

OPTIONS TO ADDRESS SHORT-LIVED CLIMATE FORCERS EMITTED BY SHIPS AS PART OF EU ACTION TO REDUCE GREENHOUSE GAS EMISSIONS FROM SHIPPING

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Summary

It is unquestionable that climate change mitigation strategies should primarily focus on the reduction of CO₂. However supplementary actions should also be undertaken to reduce the emissions of short-lived climate forcers because they produce significant short-term climate forcing. Recent scientific reports indicate that reducing both CO₂ and the non-CO₂ climate forcers is in fact the only viable solution to keep the global temperature increase below the UNFCCC 2°C target. This paper describes some of the climate impacts of black carbon emissions from shipping, in particular in the light of the future opening of new shipping lanes in the Arctic. The paper proposes five policy options that could be adopted by the European Union to address non-CO₂ climate forcers as part of an EU instrument to reduce greenhouse gas emissions from shipping. These options range from consideration and monitoring of the impact of CO₂ mitigation policies on the emissions of non-CO₂ forcers to a black carbon emissions charge, ship speed limits in specific areas, earmarking of revenues to fund black carbon abatement technologies and the adoption of an emissions standard for particulate matter and black carbon.

Identification of the most important non-CO₂ forcers from shipping

Emissions from ships worldwide are a significant and growing source of greenhouse gases (GHG). The reduction of carbon dioxide emissions is essential to limit the environmental effects of shipping on the world climate. While mitigation strategies should primarily focus on this objective, supplementary actions should also be undertaken to reduce the emissions of short-lived climate forcers (SLCF) because they produce significant short-term climate forcing which can have considerable climate change impacts, both regionally and globally.

Black carbon (BC), methane (CH₄) and tropospheric ozone (O₃) are considered the main non-CO₂ climate forcers from shipping. Ship engine exhaust emissions of methane are relatively low and are mainly due to the lean combustion of some gas engines, where part of the methane cannot be completely burnt. These emissions can virtually be eliminated by replacing lean premixed

combustion with high-pressure gas injection.¹ Reducing O₃ concentrations can be achieved through reduction of ozone precursors such as nitrogen oxides (NO_x) which are in fact a growing source of air pollution from shipping. However NO_x also has cooling effects and the net climate impact from shipping NO_x is in fact cooling. NO_x has significant non climate environmental impacts and these are best addressed as part of an air pollution reduction strategy. This paper proposes therefore to concentrate on black carbon as the shipping non-CO₂ forcer with the greatest climate impact.

Peer reviewed literature tends to show that the net globally averaged effect of shipping on the climate is one of radiative cooling, due in particular to the indirect effect of sulphate particles on cloud formation. However, this net globally averaged balance is likely to be affected by the enforcement of new limit values on the maximum sulphur content of marine fuels, which are expected to 'unveil' the warming effect of shipping emissions. Moreover, the cooling sulphate particles and warming BC particles have different impacts in different regions. The net globally averaged forcing may be cooling, but this does not exclude warming from happening in particularly sensitive areas such as the Arctic. Although cooling dominates, it is not in regions where shipping BC has the largest climate impact. In addition to the mitigation of warming from BC, reductions in BC will contribute to improved air quality.

BC emissions from shipping

Black carbon is a component of particulate matter (PM) emitted as a result of the incomplete combustion of fuel. The amount and proportion of BC emitted varies according to the type of fuel used and other combustion conditions, but for the maritime sector, BC generally constitutes between 5% and 15% of PM emitted by ships.² Recent studies have calculated that shipping activities are therefore accountable for about 2% of global annual black carbon emissions (i.e. 71 to 160 kt).³

There is broad consensus amongst the scientific community that the BC component of particulate matter is strongly warming and is therefore the most harmful to climate. Professor Jacobson from Stanford University has suggested that BC could contribute up to 16% of global warming, making it the second most important climate forcer after CO₂.⁴ Being dark in colour, the direct atmospheric effects of black carbon involve its absorption of solar radiation that produces a significant positive radiative forcing contributing to climate change. The black carbon warming effects are magnified in cryospheric regions, such as the Arctic, where BC is deposited on ice or snow and considerably reduces the reflectivity of these surfaces, thus increasing melting.

