The costs and benefits of a nitrogen emission control area in the Baltic and North Seas

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ABSTRACT

The main purpose of this paper is to analyse the socio-economic justification of implementing a Nitrogen Emission Control Area (NECA), starting 2021, for ships in the Baltic Sea and/or the North Sea and English Channel. We analyse the potential for emission reduction, emission control costs, and monetised benefits following the introduction of a NECA. Costs and benefits are compared for 2030. We compile new data on emission control costs for shipping, use the GAINS model for calculations of emission dispersion, and the Alpha-RiskPoll model for estimating monetary values of health impacts. The model results show that costs to conform to the NOx regulations of a NECA in the Baltic Sea, North Sea or both sea regions would be 111 (100–123), 181 (157–209), and 230 (195–273) million € per year, respectively. Corresponding benefits from reduced emissions are estimated to be 139 (56–294), 869 (335–1882), and 1007 (392–2177) million € per year, respectively. Calculated benefits surpass costs for most scenarios, but less convincingly for a Baltic Sea NECA. Conforming to the NECA regulations by using Liquefied Natural Gas (LNG) propulsion engines is estimated to give the highest net benefits but also the largest variation (costs: 153 (88–238), benefits: 1556 (49–3795) million €/year). The variations are mainly due to uncertainties in the valuation of avoided fatalities and climate impacts. It is concluded that the NECAs for the Baltic and North Seas can be justified using CBA under all but extreme assumptions.

1. Introduction

Air pollution is the largest health risk from environmental causes (World Health Organization, 2014a), mainly driven by human exposure to fine particulate matter with aerodynamic diameter < 2.5 μm (PM2.5) (World Health Organization, 2014b). Emissions from combustion engines (including ship engines) contribute to PM2.5 in ambient air both with primary particles (black carbon (BC), organic carbon (OC), and other particles) and with secondary particles formed from exhaust gases – mainly nitrogen oxides (NOx) and sulphur oxides (SOx). NOx and SOx react with ammonia (NH3) in the atmosphere to form secondary inorganic aerosols, which have been shown to constitute ~30–50% of PM2.5 levels in ambient air in northern and central European countries (Putaud et al., 2010). In Europe 2012, ~380,000 premature fatalities occurred due to PM2.5 (Lelieveld et al., 2015). The contribution of shipping emissions...
to premature fatalities from PM$_{2.5}$ in ambient air in Europe and other countries in the Mediterranean region in 2012 has been estimated at $\approx 6000$–$44,000$ (Corbett et al., 2007). NO$_x$ emissions from shipping also contribute to acidification, eutrophication, and the formation of ground-level ozone. Without further control the emissions of NO$_x$ to air from shipping in the European seas are projected to soon become larger than land-based emissions (European Environment Agency, 2013). Shipping is also a source of carbon dioxide (CO$_2$) emissions, and the shipping industry’s relative share of anthropogenic CO$_2$ emissions is also expected to grow significantly if no measures are taken (Eide et al., 2013).

Emissions of air pollutants and greenhouse gases from international shipping are regulated by the International Maritime Organization (IMO) MARPOL convention. The convention applies globally but with regional exceptions for emission control areas (ECA). Stricter regulations apply in these areas. The Baltic Sea (BS), the North Sea and the English Channel (NSE) are classified as sulphur ECAs (SECAs). From 2015, the emission regulations in SECAs were strengthened to allow no more than 0.1% sulphur by weight in the fuel unless exhaust-gas emission control technology is used to reach corresponding SO$_2$ emission levels (IMO, 2015). NO$_x$ emissions from shipping are regulated in a three tiered emission standard scheme, with permitted emissions dependent on ship construction year and engine speed. In July 2017, IMO adopted proposals for designation of BAS and NSE as nitrogen ECAs (NECAs), implying that ships keel laid (the date of formal recognition of the start of a ship’s construction) after the 1st of January 2021 have to comply with the most strict (Tier III) emission standards (IMO, 2017). The use of Tier III technologies is anticipated to increase costs of emission control from shipping.

