an analysis of activities, performances and work. The contribution of the practice approach is to uncover that behind all the apparently durable features of the world there is always the work and effort of someone." (Nicolini, 2012, p. 3). The analytic framework of practice-theory focuses on how everyday activities are formed, developed, reproduced and changed. The contrast to the techno-economic framework which impels the researcher to search for barriers is thus clear; the practice based approach urges the researcher to interpret the practical intelligibility (what it makes sense for individuals to do) inherent in activity rather than merely labeling and categorizing barriers, or as expressed by Shove and Walker (2014, p. 47):

> "…accounting for change is not a matter of abstracting sets of forces or systems (e.g. of technology, economics, politics, etc.) but of detailing precisely how social practices, and bundles and constellations of practice, hang together, and of identifying the material and other arrangements amidst which they 'transpire', and which they also sustain and reproduce."

Investigating work and organizing from a practice theory perspective involves "describ[ing] important features of the world we inhabit as something that is routinely made and re-made in practice using tools, discourse, and our bodies. From this perspective the social world appears as a vast array or assemblage of performances made durable by being inscribed in human bodies and minds, objects and texts, and knotted together in such a way that the result of one performance becomes the resource for another." (Nicolini, 2012, p. 2).

The study of practice thus "requires attention to the mundane detail of everyday life so as to uncover the local habits, assumptions, taken-for-granted context and tacit knowledge that members of the social group have difficulty articulating" (Schultze and Boland, 2000, p. 195). Or as argued by Nicolini, "the study and theorization of practice must start with zooming in on the real-time practising as an organized set of doings and sayings carried out using a variety of tools and mediatory resources." (Nicolini, 2009, p. 1400).

4 Methodology and methods

Within qualitative approaches to the study of social and organizational phenomena it is commonly acknowledged that the theoretical underpinnings of a study, together with the research questions, should be reflected in the methodology (Silverman, 2014). Given this study's aim of exploring the practices (conceived of as situated phenomena, see ch. 3) onboard ships in order to get a better understanding of energy consumption and hence energy (in)efficiency in shipping, it was appropriate to choose a context-sensitive methodology, that is, one that allowed collection of naturally occurring data and enabled investigation of the local constitution of the social phenomena, without imposing any preconceived operational definitions (variables). A common misunderstandings of qualitative methodology is that it is exclusively concerned with the subjective experience or how people 'see' things. Instead it is possible to use qualitative methodology to understand how social phenomena are constructed in particular contexts by looking at and listening to "the activities through which everyday actors produce the orderly, recognizable, meaningful features of their social worlds" (Holstein and Gubrium, 2008, p. 375). For this reason, an ethnographic case study (Hammersley and Atkinson, 1995) approach was used to explore in-depth the contextual dimensions that influenced the social phenomena under investigation (the organization of energy efficiency), grounding the hypotheses and research trajectory in the data analysis and staying open to possible interpretations (Charmaz, 2014).

4.1 Research setting and project background

The research setting for the conducted case study was an international maritime transport- and travel service company with more than 5000 employees and the most comprehensive network of routes in Europe. The company was deemed to be an interesting setting for a case study about the social and organizational aspects of energy efficiency in shipping because of its alleged concern about sustainability. Notwithstanding the nearly 300 energy efficiency improvement projects since 2005 (including a fuel management system supposedly used for performance analysis onboard), an energy target of 2,5 % annual reduction of carbon dioxide, and an environmental training program for employees, the company still believed that more could be done to save energy. One particular area which the company had pronounced as challenging was what was called 'crew energy behavior'. Some company managers believed that there existed variation in the energy performance of crews'

and thus contacted Chalmers University of technology to convey that they would welcome a research project that investigated this in depth. After the funding for the project by the Swedish Energy Agency was approved and some initial meetings with the company it was decided that the field study was to be mainly carried out onboard five ferries (out of the company's 36 ships) carrying passengers, freight, cars, trucks, lorries, trailers and coaches, and trafficking the Danish strait connecting the Baltic sea to the North sea through Kattegat, Skagerrak and Oresund. Most of the field work (observations and interviews) took place at the navigation bridge and the engine control room, but also at car decks, engine rooms, messes, crew offices, crew cabins, and other places where crew members lived and worked.