IPCC estimations of BC direct radiative forcing lie at 0.34 Wm⁻² (±0.25).⁵ However, several studies suggest that this estimate is rather conservative as it does not take into account the interaction of BC particles with other particles. For instance it has been demonstrated that BC warming effects may

¹ Buhaug et al. (2009): Second IMO GHG study 2009, p.52

² Lack et al. (2009), Particulate emissions from commercial shipping; chemical, physical and optical properties, J. Geophysical Research 114

³ Corbett et al. (2010), Arctic shipping emissions inventories and future scenarios, 10 Atmos. Chem. and Phys. 9689

⁴ Jacobson (2007), Testimony for the Hearing on Black Carbon and Global Warming, United States House of Representatives, 18 October 2007

⁵ IPCC (2007), "Changes in Atmospheric Constituents and in Radiative Forcing", in Climate Change 2007: The Physical Science Basis, Contribution Of Working Group I To The Fourth Assessment Report Of The Intergovernmental Panel On Climate Change

even be magnified when BC particles mix with particles that normally scatter light such as sulphates.⁶ In June 2009, the International Council for Clean Transportation estimated the global warming potential (GWP) of black carbon using the formula provided in the IPCC 4th assessment report. The ICCT concluded that the GWP of black carbon was 1,600 times higher than that of CO₂ at 20 years, and 460 times higher over a period of 100 years.⁷

Effects in the Arctic

While the long-term impact of CO₂ emissions on the warming pattern in the Arctic is undeniable, recent studies indicate that BC may in fact account for half of all Arctic warming.⁸ In January 2010, the joint submission by Norway, Sweden and the United States to the IMO (MEPC 60/4/24) on the reduction of BC emissions from shipping in the Arctic, stressed that the BC warming effect of shipping is especially important in the Arctic and within the Arctic Front which can extend as far south as ~40 degrees latitude North – i.e. approximately all points north of Sardinia. The Arctic environment is thus impacted by both emissions occurring in the Arctic itself (i.e. within the Arctic Circle) and from the transport of ship emissions from other regions such as Europe.

The opening of new Arctic sea routes, resulting from the increased and fast melting of the Arctic ice-cap, will undoubtedly increase shipping volumes in the Arctic thus substantially accelerating the impact of shipping BC on the Arctic climate. A recent study drew up various Arctic emissions inventories for black carbon, taking into account the predicted growth of regional shipping and the potential diversion of global traffic to the emerging Arctic sea routes.⁹ The report concluded that without control measures, BC emissions in the Arctic will increase in all future scenarios: from 0.88kt per year in 2004 to between 2.7kt per year (under a business as usual scenario) and 4.7kt per year (under a high-growth scenario) by 2050, i.e. an increase ranging from three to fivefold.

Potential BC control measures in the European Union will be all the more important because of the transport of aerosols to the Arctic. Studies have shown that on a seasonal basis, Europe is the largest contributor to the deposition of sulphate and BC at the surface of the Arctic ice cap.¹⁰ As 85% of shipping emissions are estimated to occur in the northern hemisphere and because northern sea routes are likely to attract additional traffic due to melting of the Arctic ice-cap (diversion of international traffic), the regulation of BC emissions from shipping appears to be necessary. As a result of increased shipping in the Arctic and elsewhere, radiative forcing in the Arctic from shipping BC could increase by a factor of 2 by 2030 and shipping emissions as far south as 40°N will continue to contribute to direct and albedo effects in the Arctic.¹¹

⁶ Jacobson (2001), Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols, *Nature* 409, 695-697

⁷ ICCT (2009): 'A policy-relevant summary of black carbon climate science and appropriate emission control strategies', page 7

⁸ Shindell and Faluvegi (2009): 'Climate response to regional radiative forcing during the twentieth century', in *Nature Geoscience*, Vol 2, April 2009, pp 294-300

⁹ Corbett et al. (2010): Arctic shipping emissions inventories and future scenarios, *10 Atmos. Chem. And Phys.* 9689-9704

