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Expert Group on Black Carbon and Methane
Summary of Progress and Recommendations

2017

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ABBREVIATIONS

AMAP	Arctic Council Working Group on Arctic Monitoring and Assessment Programme
APG	associated petroleum gas
CCAC	Climate and Clean Air Coalition
CLRTAP	Convention on Long-range Transboundary Air Pollution
DPFs	diesel particulate filters
Expert Group	Expert Group on Black Carbon and Methane
Framework	Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action
IMO	International Maritime Organization
OGMP	Oil and Gas Methane Partnership
PAME	Arctic Council Working Group on Protecting the Arctic Marine Environment
PM	particulate matter
PPR	Sub-committee on Pollution Prevent and Response
SLCPs	short-lived climate pollutants
Summary Report	Summary of Progress and Recommendations
U.S. EPA	United States Environmental Protection Agency
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Rapid warming of the Arctic has profound consequences not only for the Arctic itself but also worldwide. Loss of Arctic snow cover and sea ice and the thawing of permafrost accelerate warming on a global basis[1], and melting of land-based ice contributes to sea-level rise. In addition, as the Arctic continues to warm at twice the global average rate[2,3], emerging science suggests that the reduced temperature differential between the Arctic and other areas may contribute to destabilization of the jet stream in a way that intensifies weather extremes in mid-latitude regions[4]. Within the Arctic, buildings collapse as long-frozen soils destabilize, storms increasingly batter newly exposed coastlines, and subsistence hunting and fishing – the mainstay of generations of Arctic communities – becomes ever more challenging.

To slow the pace of warming over the next two to three decades, both globally and in the Arctic, countries must reduce emissions of powerful short-lived climate pollutants (SLCPs) such as black carbon and methane as an essential complement to reductions of carbon dioxide and other long-lived greenhouse gas emissions. In fact, global action on carbon dioxide and other long-lived greenhouse gases together with SLCPs offers the only path to achieve the internationally agreed goal, as set forth in the Paris Agreement adopted by the Parties to the United Nations Framework Convention on Climate Change, to limit warming to "well below" 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius[5].

In addition to its powerful atmospheric warming, black carbon that falls on snow and ice also accelerates the melting of these reflective surfaces and consequently global warming. Due to their proximity to the Arctic, Arctic States are uniquely positioned to slow Arctic warming caused by emissions of black carbon: despite generating just ten percent of global black carbon emissions, Arctic States are responsible for 30 percent of black carbon's warming effects in the Arctic[6].

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[1] Schuur, E.A.G. et al. 2015. "Climate Change and the Permafrost Climate Feedback." *Nature* 520, 171-179.

[2] AMAP. 2011. "Executive Summary: Snow, Water, Ice, and Permafrost in the Arctic." *Arctic Monitoring and Assessment Program*. AMAP: Oslo, Norway.

[3] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 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 [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[4] Barnes and Screen. 2015. "The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it?" *WIREs Clim Change* 6:277–286.

[5] UNEP/WMO. 2011. "Integrated Assessment of Black Carbon and Tropospheric Ozone". Available at: http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf

[6] AMAP. 2015. "AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers." Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. vii + 116 pp

Black carbon and methane emissions also contribute directly to air pollution that harms human health, in addition to the health impacts due to climate change itself. Black carbon does so directly as a component of particulate matter (PM), while methane does so by contributing to formation of ground-level ozone, which also significantly impairs agricultural productivity. Therefore, actions that reduce emissions of black carbon and methane today also achieve substantial local and global non-climate benefits[7,8].

Prompted by the climate impacts of black carbon and methane emissions, in April 2015 the Ministers of the Arctic Council adopted a framework titled "*Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action"* (the Framework)[9]. Key commitments in the Framework include:

- Taking "enhanced, ambitious, national and collective action to accelerate the decline in our overall black carbon emissions and to significantly reduce our overall methane emissions;"
- Adopting, by the 2017 Ministerial meeting, an "ambitious, aspirational and quantitative collective goal on black carbon, and to consider additional goals;" and
- Submitting biennial national reports on countries' existing and planned actions to reduce black carbon and methane, national inventories of these pollutants and, if available, projections of future emissions.

To help implement these commitments, the Framework established an Expert Group on Black Carbon and Methane (Expert Group), to be chaired by the nation holding the Chairmanship of the Arctic Council for that two-year cycle. The Expert Group was tasked with developing a biennial "Summary of Progress and Recommendations" (Summary Report) based on the national reports and other relevant information, for submission through the Senior Arctic Officials to Ministers at Arctic Council Ministerial meetings. The Framework invites Observer States to join the Arctic States in implementing the Framework, and to participate in the Expert Group upon submission of a national report. The Framework also tasks the Expert Group with providing recommendations for an aspirational collective goal on black carbon.

This document is the Summary Report prepared by the inaugural Expert Group for consideration by Arctic Ministers at the 2017 Arctic Council Ministerial. In developing recommendations for this first Summary Report, the Expert Group sought to identify a focused list of priority actions, rather than a comprehensive catalogue of options. This report provides specific recommendations to directly address major emission sources, as well as broader policy recommendations on transformative approaches for some key sectors (e.g., modal shifts for transportation) needed to realize the shift to a low carbon

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[7] AMAP. 2015. "Summary for Policymakers: Arctic Climate Issues 2015." Available at: http://www.amap.no/documents/doc/summary-for-policy-makers-arctic-climate-issues-2015/1196

[8] M. Sand, T.K. Berntsen, K. von Salzen, M.G. Flanner, J. Lagner, and D.G. Victor. 2016. "Responses of Arctic Temperatures to Changes in Emissions of Short-term Climate Forcers. *Nature Climate Change* 6: 286-289.

[9] Arctic Council. 2014. "Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action." Available at: https://oaarchive.arctic-council.org/bitstream/handle/11374/610/ACMMCA09_Iqaluit_2015_SAO_Report_Annex_4_TFBCM_Framework_Document.pdf?sequence=1&isAllowed=y

economy and the deeper reductions required over the longer term, in line with the temperature goals set forth in the Paris Agreement.

Summary of Black Carbon and Methane Emissions and Projections

All eight Arctic States and five Observer States (France, India, Italy, Spain and the United Kingdom) developed and submitted inventories of black carbon and methane emissions, as well as methane projections. Six out of eight Arctic States provided black carbon projections, along with the United Kingdom. For some countries, black carbon emission inventories or projections were developed for the first time in fulfillment of the commitment to do so under the Framework, a foundational step in the Framework's implementation

The oil and natural gas sector accounts for more than half of all methane emissions from Arctic States, though emissions from Nordic States are dominated by methane releases from digestive tracts of livestock (enteric fermentation). In Observer States, enteric fermentation and solid waste are generally the largest sources of methane emissions. Because methane projections were on average updated in 2013/2014, they do not capture the significant additional emissions reductions that would result from implementation of policies subsequently announced by some Arctic States regarding oil/gas emissions. Consequently, the current projections show little change in the total methane emissions across all Arctic States between 2013 and 2030.

Black carbon inventories submitted by Arctic States (which generally did not include wildfire or open burning emission sources) indicate that diesel engines are the largest source followed by residential emissions from biomass combustion. Although black carbon emissions from oil and gas flaring are not reported by all Arctic States, the Arctic Council's Arctic Monitoring and Assessment Programme has indicated that flaring is the second largest source of black carbon emissions from Arctic States, mainly due to Russian Federation emissions. Most but not all Arctic States submitted projections. Assuming no change in emissions by those Arctic States that did not submit projections, black carbon emissions across Arctic States are collectively projected to decrease by 24 percent from 2013 levels by 2025. This decrease is due mainly to standards for new vehicle engines and retirement of older, higher-emitting vehicles. Significantly, many Arctic countries substantially cut their emissions of black carbon prior to 2013, and these reductions are already reflected in the baseline for the current projections.

Recommended Collective Goal on Black Carbon

In this Summary Report, the Expert Group proposes the following ambitious, aspirational and quantitative collective goal on black carbon for consideration by Senior Arctic Officials and adoption by Arctic Council Ministers:

> "Recognizing that several Arctic States have already drastically reduced emissions, Arctic States resolve to collectively further reduce their black carbon emissions by at least 25-33 percent below 2013 levels by 2025.

> Moreover, recalling our commitment under the Framework to continually improve our black carbon emissions inventories and projections, as well as to improve ambition and promote enhanced action over time, we resolve to revisit this goal during the Finnish Chairmanship and future chairmanships at the discretion of the Chair as merited."

Recommendations for Enhanced Action on Black Carbon and Methane

This report proposes recommendations to tackle methane and black carbon emissions from four priority sectors with substantial warming impact on the Arctic. These recommendations take into account actions that are already in place in Arctic States, and are intended to present a menu of options for Arctic and Arctic Council Observer States to consider. The Expert Group also notes that the recommendations below are broadly applicable and would realize local benefits in the countries in which they are implemented, including for human and ecosystem health. Countries within and beyond the Arctic are encouraged to implement these recommendations in light of their national circumstances.

1. Diesel Powered Mobile Sources

Arctic States should reduce emissions from new diesel vehicles and engines by adopting world-class PM exhaust emission standards that require the use of best available control technologies (such as diesel particulate filters (DPF)) or use of alternative fuels. Emissions from legacy diesel vehicles and engines should be reduced by adopting targeted grants, fiscal measures, and/or regulations that support or require the early upgrading or replacing of legacy equipment. In addition, because high-sulphur diesel fuel disrupts operation of advanced emission control technologies, Arctic States should ensure the availability and use of clean fuels through policies and programs including mandatory fuel quality standards for on- and non-road[10] applications, with regional requirements and fiscal policy incentives where needed, as well as robust compliance programs. Arctic States should also engage with other countries to provide technical cooperation to reduce emissions from diesel powered mobile sources. Countries can complement policies and programs targeting diesel vehicles and engines by adopting incentives that encourage a shift from diesel passenger vehicles to lower emitting vehicle technologies, modes of transportation, and alternate fuels, as well as implementing transportation efficiency measures.

To reduce black carbon emissions from international shipping, Arctic States should identify, collect, and evaluate data to understand the value and effectiveness of black carbon reduction efforts in Arctic and near-Arctic waters. As warranted by the results of this evaluation, Arctic States should jointly develop recommendations to inform and accelerate the work of the International Maritime Organization on black carbon mitigation measures.

[10] The terms "off-road" and "non-road" are used differently in different jurisdictions. For simplicity, the term "non-road" is employed in this report to capture emissions from diesel vehicles not typically driven on a road, as well as mobile diesel engines used in a variety of equipment.

Key lessons underlying these recommendations:

- Mandatory emissions standards for new diesel vehicles that in practice require a combination of DPFs and low-sulphur fuel have been highly effective, net beneficial, and widely adopted across most participating countries.
- Fuel-quality standards that limit sulphur to 15 parts per million or below are an essential pre-requisite to stringent emissions standards, since these enable the use and effective operation of vehicle and engine exhaust after-treatment systems, such as DPFs that can nearly eliminate black carbon emissions.
- Addressing emissions from legacy fleets requires targeted measures that complement standards for new vehicles and engines.
- Encouraging shifts to less-polluting modes of transit and taxing pollution are also effective in reducing black carbon emissions.
- In the shipping industry, incentives help spur voluntary adoption of emission control measures.

2. Oil/Gas Methane Leakage, Venting and Flaring

Arctic States should reduce methane emissions from the oil/gas sector by developing and promptly implementing national oil/gas methane emission reduction strategies, including steps to improve emissions data. Arctic States should also urge firms headquartered or operating within their borders to join multilateral fora (e.g., Climate and Clear Air Oil and Gas Methane Partnership) and domestic programs (e.g. Natural Gas STAR) to promote voluntary action and enhance methane emissions data availability.

