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Energy efficiency in maritime logistics chains

1. Introduction

Energy security is high on the political agenda of many countries, and only in recent years has the debate on how to improve the energy efficiency of international transportation included the shipping and port industries. As far as shipping is concerned, its international nature and the fact that ocean-going vessels have one of the highest energy efficiency per tonne of cargo transported among all transportation modes implied that the fuel consumption attributable to the maritime industry was not a priority for national security. The exceptionally high fuel prices experienced between 2009 and 2011, however, have brought attention to the economic repercussions of increasing operating costs. This situation is aggravated by excess vessel supply and the emergence of *slow steaming*, i.e. the practise of sailing at slower speeds, as a measure to reduce operational costs, with clear implications on international trade (e.g. Maloni, Paul and Grigor, 2013).

In the port sector energy efficiency and consumption were not perceived as a consequential topic during the last decades of sustained growth of throughput and expansion. However, in the current environment of economic challenges, a changing geography and structure of trade, and greater awareness and demand for sustainable logistics, the topic of energy efficiency has come to the forefront of academic and industry discussion. Furthermore, societal and political pressures to reduce the external effects at local and global level, particularly of emissions, have further contributed to the growing relevance of the topic (Acciaro, 2015).

Energy efficiency is, in fact, intrinsically linked to the pressures and efforts to reduce the greenhouse gas emissions of the logistics and transportation sector. According to the *Third* IMO *Greenhouse Gas Emission Study* (IMO 2015), over the period 2007–2012, average annual fuel consumption attributable to the global shipping fleet ranged between 247 million and 325 million tonnes of fuel, where the difference between the two estimates reflects the use of top-down or bottom-up estimation methods. International shipping accounted for between 201 million and 272 million tonnes per year. Based on these figures international shipping emissions for 2012 are estimated to have reached 796 million tonnes of CO_2, representing between 2.2 and 2.9% of global CO_2 emissions.

While overall CO_2 emissions are falling in many other sectors, emissions from transportation are still expected to rise in the future as freight transportation activity is expected to expand further over the next decades (ITF, 2015). In particular emissions from ships are likely to increase and become an even higher portion of global GHG emission (Anderson and Bows, 2012). This is the main rationale behind the widespread, albeit often unsuccessful, attempts to develop regulation to reduce energy consumption and provide incentives to the implementation of energy efficiency measure at a global, regional and local level (Miola, Marra and Ciuffo, 2011) as attested by the adoption of Emission Control Areas within the IMO and the efforts of the European Commission to regulate on shipping and aviation emissions.

Although emissions within the port sector are a negligible portion of global transportation emissions, their reduction has a significant impact on air quality locally, especially for sulphur oxides (SO_X) and particulate matter. In addition, improving energy efficiency within the port contributes to the reduction of energy consumption, that can benefits the local energy balance, and favour the development of renewables within the port (Acciaro, Ghiara and Cusano, 2014). Moreover, a reduction in energy consumption has direct impacts on emissions along the supply chain, allows reducing logistics costs and, in particular in developing regions, contributes to energy security (Asif and Muneer, 2007).

Technology and innovation offer a promising avenue to improve energy efficiency in maritime logistics chains (e.g. Miola, Marra and Ciuffo, 2011; Acciaro et al. 2014). Similarly to other industries, however, a number of measures that would improve fuel efficiency have yet to be fully implemented despite their known cost efficiencies, creating what is often referred to as the *energy efficiency gap* (Johnson et al., 2014). There is also an emerging literature on the barriers to energy efficiency that explain the limited adoption of some of the available measures (e.g. Acciaro, Hoffmann and Eide, 2013). Sorrell et al. (2004) groups these barriers into risk, imperfect information, hidden costs, access to capital, split incentives and bounded rationality.

The challenges in implementing innovative technologies and the adoption of effective policy measure are a clear example of the complexity of dealing with energy efficiency in maritime logistics chains. Such complexity often requires integrating multiple perspectives, including that of economics, political science, marine biology, engineering, naval architecture and management, and energy efficiency in maritime logistics chains certainly benefits from an interdisciplinary dialogue.

Because of the limited number of interdisciplinary studies and the only recent emergence of the scientific debate on energy efficiency in maritime logistics chains, several challenging questions are still unanswered. How is and should energy consumption be measured? What assumptions should be used in the energy consumption estimation and in what circumstances should actual consumption values be considered? How does the fundamental transformation of maritime transportation, notably the rise of maritime logistics and multimodal supply chains, affect the research and estimation of energy consumption and efficiency? What are the synergies and trade-offs between reducing emissions and energy consumption? What is the role of the human factor in favouring energy efficiency and the implementation of greener technologies? What role should policy play and what regulatory instruments are available to ensure a faster uptake of energy efficiency technologies?

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In view of the above challenges, this volume investigates energy efficiency from a variety of academic and multidisciplinary viewpoints and provides an in-depth, although by necessity incomplete, discussion on measures, strategies and concepts that would improve energy efficiency in shipping and ports. The publication of this volume is based on the understanding that energy efficiency has the potential of improving the sustainability of maritime logistics chains, and that experiences and research can play a significant role to progress the current and future debate in the industry and among policy makers.

The remainder of this editorial discusses the current state of research, relating it to the discussions of the papers presented in this volume, and advances from the "sea" to the "shore" finishing with a logistics perspective.