¹⁰ Shindell et al. (2008), A multi-model assessment of pollution transport to the Arctic, *8 Atmos. Chem. and Phys.*, 8385-8429

¹¹ Tsigaridis and Koch (2010), Climate impacts of Arctic shipping, Columbia University and NASA Goddard Institute For Space Studies, document in Annex II of the IMO document BLG 15/INF.5

Evidence suggests that the EU may be responsible for an important part of in-Arctic shipping. Statistics from the Norwegian coastal authority on the transport of petroleum products and gas from Russia and the High North, show that in September 2011, two thirds of the ships transporting this type of cargo were calling at EU ports.¹² If Norwegian ports are taken into account, then EU and Norway account for three quarters of the port calls from oil and gas tankers coming from Arctic sea routes. These statistics do not take into account other types of traffic (eg cruise ships, fishing vessels, etc.) but nevertheless may well be a good proxy for the overall traffic patterns in this part of the Arctic.

Why is the shipping sector crucial for BC reductions?

Historically, black carbon emissions have been indirectly reduced as a result of air pollution regulation of PM emissions. Overall BC emissions in the UNECE region are expected to decline by about one third between 2000 and 2020 as a result of emissions control legislation (primarily covering road vehicles and power stations).¹³ However, compared to other industrial sectors, ship air pollutants and thus BC emissions are poorly regulated. Unlike other transport modes, no PM limits have yet been introduced for international shipping. Moreover as the shipping sector will continue to grow, projections of future BC emissions suggest that the maritime sector will become one of the major sources of black carbon pollution. Under a business-as-usual scenario, it has been estimated that by 2050, shipping may account for 25% of all EU BC emissions.¹⁴

The report of the co-chairs of the UNECE ad hoc expert group on black carbon repeatedly recognises the growing importance of BC emissions from the shipping sector and calls on the UNECE Executive Body to urge the IMO “to enact requirements to reduce emissions of BC from international shipping”. In a specific chapter, it also lists the additional potential reductions per sector:

“Shipping. To encourage the use of best available techniques and accelerate the introduction of cleaner fuels and ships, IMO regulations could be complemented by strict national or regional emission standards and/or by economic instruments, such as emission charges. Additional mitigation may be achieved from sources associated with port activities, for example port electrification.”

UNECE (2010): op.cit. p.14

The authors of the report suggest that in order to produce a significant level of BC reduction, regional instruments could be adopted to complement IMO regulations.

Why is an integrated approach to all climate forcers necessary?

Climate change mitigation strategies should unquestionably focus primarily on the reduction of CO₂. However, because of their short lifetime in the atmosphere, cutting non-CO₂ forcers may represent a compelling opportunity to achieve a rapid impact on regional climate effects such as in the Arctic, regarded as one of the most important of all ‘tipping points’ for irreversible climate change.

¹² Available on: <http://www.kystverket.no/Om-Kystverket/Brosjyrer-skjema-og-andre-publikasjoner/Statistikk/Risikolaststatistikk/> Last viewed in November 2011

¹³ UNECE (2010), Report by the Co-Chairs of the Ad Hoc Expert Group on Black Carbon, ECE/EB.AIR/2010/7

¹⁴ Calculation made on the basis of a dataset on Air Pollution from transport sources provided by IIASA for Transport & Environment (2010)

Reducing emissions of short-lived climate forcers can have significant regional impacts such as in the Arctic but these benefits are not limited to specific regions and can also have an overall climate impact. Owing to the committed warming already in the system, as inferred by scientists from recent IPCC data, it is increasingly clear that CO₂ reductions alone will not be sufficient to achieve the objective of avoiding more than 2°C of warming¹⁵.

“Lastly, even the most aggressive CO₂ mitigation steps as envisioned now can only limit further additions to the committed warming, but not reduce the already committed GHGs warming of 2.4°C.”

Ramanathan and Feng (2008): op.cit. page 1

A recent UNEP report indicates that addressing black carbon and tropospheric ozone, as well as maintaining pressure on CO₂, is the only viable way in the next decades to keep the global temperature increase below the 2°C rise target.¹⁶

“Both near-term and long-term strategies are essential to protect climate. Reductions in near-term warming can be achieved by control of the short-lived climate forcers whereas carbon dioxide emission reductions, beginning now, are required to limit long-term climate change. Implementing both reduction strategies is needed to improve the chances of keeping the Earth’s global mean temperature increase to within the UNFCCC 2 °C target.”