The four Arctic States with appreciable oil/gas production – Canada, Norway, the Russian Federation and the United States – have already endorsed the World Bank's Zero Routine Flaring by 2030 Initiative[11] and should further commit to develop, by no later than the 2019 Ministerial, implementation plans for achieving that objective. Where flaring is necessary, countries should implement regulations, programs or collaborate to increase the use of effective technologies and best practices to minimize emissions from this sector.

Key lessons underlying these recommendations:

- Significant no-cost and low-cost opportunities exist to reduce methane emissions from oil/gas operations.
- Regulation combined with economic incentives can drive innovation and reduce emissions.
- Where methane recovery is not viable, recovery of hydrocarbon liquids can help substantially reduce black carbon emissions from flared gas to reduce its climate impact.

[11] Governments, oil companies, and development institutions endorsing the World Bank "**Zero Routine Flaring by 2030" initiative** agree to cooperate to eliminate routine flaring no later than 2030. For more information, see http://www.worldbank.org/en/programs/zero-routine-flaring-by-2030

- Cooperation with industry can be valuable in prompting voluntary emission reductions as a complement to the above approaches.

3. Residential Biomass Combustion Appliances

Arctic States should seek to reduce black carbon emissions[12] from new *and* legacy residential-scale biomass combustion appliances, while also adopting energy efficiency measures for homes that are primarily heated using biomass. Developing and deploying effective education and awareness campaigns to reduce operator error is essential to reducing emissions from *all* in-use heating appliances.

To ensure that *new* biomass combustion appliances are cleaner and more efficient Arctic States should develop and, where possible, adopt a standardized testing protocol for black carbon emissions. This can support the development of voluntary or regulatory performance and energy efficiency standards and incentive programs. Governments should work with appliance manufacturers to ensure lower emitting and more efficient appliances are widely available and affordable.

To reduce emissions from *legacy* heating appliances, Arctic States should incentivize replacement of older biomass combustion appliances with cleaner and more efficient alternatives.

Arctic States should promote transformational change in the sector to achieve substantial black carbon emissions reductions over the long-term by promoting enhanced home heating efficiency, and thereby reducing fuel usage.

Key lessons underlying these recommendations:

- Because the climate impact of total $PM_{2.5}$ emission reductions is uncertain, there is a particular need to understand which heating sources reduce black carbon specifically and therefore result in a climate benefit.
- Legacy appliances remain a particular challenge, and it has proven difficult to find sufficient, sustained funding and to determine the appropriate levels of incentives for change-out programs aiming to accelerate replacement by cleaner heating sources.
- Operator error and maintenance substantially influence the level of emissions generated by both new and legacy wood combustion appliances, therefore public education initiatives are essential in promoting appliance replacement and better usage. However, more data are needed to assess and enhance the effectiveness of such campaigns and support the dissemination of those shown to be most effective.

[12] Combustion of biomass produces a high share of organic carbon compared to black carbon; as organic carbon aerosols have a cooling effect, these aerosols could potentially offset the direct warming effect of black carbon aerosols from biomass burning. Because the climate impact of total particular matter (PM) emission reductions is uncertain, there is a particular need to understand which heating sources reduce black carbon specifically and therefore result in a climate benefit.

4. Solid Waste Disposal

Arctic States should avoid methane emissions from solid waste through policies that encourage waste minimization (especially food waste), diversion and alternative treatment, and ban or incentivize the banning of landfilling organic waste.

To drive down emissions from existing, new, modified or reconstructed landfills, Arctic States should adopt policies or regulations that incentivize or require landfill gas capture and control, as well as require or incentivize utilization of methane generated from landfills.

Key lessons underlying these recommendations:

- Combining regulation, fiscal instruments, and voluntary programs offers the best opportunity to reduce methane emissions from solid waste disposal.
- In many countries, organics landfill bans have been highly effective policy tools to reduce methane emissions, especially when supported by the establishment of municipal or private composting programs for alternative management of these materials.
- Where national governments lack authority to regulate solid waste, they can help promote successes at the local level through collaboration with local governments, civil society and industry.

LIST OF RECOMMENDATIONS

1. Diesel-Powered Mobile Sources

Recommendation 1a: Reduce emissions from *new* diesel vehicles and engines, by adopting and implementing world-class particulate matter exhaust emission standards, and ensuring the widespread availability of ultra-low sulphur fuels

Recommendation 1b: Reduce emissions from *legacy* diesel vehicles and engines by adopting targeted policies and programs

Recommendation 1c: Reduce black carbon by stimulating the shift to alternative vehicle technologies and modes of transportation, and through transportation efficiency measures

Recommendation 1d: Work to accelerate efforts under the International Maritime Organization to mitigate black carbon from international shipping

2. Oil/Gas Methane Leakage, Venting, and Flaring

Recommendation 2a: Adopt and implement oil and gas methane emission reduction strategies

Recommendation 2b: Develop implementation plans for the Zero Routine Flaring by 2030 Initiative and report on progress and best practices to the Arctic Council

Recommendation 2c: Urge firms to engage in multilateral fora and domestic programs aimed at promoting voluntary methane and black carbon emission reductions

3. Residential Biomass Combustion Appliances

Recommendation 3a: Reduce emissions from *new* biomass combustion appliances by accelerating deployment of cleaner and more efficient new heating sources and promoting proper stove operation and maintenance

Recommendation 3b: Reduce emissions from *legacy* biomass combustion appliances by accelerating replacement with cleaner and more efficient new heating sources and promoting proper stove operation and maintenance

Recommendation 3c: Reduce emissions by promoting enhanced home heating efficiency for residential dwellings, especially those heated with biomass

4. Solid Waste Disposal

Recommendation 4a: Avoid methane emissions by preventing the landfilling of organic waste

Recommendation 4b: Adopt regulations or incentives for landfill gas capture and control

CONTEXT

Rapid warming of the Arctic has profound consequences not only for the Arctic itself but also worldwide. Loss of Arctic snow/ice cover and thawing of permafrost accelerate warming on a global basis[13], and melting of land-based ice contributes to sea-level rise. In addition, as the Arctic continues to warm at twice the global average rate[14,15], emerging science suggests that the reduced temperature differential between the Arctic and other areas may contribute to destabilization of the jet stream in a way that intensifies weather extremes in mid-latitude regions[16]. Within the Arctic itself, buildings collapse as long-frozen soils destabilize, storms increasingly batter newly exposed coastlines, and subsistence hunting and fishing – the mainstay of generations of Arctic communities – becomes ever more challenging.

Methane is a potent greenhouse gas, with anthropogenic (human-caused) emissions occurring primarily from the agricultural, oil/gas, and waste sectors. Black carbon, a component of fine particulate matter ($PM_{2.5}$), is formed by the incomplete combustion of fossil fuels and biomass[17]. Ton for ton, these pollutants trap far more heat than carbon dioxide, though they persist in the atmosphere for far shorter periods - hence their designation as "short-lived" climate pollutants (SLCPs). [18]

To slow the pace of warming over the next two to three decades, both globally and in the Arctic, reducing SLCP emissions is an essential complement to global action to reduce carbon dioxide emissions. In fact, global action on carbon dioxide and other long-lived greenhouse gases together with SLCPs offers the only path to achieve the internationally agreed goal, as set forth in the Paris Agreement, to limit warming to “well below” two degrees Celsius above pre-industrial levels and move towards 1.5 degrees Celsius[19].

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[13] Schuur, E.A.G. et al. 2015. “Climate Change and the Permafrost Climate Feedback.” *Nature* 520, 171-179.

[14] AMAP. 2011. “Executive Summary: Snow, Water, Ice, and Permafrost in the Arctic.” *Arctic Monitoring and Assessment Program*. AMAP: Oslo, Norway.

[15] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 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 [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[16] Barnes and Screen. 2015. “The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it?” *WIREs Clim Change* 6:277–286.

[17] Reducing emissions of particulate matter results in emission reductions of black carbon, but can also reduce emissions of organic carbon, potentially offsetting at least a portion of the direct warming effect of black carbon. Reducing particulate emissions with a high share of black carbon compared to organic carbon is therefore more likely to provide net climate benefits.

[18] Certain hydrofluorocarbons (HFCs) are also typically categorized as SLCPs. These compounds are primarily used in refrigeration and air-conditioning applications.

[19] UNEP/WMO (2011). “Integrated Assessment of Black Carbon and Tropospheric Ozone.” Available at: http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf

Black carbon and methane also contribute directly to air pollution that harm human health, in addition to the health impacts due to climate change itself. Black carbon does so directly as a component of PM, while methane does so by contributing to formation of ground-level ozone, which also significantly impairs agricultural productivity. Therefore, actions that reduce emissions of SLCPs today achieve real and significant climate mitigation benefits in the near- and medium-term, with substantial non-climate benefits to Arctic communities and beyond[20,21].

Arctic States have an important role to play in reducing SLCP emissions. As noted in the 2015 "Summary for Policy Makers: Arctic Climate Issues" report by the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP)[22]:

- For black carbon, emissions from within Arctic States account for about one third of black carbon's warming effects in the Arctic, despite accounting for only 10 percent of global black carbon emissions[23]. This is because black carbon from proximate sources is readily transported to the Arctic, is found in the lower Arctic atmosphere and can fall onto Arctic ice or snow. These processes lead to strong surface warming through direct atmospheric effects and by enhanced melting of ice and snow (i.e. ice-albedo feedbacks). It should be noted that even black carbon from non-proximate sources contributes to overall warming of the planet, including the Arctic.
- For methane, Arctic States account for roughly one fifth of global anthropogenic emissions. While methane emitted anywhere in the world warms the Arctic, Arctic States have the largest technical abatement potential of any major world region and could achieve one fourth of global methane emission reductions primarily by: reducing methane leakage, venting, and flaring from the oil and natural gas sector; preventing the landfilling of biodegradable waste; and improving coal mining practices[24].

In light of these findings, Arctic Council Ministers adopted the *Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action* (the Framework) at the Iqaluit Ministerial meeting in April 2015[25]. The Framework includes commitments to:

- Taking "enhanced, ambitious, national and collective action to accelerate the decline in our overall black carbon emissions and to significantly reduce our overall methane emissions";

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[20] AMAP. 2015. "Summary for Policymakers: Arctic Climate Issues 2015." Available at: http://www.amap.no/documents/doc/summary-for-policy-makers-arctic-climate-issues-2015/1196;

[21] M. Sand, T.K. Berntsen, K. von Salzen, M.G. Flanner, J. Lagner, and D.G. Victor. 2016. "Responses of Arctic Temperatures to Changes in Emissions of Short-term Climate Forcers. *Nature Climate Change* 6: 286-289.

[22] Ibid.

[23] AMAP, 2015. "AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers." vii + 116 pp

[24] AMAP (2015). "Arctic Climate Issues 2015: Short-lived Climate Pollutants (Summary for Policy-makers)." Available at http://www.amap.no/documents/doc/summary-for-policy-makers-arctic-climate-issues-2015/1196

[25] Arctic Council. 2014. "Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action." Available at: https://oaarchive.arctic-council.org/bitstream/handle/11374/610/ACMMCA09_Iqaluit_2015_SAO_Report_Annex_4_TFBCM_Framework_Document.pdf?sequence=1&isAllowed=y

- Adopting, by the 2017 Ministerial meeting, an ambitious, aspirational and quantitative collective goal on black carbon and to consider additional goals"; and
- Submitting biennial national reports on countries' existing and planned actions to reduce black carbon and methane, as well as national inventories of these pollutants and, as available, projections of future emissions.[26]

To help implement these commitments, the Framework established an Expert Group on Black Carbon and Methane (Expert Group), to be chaired by the nation holding the Chairmanship of the Arctic Council for that two-year cycle. The Expert Group was tasked with developing a biennial "Summary of Progress and Recommendations" (Summary Report) based on the national reports and other relevant information, for submission through the Senior Arctic Officials to Ministers at Arctic Council Ministerial meetings. The Framework invites Observer States to join Arctic States in implementing the Framework, and to participate in the Expert Group upon submission of a national report. The Framework also tasks the Expert Group with providing recommendations for an aspirational collective goal on black carbon.

