Chapter 2
Literature Review

Abstract In the book's second chapter, a background related to design energy efficiency improvements and their connection to the maritime regulatory framework is presented. Consequently, a subsection is devoted to the types of charter party agreements that are commonly used within shipping and a brief on the parties' duties is provided. Then, a short discussion on the barriers that could inhibit the introduction of the design energy efficiency improvements is given.

2.1 Preamble

Although the energy saving potential of new technologies would be higher than the one offered by existing ones, the substitution of the latter by the former could be delayed albeit to proven results. The adoption of new energy efficient technologies is followed by further competence building entailing that previous expertise becomes obsolete and familiarization efforts are required (Mulder 2005). Moreover, the acceptance of new technologies is governed by each user's risk perception on performance. These obstacles could be overwhelmed when the regulations are shaped towards addressing not only safety, security and environmental protection standards, but also nurturing innovation, growth and advancement needs (Herzenstein et al. 2007).

2.2 Design Energy Efficiency Improvements

In response to tackling the climate change in maritime transport, amendments to the MARPOL Convention were adopted in July 2011 and were entered into force in January 2013. To this end, a new chapter containing regulations aimed at improving the energy efficiency of vessels was added on Annex VI, the dedicated part of the Convention related to the prevention of air pollution from vessels. These changes made mandatory the introduction of the EEDI for new vessels which is concerned

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with design improvements. Furthermore, they stipulated the establishment of a mechanism for all vessels (SEEMP) in order to use operating measures that improve the energy efficiency of the vessel and requirements for survey and certification, including the format for IEEC (IMO 2012a). During the EEDI's development, conducted research (Kristensen and Lützen 2012; Ozaki et al. 2010) was associated with this regulation's thorough analysis and such technical detail will not be covered herein.

The EEDI regulation is believed to be a proactive performance based mechanism designed to induce technical measures for improving the energy efficiency of vessels and represents an expression of CO_2 emissions per ton-mile of transport work. Its non-prescriptive nature is attributed to the fact that the industry players are free to choose the optimum combination of energy saving technologies, as long as the required energy efficiency level is attained and compliance with the regulation is obtained (Otsubo 2015). In defense of this view, Chang (2012) and Smith (2012) concluded that for a long term solution to the issue of shipping emissions, the regulations need to address energy efficiency in the design of vessel engines and hulls. Besides, the effects of the application of the new technologies need to be taken into consideration without affecting basic vessel design parameters such as deadweight capacity and speed (Chang 2012; Smith 2012). Intuitively, these parameters are vessel and trade specific, thus embrace distinctive characteristics of an ocean freight service. Hence, through the EEDI, it should be attempted to thrust ship-owners to invest in vessels that have state of the art technologies for reducing fuel (energy) consumption and should not be interpreted to penalize vessels with higher installed power. Then, the operation of the vessel is affected by the SEEMP which supplements EEDI and impacts the fuel (energy) consumption (Stevens et al. 2015).

Additionally, it is asserted that with the input of industrial stakeholders (equipment manufacturers, shipbuilders, ship-owners, verifiers, etc.), technology roadmaps for exploring potential benefits and challenges of radical new developments or retrofit options can be identified for different types of vessels (Gilbert 2014; Vergara et al. 2012). It is also recognized that such flexibility, sets the requirements and inherently specifications for future vessel designs albeit to the feedback from new vessels allowing a dynamic change on the required EEDI and thus stringent control (Ančić and Šestan 2015). The latter will be facilitated through the need to demonstrate the performance of each technology in terms of (reduced) energy usage for a given vessel under a range of operational scenarios and environmental conditions (Calleya et al. 2015). Further lines of argument have been urged by Devanney (2011) to design vessels that are capable of attaining the contracted speed (albeit to the allowable margin) during market peaks, including heavy weather and without reaching the engine's limits in order to avoid any machinery failures. Reference is given to vessels with large propeller diameter (hence increased propulsion efficiency) due to a combination of large bore size (translated into higher power per cylinder), lower rotational speeds and greater fuel economy (Devanney 2011).

2.2.1 Design Energy Efficiency Specification

Energy efficient technologies concerned with the vessel's design can be categorized depending on their characteristics and effects on EEDI, i.e. reduction of main engine and auxiliary power in terms of fuel consumption (IMO 2013):

1. Reduction of main engine power:

- Cannot be separated from overall performance of the vessel;
  - Low friction coating,
  - Bare optimization,
  - Rudder resistance,
  - Propeller design.
- Can be treated separately from the overall performance of the vessel;
  - Hull air lubrication system (an air carpet is created beneath the vessel's hull via air injection to reduce frictional resistance—it can be switched-off),
  - Wind assistance (sails, Flettner Rotors, kites—subjected to wind condition).