The case study approach (Yin, 2013) used in this research project aimed at generalizing the findings to theoretical propositions about the organization of energy efficiency, developed through the analysis, rather than to the whole population. Qualitative research methods usually depend on purposive theoretical sampling rather than statistical sampling (Silverman, 2014). Flyvbjerg (2006) has argued that generalizability is a matter of selecting an appropriate case, for example one that has "strategic importance in relation to the general problem" (Ibid. p. 229). The case used in this study was deemed as critical because it involved a company that supposedly cared about sustainability (they had set up energy targets, a whole department only working with energy efficiency upgrades, installed fuel management systems on most of their vessels, and launched environmental training programs) but that nevertheless experienced challenges with 'variable crew energy performance'. The case was thus relevant for in-depth analysis of the practice and organization of energy efficiency because it could be excluded that any of the challenges found would be the result of share ignorance (low priority) or a lack of initiatives on the part of the company as a whole. Moreover, the claim, often made in analyses of the so called energy efficiency gap in shipping, that the primary reason for it is the lack of performance monitoring and information sharing between ship and shore (Poulsen and Johnson, 2016), could now be tested since the company did in fact have a system for analyzing performance and sharing information.

4.2 Literature review

In order to direct and narrow down this research project's goal of investigating the human and social dimension of energy efficiency in shipping an effective literature review was needed. The review was guided by three questions (Silverman, 2014).

- What is already known about the topic?
- What can be said critically (gaps, limits, shortcomings) about what is already known?
- Where does my work fit in what has gone before and what is worth doing?

The literature review of this study started with identifying and analyzing the research that had been conducted on the topic of energy efficiency in shipping. However, it soon became obvious to me that very few studies existed that examined the human, social or organizational aspects of energy efficiency. Neither was energy consumption explicitly covered or scrutinized by the applied research discipline known as maritime human factors, which mainly deals with safety and design (Grech et al., 2008). It was thus necessary to broaden the sources for this thesis and one of the aims of it became to bring together and cross-fertilize different research traditions and topics. Suspending my reading of research in shipping for a while, I entered the more general field of energy studies, in particular energy consumption and energy management, guided by a broadly social science perspective. Interested in the social and organizational dimensions of energy use, rather than the purely psychological processes of decision making, I also reviewed some of the latest trends and topics in organizational theory (by reading well cited text books, eminent journals and attending PhD courses covering the discipline). An interesting theme soon appeared in both the literature in energy research and organizational theory; practice theory. Social and human phenomena, such as action, knowledge, meaning, learning, were not understood in terms of individualistic or structural factors (informational, economic or technological determinants), but rather as transpiring in the production, reproduction and change of everyday practices at work and in the private life. I saw it as a great opportunity to make a scientific contribution by using the practice lens for empirically investigating an issue in a research context (energy efficient shipping) that had previously mostly been preoccupied with technical potential and market failures, overlooking the social practices influencing energy consumption and determining innovation, improvement and change. The interweaving of theory and method from different research areas was also seen to potentially benefit the broader field of energy research, in which I wanted to situate my research. The current practice based energy research was seen to focus primarily on domestic settings and could therefore be expanded by using a case of work in a shipping organization. Moreover, the practice based approach in organizational theory was seen to be more developed than in energy research which made it relevant to try to advance energy research also on a theoretical level by introducing some of the analytical resources

from the former tradition into energy research. In sum, the literature review thus had the dual role of helping me to define the academic context and research questions of this research project as well as giving me a set of theoretical and methodological resources utilized throughout the research process and writing.

