Arctic Council Task Force on Short-Lived Climate Forcers

Recommendations to Reduce Black Carbon and Methane Emissions to Slow Arctic Climate Change

ARCTIC COUNCIL

Recommendations to Reduce Black Carbon and Methane Emissions to Slow Arctic Climate Change

Nations of the Arctic Council are well positioned to reduce black carbon and methane emissions to slow the rate of Arctic climate change over the next few decades. Existing technologies and proven best practices are available to reduce these emissions. Arctic nations have different policy options—regulatory and voluntary—that already have been and can continue to be used to deliver black carbon and methane emission reductions. Measures that reduce methane and especially black carbon emissions provide significant health and environmental co-benefits.

The Arctic Council can encourage the exchange and sharing of knowledge and data; facilitate collaboration and collective action where needed among Arctic nations; and incentivize sustained actions to reduce emissions of black carbon and methane. The Arctic Council can also facilitate the pursuit of common objectives among Arctic nations to reduce short-lived climate forcers in collaboration with other international forums and Observer nations.

For science and policy reasons, the Arctic Council is especially well suited to play a leadership role in addressing black carbon emissions.

The key messages and recommendations here are from the Task Force on Short-Lived Climate Forcers that was established by the Arctic Council in 2009. In 2011, the Task Force delivered its first report, focused primarily on black carbon. It was asked to continue its work by focusing on methane and tropospheric ozone, as well as further black carbon work where necessary, and provide a report to the next Arctic Council Ministerial meeting in 2013. This is the second report from the Task Force. It focuses on both methane and black carbon. Tropospheric ozone has not been addressed at this time given that work is still ongoing within the Arctic Monitoring and Assessment Programme to quantify the impacts of ozone in the Arctic.

Context and Key Messages

CONTEXT AND KEY MESSAGE 1

Immediate reductions in black carbon and methane emissions can slow Arctic warming over the next few decades. Simultaneously, reducing emissions of carbon dioxide (CO_2)—the largest contributor to global and Arctic climate change—is the most important means of preventing dangerous levels of climate change over the long term.

Black carbon and methane mitigation strategies should be viewed as a complement, not as a substitute, for strategies that reduce CO_2 emissions, which are needed to prevent dangerous global and Arctic climate change. However, unlike the case for CO_2, where the climate effect of reducing emissions is realized over a long time span, reducing emissions of black carbon and methane—both strong warming pollutants—offer a unique and vital opportunity to slow Arctic warming in the near term (hence the term "short-lived climate forcers or pollutants").

The Arctic is warming twice as fast as the global average,[1] and the extent of Arctic sea ice is declining more rapidly than has been projected to date,[2] having broken a new record low in September 2012.[3] Black carbon and methane emissions are contributing to Arctic climate change, but the question is "by how much?"

Methane is estimated to be the second most important greenhouse gas (GHG) emitted by human activities after CO_2. Historical anthropogenic methane emissions have contributed about half as much as CO_2 in terms of influence on today's global warming. Clearly, anthropogenic methane emissions have made a significant contribution to observed global warming, and by extension, Arctic warming.

Black carbon plays a unique role in the Arctic due to its multiple influences there. Black carbon is an aerosol component or particle with strong climate-influencing properties. It is contributing to Arctic warming both by absorbing sunlight directly in the air (and reflected sunlight from the ground) and by darkening the snow and ice, which in turn leads to further warming and melting, thus giving it an Arctic amplification effect. Since the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,[4] a number of more recent studies have estimated a higher globally averaged direct heating effect for black carbon. Most recently, the report "Bounding the role of black carbon in the climate system:

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[1] 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*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, UK and New York.

[2] Stroeve, J., M. Holland, W. Meier, T. Scambos, and M. Serreze. 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters 34(L09501); doi: 10.1029/2007/GL029703.

[3] National Snow and Ice Data Center. 2012. Arctic sea ice news and analysis.

[4] 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*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, UK and New York.

A scientific assessment"[5] estimated that black carbon (including its direct, snow, ice, and cloud effects) is exerting an anthropogenic heating effect on the global climate that is second to only that of CO_2. Robust estimates for how much Arctic warming can be attributed to black carbon are not yet available.

CONTEXT AND KEY MESSAGE 2

The geographic location of black carbon reductions influences the Arctic climate effect, meaning that measures taken in or near the Arctic can have the greatest impact per unit of emission. Methane emission reductions anywhere in the world slow both Arctic and global climate change. For both black carbon and methane, there are therefore opportunities for Arctic nations to engage with Observer and other nations to pursue measures that protect the Arctic climate.