2. Reduction of auxiliary power:

- Effective at all time;
  - Waste heat recovery system (exhaust gas heat recovery and conversion to electric power).
- Depending on ambient environment;
  - Photovoltaic cells.

Although the reader may argue that the aforementioned technologies are far-fetched, recent research in conjunction with simulated experiments as well as full scale trials provides evidence that some of them can be adopted in short term, while others need refinements and adjustment of production capacity to lower their costs. For instance, this is quite relevant for hull air lubrication where up to 13% of net energy savings have been recorded (Fukuda et al. 2000; Mizokami et al. 2013; Kawakita et al. 2015; Kumagai et al. 2015). However, a lower energy saving potential has been observed (4%) for other technical improvements such as propeller design and hull coating (Armstrong 2013). This result coincides with the duct (Kim et al. 2015) as well as rudder with bulb and fins appendages (Hai-long et al. 2016) predicted propulsive efficiency from simulated calculations. With respect to the other technologies, only desk studies have been published and it is worth pointing out the efforts of Fujiwara et al. (2005), Luyu et al. (2010), Traut et al. (2014), Viola et al. (2015) for wind assisted propulsion, Lindstad et al. (2013), Marzi and Gatchell (2012) for hull optimization, Livanos et al. (2014) for waste heat recovery and Glykas et al. (2010) for photovoltaic cells.

Table 2.1 Upper bound of the fuel savings that may result from the implementation of different measures

Technology/design improvement	Fuel efficiency gain (%)
Low friction coating	<5
Bare optimization	<9
Rudder resistance	<4
Propeller design	<4
Air lubrication	<15
Wind assistance	<25
Waste heat recovery	<10
Photovoltaic cells	<4

Source Fulton et al. (2009)

Description of the energy saving equipment is contained in the EEDI technical file, where the potential energy saving (i.e. reduced percentage of fuel consumption) is indicated for modifying the design of existing installations, replacing existing equipment or adding new equipment and modifying the operating conditions of an existing installation (IMO 2012b). Admittedly, it is challenging to track the energy saving potential and in the absence of any tangible results the following tentative values can be realized as shown in Table 2.1. It is claimed that when these measures are combined, an overall up to 20–30% reduction in CO_2 emissions on average from the existing fleet can be anticipated (Fulton et al. 2009). It should be emphasized that this uncertainty nurtures the need for transparent monitoring of efficient vessel operations where the collation of real time data can be fed up into bottom up models for quantifying more accurately the energy usage on-board vessels (Gilbert and Bows 2012).

There is indeed evidence to support the latter statement by the initiative of industrial players to equip vessels with data acquisition systems installed within the machinery and navigation systems. The purpose is firstly to monitor the performance of their fleets along various routes and verify the simulated results during the vessel's design phase as well as provide a cornerstone to comply with the requirements of the SEEMP (Marty et al. 2012; Baldi et al. 2014; Perera et al. 2015; Fun-sang and Caprace 2015; Bialystocki and Konovessis 2016; Deligiannis 2016). Secondly, to develop a methodology for benchmarking and analyzing real time measurements based on probabilistic methods (Petersen et al. 2012; Sasa et al. 2015; Trodden et al. 2015; Bocchetti et al. 2015; Meng et al. 2016; Kakuta et al. 2016; Orihara et al. 2016). As a matter of fact, much more visibility, clarity and scrutiny than ever before can be immortalized by such evolvement, and with no exaggeration, simple regulatory compliance will not be adequate in the future. Essentially, in turn this may acquaint the business and economic benefits (i.e. enforce performance guarantee and energy efficiency specification clauses) of design improvements between charterers and owners as well as facilitate better communication of the financial benefits which can be expected from installing energy efficient technologies (Rehmatulla and Smith 2015a).

2.3 Types of Charter Party Agreements

From a functional point of view (i.e. volume of cargo to be transported from one location to another or the need for an extra vessel for a period of time) the freight market has two different types of transaction. One is the *freight contract* (voyage charter) in which the shipper or charterer buys transport from the ship-owner at a fixed price per ton of cargo. The second is the *time charter* (contract) under which the vessel is hired by the day with the length of the hire taken to complete a single voyage (trip charter) or a period of months or years (period charter) (Gorton et al. 2009; Stopford 2009). The freight contract suits players who prefer to pay an agreed sum and leave the management of the transport, hence commercial risk to the ship-owner (spot market). The time charter is for experienced ship operators who prefer to manage the transport themselves and it creates the business of industrial shipping based upon the charterers' decision to carry the commercial risk (Stopford 2009). There are other types of contracts such as contract of affreightment or consecutive voyages which correspond to a hybrid form of voyage charter; whereas the bareboat or demise charter amounts to the lease of the vessel from the owner to the charterer. The latter is really a financing arrangement and it is not related to the use of the vessel for transporting cargoes (Gorton et al. 2009; Stopford 2009).