Emission reduction has – to various extents – positive impacts on human health and the environment. Through stated preference (willingness to pay) studies and/or through revealed preference studies it is possible to monetize these impacts, which in turn enables comparison of expected monetary benefits and costs of a policy proposal.

For the Baltic and the North Seas, the sea regions studied in this paper, 2010 NO$_x$ emissions are projected to decrease by 27–42% by 2030 through the implementation of NECA (Winnes et al., 2016, Kalli, 2013) while CO$_2$ emissions are projected to remain stable if no further regulations are put in place (Kalli et al., 2013). Peer-reviewed analyses of the socio-economic impacts of SECAs are more common than for NECAs. Wang and Corbett (2007) conclude that the introduction of a SECA in the western sea areas of the United States has favourable socio-economic benefit/cost (B/C) ratios for both 1.5% and 0.5% as limits for the sulphur content in fuel with the 0.5% limit having the higher B/C ratio. Tzannatos (2010) show that fuel sulphur limits of either 1.5% or 1% in the Mediterranean Sea would imply net socio-economic benefits for society. A report by Bosch et al. (2009) shows that SECA in the Baltic and North Seas by 2020 would imply net socio-economic benefits (B/C ratio 2–26). For NECA for the northern European region recent reports show that a NECA implemented by 2016 in the North Sea would imply benefits about twice as high as costs (Danish Environmental Protection Agency (DEPA), 2012, Hammingh et al., 2012).

In this paper, we add to earlier research by analysing the net socio-economic impacts in 2030 for Europe of a 2021 introduction of NECA for either the Baltic Sea or the North Sea, or for both sea regions, an analysis needed to give scientific support of the decision to implement NECA by 2021. For these sea regions we also analyse the potential for co-benefits or trade-offs between air quality and climate change from the possible use of LNG-fuelled propulsion technologies in new ships – a technology that reduces emissions of most air pollutants (Anderson et al., 2015) – as a means to comply with NECA requirements. Specifically, we focus this paper on two research questions:

- What are the costs and benefits in 2030 of implementing a NECA by 2021 in the Baltic and North seas, jointly and separately?
- Would the results change with an introduction of LNG-fuelled propulsion technologies in new ships, and would this imply co-benefits or trade-offs with greenhouse gas emission control?

2. Method

Cost-benefit analysis (CBA) (Pearce et al., 2006, Boardman et al., 2001) and the impact pathway approach (Bickel and Friedrich, 2005) are used to analyse the net socio-economic benefit of NECA (presented as B/C ratios of benefits from reduced human health and crop damages and costs of emission control and potential climate change impacts). CBA is suitable for analysing environmental policy (Arrow et al., 1996) and plays an important role for air pollution policies (Burtraw et al., 1998; Holland et al., 2000, 2014; Schucht et al., 2015; Wang and Corbett, 2007; Tzannatos, 2010).

In the analysis we integrate new emission and control cost calculations with existing methods for estimating and valuing climate change-, crop growth-, and human health impacts. The analysis is done using scenarios; first a baseline (BSL) scenario up until the year 2030 is constructed, followed by four NECA scenarios. The control costs, climate change-, crop growth-, and human health impacts in BSL are then compared to the corresponding values in the NECA scenarios. Based on fuel consumption data and average ship age data we construct age-specific fuel use estimates as the basis for all scenarios. Each age group uses a scenario-specific emission control technology which gives scenario-specific emissions and emission control costs. We use a linear emission dispersion model and through calculations of human exposure to ambient PM$_{2.5}$ combined with concentration-response functions recommended by WHO we can calculate human health impacts. These impacts and impacts on crop damages as well as – if applicable – climate impacts are then monetized to enable direct comparison with costs (Fig. 1). The scenarios for 2030 considered in the analysis are described in Table 1.

Uncertainties in costs and benefits are analysed by calculating benefit/cost ratios for low, mid, and high estimates of costs and benefits for each scenario. The full analysis required many steps of calculations, which cannot all be included in this paper. All equations and input data for calculations of emissions and control costs are available in the supplementary material, referred to with the prefix “A” in this text.
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