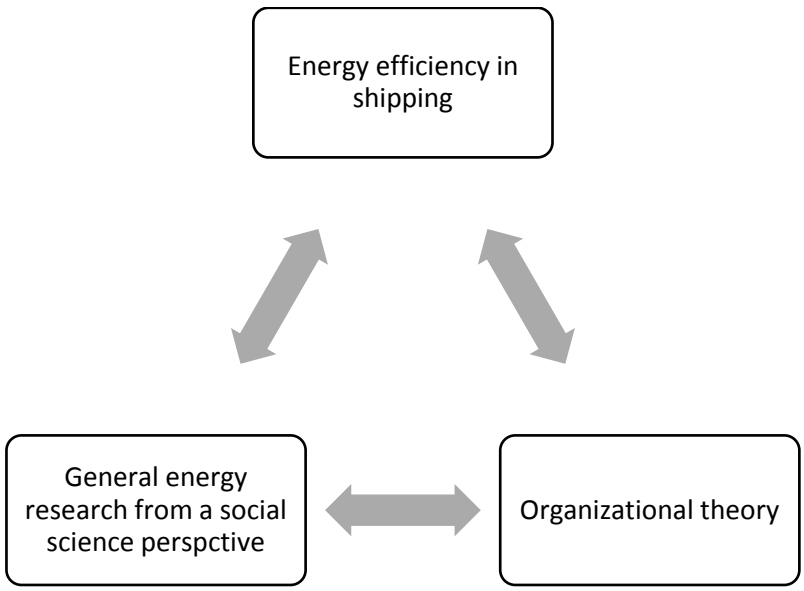

Figure 2. The fields of literature utilized in the thesis.

4.3 Data collection

The collection of the data was based on a multi-method approach comprising observation, interviewing, document analysis, and examination of the use of artefacts (Eberle and Maeder, 2016). The data was collected on recurrent visits onboard the five ships and focused on the cycle of work starting before voyages (e.g. cargo planning and loading, engine preparation, unmooring), during the execution of voyages (e.g. harbor maneuvering, open sea navigation) and after voyages (unloading of cargo, administrative and maintenance tasks). The focus of the study was the practices of the crew in two departments. The deck department included Captains, Chief Officers, 2nd Officers and 3rd Officers, and the engineering department included Chief engineers, 2nd engineers, 3rd engineers. The main locations of data collection included the navigating bridge and the engine control room, however, the

shadowing (Czarniawska, 2007) of crew members brought the researcher to many other places onboard such as car decks, offices, messes, and many other compartments where crew members worked and lived. Approximately 195 hours of observation were spent onboard the ships during the data collection phase. In addition to the observations, semi-structured interviews were held with 40 crew members (captains, officers, Chief engineers, engineers). The interviews lasted between 30 to 120 minutes and covered questions related to the crew members' work with energy efficiency, the technology they used and the challenges they perceived in improving energy efficiency. Field notes from the observations and recordings from the interviews were transcribed. The documents collected for analysis included company policies, energy efficiency management plans, safety management system documents and sustainability reports.

Additional 9 semi-structured interviews were also conducted with four managers (one technical operation manager, one safety & environmental manager, one network and fleet manager, and one energy saving project manager), one production & capacity analysts and four energy saving project leaders in the shore office at the company's headcounters. Since the primary interest in this study was the work practices onboard the ships these interviews only had a complementary role in the field study and mainly had the purpose of giving me some insights about the shore office employees' perspective on crew members and whether there had been any energy saving initiatives, projects or other organizational measures, launched from the shore office, to change or control the practices onboard.

4.4 Analysis

The adoption of a practice based approach to the study of the organization of energy efficiency onboard ships does not specify in advance any particular empirical issues or topics to analyze. Instead it only directs the research to a certain unit of analysis (i.e. organization-as-practices) and provides a conceptual frame of interpretation of the collected data. Nevertheless, the analysis of all the transcribed data was guided by three basic questions derived from practice theory, with particular emphasis being put on the second and third.

What was actually done, or not done, onboard the ships with the purpose of improving energy efficiency?

How was the organization of energy efficiency, produced, if at all, by the actors' everyday practices?

Why were the practices the way they were, i.e. how did the socio-material context shape the performed practices?

Adopting a constructionist agenda (Holstein and Gubrium, 2008) I was interested in understanding how the 'social reality' onboard the ships was produced, assembled and maintained. The conceptualization of social reality as something constructed through peoples' practices and artefacts is essential to the practice based approach described in chapter 3. Again, although practice theory served as sensitizing framework it did not determine the analysis *a priori*. Instead, the empirical issues in this study, as described in the three papers, were discovered during the analysis using a grounded theory-inspired methodology (Charmaz, 2014).