To this end, it is not unreasonable to suggest only two types of contracts for the carriage of goods by sea since from the inaugural work of Pirrong (1993) it is reported that long term contracting is interchanged between spot deployments. In addition, the contractual specificities depend on the characteristics of the cargo flows, the nature of the markets for the transported commodity, the geographic dispersion of supply sources and the characteristics of the vessels employed in that trade. For instance, there is little incentive to haggle over the services of an obsolete vessel when her contract expires because the quasi gains are trivial (Pirrong 1993). Similarly, it is advocated by Nomikos and Giamouzi (2013) as well as Fagerholt et al. (2010) that vessels are allocated by considering the best performing contract (whether a spot or a period arrangement will be signed or extended) not only in terms of profitability and avoidance of significant freight rate risks, but also accounting for strategic positioning aspects. For example, during a market upturn, ship-owners prefer chartering their vessels under (short) voyage contracts as opposed to time charter contracts (thus maintaining resource flexibility). Though at the same time, charterers switch to hire vessels under (lengthy) time charter contracts as opposed to voyage contracts (preferring thus resource commitment) (Axarloglou et al. 2013). What is really remarkable however, is that, fuel consumption as perceived to be correlated to technology advancements, was found to be completely unrelated to time charter rates during buoyant market conditions. Thus, different consumption rates impacting on charterers' costs mattered only marginally for contract rates (Köhn and Thanopoulou 2011).

The commercial operation of a vessel always involves certain costs and responsibilities which are allocated in a slightly different way under the type of charter, as shown in Table 2.2. Under a voyage charter, the ship-owner contracts to

Table 2.2 Allocation of costs and responsibilities under voyage and time charters

		Voyage charter ($/t)	Time charter ($/day)
Voyage costs	Despatch/demurrage Loading/discharging Stevedoring/trimming Port charges, fees Cleaning holds Cargo claims Canal transit dues Bunker fuel Other voyage expenses	Costs that may be shared in different ways	Costs of the charterer
		Certain costs to be paid by charterer	
		Costs of the owner	
Operating costs	Wages Provisions Maintenance Repairs Stores and supplies Lube oil Water Insurance (Hull, War, P&I) Overheads		Costs of the owner
Capital costs	Capital repayment Interest on own and borrowed capital Depreciation on invested capital Brokerage		

Source Gorton et al. (2009) and Stopford (2009)

carry a specific cargo in a specific vessel for a negotiated price per ton which covers all the expenses incurred during the voyage, such as voyage (including cargo handling and port/canal charges) costs, operating costs and capital costs. The time charter is an agreement between owner and charterer to hire a vessel, complete with crew, for a fee per day, month or year. In this case, the ship-owner is responsible for the capital and operating costs, whereas the charterer pays all incurred expenses associated with the voyage (Gorton et al. 2009; Stopford 2009).

In an attempt to balance the interests of the ship-owner and charterer, as well as the fact that sea trade is performed internationally albeit to special and hazardous conditions, where it is practically impossible for one party to supervise the work of the other daily, legal regimes (i.e. Hague-Visby Rules, Hamburg Rules, Rotterdam Rules) were enacted to govern the contracts for the carriage of goods by sea (i.e. bills of lading). This development introduced a set of contractual duties which was to be used as a base for performance (Dockray and Thomas 2007; Singh 2011). The implied duties cover seaworthiness, care for the cargo, deviation, reasonable dispatch and not to ship dangerous cargo, whilst for the first three exempting liability must be transparently attained. The suitable incorporation of the Rules into the charter party is secured by a clause paramount, or setting out sections of the Rules

in the charter party, or the provision that any set of Rules that applies to any bill of lading issued under the charter party shall also apply (Baatz 2014; Todd 2016).

2.4 Barriers on Implementing the Design Energy Efficiency Improvements

As it has been shown from Table 2.2, due to the different responsibilities and costs allocated in voyage and time charters, the carrier or ship-owner (agent) and the shipper or charterer (principal) are not provoked into a steady implementation of design energy efficiency improvements. In essence, this can be explained by the fact that the two players have different profit maximization goals from the trade-off between the cost of energy efficiency and the cost of measuring the performance. Moreover, assessing the vessel's performance accurately within a practical amount of time (i.e. contract's duration) insurmountably creates uncertainty for curbing any varying levels of cost sharing (Eisenhardt 1989; Jensen and Meckling 1976). To further elaborate on this point, it is asserted by Sorrell et al. (2004) as well as Fleiter and Plötz (2013) that owning to constraints on time, attention and the lack of ability to process information that may lead to cost effective opportunities, the players do not make decisions in the manner assumed in economic models (i.e. life cycle cost consideration). As a consequence, additional costs related to management overheads, information collation and analysis may not be accounted for, thus implying uncertainty and lack of confidence (bounded rationality). In turn, the players may neglect energy efficiency opportunities, even when given good information and appropriate incentives are available or even known (Sorrell et al. 2004; Fleiter and Plötz 2013).