Unlike CO_2 and methane that are GHGs well mixed in the atmosphere, the climatic effects of black carbon are much more variable from one region to another. This is because black carbon remains in the atmosphere for a few days to weeks. By contrast, the amounts of CO_2 and methane[6] in the entire global atmosphere are fairly uniform regardless of emission source location.

Based on the Arctic Monitoring and Assessment Programme results,[7] black carbon mitigation actions in close proximity to the Arctic region can be expected to have a greater Arctic climate effect compared to the same amount of black carbon mitigation occurring farther away from the Arctic.

CONTEXT AND KEY MESSAGE 3

Reducing emissions of methane and particularly black carbon results in significant health benefits.

In addition to their climate effects, both black carbon and methane contribute to adverse health effects, and therefore reducing these emissions has the potential to generate health benefits. The health benefits of reducing black carbon depend much more on the proximity to human populations, whereas methane reductions yield health benefits both in the Arctic and globally because of the associated decreases in global ozone levels.

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[5] Bond, T., S.J. Doherty, D.W. Fahey, P.M. Forster, T. Berntsen, B.J. DeAngelo, M.G. Flanner, S. Ghan, B. Kärcher, D. Koch, S. Kinne, Y. Kondo, P.K. Quinn, M.C. Sarofim, M.G. Schultz, M. Schulz, C. Venkataraman, H. Zhang, S. Zhang, N. Bellouin, S.K. Guttikunda, P.K. Hopke, M.Z. Jacobson, J.W. Kaiser, Z. Klimont, U. Lohmann, J.P. Schwarz, D. Shindell, T. Storelvmo, S.G. Warren, and C.S. Zender. 2013. Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of Geophysical Research: Atmospheres*. DOI: 10.1002/jgrd.50171.

[6] Despite being referred to as a short-lived climate forcer or pollutant, methane remains in the atmosphere long enough to become globally well mixed, which is true for other GHGs under the United Nations Framework Convention on Climate Change (UNFCCC).

[7] AMAP. 2011. The Impact of Black Carbon on Arctic Climates. AMAP Expert Group on Short-lived Climate Forcers. By: P.K. Quinn, A. Stohl, A. Arneth, J.F. Burkhart, J. Christensen, M. Flanner, K. Kupianien, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov, and V. Vestreng. Available: http://www.amap.no/. Accessed 10 September 2012.

Black carbon is a component of particulate matter (PM), and is most strongly associated with the smaller “fine particles” or $PM_{2.5}$. Exposures to $PM_{2.5}$ are associated with a broad range of adverse health effects, including premature mortality, increased hospital admissions and emergency visits for cardiovascular and respiratory diseases, and development of chronic respiratory disease.[8]

Over the past decade, health scientists have investigated whether the observed health effects are attributable to specific PM components, including black carbon, or specific sources, such as traffic. The growing body of evidence includes studies that link exposure to black carbon with adverse health effects, consistent with the broader health literature on particles. This evidence is strongest for cardiovascular outcomes, including changes in blood pressure, heart rate variability, hospital and emergency department visits, and mortality. Evidence linking black carbon to respiratory effects is also available, but is more limited. Toxicological studies[9] have suggested that black carbon may operate as a universal carrier of a wide variety of chemical constituents of varying toxicity to sensitive pulmonary and cardiovascular areas.

In 2012, the World Health Organization’s International Agency for Cancer Research[10] reclassified diesel engine exhaust as carcinogenic, listing it as a cause of lung cancer, and also associating it with the increased risk of bladder cancer.

Methane, as a precursor to tropospheric ozone (in the lower atmosphere), contributes to the adverse health and environmental effects associated with ozone. Methane emissions can lead to ozone formation far from the original source. The effects of tropospheric ozone on health and the environment are well established. Exposure to ozone is linked to respiratory health problems ranging from decreased lung function and aggravated asthma to increased emergency department visits, hospital admissions, and premature death. In addition, tropospheric ozone has been shown to have significant adverse effects on crop yields, pasture and forest growth, and species composition.

[8] U.S. EPA. 2009. Integrated Science Assessment: Particulate Matter. Available: http://www.epa.gov/ncea/pdfs/partmatt/Dec2009/PM_ISA_full.pdf. Accessed 22 February 2013.

[9] Janssen, N.A.H., M.E. Gerlofs-Nijland, T. Lanki, R.O. Salonen, F. Cassee, G. Hoek, P. Fischer, B. Brunekreef, and M. Krzyzanowski. 2012. Health effects of black carbon. WHO Regional Office for Europe, Copenhagen.

[10] WHO. 2012. IARC: Diesel Engine Exhaust Carcinogenic. Press release, 12 June 2012. Available: http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf. Accessed 22 February 2013.