Since the adoption of the Framework, opportunities for black carbon mitigation actions to be "mainstreamed" have begun to emerge. Although black carbon, unlike methane, is not covered by the United Nations Framework Convention on Climate Change (UNFCCC), some countries are including black carbon in their Nationally Determined Contributions, or national climate targets, and/or their long-term low greenhouse gas emission development strategies (i.e., mid-century strategies) under the Paris Agreement. Furthermore, the Intergovernmental Panel on Climate Change will develop two special reports that will help inform future Expert Group discussions: in 2018, a report on the impacts of 1.5°C warming above pre-industrial levels and related global greenhouse gas emission pathways, and subsequently, on Oceans and the Cryosphere. Finally, a number of the recommendations here support, and can be leveraged by, relevant United Nations Sustainable Development Goals, including Goal 13 to "take urgent action to combat climate change and its impacts."

Arctic States must demonstrate leadership at home by continuing to drive down their emissions. It is important to note, however, that black carbon and methane emissions from non-Arctic States are a significant contributor to Arctic warming. Therefore, the Expert Group invites Arctic Council Observer States, and other States whose emissions impact the Arctic region, to consider adopting these recommendations or related measures keeping in mind the urgency of the long-term temperature goal set forth in the Paris Agreement. The Expert Group also encourages Arctic States to consider areas where domestic mitigation could be complemented by international cooperation with non-Arctic States, especially for major source categories that strongly impact the Arctic. These contributions through international cooperation should be systematically evaluated and included in future biennial national reports as called for under the Framework.

[26] All reports on national black carbon and methane emissions submitted to the Arctic Council are available at http://www.arctic-council.org/index.php/en/expert-groups/339-egbcm.

EMISSIONS AND PROJECTIONS

Understanding the major emission sources and their projected growth or decline is essential for identifying and prioritizing opportunities for reducing emissions and tracking progress towards mitigation goals. Under the Framework, Arctic States agreed to share summaries of their methane inventories and projections, as previously submitted to the UNFCCC. They also committed to develop and improve emission inventories and projections for black carbon (a substance not covered by the UNFCCC) using, where possible, relevant guidelines from the Convention on Long-Range Transboundary Air Pollution (CLRTAP). This report summarizes national and regional emissions information, which provides the foundation for the Expert Group's prioritization of mitigation opportunities.

Methane

Methane Inventories

The methane inventories (summarized in the Annex of this Summary Report) are drawn from countries' 2016 submissions to the UNFCCC, which include data from 1990-2014. Overall, Arctic Council nations' methane emissions are about seven percent lower than their 1990 levels. The oil/gas sector is the largest source of methane emissions for Arctic States collectively, accounting for more than half of all methane emissions in 2014, though emissions from Nordic States are dominated by enteric fermentation (i.e., methane releases from digestive tracts of ruminants such as cattle). Manure emissions have been the fastest growing sector since 1990 (34 percent growth over that time period, though representing only 4 percent of methane emissions in 2014) and other energy and industry emissions have decreased the most over that time period (a 34 percent decline, now representing 9 percent of total methane emissions). In Observer States, enteric fermentation and the solid waste sector are generally the largest sources of methane emissions.

Methane Projections

Most Arctic Council States last updated their methane projections in their 2013 Biennial Reports, which predate their latest inventory submissions. Although those projections show little change in the total methane emissions across all Arctic States between 2013 and 2030, significant additional methane emission reductions could occur over the next one to two decades as a result of methane mitigation policies that have been implemented, adopted or planned subsequent to the projections. For example, the U.S. and Canada jointly committed in March 2016 "to reduce methane emissions by 40-45 percent below 2012 levels by 2025 from the oil and gas sector, and explore new opportunities for additional methane reductions"[27].

[27] U.S. – Canada Joint Statement on Climate, Energy and Arctic Leadership. March 10, 2016. Available at https://www.whitehouse.gov/the-press-office/2016/03/10/us-canada-joint-statement-climate-energy-and-arctic-leadership

Black Carbon

Black Carbon Inventories

Unlike methane, there is currently no globally agreed framework for black carbon inventories, and international action on inventory development is relatively recent. The Gothenburg Protocol to CLRTAP, as amended in 2012, calls for Parties to voluntarily submit black carbon emissions inventories and projections using guidelines developed by the CLRTAP Task Force on Emission Inventories and Projections. While Sweden is currently the only party to the amended Gothenburg Protocol, all Arctic States and some Observer States developed black carbon inventories for the year 2013 to fulfill their commitment under the Framework. These inventories were also submitted to CLRTAP for countries that are party to the convention. A number of Observer Countries signaled their intention to provide black carbon inventories in future reporting cycles under the Framework.

As of late 2016, all eight Arctic States have developed and submitted inventories, along with five Observer States (France, India, Italy, Spain and the United Kingdom). This represents a foundational step in the Framework's implementation. According to the submitted inventories, the largest black carbon emissions sector in the Arctic is transportation (from diesel engines), followed by emissions from residential biomass combustion. Although black carbon emissions from oil and gas flaring are not reported by all Arctic States, AMAP has concluded that flaring is the second largest source of black carbon emissions from Arctic States.

As discussed in greater detail in the Annex below, comparisons between Russian Federation emissions and other national emissions are challenging, as the Russian Federation has submitted data using different sectoral definitions than those used by other Arctic States.

Black Carbon Projections

Six out of eight Arctic States provided black carbon projections, along with the United Kingdom. As there are differences across countries in methodologies used as the basis of these projections, they should not be regarded as definitive. Based on projections as submitted, black carbon emissions are expected to decrease by 24 percent from 2013 levels by 2025, assuming no change in emissions in Arctic States that did not submit projections. Such reductions are due mainly to standards for new vehicle engines and retirement of older, higher-emitting vehicles. Emissions from other sectors are not projected to change dramatically.

It is important to recognize that many countries have already significantly cut their emissions of black carbon. For example, 2013 emissions in the Nordic States are 20 percent below 2000 levels due mainly to a decrease of almost 50 percent in black carbon emissions from the on- and non-road sector. As discussed in the Annex, some Arctic States had begun reducing their black carbon emissions even earlier, likely before 2000. For example, Denmark's 2014 inventory (it's most recent) indicates that emissions have declined by half since 1995 when black carbon emissions peaked and major emission-reduction initiatives were instituted.

AMBITIOUS, ASPIRATIONAL, AND QUANTITATIVE COLLECTIVE BLACK CARBON EMISSIONS REDUCTION GOAL

Under the Framework, the Arctic States agreed to "adopt an ambitious, aspirational and quantitative collective goal on black carbon, and to consider additional goals, by the next Arctic Council Ministerial meeting in 2017." The Ministers tasked the Expert Group with identifying options for this goal.

The collective goal proposed below is premised on full implementation of measures that underlie the black carbon emissions projections provided to the Expert Group. It also includes further reductions anticipated from the full implementation of additional measures contributing to the implementation of the Framework, such as those adopted or planned since the development of the projections. Achieving the collective goal may require mitigation actions beyond those currently identified. Because many Arctic States substantially cut their emissions prior to 2013, additional reductions by those States may be more challenging to achieve.

The collective goal, as identified by the Expert Group for the consideration of the Senior Arctic Officials and adoption by ministers, is proposed as follows:

> "Recognizing that several Arctic States have already drastically reduced emissions, Arctic States resolve to collectively further reduce their black carbon emissions by at least 25-33 percent below 2013 levels by 2025.
>
> Moreover, recalling our commitment under the Framework to continually improve our black carbon emissions inventories and projections, as well as to improve ambition and promote enhanced action over time, we resolve to revisit this goal during the Finnish Chairmanship and future chairmanships at the discretion of the Chair as merited."

RECOMMENDATIONS FOR ENHANCED ACTION

As directed by the Framework, the Expert Group has developed recommendations for further reducing black carbon and methane emissions, based on its evaluation of best practices and lessons learned to date. The Expert Group relied heavily on prior work conducted by the Arctic Council subsidiary bodies[28], as well as information provided in the national reports submitted per the Framework by Arctic States, participating Observer States, and the European Union[29], and follow-up conversations with internal and external experts. The Expert Group also drew upon complementary work underway in other multilateral fora such as the Climate and Clean Air Coalition (CCAC), the Gothenburg Protocol of CLRTAP, the Global Methane Initiative, the Zero Routine Flaring by 2030 Initiative, and the International Maritime Organization (IMO).

The recommendations provide a menu of non-binding, potential measures that could yield significant near- and long-term reductions. All Arctic States and Arctic Council Observer States are encouraged to implement recommendations in light of their national circumstances.

In developing its recommendations, the Expert Group focused on developing a finite number of priority recommendations, rather than an extensive or comprehensive list, in order to highlight practical steps that can most quickly reduce black carbon and methane emissions, thereby slowing the pace of Arctic warming. These considerations led the Expert Group to identify the following sectors as priority sources for Ministerial consideration in 2017:

- Diesel-powered mobile sources (black carbon);
- Oil and gas production (both methane and black carbon);
- Residential biomass combustion appliances (black carbon); and
- Solid waste (methane).

The recommendations directly address these sources, as well as broader policy measures on transformative approaches for some key sectors (e.g., modal shifts for transportation) needed to realize the shift to a low carbon economy and the deeper reductions required over the longer term, in line with the temperature goals set forth in the Paris Agreement[30].

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[28] Relevant reports by the Arctic Monitoring and Assessment Programme can be found here: http://www.amap.no/documents/18/scientific/21. Relevant reports by the Arctic Contaminants Action Programme can be found here: https://oaarchive.arctic-council.org/handle/11374/1.

[29] Participating Observer States include France, India, Italy, Japan, Poland, Republic of Korea, Spain, and the United Kingdom. The European Union also participates in the Expert Group.

[30] The Expert Group also identified other sectors warranting further consideration by successor Expert Groups, notably open burning (agricultural burning and associated wildfires), enteric fermentation and stationary diesel. While these are significant sources, two factors led the Expert Group to exclude them from the current set of recommendations: first, the desirability of presenting a concise set of prioritized recommendations; and second, the need to have additional information on specific mitigation measures appropriate for these particular sources.

1. Diesel-Powered Mobile Sources

Mobile sources -- light -and heavy-duty vehicles, non-road equipment and engines, locomotives, and ships -- generate black carbon emissions through the incomplete combustion of fuels, especially in diesel fueled engines.

According to the 2013 inventories, on-road and non-road mobile sources (excluding international shipping and international aviation) represent 61 percent of black carbon emissions for Arctic States.[31] All Arctic States, and all Arctic Council Observer States participating in the Expert Group, have implemented some combination of the following approaches to reduce black carbon emissions from diesel mobile sources:

- Mandatory *exhaust emission standards* for new vehicles and engines;
- Targeted policies and programs for *legacy vehicles and engines* (i.e., those still in use that were manufactured before current standards took effect);
- Mandatory standards to *reduce sulphur levels in fuels* for use in vehicles and engines, which enable the use of best available control technologies, such as diesel particulate filters (DPFs); and
- Shifts to reduce emissions overall, such as to alternate fuels or transportation modes.

Arctic shipping currently accounts for about 5 percent of black carbon emissions within the Arctic; absent emission controls, shipping emissions within the Arctic could double by 2030 under some projections of Arctic vessel traffic[32]. In response to concerns over air quality and human health impacts associated with shipping emissions, a number of relevant actions have been undertaken, such as:

- The establishment through the IMO of Emission Control Areas where the adoption of special mandatory measures for emissions from ships limits nitrogen oxide emissions, sulphur oxide emissions, or both;
- Agreement under the IMO to a global sulphur cap of 0.5 percent for fuel to be implemented starting 1 January 2020;
- Incentivizing the uptake of emission abatement technologies, electrification of ports, fuel efficiency improvements, or use of alternative fuels;
- Engaging in ongoing work within the IMO's Sub-Committee on Pollution Prevention and Response (PPR) to identify appropriate methods for measuring black carbon emissions from international shipping and to consider possible control measures; and

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[31] This calculation does not include Russian emissions (due to incomparable sectoral aggregation) and does not include emissions from open biomass burning and wildfires.

