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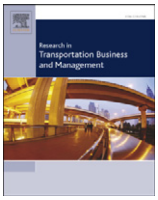

Reducing GHG emissions from ships in port areas

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ABSTRACT

Climate change has recently received more attention in the shipping sector. This is mainly due to a growing demand for reduced global emissions and the fact that shipping is one of the fastest growing sectors in terms of greenhouse gas (GHG) emissions. In parallel, ports have started to introduce programmes and policies to address these emissions.

This study aims at quantifying potential reductions of ships' emissions of GHG from efforts implemented by ports. Building on a model that calculates GHG emissions from ships in various scenarios for individual ports, different kinds of measures for emission reductions are investigated for diverse types of vessels and parts of the port area. A case study of the ship traffic to the Port of Gothenburg is performed. Projections of ship emissions in the port area for 2030 are made, and three scenarios, '1. Alternative fuel', '2. Ship design' and '3. Operation', are analysed. These scenarios are related to a business as usual development. GHG emissions from ships in the port are projected to increase by 40% to 2030 in a business as usual (BAU) scenario. The highest reductions were seen in the 'Operation' scenario where GHG emissions were 10% lower than the BAU level.

1. Introduction

International shipping contributes with approximately 2.4% of global anthropogenic greenhouse gas (GHG) emissions, and its share is expected to increase in the future (International Maritime Organization, 2014). GHGs from shipping include mainly carbon dioxide (CO_2), methane (CH_4) and dinitrogen oxide (N_2O), of which CO_2 dominates the global warming potential. In addition, ships emit also other gases with climate impact such as black carbon which has a warming potential and sulphate particles which have a cooling effect. The goal to keep the increase in global mean temperature below 2 °C, as agreed upon in the Copenhagen Accord (UNFCCC, 2009), is becoming more and more difficult to reach since global action has been slow and all greenhouse gas emitting sectors would need to decarbonise to a high degree within a few decades. Energy efficiency measures are important to implement in order to decrease fuel use, but significant reduction in GHG emissions can be achieved only by the replacement of fossil fuels with renewable fuels. Energy efficiency can be defined by the relationship between the benefit or performance of a service and the energy input. By this definition, there are measures that reduce the GHG emissions of a service that do not necessarily increase energy efficiency. Changing from a fossil fuel to a renewable fuel is one example of this, as the amount of energy input does not necessarily change at a fuel shift. Fossil fuels store carbon from the atmosphere for long-term time horizons. The hydrocarbons in fuels from renewable sources, biogenic fuels, store carbon for short-term time horizons and CO_2 originating from these sources will not influence the long-term build-up of CO_2 in the atmosphere. In this paper, the term GHG reduction measure is used to describe both energy efficient measures and measures where fossil CO_2 is replaced by biogenic CO_2.

Environmental impact from international shipping has traditionally not focussed on climate change. The reasons are, according to Gilbert and Bows (2012), more obvious local pollutants such as nitrogen and sulphur oxides; the omission of shipping from national inventories under the Kyoto Protocol; its importance in globalisation; and its reputation as the most energy efficient mode of transportation. Main topics for discussions have instead been, for example, the usage of toxins in antifouling paints, release of non-indigenous species with ballast water and fouling, noise, and emissions of combustion gases and particles to air. However, the problem of climate change has received increased attention in the shipping sector (Gibbs, Rigot-Muller, Mangan, & Lalwani, 2014). One important reason for this is that the global community has recognised the need to reduce global emissions and the fact that shipping is expected to become one of the fastest growing sectors in terms of greenhouse emissions, along with the aviation sector (Gilbert, Bows, & Starkey, 2010).

There has in recent years been a focus on slower speed at sea in order to reduce fuel consumption, and there has indeed been a significant reduction in CO_2 emissions per transport work as a consequence of slow steaming. However, the average speed of the world fleet depends foremost on freight rates and on the bunker price (Faber, Nelissen, Hon, Wang, & Tsimplis, 2012; Smith, 2012). There is thus a risk that ships will speed up again and that emissions will increase when freight

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rates rise in times of prosperity. There has also been a focus on improved ship design, for example the development of the energy efficiency design index (EEDI) at the International Maritime Organization (IMO).

Only relatively recently, ports have started to introduce specific programmes and policies to address greenhouse gas emissions (Gibbs et al., 2014). These programmes are important since a significant share of CO_2 emissions from shipping are derived from the time the ships stay in ports. Emissions from ships at berth have been estimated to approximately ten times greater than those from the ports' own operations and there is a greater potential to reduce GHG emissions from ships in port than from port activities on the landside (Habibi & Rehmatulla, 2009). Villalba and Gemechu (2011) calculated emissions in the port of Barcelona and found that the emissions of GHG from the port area originated in equal amounts from the ships and from land-based activities. Gibbs et al. (2014) also consider the impact of the hinterland traffic, and found that its emissions are substantially less than from shipping, but higher than emissions from the port operations.

There are several arguments for ports to address CO_2-emission reductions for visiting ships. The main reason is the expected benefits from reducing climate impact by CO_2 emissions. Positive side effects of using less fuel during a ship call are reductions in emissions of nitrogen oxides, sulphur dioxide and particles, which all cause health risks and can have significant effect on the air quality in the port city. These arguments are, to a large extent, driven by the port cities' political goals on environmental standards. A city's efforts to reach political climate goals can be allocated to different activities within the city's jurisdiction, as is done in the City of Gothenburg. Private ports might not be driven to the same extent by political goals. Important for all ports, however, are the aspects of potential marketing benefits as a proactive green port.