CONTEXT AND KEY MESSAGE 4

Anthropogenic emissions of black carbon and methane in Arctic nations are significant for the Arctic climate relative to global emissions. Without further action over the next few decades, anthropogenic methane emissions from Arctic nations are projected to increase. Current policies to reduce PM have reduced or are expected to reduce black carbon emissions, most significantly from diesel vehicles. However, without further action, emissions from several other sources may remain significant, or even increase.

The most significant sources of anthropogenic black carbon and methane emissions for the Arctic nations are well known, and nearly all emission sources have been quantified by either national agencies or research institutes, but with varying degrees of confidence. Black carbon emission estimates are generally less certain than for methane and other GHGs; however, it is doubtful that improved black carbon emission inventories would significantly change what are identified here as the most important sources for Arctic nations.

Arctic nations make up approximately 20% of global anthropogenic methane emissions. Aggregated methane emissions from Arctic nations are projected to increase, according to two recent estimates, by between 8% and over 20% by 2030 compared to 2005 levels.[11] The United States, Russia, and Canada are the largest methane emitters among Arctic nations, and rank among the world's top emitters.

The largest anthropogenic methane emission source for Arctic nations as a whole is the oil and gas sector, followed by agriculture (primarily livestock), solid waste, and coal mining sectors. Some methane emissions result from agricultural and forest burning but these emissions are relatively small.

Arctic nations as a whole are currently estimated to be responsible for approximately 10% of global black carbon emissions.[12] However, because of their proximity to the Arctic, many of these emissions likely have a more significant Arctic climate effect *per unit of emissions* compared to black carbon emissions that occur farther away from the Arctic. Black carbon emissions outside of Arctic nations, many of which occur in mid to high

[11] Höglund-Isaksson, L. 2012. Global anthropogenic methane emissions 2005–2030: technical mitigation potentials and costs. Atmos. Chem. Phys., 12, 9079–9096; U.S. EPA. 2012. Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990-2030. EPA 430-S-12-002. These current and projected methane emissions estimates are from the International Institute for Applied Systems Analysis (IIASA) and the U.S. EPA. The difference between IIASA and EPA future methane emission projections appears to primarily be the result of differences in underlying assumptions about methane emission releases in the oil and gas production sector. Additional differences are likely due to methodological differences in the estimation of country level emissions. Globally, methane emissions are projected to increase at a slightly higher rate than projected for the Arctic Council.

[12] Klimont, Z. 2013. Personal communication. IIASA-GAINS modeling consistent with Bond et al. 2013, referenced above.

latitudes of the Northern Hemisphere, are likely having a large Arctic climatic impact according to AMAP.[13]

The largest black carbon emission sources in Arctic nations are forest burning and wildfires, and on-road diesel vehicles, followed by residential burning, off-road diesel and stationary diesel engines, agricultural burning, and industrial combustion. Gas flaring may currently be a significant source as well, with a significant share occurring at high latitudes.[14] Marine shipping emissions are currently not large in the polar region, but are expected to grow with increasing resource extraction and tourism activity. Emission estimates for forest and agricultural burning and gas flaring are especially uncertain due to difficulties in characterizing the actual combustion activities, and a lack of emission measurements; nevertheless, these sources deserve considerable attention for mitigation opportunities.

Assuming efficient enforcement of current legislation, black carbon emissions from Arctic nations as a whole are projected to continue to decrease over the next couple of decades by up to 35% (percentages vary by nation),[15] primarily as a result of PM controls on most new diesel engines, along with improved diesel fuel quality, as well as new requirements in most countries that are expected to reduce PM emissions from a range of smaller source categories. The expected decrease assumes that all standards are fully implemented. Future trends for black carbon emissions from open biomass burning are difficult to project. Black carbon emissions from shipping and oil and gas operations within the Arctic are expected to increase, but to what degree is uncertain. Increased emissions from these sources could have strong climatic impacts given their proximity to Arctic snow and ice. In several Arctic nations, residential combustion is projected to remain or become the key anthropogenic source of black carbon.

[13] AMAP. 2011. The Impact of Black Carbon on Arctic Climates. AMAP Expert Group on Short-lived Climate Forcers. By: P.K. Quinn, A. Stohl, A. Arneth, J.F. Burkhart, J. Christensen, M. Flanner, K. Kupianien, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov, and V. Vestreng. Available: http://www.amap.no/. Accessed 10 September 2012. See page 53: "For both models, the atmospheric direct RF [radiative forcing] is largest for ROW [rest of world] emissions in all source categories except for grass plus forest fires which is dominated by Russia."