[32] AMAP. 2015. "Arctic Climate Issues 2015: Short-lived Climate Pollutants (Summary for Policy-makers)." Available at http://www.amap.no/documents/doc/summary-for-policy-makers-arctic-climate-issues-2015/1196

- Participating in the Arctic Council's Working Group on the Protection of the Arctic Marine Environment (PAME) and its Shipping Experts Group.

Lessons Learned and Best Practices

Mandatory emissions standards for new diesel vehicles and engines that in practice require a combination of DPFs and low-sulphur fuel have been highly effective, net beneficial, and widely adopted across most participating countries. Arctic Council States as well as Observer States have achieved substantial benefits from such actions. For example, benefits of implementing standards promulgated in 2007 for on-road heavy duty diesel vehicles in Canada and the U.S. outweighed costs by around 16-to-1, and benefits of implementing "Tier 4" standards for non-road diesel engines[33] in the U.S. exceeded costs by 40-to-1 (these standards were issued in 2004 and phased in from 2008 through 2015). As such standards are phased in, vehicle-inspection programs are important in ensuring that emissions are within acceptable parameters.

Similarly, stringent regulation of particulate matter exhaust from vehicles in Tokyo, Japan resulted in a decrease of approximately 80 percent in measured black carbon mass concentrations between 2003 and 2010. In the European Union, efforts to achieve European Union-wide air quality standards that limit the annual mean value of $PM_{2.5}$ to 25 µg/m³ have required substantial reductions in $PM_{2.5}$ emissions from passenger cars and heavy-duty vehicles and buses; Spain, for example, has experienced reductions of 46 percent and 70 percent since 2000, respectively. Other Arctic and Observer States that have implemented similar measures have also realized important air quality and health benefits, and report that measures are generally highly cost effective.

Implementation of standards that require a fuel sulphur level of 15 parts per million or below is an essential pre-requisite to stringent emissions standards, since these enable the use and effective operation of vehicle and engine exhaust after-treatment systems, such as DPFs that can nearly eliminate black carbon emissions. While low sulphur fuel is widely available in many Arctic States, there are a number of barriers that can impede its availability in some countries. These barriers include the cost of upgrading refineries, and of keeping fuels low sulphur throughout the fuel distribution chain (i.e. avoiding contamination with higher sulphur fuels).

Addressing emissions from legacy fleets requires targeted measures that complement standards for new vehicles and engines. Because vehicles and engines often remain in use for years or decades, it is important to complement standards for new vehicles and engines with programs addressing "legacy" items – those items produced before current standards took effect. Significant emission reductions can be achieved through several types of measures, such as those that encourage retrofitting with advanced technologies, scrappage and replacement with newer vehicles and engines, and repowering vehicles and

[33] The terms "off-road" and "non-road" are used differently in different jurisdictions. For simplicity, the term "non-road" is employed in this report to capture emissions from diesel vehicles not typically driven on a road, as well as mobile diesel engines used in a variety of equipment.

engines with engines that use alternative fuels. In the U.S., for example, grants awarded under the National Clean Diesel Campaign are expected to achieve more than 14,700 short tons of $PM_{2.5}$ reductions, resulting in up to USD12.6 billion in health benefits[34,35]. This effort has been successful in part because the program focused on the use of DPFs and other technologies initially through the Clean School Bus USA Program designed to reduce children's exposure to diesel exhaust, and in turn, black carbon.

Mandatory labeling of vehicles or engines with emissions equipment and performance information can support enforcement of various policies and programs by allowing inspectors to verify that emissions reduction equipment present at time of manufacture remains in use. Regulations that prohibit tampering of emissions reduction equipment can also support reductions by discouraging owners of diesel-powered vehicles and machines and businesses from modifying or removing DPFs, diesel oxidation catalysts, and other technologies.

In addition, operational measures can complement end-of-pipe control technologies for addressing emissions from in-use vehicles. Low emission zones, inspection and maintenance programs, and programs to encourage reductions in idling have been used in several Arctic States to achieve emission reductions from legacy fleets.

Encouraging shifts to less-polluting modes of transit and taxing pollution are effective in reducing black carbon emissions. Many Arctic and Observer States have also implemented sustainable transportation initiatives that encourage a shift from diesel passenger vehicles to more environmentally friendly vehicles or transport modes with lower emissions. For example, Germany is awarding EUR4,000 per electric vehicle purchased, and EUR3,000 per plug-in hybrid vehicle purchased.

Incentives help spur voluntary adoption of emission control measures in the shipping industry. Some Arctic States are providing incentives to motivate industry adoption of emission-reduction strategies and technologies. These include engine rebuilds and the use of advanced after-treatment technologies including installation of DPF and deployment of marine shore power technology at ports so that ships do not need to run marine diesel generators to power onboard systems while pier-side. In Europe, many ports are required to be equipped with shore-side electricity supply for inland waterway vessels and sea-going ships by December 31, 2025[36]. In Germany, the "Blue Angel" ecolabel, existing since 1978, contains a sub-category certifying environmentally-friendly ship design and operation, incentivizing the use of clean fuels and environmentally conscious ship management.

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[34] U.S. EPA. 2016. "Third Report to Congress: Highlights from the Diesel Emission Reduction Program." Available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OHMK.pdf

[35] United States Government. 2015. "U.S. National Black Carbon and Methane Emissions: A Report to the Arctic Council." Available at https://oaarchive.arctic-council.org/bitstream/handle/11374/1168/EDOCS-%232713-v1-USA_2015_Black_Carbon_Methane_National_Report.PDF?sequence=6&isAllowed=y

[36] Directive 2014/94/EU is applicable to ports within the TEN-T Core Network.

Recommendations for Enhanced Action

Arctic States can most effectively further reduce black carbon emissions from diesel vehicles and engines by (1) implementing stringent exhaust emission standards for new diesel vehicles and engines, (2) employing targeted measures to encourage early upgrading of legacy engines, (3) stimulating the shift from diesel vehicles and engines to alternative transportation technologies and modes, and (4) working to accelerate efforts under the IMO to mitigate black carbon from international shipping.

The recommendations below account for the fact that all Arctic States have already implemented ultra-low sulphur fuel requirements, the foundational actions required to reduce emissions from diesel vehicles and engines.

Recommendation 1a: Reduce emissions from new diesel vehicles and engines, by adopting and implementing world-class particulate matter exhaust emission standards, and ensuring the wide-spread availability of ultra-low sulphur fuels

World-class PM exhaust emission standards require the use of best available control technologies, such as DPFs, or use of alternative fuels. Standards should be broad in coverage, aiming to control emissions from on-road vehicles and engines, and non-road vehicles and engines found in construction, mining, farming, forestry and other applications. Examples of world-leading emission standards for on-road light/heavy-duty vehicles and engines include Euro 6/VI standards in the European Union and Tier 3/US2007 standards in the United States (also adopted in Canada); for non-road applications, examples include Stage V standards in the European Union and Tier 4 standards in the U.S. (also adopted in Canada).

Many advanced emission control technologies are rendered inoperative by high-sulphur fuel, so policies and programs to ensure the widespread availability of ultra-low sulphur fuel (diesel fuel with sulphur content of no more than 15 parts per million) are an essential complement to emission-control standards. A fuel price or taxation differential that makes cleaner fuel cheaper can incentivize accelerated supply and consumption of ultra-low sulphur diesel. Also essential are robust fuel quality compliance programs, as even very short-term use of high-sulphur fuel can irreversibly impair the performance of advanced emission controls. Approaches such as "presumptive liability"[37] encourage all actors in the fuel supply chain to test and report on fuel quality and isolate where compliance problems exist.

Because most Arctic States are already implementing such emission-control and fuel standards, a key opportunity to reduce mobile-diesel emissions exists by engaging in technical cooperation with other countries. Doing so advances the Framework's commitment to work with Arctic Council Observer States and others "to also reduce emissions produced beyond the borders of Arctic States." Mechanisms for

[37] In the U.S., presumptive liability is a legal definition under which the operator of any facility where noncompliant fuel is located, and any distributor that stored or transported noncompliant fuel to that downstream facility, can be found legally liable for violations of low-sulphur content regulations. Where the brand name of a refiner is displayed, the EPA's regulations provide that the branded refiner is also presumptively liable.

doing so include multilateral forums such as the CCAC's heavy duty diesel vehicles and engines initiative as well as the United Nations Environment Programme's Partnership for Clean Vehicles and Fuels.

Recommendation 1b: Reduce emissions from legacy diesel vehicles and engines by adopting targeted policies and programs

Arctic States should implement targeted national and local-level policies and programs to encourage and support the early upgrading of equipment, taking into account that the most appropriate and effective measures to reduce emissions from legacy vehicles and engines vary across engine types and applications.

- **Flexible national grant programs** applied across a wide array of applications (including on- and non-road vehicles and engines, stationary diesel engines, rail, and marine) and project types (including retrofitting, engine replacement, refueling, and scrappage) give governments a larger pool of projects to choose from and enable the most cost-effective solution for each application. Grant programs should require the use of retrofit technologies that have been certified for use in the specific application for which funding support is requested, and simultaneously consider multiple pollutants in addition to black carbon, such as PM, nitrogen oxide, and greenhouse gases. Examples include the U.S. Environmental Protection Agency's (EPA) Clean Diesel Program and California's Carl Moyer Program.
- **Fiscal measures linked to emissions performance** may also drive early upgrading of equipment. Examples include extra taxes on diesel engines without particle traps; congestion charging linked to emissions performance; and tolls levied according to factors such as emissions performance and distance. For example, Norway has a higher annual tax for diesel cars without DPFs, and Denmark has a small annual tax on diesel cars without such filters. Both measures shorten the payback time for consumers retrofitting with filters.
- **Regulations targeting emissions of legacy engines** serve as an alternative or complement to grant and fiscal programs. For example, mandatory "regulatory backstops" (e.g. a requirement that all engines in a certain application be fitted with a filter by a certain date) paired with grant or other voluntary programs support and incentivize early compliance. Such an approach has been adopted in the United States by the state of California, which requires diesel retrofits and/or vehicle replacements for on-road heavy-duty diesel vehicles. As a result, all heavy-duty diesel vehicles will have a 2010 model year engine or equivalent by 2023. Similarly, with its new "Blue Plaque" regulation, the German national government laid the foundations for municipalities to establish even more stringent requirements for their respective low emission zones.

Recommendation 1c: Reduce black carbon by stimulating the shift to alternative vehicle technologies and modes of transportation, and through transportation efficiency measures

Arctic States should reduce diesel emissions by adopting incentives that encourage a shift from diesel passenger vehicles to non-diesel vehicles and transport modes with lower emissions. Options include development of public transportation, incentives for car-pooling, promotion of bicycling, and shift of freight transportation to rail or other cleaner modes where possible.
Policies and programs that have been shown to influence consumers' and companies' choice of vehicle technology include those that reduce purchase price (e.g., tax breaks or other incentives for electric vehicle purchases), as well as investments in enabling infrastructure, such as charging stations and natural gas infrastructure, and creation of reserved parking spaces for alternative vehicles. For example, Norway aims to rapidly transition to electric forms of transportation by setting targets for the number of zero emission vehicles (including cars, vans, trucks and buses) in 2025. To that end, it is providing user incentives including substantial tax breaks, free parking, access to bus lanes in urban areas, and exemptions from road tolls and car ferry charges. Electric models accounted for 15.7 percent of new car sales in Norway in 2016, the highest of any country in the world.