However, the rich body of data collected during the field study soon revealed that a number of different (although interconnected) themes could be found. How to carve up the analysis and present it in the papers was, to a certain extent, an arbitrary decision, or at least one having many answers. For this licentiate thesis I choose to go deeper into three topics as reflected in the papers: the role and use of fuel management technology onboard the ships (paper I), the social, embodied and situated nature of knowledge in energy efficient ship operation (paper II), and paradoxes in energy practices (paper III).

4.5 Credibility: validity and reliability

The quality and credibility of qualitative research depends on validity and reliability. Given the fact that qualitative research often depends on 'naturally occurring data' and not replicable experiments, the notion of reliability in qualitative research differs from that in quantitative research. Silverman (2014), following Clive Seale (1999), suggest that low-inference descriptors, involving "recording observations in terms that are as concrete as possible, including verbatim accounts of what people say" (Seale 1999; 148), can be used to assure reliability in qualitative research. The analysis presented in the papers of this thesis were therefore illustrated with direct citations of the interviewees in order for the reader to get a sense of the relation between the data and the analysis. Moreover, being explicit about, and describing, the theoretical models guiding analysis is another way of making the research transparent, and hence credible, to the reader. The extensive theoretical chapter of this thesis is meant to serves this purpose.

Validity, i.e. "the extent to which an account accurately represents the social phenomena to which it refers" (Hammersley, 1990, p. 57), was ensured by the

constant comparative method which is characterized by attempts to search for cases through which to test a provisional interpretation of the data or hypothesis induced from it, in particular by looking for deviant cases, that is, cases that do not confirm the hypothesis (Silverman, 2014).

The collection of data on the five different ships contributed to the validity of the results because it allowed the use of the constant comparative method. Although the data collected on each of the ships was treated as self-sufficient and independent from the data derived from the other ships, the final analysis of the practices of energy efficiency was the result of comparing the themes in the ship-specific data.

Triangulating the data and methods further contributed to the validity. As described above, the multi-method approach comprising observation, interviewing, document analysis, and examination of the use of artefacts allowed a comparison of different types of data (talk, action, text, artefacts and technical equipment). This was considered important given the focus on practices, which as described in chapter 3, consists of all these things. Moreover, only relying on interviews is problematic given the acknowledged difference between espoused theories and theories-in-use, i.e. what people report to be the basis of their actions and the explanations inferred from how people actually behave (Argyris, 1976).

Furthermore, the analysis of the onboard practices was compared to the interviews with managers, conducted in the shore office at the headcounters of the company. This enabled a more balanced view and avoiding extreme accounts portraying managers as ‘ignorant dictators’ or crew members as ‘ignorant and lazy’.

The constant comparison method was also applied within the cases of the individual ships as the recurrent field visits, with intermediate data analysis, allowed testing hypothesis emerging from already collected data, and then directing observations to particular phenomena and asking specific questions during the next visit.

The data collected onboard the five ships was also compared with additional 14 interviews (lasting 30-60 min) conducted with masters, officers and engineers, as well as observations (during one voyage lasting 6 h) on another ship operated by another company. This was made in order to test for differences between shipping companies and to increase the probability that the findings in the main company wasn’t ‘just local phenomena’.

Two limitations of the research design should be mentioned. The strong emphasis on validity in this study, by including several settings to be compared and a large number of interviews on different ships, was made at the cost of an in-depth focus on only one ship (and its practices). Such a focus might have resulted in a deeper understanding of the particular practices found onboard and possibly in a slight difference in analysis. Moreover, the use of mixed methods (including quantitative data) might have complemented the analysis by, for example, comparing the ships' energy efficiency. However, notwithstanding the complexity of such an analysis (involving the differences between the ships' design, and contingent factors such as wind, currents and cargo load varying on every voyage), it is unclear how such a quantitative analysis would have complemented the qualitative data analysis. The aim of the study was, after all, not to 'prove' what non-technical 'factors' 'cause' a certain level of energy efficiency, but rather to understand how the *organization* of energy efficiency onboard ships is constructed through practices.

5 Result

5.1 Paper I

The purpose of the paper was to explore the practices of energy performance monitoring and analysis onboard ships. Given the great promise, attributed by previous research and policy, of changed operational practices by the availability of information and energy performance data, the research question addressed in this paper was what role this information can have in changing operational practices onboard ships. How is energy performance data integrated into the everyday practices of ship operation? The results showed, however, that the availability of fuel-meters and computer programs facilitating access to information was not enough for integration in practice. The lack of use of performance monitoring equipment was dependent on social practice that were not adapted to numerical analysis of the numerous variables monitored. A number of different issues were seen to contribute to the infrequent use of the newly installed fuel management system (performance monitoring tool).