[14] Stohl, A., Z. Klimont, S. Eckhardt, and K. Kupiainen. 2013. Why models struggle to capture Arctic Haze: the underestimated role of gas flaring and domestic combustion emissions. Atmos. Chem. Phys. Discuss, 13, 9567-9613. This recent modeling suggests flaring could be the dominant source of black carbon above 66 degrees north latitude.

[15] IIASA-GAINS model estimates for the current legislation scenario; consistent with emissions presented in the UNEP Black Carbon and Tropospheric Ozone Assessment (UNEP, 2011).

Recommendations for Individual Arctic Nations and the Arctic Council to Reduce Black Carbon and Methane Emissions

RECOMMENDATION 1

Arctic nations can achieve significant methane mitigation to curtail the projected increase in these emissions over the next few decades. Arctic nations should take actions to ensure broad implementation of the many methane mitigation technologies and practices currently available.

There is a robust understanding of methane emission mitigation opportunities, many of which are not currently pursued in Arctic nations. Recent analyses demonstrate that there is significant further methane mitigation potential in Arctic nations in the near term. According to EPA and IIASA analyses, **Arctic nations make up approximately 14-30% of the estimated global methane mitigation potential by 2030.**[16] Arctic nations can therefore play a significant role in mitigating methane emissions. It is also important for Arctic nations and the Arctic Council to engage with other forums and nations to encourage global methane reductions.

The oil and gas sector represents, according to recent analyses, approximately 60-75% of the total methane mitigation potential across all Arctic nations, with the United States, Russia, and Canada comprising the lion's share of this mitigation potential.[17] **Black carbon reductions can be achieved in this sector as well, particularly from gas flaring** (see information box). A number of mitigation measures are available to minimize or avoid methane losses from activities associated with or directly from the operation of equipment components common across upstream oil production and natural gas production, processing, transmission, and distribution. These mitigation options in the oil and gas system generally fall into three categories:

1. Equipment changes and upgrades;
2. Changes in operational practices (including leak detection and repair, direct inspection and maintenance); and
3. Installation of new equipment.

The mitigation measures may be applied to components and equipment used in oil and gas operations, including compressors/engines, dehydrators, pneumatics/controls, pipelines, storage tanks, wells, and other processes commonly used in some or all of the oil and gas system segments.

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[16] Höglund-Isaksson, L. 2012. Global anthropogenic methane emissions 2005–2030: technical mitigation potentials and costs. Atmos. Chem. Phys., 12, 9079–9096; U.S. EPA. 2013. DRAFT Global Mitigation of Non-CO_2 Greenhouse Gases Report.

[17] Ibid.

Gas flaring is a particular source for both black carbon and methane mitigation:

In the oil production sector, excess gas that may be associated with production is either vented (i.e., released to the atmosphere), flared (i.e., burned), recovered when there is a market or use for the gas, or re-injected into underground reservoirs. Flaring is widely practiced across all Arctic oil and gas producing nations. Flaring is preferred to venting for safety and climate reasons. Flaring eliminates flammable methane (and other hydrocarbons) during combustion and converts it into CO_2, which has less heat-trapping capacity than methane. However, if inefficient technologies are used, gas associated with oil production often contains non-methane hydrocarbons that can produce large quantities of black carbon when flared.* Moreover, methane can still be emitted during flaring under certain conditions. Gas recovery and utilization is therefore encouraged or required by many jurisdictions as the best alternative to minimize emissions.

Ideally, both venting and flaring would be eliminated in favor of gas recovery and utilization. However, in cases where this is impracticable, it is nevertheless possible to flare cleanly by minimizing these emissions via practices and technologies that are currently available. In many cases, these practices can be cost-effective. These improvements range from improving flare tips in order to ensure cleaner flaring, to using recovery technologies to capture valuable non-methane hydrocarbons for productive use. Associated gases can also be re-injected into the producing reservoir. This is very often an efficient method for enhanced oil recovery.

A wide range of policy options can yield significant reductions in flaring. For example, in Alberta (Canada), gas from upstream production is subject to a royalty fee. Companies venting or flaring large volumes of gas are also required to recover the gas if it is deemed economical to do so. In cases where it is not deemed economical, companies that nonetheless elect to conserve gas may apply for a royalty exemption. Between 1996 and 2003, this policy helped reduce flaring levels by over 70% in Alberta (Alberta Energy Resources Conservation Board). In Norway, a 1972 ban on “production flaring” coupled with the 1991 CO_2 tax have kept flaring in Norway at a low level, most probably 90% lower per unit production than it otherwise would have been (Norwegian Petroleum Directorate, personal communication, 19 Feb. 2013). These cases demonstrate **examples where some Arctic nations have successfully reduced flaring and venting, and associated emissions of methane and black carbon, by combining regulatory certainty with strong financial incentives.**

* There have been several recent publications on black carbon emissions from flaring, for example, McEwen, J. D. N. and Johnson, M. R. (2012) Black carbon particulate matter emission factors for buoyancy driven associated gas flares, *J. Air Waste Manag. Assoc.*, 63, 307–321. However, considerable uncertainty remains with respect to quantifying black carbon emissions from flaring, and, given the potentially large contribution of gas flaring to Arctic black carbon depositions, more experimental work should be encouraged and supported by Arctic nations.