Countries may also consider operational measures that reduce emissions from all on-road vehicles. For example, low-emission zones may target specific vehicles, such as older diesel vehicles, or reduce traffic overall, thereby reducing black carbon emissions, while over the longer term also influencing the kind of vehicles end-users choose to purchase. In Norway, Parliament has recently passed a new rule enabling municipalities to establish low emission zones. Actions elsewhere include inspection and maintenance programs that can address super-emitters. Reduction of idling through regulation, education, electrification of rest stops, and other means can also reduce emissions, and the U.S. EPA has instituted several idling reduction measures and programs.

Recommendation1d: Work to accelerate efforts under the International Maritime Organization to mitigate black carbon from international shipping

Arctic States should identify, collect, and evaluate data to understand the value and effectiveness of black carbon reduction efforts in Arctic and near-Arctic waters. The evaluation should include switching from heavy fuel oil to cleaner burning fuels as well as the deployment of appropriate emission-control technologies that enable black carbon emission reductions from some fuels, such as DPFs. Criteria should include climate, environmental and health benefits, as well as economic costs to indigenous communities, the commercial shipping industry, the resource extraction industry, and other markets where increased fuel and technology costs may increase related market costs. In order to perform rigorous analyses of costs and benefits, more information about current practices may be needed.

The Arctic States should convene under PAME to share information and outcomes, and develop new evaluation methods, as appropriate. As warranted by the results of this evaluation, PAME and the

Expert Group could jointly develop recommendations that one or more of the Arctic States could submit to the IMO PPR to inform the latter's work on black carbon. To ensure appropriate follow-up, these activities should be included in the 2017-2019 PAME work plan.

In addition, Arctic States should jointly urge the IMO PPR to accelerate work on potential mitigation measures.

2. Oil/Gas Methane Leakage, Venting, and Flaring

Methane is emitted during operations, maintenance, and system disruptions in the oil and natural gas industry. According to the 2013 inventories, the oil and gas sector represents 58 percent of methane emissions for Arctic States. Globally, the oil and gas sector accounts for approximately 20 percent of methane emissions, though available data are not definitive[38]. Because methane is a well-mixed gas in the atmosphere, methane emissions affect the Arctic regardless of their point of origin. The International Energy Agency recently identified minimizing methane emissions from upstream oil and gas production as one of five key global greenhouse gas mitigation opportunities, noting that low-cost reductions in this area could account for nearly 15 percent of the total greenhouse gas reductions needed by 2020 to keep the world on a path to limit warming to under two degrees Celsius[39]. Flaring of natural gas, though preferable to venting, produces black carbon emissions (as well as carbon dioxide). In addition to climate benefits, implementing measures to reduce methane emissions can have important occupational health and safety benefits. Current methane and black carbon emission control strategies in the oil/gas sector can largely be classified as follows:

- Regulations or incentives to reduce *venting* of methane*;*
- Regulations or incentives for methane *leak detection and repair,* for use of low-emission completions at hydraulically fractured oil wells and gas wells, and other specific practices*;*
- Regulations or incentives to *reduce flaring;* and
- *Voluntary programs and partnerships* to share best practices among the public and private sector.

Lessons Learned and Best Practices

Significant no-cost and low-cost opportunities exist to reduce methane emissions. Operational benefits of reducing methane emissions from oil and gas operations/assets include improved gas recovery, leading to increased volumes available for sale. For example, the U.S. EPA estimates its 2016 new source performance standards would result in methane emission reductions of 510,000 short tons in 2025, the equivalent of reducing 11 million metric tons of carbon dioxide. U.S. EPA estimates the

[38] U.S. EPA's Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases: 1990–2020 (EPA Report 430-R-06-003), www.epa.gov/climatechange/economics/international.html.

[39] International Energy Agency. 2015. "Climate and Energy: World Energy Outlook Special Report." Available at https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf

standards will yield climate benefits of USD690 million in 2025 (in 2012 dollars), which will outweigh the estimated costs of USD530 million for a net benefits of USD170 million in 2025. In addition, natural gas that is recovered as a result of the rule can be used as a fuel on site or sold[40]. Recent studies also indicate that a significant fraction of total leaks from existing sources come from a relatively small group of disproportionately large emitters. One study, published in October 2016 by Stanford University researchers, indicates that the largest 5 percent of leaks are typically responsible for more than 50 percent of the total volume of oil/gas methane leakage in the United States[41]. By focusing on a small number of large emitters, countries may be able to achieve significant oil/gas methane emissions reductions.

Regulation combined with economic incentives can drive innovation and reduce emissions. Norway, for example, prohibits flaring of natural gas at oil wells except for security reasons, so oil companies cannot sell the oil until they find a use for the associated gas – either by re-injecting it for pressure support or by arranging for pipeline transport to customers. This regulation, in addition to a carbon tax introduced in 1991, became a driving force for development of new technologies such as the "closed flare system". Today this system is a conventional technology for most new field developments in Norway, is installed on a majority of sites on the Norwegian Continental Shelf, and is also used in other States. As a result of the ban on flaring, together with Norway's tax on greenhouse gas emissions, the average total methane emissions from petroleum activities on the Norwegian Continental Shelf are one-third of the global average. In addition, the Russian Federation has implemented a payment system for exceeding the established associated petroleum gas (APG) flaring or/and venting limit of five percent of total APG production. Under this approach, APG flaring in the Russian Federation has been cut in half and investments into projects supporting APG utilization have increased several-fold.

Recovery of hydrocarbon liquids can help substantially reduce black carbon emissions from gas flaring. Research in Canada and associated pilot projects in Mexico, Colombia and Nigeria have shown that the formation of black carbon from flaring is correlated with the concentration of condensable, high-value hydrocarbon gases such as butane, pentane or hexane in the flare fuel. This work has also shown that hydrocarbon liquids recovery projects can generate significant economic opportunities while reducing black carbon emissions. In some circumstances, at least a portion of that associated gas can be used to generate on-site power to operate liquids recovery technologies. In Germany, emissions must be collected or flared. Flare-gas recovery systems liquefy collected methane gases and return them to refining processes or to refinery combustion systems. In the process, more than 99 percent of the hydrocarbons in the gases are converted to carbon dioxide and water, contributing to a 14 percent reduction in Germany's methane emissions from venting and flaring in the period 1990-2012.

[40] For more information on U.S. EPA's efforts to control air pollution from the oil and natural gas industry, visit https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry

[41] Brandt et al. 2016. "Methane Leaks from Natural Gas Systems Follow Extreme Distributions." *Environmental Science & Technology*. October 2016, 50 (22), pp 12512–12520. Available at http://pubs.acs.org/doi/abs/10.1021/acs.est.6b04303

Cooperation with industry can be valuable in prompting emission reductions. Experience suggests that close cooperation between regulators and oil and gas companies helps accelerate reductions. U.S. EPA's Natural Gas STAR program has successfully worked with industry partners to identify and promote 50 best practices for methane emission reductions[42]. Participating firms have collectively achieved methane reductions equal to over 600 million tons of carbon dioxide equivalent (MTCO2). Internationally, the CCAC's Oil and Gas Methane Partnership (OGMP) is a voluntary public-private partnership through which partner companies identify, measure, and control/reduce methane leaks[43]. Participating States have played a critical role in launching and recruiting companies into the OGMP, providing technical cooperation, and developing the foundational processes and methodologies to support corporate action. The ten member companies of the OGMP produce roughly 15 percent of global natural gas; companies participating since OGMP's initiation recently submitted their first reports[44].

Recommendations for Enhanced Action

The oil and gas sector offers the largest immediate opportunity for methane abatement in the Arctic as well as worldwide and a major opportunity for Arctic black carbon emission reductions. Key approaches include (1) adopting and implementing oil/gas methane emission reductions strategies; (2) implementing measures to make progress toward eliminating routine flaring by 2030; and (3) encouraging firms to engage in voluntary partnerships.

Recommendation 2a: Adopt and implement oil and gas methane emission reduction strategies

Arctic States should adopt and implement methane emission reduction strategies that include: (a) leak detection and repair to address fugitive emissions, and (b) use of emission reduction practices and technologies to reduce emissions from key sources such as hydrocarbon liquid storage tanks, pneumatic controllers, reciprocating and centrifugal compressors, and other devices. For example, Canada and the U.S have committed to a joint policy target to reduce oil and gas methane emissions by 40-45 percent from 2012 levels by 2025, supported by regulatory and voluntary action to reduce emissions from new and existing sources. Such strategies should also encompass mandatory reporting of methane emissions by oil/gas facilities, with sufficient detail as to allow transparent and comprehensive tracking of progress towards emission reduction objectives.

Arctic States with relevant technical expertise should also assist other oil/gas producing nations to adopt and implement oil and gas methane emission reduction strategies, by providing technical assistance through bilateral and multilateral mechanisms.

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[42] Natural Gas Star Program. 2016. Recommended Technologies and Practices. Available at: http://www.epa.gov/gasstar/tools/recommended.html

[43] Information on the Oil and Gas Methane Partnership can be found at http://www.ccacoalition.org/en/content/ccac-oil-gas-methane-partnership

[44] Climate and Clean Air Coalition. 2016. Oil and Gas Methane Partnership (OGMP): First-Year Report. Available at: http://ccacoalition.org/es/resources/oil-and-gas-methane-partnership-ogmp-first-year-report

Recommendation 2b: Develop implementation plans for the Zero Routine Flaring by 2030 Initiative and report on progress and best practices to the Arctic Council

The four Arctic States with appreciable oil/gas production – Canada, Norway, the Russian Federation and the United States – have already endorsed the Zero Routine Flaring by 2030 Initiative and should further commit to developing implementation plans for achieving that objective no later than the 2019 Arctic Council Ministerial. Arctic States should include an update on those plans through biennial reports on black carbon and methane submitted to the Arctic Council. In addition, interested nations and the World Bank should convene a workshop to share lessons from Norway's success in eliminating routine flaring including experts from government, industry, and civil society. Relevant Arctic States should also promote use of hydrocarbon liquids recovery wherever economically viable.

Recommendation 2c: Urge firms to engage in multilateral fora and domestic programs aimed at promoting voluntary methane and black carbon emission reductions

Arctic States should encourage firms headquartered or operating within their borders to engage in multilateral fora and domestic programs aimed at promoting voluntary reductions of methane and black carbon emissions. It is also important to recognize those companies that are demonstrating global leadership by joining and implementing commitments under key initiatives such as the 10 companies of the CCAC OGMP – BP, ENGIE E&P, ENI, Pemex, PTT, Repsol, Shell, Southwestern Energy, Statoil, and Total. Such initiatives provide useful mechanisms for driving methane and black carbon emission reduction actions, sharing experiences among local and national governments and the private sector, and are a key source for information on leading practices to reduce emissions from the sector. Given data limitations on oil/gas methane emissions from most jurisdictions, companies should also be strongly encouraged to engage in on-going efforts to ensure better methane data collection, emissions quantification and transparency of reporting, such as the new international methane studies initiative now being organized under CCAC.

3. Residential Biomass Combustion Appliances

Residential biomass combustion appliances – such as woodstoves, furnaces, and fireplaces – typically emit particulate matter, including black carbon, and a smaller amount of methane as a result of incomplete combustion. The quantity of black carbon produced varies significantly depending on factors such as the moisture content of the wood, the ability of the chimney to provide an adequate draft, and whether the end-user applies optimal practices in operating the stove.

Combustion of biomass produces a high share of organic carbon compared to black carbon; as organic carbon aerosols have a cooling effect, these aerosols could potentially offset the direct warming effect of black carbon aerosols from biomass burning. However, organic carbon emissions over areas with snow/ice may be less reflective than emissions over dark surfaces, and may even have a slight warming effect[45,46]. Because the climate impact of total PM emission reductions is uncertain, there is a particular need to understand which heating sources reduce black carbon specifically and therefore result in a climate benefit. Measures to reduce black carbon emissions from residential biomass combustion can, in any case, result in important co-benefits for public health, especially in urban areas with poor air quality.