First, although the importance of energy efficiency was acknowledged by all crew members, the task of analyzing past voyages quantitatively, i.e. with the use of data from the fuel management system, was not part of what the crew members perceived to be their profession. The analysis of data was conceived to be a shore office duty whereas crew members' tasks mainly involved the operation of the ship. As soon as a voyage was completed the next one was prepared and thus little attention was paid to the performance of already executed work.

Second, the interpretation of the data collected by the fuel management system was perceived by many to be challenging as the high variation in fuel consumption could be related to a large number of dynamically interacting factors. Moreover, what parts of the collected data (as well as additional factors known to influence fuel consumption) to analyze and use in practice was also a matter of contestation and uncertainty. The form in which the data was presented to the crew (either as a real-time value of an isolated variable, or as the variation of some variable plotted over time) abstracted from the mode of thinking characterizing officers action-in-practice and reflection-in-action. Consequentially, the abstracted data was perceived to be incommensurable with the situated, embodied and holistic understanding of ship operation enacted in practice.

Third, the practice of monitoring and analyzing performance was furthermore seen to be inhibited by social boundaries within and between the deck and engineering departments onboard. While engineers could access a wide range of monitored parameters related to energy consumption they were generally hesitant to comment on the operational practices of the deck crew (officers and masters) since this would have implied a transgression of professional domain and authority.

Finally, although the formal requirements of having a fuel management system onboard were fulfilled, and some crew members had been sent to a one day course about the system, no attempts were seen to have been made, by the shipping company, to introduce performance monitoring and analysis into the everyday practices onboard.

5.2 Paper II

The purpose of this paper was to explore the nature of the skills and knowledge enacted in the practice of operating ships with the intention of performing energy efficiently. The paper narrated the ways in which officers drew on their situated knowledge about the ship and the route in order to adjust the speed such that peaks in fuel consumption could be avoided. Officers' embodied experience of how the ship worked and reacted in different weather conditions and water depths, together with their understanding of how the ship was performing at the time and expectations of how the weather and depth would change, guided their decisions about the optimal speed at each particular moment of the voyages. Officers emphasized the importance of developing an understanding of the ships limitations and dynamics, and hence the span of actions influencing energy consumption, by interacting with the ships equipment and technology under different conditions. This process of learning for energy efficiency was however a time consuming one and depended on collective social engagement. New officers, even if they had worked on other ships and were thus experienced, were introduced to the local practices onboard each ship and learned the locally developed 'theories' of how to operate energy efficiently. Social engagement was also important for crew members' motivation to collectively develop their practices and try out different strategies in order to reduce fuel consumption.

5.3 Paper III

The purpose of the third paper was to expand the practice based approach in energy research by introducing cultural-historical activity theory as a framework for analyzing heterogeneous practices in complex socio-technical contexts. It is argued that previous energy research adopting the practice based approach has focused too much attention on the integrated and coordinated nature of practices. Instead it is demonstrated in this paper, how recognition of the contradictory and paradoxical nature of ordinary activity might highlight important aspects of organizational practice related to energy consumption. Applying cultural-historical activity theory to the interpretation of the data collected in this study revealed that the work onboard the ships was guided by contradictory objectives reproduced by misalignments between the elements of the activity system. Tensions between the goals of energy efficiency, safety, commercial objectives, profitability, punctuality and customer service permeated everyday practice and could not easily be resolved without a more radical re-mediation of the instrumentality (tools, rules and division of labor) of the activity system.

6 Discussion: Towards a social practice theory of energy efficiency in shipping

This thesis has taken the first few steps towards a practice theory of energy efficiency in shipping. The picture emerging from the findings has characterized the organization of energy efficiency onboard ships as an ongoing situated accomplishment performed by humans acting as members of communities of practice, shaping and shaped by activity systems structured by objects and mediated by a heterogeneous instrumentality. The following highlights some of the key dimensions of the organization of energy efficiency identified in this thesis.