UNEP (2011):op.cit. page 3

An integrated approach addressing both CO₂ and non-CO₂ climate forcers seems therefore to be the way forward to provide effective climate change mitigation. We therefore believe it is particularly important to include the role and the impacts of black carbon in any EU measure addressing the climate effects of shipping activities.

An EU regional measure on black carbon in the international context

This holistic approach would also best equip the Commission to respond and actively contribute to international work on these issues now underway including the recent recommendations of the Executive Body to the UNECE Convention on Long Range Transboundary Air Pollution¹⁷, as well as the climate change debates now underway among the Arctic Council of Nations¹⁸.

The issue of shipping BC emissions has also been raised in the IMO and different papers have been submitted on this matter over the past two years. At MEPC 62 in July 2011, the IMO adopted a work-plan to address the issue of black carbon emissions from international shipping. All EU Member States of IMO supported this decision. The work-plan constitutes the first step for international

¹⁵ Ramanathan and Feng (2008): ‘On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead’, Proceedings of the National Academy of Sciences, 23 September 2008, Vol. 105 No. 38

¹⁶ UNEP (2011): Integrated Assessment of Black Carbon and Tropospheric Ozone, Summary for Decision Makers,

¹⁷ UNECE (2010): Report by the Co-Chairs of the Ad Hoc Expert Group on Black Carbon, ECE/EB.AIR/2010/7

¹⁸ Arctic Council (2009): Tromsø Declaration on the occasion of the Sixth Ministerial Meeting of the Arctic Council of Nations, 29 April 2009

action through the IMO. However, rapid EU action on BC emissions needs also to be considered because of Europe's proximity to the Arctic and the significant transport of BC emissions from the EU to the Arctic.

This would not represent a duplication of the IMO's work, but rather constitute a complementary regional measure as recommended by the UNECE. Moreover, early regulation of BC emissions from shipping to reduce current levels and prevent any growth of emissions would significantly benefit the climate of the Arctic. In addition such regulation would also provide substantial side benefits in Europe; reducing premature deaths and other human health impacts of BC emissions.

Policy options for EU action on short-lived climate forcers from shipping

The policy options listed below constitute measures that could be taken by the EU specifically as part of a broader strategy to reduce greenhouse gas emissions from shipping. These policies do not represent an alternative to discussion of CO₂ reduction options, which should remain the primary objective. They also do not preclude additional black carbon mitigation strategies that could be decided at the IMO level. We should however recognise the need for early EU action due to Europe's significant contribution to Arctic BC deposition and the growing demand in Europe for the use of Arctic sea routes.

Option 1: Monitoring and data collection

As different approaches to mitigating CO₂ from shipping may give rise to different effects on emissions of particulate matter and its subspecies, such as black carbon, an integrated approach to mitigating the climate impacts from this sector requires consideration of the full range of climate forcing emissions.

The first policy option is less ambitious in terms of BC mitigation. It would require the Commission to evaluate and study the expected impact on BC emissions of the different instruments considered for reducing GHG emissions. The Commission should then decide the policy instrument so that ideally emissions of all climate forcers are optimally reduced. On the basis of this first analysis, the Commission could also study opportunities for additional policy instruments that could be introduced at a later stage to provide cost-effective reductions of BC emissions.

Although typical BC emission factors per ton of fuel exist, their relevance is limited in the case of BC as the level of black carbon emissions is a product of both fuel consumption and combustion efficiency. Technical adaptation of engines and/or use of after-treatment systems can have a considerable effect on the level of BC emissions. Fuel used cannot therefore be the only element taken into consideration to establish the impact of policies on black carbon emissions. We therefore recommend that the Commission establish a more robust system of monitoring that could serve as the basis for further air quality and climate policies.

This policy option is not expected to have any real impact on black carbon emissions but is more designed as a safeguard providing the minimum level of consideration in the design of any EU shipping measure to address CO₂.