According to the 2013 inventories submitted by Arctic States, this sector represents 11 percent of black carbon emissions by Arctic States, though this figure is subject to considerable uncertainty. This figure does not include Russian Federation emissions (due to use of different sectoral definitions), nor does it reflect any emissions from open biomass burning and wildfires.

Government policies and programs to reduce emissions from residential biomass combustion in Arctic and Observer States generally consist of the following measures:

- *Environmental performance standards, emission limits, equipment certification, and ecolabels* for new biomass combustion appliances;
- *Change-out programs* to replace inefficient existing wood-burning appliances, especially in urban areas with poor air quality;
- *Education campaigns* for operators on biomass combustion practices and stove maintenance;
- Improving *energy efficiency of buildings* to reduce the need for heating; and
- *Banning biomass burning* in high pollutant combustion appliances on a temporary basis during periods of poor air quality, with the exception of households where biomass burning is the household's primary source of heating.

The recommendations in this document build upon the work by the Arctic Council Working Groups Arctic Contaminants Action Programme[47] and AMAP[48], where additional details and background are available.

Lessons Learned and Best Practices

There is a particular need to identify heating sources that have low black carbon emissions. Measuring black carbon emissions from heating sources, especially biomass combustion appliances, can be quite complicated due to differences in appliance and wood species type and how appliances are used. At present, manufacturers generally do not report on black carbon emissions and there is no standardized and accepted protocol for doing so. Standardizing black carbon emissions test methods

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[45] U.S. EPA. 2016. "Third Report to Congress: Highlights from the Diesel Emission Reduction Program." Available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OHMK.pdf

[46] United States Government. 2015. "U.S. National Black Carbon and Methane Emissions: A Report to the Arctic Council." Available at https://oaarchive.arctic-council.org/bitstream/handle/11374/1168/EDOCS-%232713-v1-USA_2015_Black_Carbon_Methane_National_Report.PDF?sequence=6&isAllowed=y

[47] ACAP. 2014. "Reduction of Black Carbon Emissions from Residential Wood Combustion in the Arctic – Black Carbon Inventory, Abatement Instruments and Measures." 164 pp

[48] AMAP. 2015. "AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers." vii + 116 pp.

would generate the data necessary for voluntary labelling or regulatory approaches for new appliances. Such data would also help to identify appliances eligible for incentives through a change-out program.

Legacy appliances remain a particular challenge. Because residential biomass combustion appliances have a typical lifetime of two to three decades, new-stove standards and relevant PM regulations take effect only gradually. Although several Arctic States have sought to address this issue through change-out programs, it has proven difficult to find sufficient, sustained funding for, and the appropriate level of, incentives to substantially accelerate replacement. The level of the incentive may vary by location, year, economic and regulatory measures in place, the weather, the price of alternative fuels and new appliances, etc. Experience in U.S. EPA programs suggests that providing 30 percent of the entire project cost is a good starting figure to incentivize replacement, unless the program focuses on lower income households, in which case incentives near full replacement cost are needed. Denmark successfully scrapped 20,000 inefficient wood stoves within the first 2 years of a EUR6.5 million scrapping scheme for old wood stoves. Households with woodstoves from 1990 or earlier were eligible to receive EUR300 for scrapping the stove. In addition to the incentive, the government engaged chimney sweepers to serve as a trusted interlocutor with households, and deterred the sale of old stoves in the second-hand market by applying emissions standards to both new and second-hand stoves.

Addressing operator error and maintenance is important in reducing emissions. For example, research suggests that putting excessive amounts of wood in the stove can increase black carbon (and $PM_{2.5}$) emissions by a factor of three[49]. Proper regulation of airflow is also critical to efficient biomass combustion. Advances in design that reduce the potential for user error would help in this regard. In the United States, wood stove operators are encouraged to use biomass moisture meters and stove thermometers in order to enhance their ability to achieve optimal stove operation. New technologies may also help optimize stove operation, such as devices for automatically regulating air intake into the combustion chamber and digital phone apps that make it easier for stove operators to monitor temperature and oxygen levels and prompt users when they should add more air and/or fuel. Research shows that a higher degree of automation of devices results in lower emissions[50].

Maintenance of biomass combustion appliances to prevent leakage is also important. For example, laboratory tests carried out in Norway found that when the seal gasket around a stove's door was completely removed, elemental carbon emission factors (often used as a proxy for black carbon in emission inventories) were two to four times higher than under normal conditions.

Public education initiatives may be useful in promoting appliance replacement and better usage, but more data are needed to assess and enhance their effectiveness, particularly over time. In order to improve the design of educational programs, Arctic States would benefit from data that couples

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[49] U.S. EPA. 2012. Report to Congress on Black Carbon. Available at https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf

[50] Deutsche Umwelthilfe et al.: Clean Heat - Residential wood burning. Environmental impact and sustainable solutions.

evaluation of outreach strategies and program design with monitoring of household-level emissions. For example, 25 percent of participants in a Danish public information campaign reported behavioral change. Canada found that a small, targeted “Burn It Smart” workshop stimulated reported behavioral change among 75 percent of participants.

Recommendations for Enhanced Action

A combination of actions is needed to promote new cleaner and efficient heating appliances or systems and accelerate the replacement of legacy biomass combustion appliances. Increasing the adoption and correct use of low-black carbon emitting heating appliances is essential. Another key strategy for reducing black carbon emissions from the heating sector is to improve home energy efficiency, to complement appliance improvements.

Recommendation 3a: Reduce emission from *new* biomass combustion appliances by accelerating *deployment* of cleaner and more efficient new heating sources and promoting proper stove operation and maintenance

Arctic States should implement key policies and programs to accelerate deployment of new and cleaner sources of space heating. This includes both non-combustion sources such as district or electric heating with centralized clean fuels and cleaner new biomass combustion appliances where necessary or desirable. Relevant policies and programs include:

- Develop and adopt, where possible, a **standardized testing protocol for black carbon emissions** for new heating appliances**.** Such a protocol could be used to support voluntary or regulatory approaches to reduce black carbon emissions for new appliances. For example, Denmark, Sweden and Norway are working on a protocol for black carbon testing of wood stoves in cooperation with CCAC. This protocol, which will be used by the Swan label, the largest eco-label for products in the Nordic States, aims to enable governments and consumers to compare relative black carbon emissions across products.
- Promote **efficiency and emission-performance standards** – whether voluntary or regulatory – for new heating appliances and other clean sources of space heating**.** Appliances that produce heat more efficiently generally use less fuel and generate fewer emissions of particulate matter. For example, U.S. EPA’s new wood heater performance standards require reporting on standardized efficiency by manufacturers. The European Union’s Ecodesign directive also contains minimum required energy efficiency for boilers and space heaters. In addition, Denmark has adopted performance standards for new wood-burning stoves, limiting emissions of PM to 5 g/kg; the European Union is phasing in similar standards for room heaters (effective 2022) and boilers (effective 2020). These regulations are expected to reduce particle emissions from these sources by more than 50 percent.
- Cooperate with manufacturers to promote and bring to market **affordable designs and technologies** that improve biomass combustion appliance use, reduce operator error and thereby reduce black carbon emissions. Such technologies may include those that automatically

regulate airflow or prompt users to do so. As technologies advance, cost-competitiveness continues to serve as a barrier to deployment at scale thus industry engagement to reduce costs is essential.

- Develop, test and deploy **effective education campaigns** to improve consumer use of all biomass combusting appliances. As noted, operator error can increase black carbon emissions even with improved appliance technology. Although few data are available on the long-term effectiveness of education and awareness campaigns, such campaigns provide one of the few mechanisms for reducing operator error that increases black carbon emissions.

Recommendation 3b: Reduce emission from *legacy* biomass combustion appliances by accelerating *replacement* with cleaner and more efficient new heating sources and promoting proper stove operation and maintenance

Biomass combustion appliances typically have long lifetimes. Moreover, how appliances are used significantly affects the level of black carbon emissions produced. Accordingly, Arctic States should reduce emissions from legacy heating appliances through a two-pronged approach:

- Incentivize the **replacement of older biomass combustion appliances with cleaner and more efficient alternatives**, including cleaner biomass combustion appliances, while adopting policies to keep legacy heating appliances from reaching the second-hand market**.** For example, many Arctic States have pursued change-out programs that offer incentives for replacement of an older appliance with a qualifying low-emissions appliance. Such programs have the largest impact on black carbon emissions reductions when they promote: a) newer, certified appliances with stringent air pollutant emission standards (including pellet stoves and other clean appliance technologies); b) more-efficient appliances; and c) renewable non-combustion energy alternatives. Coupling change-out programs with scrapping incentives and/or standards for second-hand appliances is critical to ensuring that old stoves are not made available on the second-hand market.
- As with new stoves, developing, testing and deploying **effective education campaigns** to improve consumer use of biomass combustion appliances is necessary to reduce emissions associated with operator error. Education and awareness campaigns may also play an important role in increasing participation in change-out programs and making households aware of the need for proper appliance maintenance.

Recommendation 3c: Reduce emissions by promoting enhanced home heating efficiency for residential dwellings, especially those heated with biomass

As a complement to actions aimed at directly reducing emissions from heating sources, Arctic States should put in place measures to transform the residential heating sector, virtually eliminating emissions over the longer term. Measures should aim to enhance the overall energy performance of the building envelope through use of proper insulation, air sealing, and energy-efficient windows and doors, thereby reducing heating demand and corresponding emissions from biomass consumption. Such programs are most effective in reducing black carbon when targeted at areas with high usage of small-scale biomass for heating (as distinguished from occasional use of biomass combustion wood-burning appliances for aesthetic reasons). Countries should apply a two-pronged approach:

- **Adopt mandatory or voluntary standards for building energy efficiency**. For example, an European Union directive on energy performance of buildings provides that all new buildings are to be nearly zero-energy buildings by 31 December 2020. Natural Resources Canada has developed voluntary technical standards for energy efficiency for new buildings (R-2000), in partnership with Canada's residential construction industry. R-2000-certified new homes are best-in-class energy-efficient homes that include high levels of insulation and clear air features. This translates into energy savings, increased comfort, and a healthier environment for the homeowner.

- **Offer financial incentives for building energy efficiency such as tax credits, rebates, or financing for high-usage stoves**. In the United States, a number of states offer Property Assessed Clean Energy programs that allow commercial and residential property owners to finance renewable energy and energy efficiency projects via long-term loans that are repaid through property taxes, with utility-bill savings more than covering the incremental cost[51]. Norway has introduced a national support program (ENOVA) for residential installation of non-fossil fuel sources of heating and/or more energy-efficient heating systems. The enterprise is financed by the Energy Fund, which is capitalized by a small additional charge to electricity bills.

4. Solid Waste Disposal

Solid waste disposal generates methane emissions when food waste and other organic material are decomposed by bacteria under anaerobic (low oxygen) conditions, typically in landfills or large dump sites. According to the 2013 inventories submitted by Arctic States, solid waste disposal represents 14 percent of Arctic States' methane emissions. Globally, emissions from landfills account for 11 percent of methane emissions[52]. Most Arctic States and Arctic Council Observer States have regulations or voluntary approaches in place to:

- Avoid methane emissions by *reducing food waste, banning landfilling of organics* or instituting *organics diversion programs*; and
- Reduce methane emissions by *regulating or incentivizing reduction of methane emissions from landfills.*

Introducing financial incentives to promote actions that avoid and reduce methane emissions has been key in many instances.

[51] See map of participating jurisdictions at http://pacenation.us/.

[52] U.S. EPA's Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases: 1990–2020 (EPA Report 430-R-06-003). Available at www.epa.gov/climatechange/economics/international.html.