6.1 The organization of energy efficiency as situated action and practical knowledge

The operational task of ship energy efficiency was seen to be very complex and requiring a highly knowledgeable crew, cooperation in action and co-ordination of navigational and engineering competence. Understanding of how to operate the complex technical ship energy system in an energy efficient manner, given its dynamic interactions between sub-systems and components as well as with external conditions, was seen to depend, less on formal plans, technical models or 'scientific rationality', and more on the experience, or 'practical sense', developed collectively and through constant interactions with and testing of the ships systems and technology in practice during operation (**paper II**). This collective experience was, for example, manifested in the ways officers navigated to avoid peaks in the fuel consumption by adjusting the speed to the expected wind and current. The skill of speed adjustment (aiming at an even fuel consumption in spite of constantly varying resistance) was seen to depend on officers situated action and embodied knowledge about the ship (e.g. the ship's behavior in different weather conditions and safety as well as power limitations with different numbers of engines). It also rested on local knowledge about water depth and frequently encountered traffic situations along the route. The knowledge was, moreover, acquired and enacted in interaction with the particular technology and equipment available on each ship. Learning how to navigate energy efficiently was thus highly dependent on understanding how to engage with the technical, physical, operational and institutional context. The

knowing-in-action developed and expressed in the work practices onboard the ships is an example of what Cook and Brown (1999) describe as a process lying in the dynamic affordances of interaction with the social and material world. According to this concept, interaction with the social and material world dynamically affords the knowing required for action. Schön's (1983) concept of 'backtalk' and 'conversation with the materials of a practice' also captures this essential feature of the officers' knowing-in-action. Yanow and Tsoukas (2009, p. 1348) exemplified backtalk by writing that "an architect, a planner, or an engineer is constrained by the physicality of the materials used in designing an object or of the setting within which it will be situated, and these physical elements have a way of 'talking back' (Schön, 1987, p. 31) to the designer – resisting – when what she wants to do with those materials or on that site strains them beyond their limits". In a similar fashion, the physical elements (technology, ship, external environment) had a way of talking back to the officers as they navigated. Understanding the ways in which the materials made resistance during interaction constituted the knowing-in-action enacting the practice of navigation.

The practical knowledge of 'energy efficient navigation' was not isolated from the social context but depended on (was acquired through) interaction and mutual engagement between officers and was thus historically-culturally anchored (Gherardi, 2012). This was illustrated in **paper II** by the process of familiarizing new officers with the practice and characteristics of the ships as well as the differing ways in which the crews on the five ships performed, or enacted, their skill of dynamic speed adjustment. Although all relied on situated actions, that is on officers' understanding of the ship and perception of the signals emitted by the surrounding environment, the navigational strategy expressed in action, and developed over the years, differed between the ships. The historical-cultural anchoring of the onboard practices also highlighted the reciprocity between the practical knowledge directed at action, and the materiality, embedding part of that knowledge. This was, for example, seen in the event when the master and the chief engineer on one of the ships convinced the shipping company and the designer of the ship's speed pilot to add the function of regulating the speed directly via engine power. In this case it could be seen how the practical knowledge (crew's dissatisfaction with installed technology) mobilized a change in materiality (adding of function) which further developed the practical knowledge of officers (the skill of estimating required engine power). Moreover, once the practical knowledge *invested* in the practices on board the ships became entrenched it also became more resistant to change (see Carlile, 2002 for a

similar analysis of knowledge). The role of practical knowledge was thus seen to involve a paradox; while it was clearly crucial for successful work onboard, enabling crew members to spontaneously and non-deliberately engage with the work, it also had a conservative dimension concealing alternative, an possibly more energy efficient, ways of action. By being routinized and habitual, i.e. entwined with the world, the ways of being, the lived body, the being with others, and the equipment (Sandberg and Dall'Alba, 2009, p. 1355), the knowledgeable actions of crew members disappeared from their conscious reflection. This phenomena is well known in phenomenology and illustrates that "as a practice is learned, the tools of that practice tend to 'disappear' from focus – to become transparent or 'available' (Heidegger, 1962) as part of one's subsidiary, background material" (Yanow and Tsoukas (2009, p. 1350).