Option 2: A Black carbon charge

Market-based instruments are expected to constitute the central element of any EU measure to reduce GHG emissions from shipping. Applying a black carbon charge as an add-on to an EU MBM could be a solution to provide incentives to cut shipping BC. To do this would require the establishment of a formula taking into account the ratio of shipping BC emissions to CO₂ and the global warming potential of black carbon (see below). A specific BC price could be also determined independently of CO₂.

The best solution would be to determine the amount of emissions on a basis of constant monitoring of ship stacks. However, as this data is not available, we propose to establish the ratio between CO₂ and BC emissions on the basis of typical emissions factors as they are defined by the literature. Because fuel consumption cannot serve as the sole indicator of BC emissions, we propose to adjust the charge to take into account both technical adaptations and possible operational measures that reduce BC emissions.

- a. Determination of the BC charge based on emissions factors:

As a first step, we need to establish the emissions factors for CO₂ and black carbon. On this basis we can also calculate the ratio of BC emissions to CO₂.

Pollutant	CO ₂	BC
Emission factor in tons per ton of fuel	3.130	0.00035
Ratio of BC emissions compared to CO ₂ (in tons)*	1	0.00011

Peters et al. (2011)¹⁹
*own calculation

Secondly, we need to weight these results with the relative global warming potential of CO₂ and black carbon. This will allow the calculation of the price increase that a BC charge would add to a CO₂ emissions charge.

Pollutant	CO ₂	BC	%
Ratio weighted with GWP 20 (1600)	1	0.179	17.9
Ratio weighted with GWP 100 (460)	1	0.0506	5.1

Global warming potentials based on ICCT (2009)

Depending on the global warming potential that is considered, the integration of BC emissions in a future MBM on CO₂ will typically represent a price increase between 5.1 and 17.9 per cent per unit of CO₂. Because the warming effects of BC are short-term, we recommend the use of GWP₂₀ as it is a more reliable metric to reflect the real climate impacts of black carbon. As this method is strictly based on the relationship to CO₂ emissions, it does not interfere with other aspects of the design of the CO₂ instrument.

At the current carbon price of around €10 per ton of carbon, the black carbon charge would add €1.79.

¹⁹ Peters et al. (2011): Future emissions from shipping and petroleum activities in the Arctic, Atmos. Chem. Phys.,11, 5305-5320

b. Correction of the BC emissions charge to reflect technical adaptation

In order to reflect potential technical adaptations a ship might install, a BC charge designed on the basis of emission factors needs to be corrected. This is not necessary if the charge is based on the real level of emissions, measured on-board during the operation of the vessel. In all other cases the correction could be done by way of discounts or exemptions from the BC charge for those ships using specific abatement methods or adapting their operations to reduce their BC emissions.

No exemption	50% exemption	Full exemption
- Ships with no abatement technologies	- Ships equipped with abatement technologies that can provide at least 50% BC removal efficiency, e.g. slides valves, water-in-fuel emulsification, etc. - Ships that combine the use of low-sulphur distillate fuels with operational solutions such as slow-steaming (12kn).	- Ships equipped with abatement technologies that can provide at least 90% BC removal efficiency, such as particle filters - LNG powered vessels

c. Decoupling the CO₂ and the BC charge

This policy option is likely to deliver some reductions in BC emissions. While the proposed additional charge (17.9%) can be seen as considerable, it is not clear that it will provide a sufficient incentive for ship owners to reduce their BC emissions. At the current carbon price, the BC charge is not likely to have a big influence when directly linked to the international price of CO₂. If this is the case, the two charges could be “decoupled”, i.e. the price of BC would be set at a different level to that of CO₂.

This instrument could also be used as a standalone instrument, for instance along the lines of the NO_x fund. However, in this case we recommend the price be set at a level independent of the international carbon price and that there be a requirement that BC emissions be constantly monitored on board.

Option 3: Specific instrument for reducing emissions from or to the Arctic

Unless the BC charge is defined at a level where it will provide real incentives for BC reductions, market-based instruments will need to be complemented by specific measures that should target the most sensitive areas like the Arctic. Even though this issue will be discussed at the IMO in the next years, given the EU’s importance to Arctic shipping as well as the significant transport of BC emissions from Europe to the Arctic, the EU should consider the early introduction of a regional measure to reduce BC emissions from Arctic shipping.