Port authorities can influence GHG emissions from ships by supporting systems and technologies and implementation of incentive programmes that facilitate fuel savings within the port area (Acciaro, Ghiara, & Cusano, 2014). Ports can, for example, manage and administer the supply of alternative fuels and onshore power connections, and use environmentally differentiated harbour dues for ships. There are several examples of port initiatives with incentives for shipping companies to operate their ships with lower GHG emissions, e.g. the vessel speed reduction programme of Port of Long Beach and Port of Los Angeles, the EcoAction Programme and Blue Circle Award in Port of Vancouver, and reduced port fees within the scope of the World Port Climate Initiative.

This study aims at quantifying potential reductions of ships' emissions to air of greenhouse gases. Only reductions of emissions within the port area are considered. A model for calculating emissions from ships in ports and the effects of potential abatement measures has been developed. The model is suitable for scenario analyses of how to reduce GHG emissions from ships in specified ports. In this work the Port of Gothenburg on the Swedish West Coast has been used as a case study. The data used for the analysis include port call statistics and technical data for individual ships. The model differentiates between ship types and ship sizes, as well as between five operational modes. The measures included in the calculations are transition from fuel oil to other fuels such as natural gas and methanol; increased possibility to use on-shore power supply (OPS) for vessels at berth; rejuvenation of the fleet and various measures for more fuel efficient ship operation. The measures are sorted into three categories: alternative fuels, ship design and operation. The model requires an assessment of the likelihood of implementation of a certain measure for different ship types and ship sizes. Scenarios consist of combinations of measures with different degrees of implementations for different sections of the fleet.

A number of studies have looked at emissions of green-house gases in ports. Goldsworthy and Goldsworthy (2015) have produce a model using AIS data to describe ship movements and operating modes capable of providing a comprehensive analysis of ship engine exhaust emissions in a wide region which contains numerous ports, and have applied it to the Australian coast and Australian ports. Tichavska and Tovar (2015) used AIS data and the STEAM emission model (see e.g. Jalkanen et al., 2009) to calculate emissions from cruise ships and ferries in Las Palmas Port. Chang, Song, and Roh (2013) calculated the emissions from ships in the port of Incheon, Korea, and compared a bottom-up approach with a top down approach and found large discrepancies. Different policy options to influence GHG emissions in ports are discussed by Linder (2010) and Merk (2014).

2. Potential GHG reduction measures

Maritime transport is often pointed out as a highly energy efficient mode of transportation. Incentives for further improvements are constantly adopted by the industry, even though empirical studies suggest that there are cost-effective measures available that are not always implemented due to existence of barriers to energy efficiency (e.g. Johnson, Johansson, & Andersson, 2014; Rehmatulla & Smith, 2015). These barriers are mechanisms that prevent investment in technologies that are both energy efficient and economically efficient (Sorrell, O'Malley, Schleich, & Scott, 2004). Examples of barriers are related to the types of charter contracts that hinder an implementation, lack of reliable information on cost and saving, and lack of direct control over operations (Rehmatulla & Smith, 2015). Short planning horizons, financial risks by investing in new technology and work methods, a second-hand value of the vessel that does not reflect investments in energy efficient equipment, lack of life cycle approach when constructing vessels, and transaction costs are all further examples of barriers (Styhre & Winnes, 2013).

2.1. Alternative fuels

Fuel shifts from fossil to bio fuels are far from realised in the transport sector. In shipping, an increased use of liquefied natural gas (LNG) and methanol provides potential bridges in order to reach low carbon ship transports (Bengtsson, Fridell, & Andersson, 2012). Liquefied natural gas is increasingly adopted as a marine fuel also for ships other than LNG carriers. The technical solution often includes a dual-fuel engine that can run on either LNG or fuel oil, and which always uses a minor amount of fuel oil for ignition when using LNG. Liner service ships and ships in regions with an established infrastructure for LNG will more easily adopt LNG as fuel. A shift from marine fuel oils to LNG leads to significantly reduced emissions of NO_X, SO_2 and particulate matter. The CO_2 emissions are about 25% lower compared with fuel oils but the total emissions of CO_2-equivalents are not necessarily in favour of LNG as a marine fuel since a few percent of the fuel methane slip through the combustion process unburnt (Bengtsson, Andersson, & Fridell, 2011). Methane is a potent GHG; 72 times more powerful than CO_2 in a 20 year perspective and 25 times as powerful from a 100 year perspective (Forster et al., 2007). The differences for the two time horizons are due to differences in residence times and reactivity of CH_4 and CO_2 in the atmosphere.

Methanol is another fuel that similarly to LNG can be used in marine dual fuel engines. Methanol is in an earlier state of market introduction but full scale tests have been started: the Swedish ship owner Stena Line gradually replaces all conventional engines on board the RoPax ferry Stena Germanica to methanol engines. Methanol is easier to store and distribute than LNG since it is a liquid at room temperature. The production and combustion of methanol cause lower emissions of CO_2-equivalents (per energy unit of the fuel) than LNG fuel in a time horizon of 100 year but it performs worse than LNG in a 20 year time horizon. The total global-warming potential per combusted energy unit of methanol is very similar to that of conventional marine fuel oils from a life cycle perspective (Brynolf, Fridell, & Andersson, 2014).

Major reductions of emissions of GHGs from marine engines can be achieved by replacing fossil fuels with renewable ones. The availability of biofuels for the transport sector is however limited. According to statistics from the International Energy Agency, total world production