The latter constitute an important reason why energy efficiency improvements can be hampered. The most prominent example of split incentives is the investor—agent/user—principal dilemma, where the carrier or ship-owner—agent is responsible for building the vessel, but the shipper or charterer—principal under a time charter contract receives the benefit in the form of lower energy bills. In this case, the agent would not receive a financial reward for the expensive energy efficiency improvements. On the other hand, the principal, who would receive the benefit and thus have an incentive to install energy efficient equipment, does not own the vessel and cannot install it (Sorrell et al. 2004; Fleiter and Plötz 2013). Convergence of such inconsistent objectives would create agency costs being translated into incentives, whereas a premium (remuneration) would be required to compensate for these additional costs (Arnold 2010; Watson and Head 2013).

To attach more credibility in bounded rationality and split incentives, the works of Balland et al. (2015), Jafarzadeh and Utne (2014) as well as Rojon and Dieperink (2014) were based on interviews with shipping experts, where it was concluded that the absence of objective and verified data in combination with the harsh economic climate were inherently forcing short term survivability. Hence, such behavior

clearly inhibits any motivation for investing in design energy efficient improvements. Similarly, Lun et al. (2014) and Agnolucci et al. (2014) concur that the emphasis on operational efficiency in the current charter party agreements for enforcing warranties and legal legitimacy weaken the promotion of information monitoring systems as well as the cooperation between principals and agents concerning energy efficient equipment. However, from the perspective of contractual complexity, agreements encompassing only performance measures may induce the agent to engage in dysfunctional action, i.e. maximize own margins and dampen the incentive of paid bunkers, which is not necessarily in line with the principal's objective of minimizing transport cost (Baker 1992).

Armstrong and Banks (2015) suggest that although the industry is acquainted with such information systems, still the lack of shared goals and objectives between commercial and technical stakeholders (principals and agents) prevents the realization of energy efficiency. In this respect, reference is given to the misconception of performance monitoring. Voyage performance has more "commercial" nature related to voyage cost minimization, revenue maximization and efficient vessel utilization. Whereas, vessel performance has more "technical" nature and is associated with hull and propeller condition so as to plan the appropriate maintenance activities (Armstrong and Banks 2015). Additionally, energy efficient technologies are impeded with the information from performance monitoring equipment remaining imperfect due to absence of any reliable benchmark for crediting the energy saving potential (Poulsen and Sornn-Friese 2015). Therefore, it is plausible that the technologies will be selected based on the trade-off between bunker price and equipment cost, rather than their energy saving potential (Stevens et al. 2015).

In general, any agent would like to reimburse the energy efficiency investment expenditure, but such effort can be obstructed by the commercial imperatives of the observed chartering practice (see Sect. 2.3). It is not rare that costly technologies cannot be implemented to some types of charter contracts either due to short duration, or lack of control over operations. Moreover, the negotiated price does not mirror the economic benefit of the claimed fuel efficiency, even if the vessel is resold (Rehmatulla and Smith 2015b). To further reflect on that, the advantages granted by trading on the spot market (flexible employment) do not allow acute recognition of energy efficiency. Admittedly, the realization of fuel savings is a time consuming process which can take years of assessment and evaluation, whilst such charters usually expire long before these effects can be genuinely diagnosed. By contrast, vessels trading under long term contractual relationships (bareboat and long period charters); have experienced tremendous energy efficient performance (Poulsen and Johnson 2016). Though, the latter is attributed more on operational initiatives rather on implementing design measures where the principal may not be willing to share the cost with the agent. Instead, the agent may not be directly rewarded for energy efficiency, but at least it is likely to improve the possibility of winning a charter and obtain better fleet utilization. Nevertheless, principals gradually have given emphasis on the agent's energy efficiency and in some cases have influenced the vessel's design (installed wind assistance and air lubrication system).

However, the time charter duration is too short (usually half to one year) for recouping the investment which may require a longer payback period (Rehmatulla et al. 2015).

Knowing that long term contracts (time charters) are fit for incentive screening through their performance clauses and short term contracts (voyage charters) allow a better matching between the abilities of agents and the needs of principals (Macho-Stadler et al. 2014), it is necessary to provide a mechanism that specifies in detail the agent's characteristics (energy efficiency specification and costs). This should be subject to the available evidence (energy reduction potential) and their relationship is not only emerged through profit maximization (incentive compatibility), but also is blended with general utility aspects, i.e. greener lifecycle performance (Page 1991; Ochs and Roth 1989). The extent to which such undertaking (i.e. inclusion of clauses related to the design energy efficiency equipment specification of the vessel and investment sharing) is plausible will be argued in the fourth chapter.



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