More widespread application of these measures by Arctic nations should be considered, for both onshore and offshore activities. Many of these best practices are required by law in one or more Arctic nations. Examples include (for venting and flaring) requirements to minimize flaring and venting for the development and operation of new fields; general prohibition on routine flaring in excess of quantities needed for normal operational safety; and re-injection of associated gas. For transmission and distribution, new offshore fields and onshore facilities must comply with "best available technologies."

Examples of measures that could achieve additional, significant reductions across the Arctic region include:

- Minimizing leaks by replacing outdated equipment;
- Changing operational practices during maintenance and repair to reduce the volume of natural gas vented to the atmosphere when components are taken offline for maintenance or replacement; and
- Implementing inspection and maintenance programs that can eliminate as much as 80% of fugitive methane emissions from leaks.

Many Arctic nations are already participating in efforts of the Global Methane Initiative, the Global Gas Flaring Reduction Partnership (GGFR), and the Climate and Clean Air Coalition to reduce Short-lived Climate Pollutants (CCAC). Arctic nations should be encouraged to carry out best practices identified in those forums for any Arctic operations. A dialogue could be encouraged involving oil and gas companies, permanent participants, and informed environmental interests with the objective of identifying best operating practices for Arctic operations.

The coal mining systems sector represents approximately 10-15% of the total methane mitigation potential across all Arctic nations, with the United States and Russia comprising most of this mitigation potential.[18] There are three main methane mitigation technology categories that include: recovery for pipeline injection or energy generation, use as a process fuel/onsite heating, flaring; and catalytic or thermal oxidation of ventilation air methane. These measures are commercially available and have been utilized in coal mine methane projects around the world. Recent analyses by IIASA and EPA indicate that many of the mitigation opportunities in the coal mining sector can be implemented cost-effectively.

The solid waste sector represents approximately 10% of the total methane mitigation potential across all Arctic nations, with Canada, the United States, and Russia comprising the largest share of this mitigation potential.[19] According to recent IIASA and EPA reports, there are several mitigation measures that are available and cost-effective to control landfill methane emissions, commonly grouped into three major categories: (1) collection and flaring, (2) landfill gas utilization systems (capture for energy use), and (3) enhanced waste management practices that avoid methane generation from organic waste (e.g., composting). Although flaring is currently the most common mitigation measure, methane recovery options may be more cost-effective. Similarly, under favorable market conditions, organic waste diversion may provide additional means for reducing emissions from landfills and can produce valuable byproducts such as compost and renewable energy.

[18] Ibid.

[19] Ibid.

The agricultural sector is a significant source of global methane emissions. According to EPA and IIASA, in 2005 the sector contributed about 40-45% of global anthropogenic methane emissions, and 20% of methane emissions from Arctic nations.[20] Global methane emissions from agricultural sources are projected to increase in the coming decades. In many Arctic nations, significant improvements in production efficiencies in livestock have already been achieved. In some Arctic nations, cost-effective methane mitigation options for these sources can be readily identified, with the largest potential coming from livestock enteric fermentation and manure management. In other Arctic nations, these mitigation options have already been exhausted, and additional cost-effective improvements will require further research and technology transfer.

RECOMMENDATION 2

Arctic nations can pursue further PM control options that reduce black carbon to ensure the overall downward trend in these emissions continues, and to prevent emission increases for certain sectors.

Currently, no Arctic nation directly targets black carbon for mitigation; rather, any reductions are achieved via broader PM controls.

Overall, diesel vehicle emissions are projected to decline significantly due to the combination of stricter emission standards for new vehicles, low-sulfur diesel fuel (required for proper operation of particulate filters) and regional incentives to accelerate scrappage of older vehicles. **However, there remain additional opportunities from certain diesel sources. Recommended further control measures for engines include:**

- **Retrofitting of older diesel engines (i.e., those engines that do not have to comply with more stringent PM standards for new engines), where low-sulfur fuel is available, remains a significant black carbon mitigation opportunity.**
- **Setting stringent PM standards for some categories of diesel sources, such as certain off-road vehicles and stationary engines, in countries where these are not regulated.**
- **Adopting stringent standards to ensure that new diesel engines manufactured for use in a variety of mobile source applications, including locomotive and (non-ocean going) marine vessels, are employing best available control technologies for reducing PM emissions.**

Without further measures, black carbon emissions from several other sources will increase or remain significant, including:

Residential wood and coal burning are estimated to be a significant source in Arctic nations, and emissions are projected to increase from these sources, which are not regulated in all jurisdictions. Mitigation options include:

[20] Ibid.