6.2 The organization of energy efficiency as the enactment of technology and distributed cognition

Work practices, and hence the organization of energy efficiency, are not determined by technology, rules or tools as illustrated by the case of the performance monitoring system installed onboard and the ship energy efficiency management plan (SEEMP). Instead, the use of technology was seen to depend on its alignment with the primary practices (activity system) of voyage execution.

This was illustrated by the findings of this thesis showing how the performance monitoring system onboard the ships failed to integrate with the crew members' practices because of the traditional conceptions of professional identity, the system's inadequate reliance and expectations on crews' tasks, knowledge and understanding, disruption of main tasks and goals, social boundaries with a strict division of labor and authority, and divergent interpretations of the system's indented use and the company's intention of installing it. In other word, the design of the system (requiring a shift in practice from operation to analysis) and the manner in which it had been implemented onboard by the shipping company (perceived by the crew as an attempt to control them), undermined and conflicted with the established activity system (including its object and division of labor) and resulted in a low adoption and use.

Following Orlikowski (2000), it can be argued that the findings support her assertion that technology emerge as having certain structures and properties only by being "enacted through the recurrent use of a technology. The structures and properties are not embodied within the technology; rather, they emerge from the ongoing and

situated interactions that users have with the technology at hand" (Orlikowski, 2000, p. 420). Previous research on energy monitoring in shipping has not made a sufficiently clear analytical distinction between technologies as artefacts and their use. This thesis has shown that treating energy performance monitoring technology as having certain structural or organizational consequences in themselves, might result in disappointment and wasted money. Granting the importance of analysis of energy performance for improvements in energy efficiency this thesis has suggested that the distribution of cognitive processes (Hutchins, 1995) required for analysis of complex energy systems is crucial for the enactment of energy management systems directed at the everyday operation of ship. Conceiving of energy management in terms of distributed cognition emphasizes the socio-material nature of the practices required for energy performance analysis and improvement.

The thesis is thus arguing for a re-conceptualization of the role of information, rules and plans on energy performance in changing operational practices. In the techno-economic theory of energy efficiency it is often assumed that information is neutral and objective, and that rules and plans constitute the primary mechanisms for organizing. However, the relation of information, rules and plans to practice is rarely problematized. The findings of this thesis suggest that the role of information and energy monitoring technology could be better understood if it was conceptualized as requiring enactments and if energy management systems were not attributed with pre-determined effects (**paper I and III**). Rather than seeing information, rules and plans as dispassionate or disinterested entities structuring the organization of energy efficiency it is crucial to acknowledge these as features of situated accomplishments (practice) which are constitutively entangled with cognitive and cultural-historical processes of work activity.

6.3 The organization of energy efficiency as heterogeneous object and contradictory activity

In **paper III** it was suggested that the organization of energy efficiency onboard the five ships could be understood as mediated activity unfolding around a heterogeneous and conflictual object. The object of a practice (activity system) was described as the defining, meaning-producing, and motivating goal of particular instances of work. Being both a material and a symbolic construction, the object of an activity is always fragmented and conflictual. This was clearly the case onboard the ships as the object (the socio-materially co-constituted motivation) of the activity, which structured, guided and organized the practices onboard the ships, was found to be a

heterogeneous, multiple, complex and sometimes conflicting constellation of means, ends and goals. In other words, the organization of energy efficiency was seen to form a nexus together with many other practices constituting ship operation. By focusing on how the different practices forming the activity system onboard related to and constrained each other it was possible to gain a better understanding of the challenges of improving energy efficiency. Moreover, the misalignments between the mediating elements of the activity system (technology, rules, division of labor and communities of practice) further illustrated the inherent tensions of the organization of energy efficiency onboard the ships.

The thesis has also illustrated how practices are sustained by normative conceptions about what to do, how to do it and who should do it. In **paper I** the professional identity of officers, perceived as 'operators of ships' and not as 'analysts of data', influenced how they view their role as users of the performance monitoring system. Engineers, on the other hand, who did identify with the role of 'analyzers of energy systems' did not perceive it as being their role to interfere with the operational decisions made on the bridge (including the number of engines used). **Paper II** highlighted 'local speed adjustments and foresight' as the 'most efficient way of navigating' which was something all officers felt they were expected to do. In **paper III** the notion of the object of activity also contained a strong normative dimension as this notion referred to the 'reasons structuring the activity', highlighting both agreement and disagreement. Schatzki (1996) made an association between the normative and the affective, or emotional, dimension of practice in his concept of teleoaffective structure. This connection was expressed onboard the ships, for example, as the masters' need to 'feel safe' by using extra engine power in harbor maneuvering. The normative dimension of the onboard practices was identified by focusing on the practical rationality or practical intelligibility inherent in practice.