As already mentioned, the opening of new sea routes in the Arctic is likely to cause a significant increase of black carbon emissions in this region, which is most sensitive to BC warming (due to the indirect effect that black carbon has when it deposits on snow). Although aggregated statistics on port calls from the Arctic are not easily available, Europe seems to be an important destination;

recent statistics from the Norwegian coastal administration show that in September 2011 two thirds of port calls of tankers coming from Russian ports or the High North were at an EU port.

One of the possible measures to reduce emissions from the Arctic shipping is to require the use of low sulphur distillate fuels in combination with a slow speed regime. Recent studies show that switching to distillate fuels together with reducing the vessel's speed can provide promising reductions of black carbon of up to 75% per kilometre travelled.²⁰

We strongly recommend that the EU adopts such requirements for all ships sailing north of 60°N latitude and calling at an EU port. This can be exercised through port state authority.

Option 4: Earmarking a proportion of revenues for BC abatement technologies

The most efficient way to reduce black carbon emissions from ships is by the use of abatement technologies. Different technologies are already available and provide significant BC reductions and others are currently under development. Abatement systems such as particle filters would in practice reduce black carbon emissions by more than 90%.

In order to incentivise the use of these technologies and promote the uptake of abatement systems, the Commission could propose to earmark a proportion of the revenues generated by a future market-based instrument. Different studies have already listed various BC abatement technologies²¹ that could be declared as eligible for funding. This work could even be further developed by the European Commission's Joint Research Centre or the European Maritime Safety Agency.

This policy option is most likely to deliver BC emissions reductions, as it incentivises the use of BC reduction methods. However, a number of questions would need to be solved around defining the exact application of this instrument, its scope, and the conditions under which funding could be made available.

Option 5: Engine standard for particulate matter and black carbon emissions

BC reductions in other sectors have mostly been achieved through the adoption of standards leading to a progressive reduction of emissions. In the road sector for instance, air pollution standards for cars (the euro-standards) have given strong incentives to improve vehicle efficiency and incorporate efficient after-treatment technologies, such as diesel particle filters. A similar process could be undertaken for ships.

“Strict national or regional emission standards” have been recommended in the UNECE paper as complementary measures to the IMO regulations. These standards could be integrated in a general approach to ship efficiency and technical adaptation.

This policy option is most likely to deliver BC emissions reductions, depending on the stringency of the engine standard. Further research is required to design these standards, in particular as regards the level of stringency and possible emissions stages. The EU needs to consider whether to take

²⁰ Lack et al. (2011): Impact of Fuel Quality Regulation and Speed Reductions on Shipping Emissions: Implications for Climate and Air Quality, Environmental Science and Technology

²¹ Corbett et al. (2010): An assessment of technologies for reducing regional short-lived climate forcers emitted by ships with implication for Arctic shipping, Carbon Management 1(2), pp 207-225

action on standards at the EU or IMO level, taking into account the importance of BC emissions from Europe on the Arctic climate and the fact that debate at the IMO on these issues is in its infancy.

Conclusion

Even though CO₂ should remain the primary focus on future EU action on climate change, we strongly recommend the EU to also consider the emissions of non-CO₂ climate forcers. Scientific evidence suggests that reducing both CO₂ and the non-CO₂ climate forcers is in fact the only viable option to keep the global temperature increase below the UNFCCC 2°C target. The design of an EU instrument to address climate change induced by shipping should take this into account.

This paper presents five policy options that could be adopted by the European Union to incorporate action on non-CO₂ climate forcers in any EU instrument to reduce greenhouse gas emissions from shipping. The expected impacts of the different options as well as their compatibility with the four policy actions studied by the Commission are summarised in the following table:

	Monitoring	BC charge	Arctic	Earmarking	Engine std
Potential BC reductions	-	+ / ++	++	+ / ++	++
Compensation fund	x	x	x	x	-
Emission trading	x	-	-	x	-
Taxation	x	x	x	x	-
Ship Efficiency	x	-	-	-	x