- Providing alternatives to wood or coal burning
- Replacing inefficient units
- Retrofitting inefficient units.

Marine shipping activity is projected to increase in the Arctic and therefore black carbon emissions associated with shipping are expected to increase as well. In light of this, Arctic nations could collaborate to model the impacts on the Arctic environment of black carbon emissions (and co-emitted pollutants) due to increased shipping traffic arising from the expected growth in tourism, resource development and extraction (e.g., mining and oil and gas) over the coming decades, identifying potential control measures, if warranted.

Several Arctic nations have been participating in the ongoing work of the International Maritime Organization (IMO) Bulk Liquids and Gases Subcommittee to define black carbon emissions from shipping, consider measurement methods, and identify the most appropriate method to measure black carbon emissions, and, importantly, identify measures that have the potential to reduce black carbon emissions. The Arctic Council should encourage full participation by all Arctic nations in this process so that Arctic nations work to supply needed data and resolve technical issues such that robust mitigation options can be identified. At IMO, Arctic nations could reaffirm the need to address the climate impacts of black carbon emissions from shipping occurring both within and outside the Arctic.

The Arctic Council could also consider:

- Voluntarily adopting shipping standards to decrease black carbon emissions from Arctic Council-flagged ships operating within Arctic waters, with consideration for the ongoing black carbon work within the IMO, and encouraging other nations (especially Observer nations) to voluntarily adopt these measures as well.
- Encouraging incentives to motivate industry adoption of technologies and practices that reduce emissions, such as differentiated port charges, where vessels that operate with better environmental efficiency pay reduced harbor rates (e.g., Port of Gothenburg, Port of Vancouver).

For **agricultural burning**, measures can be taken to lessen the amount of black carbon when burning occurs, or to decrease the likelihood that black carbon emissions from burning will be transported to the Arctic. Recently, collaborative efforts[21] among Arctic nations have led to the identification of a number of options, such as:

- Provide subsidies or support for equipment and fertilizer needed to support reduced till or no-till agriculture, thus avoiding burning by keeping the crop residue.
- Establish procedures for burning to be done more responsibly (e.g., burning at times when the risk of wildfire is low).

Furthermore, such practices could potentially be prioritized in those regions where emission transport to the Arctic is likely to be the greatest, or where there is a significant risk of an agricultural burn creating a wildfire.

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[21] USDA Foreign Agricultural Service. 2012. Developing Options for Avoiding, Reducing or Mitigating Agricultural Burning that Contributes to Black Carbon Deposition in the Arctic. Report on Outreach Workshops Conducted in Pushkino, Russia.

Prescribed forest burning is one of the basic management tools in fire-dependent ecosystems. Prescribed fire can be used to reduce heavy fuel loads, which has the benefit of helping to prevent catastrophic fires. In some cases, an alternative to prescribed burning is the mechanical removal of woody material before the burn for possible energy use.

Wildfires may be prevented or mitigated through fire management programs and strategies aimed at preventing accidental wildfires, conducting targeted fuels reduction, and avoiding unnecessary application of fire in land management (information campaigns and community fire protection programs aimed at decreasing such fires may represent a relatively low-cost way to decrease black carbon emissions). Furthermore, the expansion of resources for fire monitoring, fire management decision support, and fire response may further help to reduce the impact of human-caused fires.

RECOMMENDATION 3

The Arctic nations should continue to improve, develop, and share black carbon emission inventories. The Arctic Council could play a role in synthesizing policy-relevant information from the national inventories.

The Arctic Environment Ministers, in a recent meeting, "emphasized the importance of emission inventories for black carbon to identify emission trends and mitigation opportunities."[22]

A revised Gothenburg Protocol to the Convention on Long Range Transboundary Air Pollution (CLRTAP) that now includes particulate matter and black carbon (as one of its components) was recently adopted. Guidelines for reporting black carbon emissions inventories and projections are being developed in order to enable Parties to voluntarily report black carbon emissions and projections in the near future. Most Arctic nations already have black carbon emission inventories of sufficient quality to inform mitigation choices. Arctic nations, all of whom are Parties to CLRTAP, should play a lead role in developing, improving, and voluntarily reporting accurate, transparent, and consistent black carbon emission inventories under CLRTAP as soon as they are able. The Arctic Environment Ministers stated, "Inventories should be submitted to CLRTAP and shared within the Arctic Council, with the ambition to have submissions starting from February 15, 2015."[23] For those in a position to do so, Arctic nations could share their national black carbon inventories with the Arctic Council and submit them to CLRTAP before guidelines under CLRTAP are finalized in order to show leadership.