2. Energy efficiency along maritime logistics chains

The importance of energy efficiency also in the maritime sector is intrinsically related to the development of the energy markets given the dominance of fossil fuels in transportation, and the role of the future availability and prices of fuels. An important consideration is also that energy commodities are one of the main types of cargo transported on board of ships and therefore any discussion on energy efficiency in shipping cannot proceed without consideration of the trends in the energy markets. The contribution of Thanopoulou and Strandenes (2015) in this volume presents mid and long-term scenarios of energy trends and relative energy price reversal and their impact on the configuration and potential volume developments of fossil fuel seaborne trades. The authors argue that fossil fuel dependency will continue despite technological innovation and question existing forecasts and scenarios as they are "by nature incomplete" since many factors cannot be quantified or even defined. In their discussion they also raise the relevance of interdependence of different fuel prices, using for example the current low oil price as having significant repercussions on the profitability of shale oil and shale gas, which also negatively impacts the economic viability of investment programmes in alternative fuels or renewable energy sources.

The importance of fuel prices is exemplified by the fact that fuel consumption accounts for over half of total ship operating costs, and ship operators and owners are making efforts to maximize the potential of every tonne of fuel burned. Notwithstanding this move towards fuel efficiency, the sector is constantly under pressure to find new and better ways to optimize its operation (Fitzgerald et al., 2011). Given the past and expected evolution of maritime trade in terms of volume and the expected structural changes in perishables trades, absolute reductions in fuel consumption and emissions from the industry are not expected despite the new regulations (Bazari and Longva, 2011; Anderson and Bows, 2012; Monios and Wilmsmeier, 2013).

Greater awareness of sustainability, fuel costs, stricter emission regulation, and the introduction of *Emission Control Areas* (ECAs), have stimulated the search for ways to improve the energy efficiency in the sector and have resulted in the development within the IMO of the *Energy Efficiency Design Index* (EEDI) that should allow for improvements in the sector's energy performance over time. Several proposals were discussed within the IMO Maritime and Environmental Protection Committee (MEPC) related to the so-called *Market-Based Measures* (MBM), but the debate on these measures seems to have come to a standstill. Despite the fact that some authors (e.g. Faber et al., 2015, Lindstad, Sandaas & Steen, 2014) argue that ship designs have improved significantly over the last years and often outperform EEDI reference values, Stevens et al. (2015) in this volume, develop a framework on the dynamics of fuel consumption showing the influences of the engine, the propeller and the hull of the ship. They emphasize the relevance of taking a more systemic viewpoint when discussion new regulation as "*just changing or adjusting the engine is not enough!*" (Stevens et al. 2015: p. 11).

A wide array of technical and operational measures is available to improve ship fuel efficiency. Advanced ship design and technical measures that reduce fuel consumption in a cost-efficient way have brought to the market highly efficient marine engines and power trains, optimized flow profiles around the hull, rudder and propeller, and innovations such as the bulbous bow (Rizet et al., 2014, Auvinen et al., 2014, Blinge, 2014, Evangelista, 2014). Still, it is not unusual for individual ships to consume up to 30% more fuel than necessary due to imperfect design, poorly applied propulsion technologies, or an inadequately maintained hull and propeller.

High expectations on energy performance from technical improvements are also found in a report for the MEPC of IMO, which estimates that design measures could potentially reduce CO_2 emissions by 10% to 50% per unit of transportation work.[1] Knowledge of the fuel-saving potential of technical measures related to hull and propeller geometry, hull construction, propulsion machinery, auxiliary machinery and equipment, heat recovery, cargo handling, and alternative energy sources is, in general, good within the industry. There is a long tradition of development and research in these areas and the improvement potential is estimated to be, on average, a small percentage of fuel savings in each category.

Among the operational measures, one of the main determinants of fuel consumption is vessel speed, an area widely researched in the maritime and engineering literature. This theme has been the subject of extensive discussion in the last few years as shown in the literature reviews carried out by Psaraftis and Kontovas (2013, 2014). In this volume, Schøyen and Bråthen (2015) analyse in the context of short sea shipping the economic linkages between operational planning and energy efficiency. Their results depict how systemic approaches, which on the one hand consider vessel sailing speed, port time, sailing time ratio and cargo capacity utilization, and on the other hand are complemented by information sharing between deep sea and feeder operators as well as port actors, can deliver towards significant energy and cost savings. They also argue that the coordination between port operations and vessel operations will influence port turnaround time for vessels and also allows to expandexpanding slow steaming en route.

A remaining challenge is to increase knowledge of how the different technical systems on a ship interact with one other and how they are affected by operational practises. Such knowledge is needed in order to enhance waste heat recovery or efficiently reduce the use of electricity on board, which are highly effective measures for overall energy economy. Ships have long lifetimes and modifications and retrofits to existing ships are more expensive than new designs. A further complication relates to the emission life-cycle assessment, especially in the case of alternative fuels (Fridell et al., 2013).

The sector has nonetheless taken voluntary steps, with some major players having made large investments in energy efficiency technologies. Although the uptake of new technologies is slow in shipping (Acciaro, Hoffmann and Eide, 2013), research on alternative sources of power, such as Liquefied Natural Gas (LNG) or fuels cells is well underway, and operational measures such as slow steaming have become somehow common practise in the industry (Cariou, 2011, Fridell et al., 2013). In addition to the multitude of technological advances, the impact of fuel prices (especially bunker prices) on the cost effectiveness of new technologies is often underestimated. Particularly, the volatility of bunker prices makes it very difficult for ship-owners to project the development of the fuel costs and negatively influences their willingness to take risks (Stevens et al., 2015); this is underlined by Faber et al. (2012) who argue that speed mainly depends on the market situation and bunker prices (see also Cariou, 2011 and more recently Lindstad, Asbjørnslett and Strømman, 2015).

In addition to efforts to reduce fuel consumption and CO_2 emissions from shipping, regulation covering other pollutants is being

[1] The transportation work is calculated by multiplying the ship's capacity as designed with the ship's design speed measured at the maximum design load condition and at 75% of the rated installed shaft power. Speed is the most essential factor in the formula and may be reduced to achieve the required index (IMO, 2011).