Lessons Learned and Best Practices

Combining regulation, fiscal instruments, and voluntary programs offers the best opportunity to reduce methane emissions. By focusing on first avoiding methane generation and then capturing emissions when they occur, Arctic as well as non-Arctic States have been able to dramatically reduce their overall emissions from this sector using combinations of nationally appropriate strategies. For example, the United Kingdom has coupled a steep tax on landfilling (approximately USD100 per ton) and regulations on landfill gas to achieve a 78 percent reduction of landfill methane from 1990 levels. Sweden has achieved a 68 percent reduction in solid waste-related methane from 1990 levels through a three-pronged approach combining: (1) a ban on landfilling organics and combustibles; (2) regulating methane emissions from landfills; and (3) a landfill tax of approximately USD60 per ton. Sweden also incentivizes alternative treatment by providing investment financing for anaerobic digestion with methane capture. Other forms of alternative treatment include recycling, composting at the community or household level, and waste-to-energy. In Denmark, older measures, such as the ban on landfilling of organic waste and a combustion tax, have more recently been supplemented with a program on bio-covers aimed at reducing methane emissions from legacy landfills.

Waste practitioners need to consider local circumstances and all relevant policies affecting waste and materials management when designing policies and programs. Some policies need companion measures to be effective. For example, landfill bans on organics will be most successful when coupled with convenient alternatives for managing these materials; otherwise the bans may result in increased illegal burning or dumping. Policies can have positive impacts on related programs: in Germany, for example, the separate collection of organic waste in special waste bins decreased the concentration of pollutants in organic compost by 95 percent compared to compost produced from mixed household waste, lowering production costs while increasing the quality and value of the compost. Policies can also have negative impacts on other programs; for example, successful organics diversion will decrease methane production at landfills over time, and should be accounted for when planning methane capture and utilization systems.

In many countries, organics landfill bans have been highly effective policy tools to reduce methane emissions, especially when supported by the establishment of municipal or private composting programs for alternative management of these materials. Further, these bans have also helped catalyze investment in alternative treatment facilities, and brought high-quality products to market. They have also promoted efficient urban land use by reducing the space needed for landfilling. Governments have facilitated industry investment, helping to develop markets by subsidizing the price of compost and providing quality assurance through a certification or grading systems for bagged commercial compost. Reducing waste generation, promoting good source separation programs, and launching education and advocacy campaigns can enhance the effectiveness of landfill bans.

Where national governments do not have a mandate to regulate solid waste, national governments can help promote successes at the local level through collaboration. National governments can play an important role by cooperating with local governments to share experiences, developing tools and offering training for local governments, catalyzing low-cost financing for projects, and creating national policy and regulatory frameworks that incentivize alternative treatment over landfilling. For example, the U.S. EPA provides technical assistance to local governments, the private sector, and communities through its Landfill Methane Outreach Program[53] to enable the voluntary reduction of methane emissions from landfills.

Recommendations for Enhanced Action

Methane emissions from solid waste can most effectively be reduced through a *combination* of policy and fiscal instruments that are intended to (1) avoid generation of methane emissions by preventing the landfilling of organics, and (2) reduce methane emissions from landfills.

Recommendation 4a. Avoid methane emissions by preventing the landfilling of organic waste

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Arctic States should minimize the generation of methane from solid waste through three complementary strategies:

- **Minimize generation of food waste and other organic waste**. National and sub-national governments should encourage waste minimization through the reduction and recovery of food and other biodegradable wastes and thereby contribute to a reduction of global food waste goal of 50 percent by 2030, in line with Goal 12 of the Sustainable Development Goals, and consider adopting national food waste reduction goals where appropriate. Reduction and recovery requires behavioral changes by upstream actors (food associations, restaurants, farmers and manufacturers), such as through a Value-Added Tax exemption for the redistribution of food to charity, and by downstream actors (consumers) that can be driven through actions such as changes in standards and labeling, public education and outreach campaigns.

- **Enhance waste diversion and alternative treatment.** After pursuing waste minimization, governments at the relevant jurisdictional level should require separate collection and treatment of organic waste; countries should also incentivize voluntary diversion, for example, by levying charges by weight or volume for collection of mixed waste, investing in infrastructure projects such as composting and anaerobic digestion facilities, and providing outreach services for consumers to encourage household diversion. These fees should increase with inflation, where possible, and can be applied at the household level or at landfills and treatment facilities. For example, Korea has household "pay-as-you-throw" policies, while Denmark charges a tax of approximately USD70 per ton for landfilling but does not charge for recycling. Finland taxed landfilling of biodegradables before putting in place an organics ban.

  Diversion must be accompanied by appropriate infrastructure to treat organics, such as composting. Countries should incentivize development of this infrastructure by offering

[53] U.S. Environmental Protection Agency. Landfill Gas Methane Outreach Program. Available at: https://www.epa.gov/lmop.

technical assistance or financial incentives, such as reducing licensing fees for composting facilities or subsidizing anaerobic digestion facilities. Sub-national governments in Sweden, for example, provide grants for up to 40 percent of project financing costs to treat organic waste. Canada has set up a Green Municipal Fund that provides matching grants and low cost loans for plans, studies and capital projects in a number of areas, including waste management, for sub-national governments that demonstrate the potential to divert 60 percent of their waste from landfills.

- **Incentivize or adopt bans on landfilling organics at the appropriate jurisdictional level.** As with diversion, bans at the national or sub-national level must be accompanied by the appropriate infrastructure for managing waste, such as anaerobic digestion, so as to facilitate compliance. Some countries have set targets for cities, and allowed for flexibility on how each city would achieve the national target. Iceland, for example, set a target for reducing 35 percent of biodegradable waste destined for landfills in 2020 compared with 1995.

Depending on whether local or national authorities have primary jurisdiction over waste management, incentivizing sub-national action may be an essential component as well.

Recommendation 4b: Adopt regulations or incentives for landfill gas capture and control

Arctic States should adopt policies or regulations requiring the capture and control of methane from existing and new landfills, as well as require or incentivize utilization of methane. Regulations can be structured to prohibit release of landfill gas directly into the air, including requiring the landfill gas to be flared where use for energy production is not practicable. As appropriate, regulations may allow exemptions for small or remote landfills where methane capture and control is cost prohibitive. The United States finalized regulations requiring landfill gas capture, control, or destruction from all landfills that emit over 34 metric tons of non-methane organic compounds annually and meet the size threshold of the regulation[54]. European Union countries require landfill gas capture and beneficial use for landfills where biodegradable waste is disposed, with exceptions for landfills in remote, island communities and landfills with a total capacity not exceeding 15,000 tons.

To support voluntary landfill gas capture and control in exempted landfills, Arctic States should offer technical cooperation programs and provide financial incentives (such as green tariffs, renewable portfolio standards that include landfill gas, or tax incentives for developers of landfill gas-to-energy projects). For example, the United Kingdom offers technical assistance through its Joint Methane Capture Programme, as does the United States through its Landfill Methane Outreach Program. Where landfills generate insufficient levels of landfill gas to merit landfill gas capture systems, operators should

[54] Actions that reduce non-methane organic compound inherently reduce landfill gas, which is a regulated pollutant and serves as a proxy for methane. Landfills that were closed prior to regulation maintain a threshold of 50 metrics tons/year. Beneficial uses are not required, but are not precluded. The rule was issued in August 2016.

consider applying bio-oxidation cover systems that reduce methane through bacterial oxidation, as is being piloted by Denmark. Such materials may provide an opportunity to reduce methane leakage from smaller landfill sites after they have been taken out of operation.

THE PATH FORWARD

Submission of black carbon inventories and biennial reports on black carbon and methane by all Arctic States represents a significant step forward in implementing the Framework endorsed by Arctic States. Future cycles of the Expert Group process will benefit from ongoing efforts to improve inventories and projections, as provided under the Framework. Also beneficial will be inclusion of additional detail in subsequent biennial national reports on particular mechanisms found to be effective in curtailing black carbon and methane emissions, including quantification of costs and benefits if available.

This report is a starting point, as Arctic States and participating Observer States work together to identify successful black carbon and methane policies that are ripe for replication, and to learn lessons from each other's experiences and challenges. Future Chairmanships should continue developing and reporting on implementation of recommendations for enhanced action.

Observer States have an important role to play in the Expert Group – some are major emitters and would benefit from cooperation, and some have implemented best practices that could help inform the mitigation actions of the Arctic States and other Observer States. Observer States are encouraged to actively participate under the Finnish and subsequent Chairmanships and contribute to the leadership of the Arctic Council in protecting the Arctic.

Finally, and most importantly, to ensure that this Arctic Council process catalyzes meaningful real-world emission reductions, all participating States should consider which of the recommendations put forward in this report they will implement. We welcome Finland's leadership of the Expert Group in 2017, and look forward to sharing experiences in the implementation of these recommendations and our progress towards our ambitious, aspirational, quantitative collective black carbon goal – the first of its kind.

ANNEX: BLACK CARBON AND METHANE EMISSIONS AND PROJECTIONS

Summary of Current Black Carbon Emissions and Projections for Arctic and Observer States

Unlike methane, there is currently no globally agreed framework for black carbon inventories; as a result, black carbon inventories have not been regularly compiled to date. Because emission inventories and projections are valuable tools for identifying mitigation targets and goals and assessing progress over time, the Framework included a commitment to develop and improve emission inventories and projections for black carbon using, where possible, relevant guidelines from CLRTAP. Such inventories and projections have been provided through the submission of national reports to the Arctic Council Secretariat, many of which are based in substantial part of materials submitted through the CLRTAP process.

In 2011, four of the eight Arctic Council States (Denmark, Finland, Sweden and the United States) provided national black carbon inventories, and Canada also submitted a black carbon assessment, that were summarized in an Arctic Council Task Force on SLCFs Technical Report[55]. As of late 2016, all eight Arctic Council States have developed and submitted inventories, as well as five Observer States. In addition to an increased number of inventories, there has been an improvement in both the quality of the inventories and in the consistency across the inventories, though there is still room for further improvement.

This section presents a high level summary of these inventories and projections. More detail is available in the National Reports and in the CLRTAP database from which these numbers have been drawn[56].

Black Carbon Inventories [57]

According to submitted inventories, the largest emission sectors across the Arctic States are generally the on- and non-road transportation sector (primarily from diesel engines) and the residential (biomass combustion) sector. Collective black carbon emissions for Arctic States are projected to decrease by 2025 due mainly to standards for new vehicle engines and turnover of the existing fleet that does not meet those standards. However, there remain uncertainties regarding black carbon inventories in most States. For example, although AMAP estimates that 40 percent of the black carbon emissions in the Arctic are from flaring (mainly from the Russian Federation), which would make flaring the second largest source of black carbon, not all Arctic States include flaring in their national black carbon

[55] An Assessment of Emissions and Mitigation Options for Black Carbon for the Arctic Council, 2011. http://library.arcticportal.org/1210/