Arctic nations should share expertise with one another to fill gaps where black carbon emission inventories still do not exist, where there is potential for increased emissions (e.g., residential combustion), and where uncertainties for certain sources, such as open biomass burning and gas flaring, remain significant.

[22] The Chair's conclusions are from the Arctic Environment Ministers meeting, Arctic Change – Global Effects, in 2013.

[23] The Chair's conclusions are from the Arctic Environment Ministers meeting, Arctic Change – Global Effects, in 2013.

RECOMMENDATION 4

The Arctic Council can facilitate a common "Arctic voice" among Arctic nations to pursue black carbon and methane reduction objectives through engagement with other international forums and with Observer nations.

The Arctic Council could, on behalf of the Arctic nations, communicate key recommendations to other international forums where black carbon and methane emissions are being addressed. For example, the Arctic Council could encourage that, for those forums where best practices and technologies are being characterized and undertaken, that the effectiveness of such technologies in the remote and sometimes extreme conditions in the Arctic be considered. Likewise, the Arctic Council could encourage that all Arctic nations participate and play a leadership role in reducing black carbon and methane emissions in other forums. The Arctic Council may also wish to consider black carbon and methane reduction actions in the *Manual for Observers*.

The CCAC offers a growing voluntary international forum where Arctic nations can spearhead black carbon and methane mitigation action that impacts the Arctic. CCAC initiatives to address oil and gas leaks and flaring, diesel emissions, and residential heating and open burning already exist or are under consideration. Arctic nations can bring their experience to bear on these programs, and provide assistance to those sectors and regions with the greatest Arctic benefit.

Many of the **methane** mitigation technologies and practices that have been identified for Arctic nations may be applicable in other countries and world regions. Several Arctic nations already participate in the Global Methane Initiative (GMI) and the GGFR initiative, as well as the CCAC, all of which complement and support the ultimate objective of the UNFCCC. Similarly, the Arctic Council could encourage that best practices and best available technologies identified in these other forums be undertaken in the Arctic, especially where methane-emitting activities (e.g., oil and gas operations) are projected to increase in the Arctic.

The Arctic Council could encourage Observer nations to pursue **black carbon** inventory development and emission reductions. Arctic nations should play a leadership role in prioritizing reductions from black carbon-rich sources of PM, as called for under the recently adopted revised Gothenburg Protocol to CLRTAP. Regarding IMO's current technical work on black carbon, the Arctic Council could facilitate continued and common black carbon objectives among Arctic nations and other nations with strong Arctic shipping interests.

RECOMMENDATION 5

The Arctic Council can request that Arctic nations submit periodic progress reports and action plans, with indicators to measure success.

One strategy for increasing the transparent exchange of information and for creating incentives for further actions is the submission of periodic progress reports or action plans by Arctic nations to the Arctic Council. Progress reports for black carbon in particular could be important given the unique role that black carbon plays in the Arctic.

These periodic progress reports/action plans could include the following elements and possibly others: (1) submission of an emission inventory, (2) progress in the development and improvement of the emission inventory, (3) report on trends and future forecasts of emissions, (4) actions being taken in each of the major emission source categories, and (5) level of engagement in other forums that are addressing black carbon and possibly methane as well. Any reporting to the Arctic Council should utilize existing international reporting products, including the national reports to LRTAP and UNFCCC, to the furthest possible extent. Progress reports could be requested and disseminated in line with other reporting mechanisms under the Arctic Council.

Furthermore, the Arctic Council could consider its role in synthesizing the information from these progress reports to provide an overview of trends, future projections, and indicators or benchmarks of success (e.g., total emissions compared to previous years; extent of implementation of certain standards, technologies, or practices; level of involvement in other related forums). The Arctic Council can consider different mechanisms by which such reporting occurs, i.e., whether it occurs through the Secretariat or via another working group.

An additional useful indicator would be the trend in black carbon/fine particulate matter concentrations measured in the Arctic. Such information, supplied by scientific efforts under the Arctic Council, could be combined with the information referenced above to provide a more comprehensive Arctic report card on progress.

RECOMMENDATION 6

As noted by the Arctic Environment Ministers, the Arctic Council could consider establishing a process to enhance efforts to reduce black carbon emissions from Arctic nations.