The findings imply that analyses of work on energy efficiency in shipping companies (and onboard ships) should not be isolated from the broader texture of practices carried by practitioners. The mutual constitution of practical knowledge, technology, rules, division of labor and communities within the organizations onboard the ships did not only present a novel understanding of organizing in shipping it also resulted in a new way of understanding the challenges related to energy efficiency.

The findings suggest that in addition to the necessary implementation of energy management systems, shipping companies in charge of crews should focus on local capacity building and encourage the development of knowledge-sharing onboard

ships, in particular between deck and engineering departments. Performance monitoring technologies will inevitably have an important role to play in this but it is likely to require changes in the practices of crew members. The implementation of technology thus does not eliminate the need for altered ways of working in which fuel consumption has a more prominent role in the decisions onboard.

7 Conclusions and suggested future research

This thesis focused on practices, both as an empirical phenomena (the organization of energy efficiency onboard ships) and as an epistemological approach going beyond problematic dualisms such as action/structure, cognition/action, mind/body (Gherardi, 2012). Its main contribution lies in opening up a new research avenue about energy efficiency in shipping and illustrating the value of understanding organizational phenomena *as* practical-knowledge activity. This perspective has been contrasted to the traditional techno-economical perspective emphasizing management systems, barriers, (bounded) rationality and which has been criticized for reducing organizing to planning, monitoring and informational flow. Adopting a practice based perspective, the ethnographic field study onboard the five ferries revealed a number of interrelated aspects of the organization of energy efficiency onboard the ships.

- The role of practical (embodied and situated) knowledge for officers' and masters' strategies of energy efficient navigation (**paper II**)
- The role of the social and cultural-historical context for the adoption and use of particular technologies (**paper I**)
- The often conflictual relations between the elements constituting an energy intensive activity system (**paper III**)

By studying how ordinary work was practically accomplished (Gherardi, 2012) it was possible to gain some deeper understanding of the organization of energy efficiency onboard the ships. This highlights the importance of focusing on practices for the understanding of how industry can become more energy efficient.

This thesis suggests that the organization of energy efficiency cannot be reduced to a flow of information, as often assumed by traditional perspectives. To the extent that the energy efficient operation of a ship is a feature dependent on the joint action of a ship crew working together (energy efficiency is not determined by a single crew member), it is also a matter of a collective activity of acquiring the organizational know *how* of energy efficient ship operation. Even if information about the technical potential of existent energy efficiency measures was widely distributed and acknowledged in shipping companies, this is not sufficient, according to the argument and findings in this thesis, for improvements in onboard operational practices. What

is needed, is the development of the dimension of knowing that is *part of the actions* of accomplishing operational energy efficiency. More than a flow of information, what seems to be required for efficient operation is the development of knowledge.

Moreover, the thesis has shown that part of the energy efficiency gap in shipping (lack of full implementation of the identified measures for improving energy efficiency) is likely to derive from local contradictions in the everyday practices of crew members and other actors. Future improvements are therefore likely to be dependent on local initiatives and developmental work inside shipping companies that address and resolve the particular conditions inhibiting progress.

However, many more questions remain to be answered. The quest for a practice based theory of the organization of energy efficiency in shipping has just begun. An important research question is how change towards more energy efficient shipping should be understood? This thesis did not study an explicit project concerned with changing operational practices towards improved energy efficiency but rather the mundane and everyday work onboard ships and the role of energy efficiency in it. However, an important future research area is the processes of change and in particular the role of technology and practices in it. It is therefore suggested that more research is needed to explore organizational processes of work practice change. In particular, studies investigating the 'situated' development of collaboration and knowledge in shipping companies and the ways in which technologies-in-practice can facilitate that, are important for the understanding of how shipping can become an environmentally sustainable industry.

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