The Arctic Environment Ministers recently concluded:

> *Ministers encouraged the Arctic Council to consider establishing a process at the Kiruna Ministerial meeting aiming for an instrument or other arrangements to enhance efforts to reduce emissions of black carbon from the Arctic States for review and appropriate decision at the next Ministerial meeting in 2015. Measures to address black carbon (and in some cases other SLCPs) that the Arctic States may wish to consider include: national action plans to be submitted to, and compiled by, the Arctic Council; a common*

> *vision for emission reductions; promotion of best mitigation practices and technologies available for relevant pollution sources in the Arctic States and the polar region; promotion of collaborative measures with the private sector; and consideration of benchmarks or targets.*[24]

RECOMMENDATION 7

The Arctic Council has a role to play in raising awareness about the effects of short-lived climate forcers on the Arctic climate and, more broadly, about the need to avoid further Arctic climate change with cascading global effects.

There still remains a lack of awareness about non-CO_2 substances that contribute to Arctic climate change.

The Arctic Council is well-positioned to highlight and raise awareness about the importance of reducing emissions of black carbon and methane to slow near-term rates of Arctic climate change, while also providing important public health and other environmental benefits. There are a number of other international forums where the Arctic Council could engage to ensure that short-lived climate forcers—and, in particular, their association with Arctic climate protection and human health—receive the proper attention. Additional work is needed, on the part of both the Arctic Council and the individual Arctic nations, to inform different audiences about the global consequences of Arctic climate change. This message bolsters the case for broader action on short-lived climate forcers.

The messages to convey include those discussed above: the potential for mitigation of these short-lived climate forcers to slow Arctic climate change over the next few decades; the health benefits of reducing these pollutants; the fact that Arctic nations' emissions are significant but that addressing only these emissions cannot completely tackle the problem; and that not only the Arctic nations but the global community has a stake in avoiding further climatic changes in the Arctic.

RECOMMENDATION 8

The Arctic Council should consider the linkages between efforts to reduce short-lived climate forcers and other work under the council

Taking action as soon as possible to further reduce black carbon and methane emissions has the potential to slow the rate of near-term Arctic warming, and could inform adaptation actions in the circumpolar North. Addressing short-lived climate forcers therefore has relevance to the work currently underway within many Arctic Council working groups, such as the report on Adaptation Actions for a Changing Arctic that is being compiled by the Sustainable Development Working Group (SDWG), the *Arctic Resiliency Report*; and, because mitigating climate change in the Arctic has the potential to help protect

[24] The Chair's conclusions are from the Arctic Environment Ministers meeting, Arctic Change – Global Effects, in 2013.

biodiversity, the Arctic Biodiversity Assessment (ABA), which is nearing completion in the Conservation of Arctic Flora and Fauna (CAFF) working group.

RECOMMENDATION 9

The continued pursuit of known research needs will improve our understanding of how mitigating methane, black carbon, and possibly other short-lived climate forcers, can slow near-term rates of Arctic climate change. There is confidence that actions recommended here could generate climate and health benefits for the Arctic—even if some are currently unquantifiable—despite a number of known uncertainties.

There is still a **need to better understand how reducing emissions of black carbon specifically, or emissions of methane specifically, would reduce near-term rates of Arctic climatic change** compared to a CO_2-driven mitigation strategy. AMAP is already moving to address these questions, and this work by AMAP and other researchers should be encouraged. This will improve the assessment of Arctic climate benefits of different mitigation options and, thus, inform the prioritization of mitigation strategies. Likewise, improved quantification of the potential health benefits in Arctic nations of reducing black carbon and methane emissions could further help to prioritize mitigation actions.

Improved emissions characterization, especially for black carbon, is needed. In particular, all open biomass burning sources and gas flaring deserve special attention. Future project activities, under the Arctic Contaminants Action Program for example, should consider the opportunities to gain a better on-the-ground knowledge of certain emission sources, especially under Arctic conditions.

Continued assessment of the emission reduction effectiveness of different mitigation options, in particular for certain sources such as gas flaring, marine shipping, and intentional forest burning.

Even when mitigation options are identified and well-characterized, there are very likely to be **questions at the local or regional scale regarding the costs of implementation and the barriers (e.g., technical, geographic, cultural) to widespread implementation.** Project-based activities, whether under ACAP or otherwise, can assess these issues for the key mitigation options identified by the Task Force.

Improved observational data about black carbon ambient air concentrations and deposition rates in snow and ice, through the efforts of the Sustaining Arctic Observing Networks (SAON) and AMAP, for example, can help provide metrics of progress for emission reduction efforts and should therefore be strongly supported. Such research could be coordinated with other observing networks such as the Global Climate Observing System (GCOS). Greater understanding of global black carbon dispersion patterns would also be useful for prioritizing regional actions and for assessing the efficacy of Arctic-specific measures in reducing Arctic warming.

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