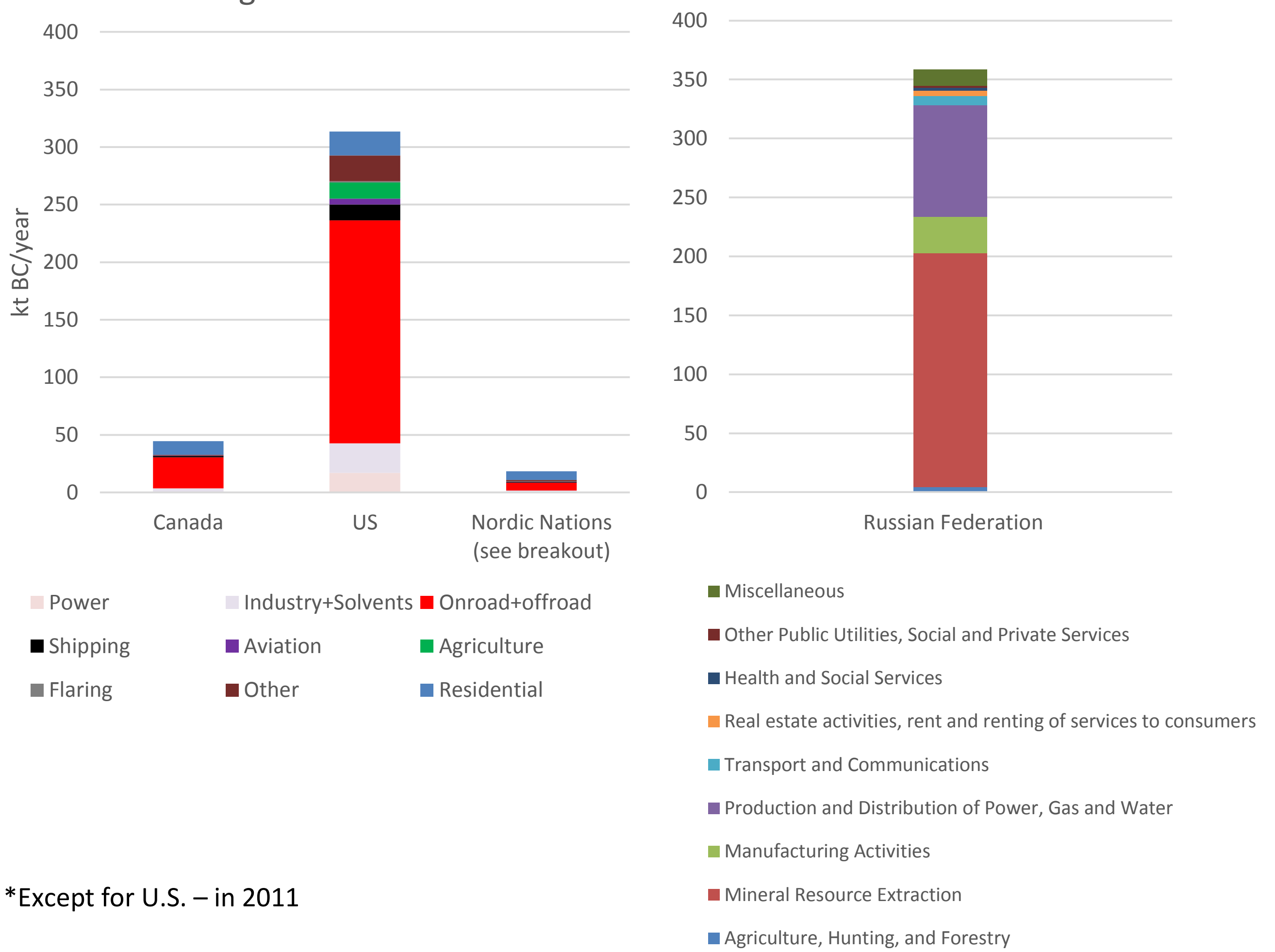
[56] All reports on national black carbon and methane submitted to the Arctic Council are available at https://oaarchive.arctic-council.org/handle/11374/1167

[57] These data do not include sources such as international shipping and aviation (though some domestic boat emissions are included in non-road sources), natural emissions, and multilateral operations. Not all nations have calculated emissions for all sectors. Black carbon emissions in Figures 5-7 from all nations except the US and the Russian Federation are from their 2016 CLRTAP submissions, available at http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2016_submissions/.

inventory. As the Russian Federation submitted data using different sectoral definitions than those used by other Arctic States, comparisons between Russian Federation emissions and other national emissions are challenging.

Black carbon emissions inventories are presented in Figures 1-3 below. Note that these figures have separate vertical-axis scales, reflecting different magnitudes of emissions among States (which also have markedly different populations and Gross Domestic Products (GDP)). Data for the Nordic States and Canada are drawn from States' 2016 CLRTAP submissions of 2013 data[58]. Because of the 3 year cycle of its National Emissions Inventory, the U.S. provided 2011 emissions[59]. The Russian Federation emissions have a different sectoral aggregation, and concentrate on stationary sources; thus, they are not directly comparable to other inventories.

Figure 1: Arctic States Black Carbon Emissions in 2013*



*Except for U.S. – in 2011

[58] 2016 black carbon inventories submitted to the Convention on Long-Range Transboundary Air Pollution are available at http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2016_submissions/

[59] Not reflected in Figure 1 are U.S. estimates of emissions from wildfires and prescribed fires, which amounted to about 39% of the total U.S. inventory in 2011.

Figure 2: Breakout of Nordic Nation Black Carbon Emissions

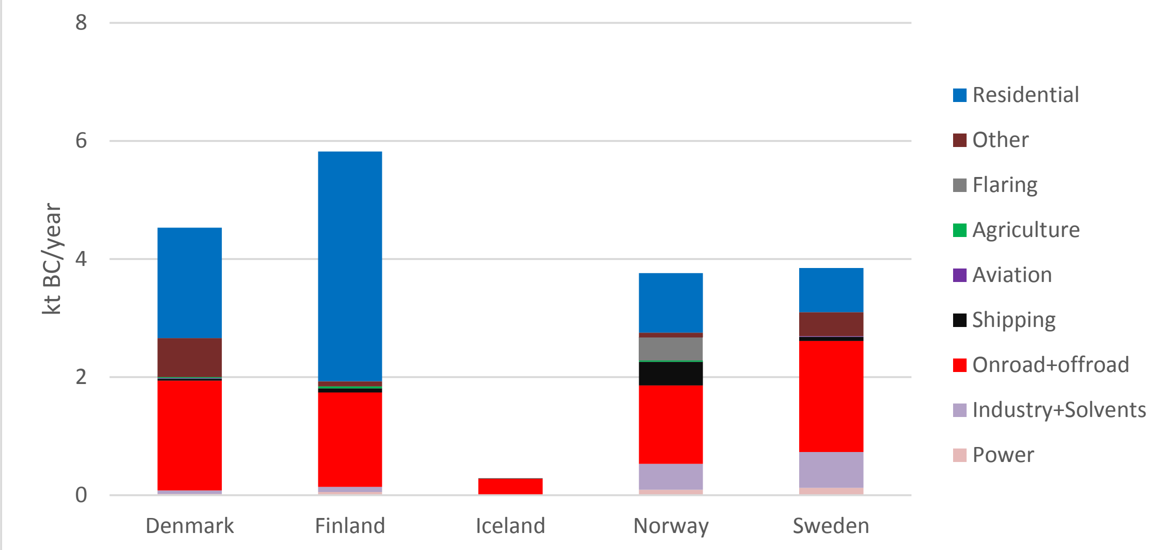
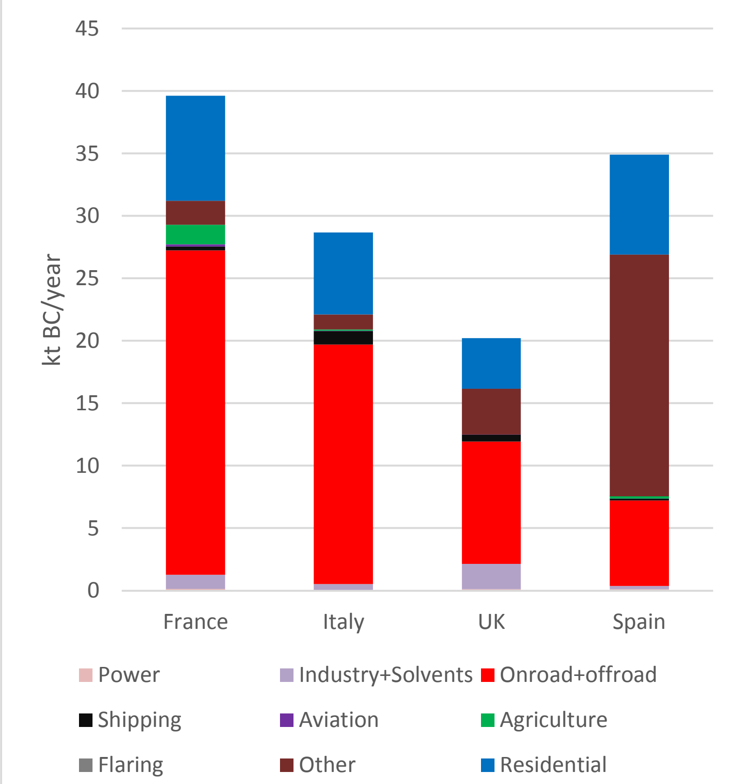


Figure 3: Observer Nation BC Emissions



It is important to note that black carbon inventories are updated on a regular basis and continuously improved as new data become available. For some countries, these figures represent the first-ever black carbon inventory or projections. Estimates presented here may change over time as countries review new data and recalculate emissions estimates.

Figure 3 presents black carbon emissions as submitted by participating Observer States. India also submitted black carbon emission data showing total black carbon emissions of 1,119 kilotons of black carbon per year in 2011, but without sectoral detail. Therefore, it could not be included here.

Presenting black carbon emissions per capita and by GDP enables evaluation of emissions *intensity* among Arctic States (see Table 1). Interestingly, the data indicates that Sweden's per capita emissions are substantially lower than other States in the region; Sweden and Norway have most successfully delinked economic activity and black carbon emissions, showing low emissions intensity of their economies.

Table 1: 2013 Black Carbon Emissions - Per Capita and Emissions Intensity[60]

	Canada	Denmark	Finland	Iceland	Norway	Russian Federation	US	Sweden
tons/1000 people	1.3	0.8	1.1	0.9	0.7	2.5	1.0	0.4
tons/billion GDP	24.2	13.4	21.6	18.9	7.2	172.4	18.8	6.6

Black Carbon Projections [61]

Six out of eight Arctic States provided black carbon projections, as well as the United Kingdom. Due to differences in sectoral definitions, a sectoral breakdown is not presented here. However, **across all six of these nations, emissions in the transportation sector are projected to decrease substantially as additional diesel standards take effect and fleet turnover occurs**, while for the most part emissions in other sectors are not projected to change dramatically.

It is important to recognize that emissions of black carbon have already been declining in many States (see Figure 4). The Nordic States report annual black carbon emissions through CLRTAP dating back to at least 2000 (Norway reports back to 1990). In 2013, combined emissions from these States are 20 percent below 2000 emission levels, due mainly to a decrease of almost 50 percent in black carbon emissions from the on-road and non-road sector. The residential sector shows year to year variability as the use of wood burning often depends on winter temperatures. Moreover, overall black carbon emissions reductions likely started before 2000. For example, Denmark's emissions today (based on

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[60] Data are from the UN World Population Prospects (https://esa.un.org/unpd/wpp/DataQuery/) and the UN National Accounts Database (http://unstats.un.org/unsd/snaama/introduction.asp). Note that GDP has been calculated in 2013 US Dollars in the database using market exchange rates, which is a standard methodology though with known limitations. US emissions are from 2011.

[61] As with the Inventories, these data do not include international shipping and aviation, natural emissions, and multilateral operations. US emissions are for 2011, not 2013, and are derived from their National Report submission. Projections for Norway and Sweden come from their 2015 CLRTAP submissions (http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2015_submissions/), for Finland from the annex to its National Report submission to the Expert Group (https://oaarchive.arctic-council.org/bitstream/handle/11374/1168/EDOCS-%232701-v1-Finland_2015_Black_Carbon_Methane_National_Report.PDF?sequence=1&isAllowed=y), and for Denmark are derived from its National Report submission (https://oaarchive.arctic-council.org/bitstream/handle/11374/1168/EDOCS-3136-v1-Kingdom_of_Denmark_2016_Black_Carbon_Methane_National_Report.PDF?sequence=27&isAllowed=y).

2014 inventories) are half of what they were in 1995 when black carbon emissions peaked and reduction efforts started. Norway's emissions of black carbon fell by 20 percent from 1990 to 2013, with reductions in the transport sector contributing the most to the overall black carbon emission reductions. Trends in fine PM from sources known to be high in black carbon, such as the transportation sector, suggest that similar successes have been achieved in some Arctic States that do not yet have long periods of historical data for black carbon. For example, $PM_{2.5}$ emissions from mobile sources in Canada decreased by about 61 percent between 1995 and 2014.

Figure 4: Nordic Nation Historical Emission Trends

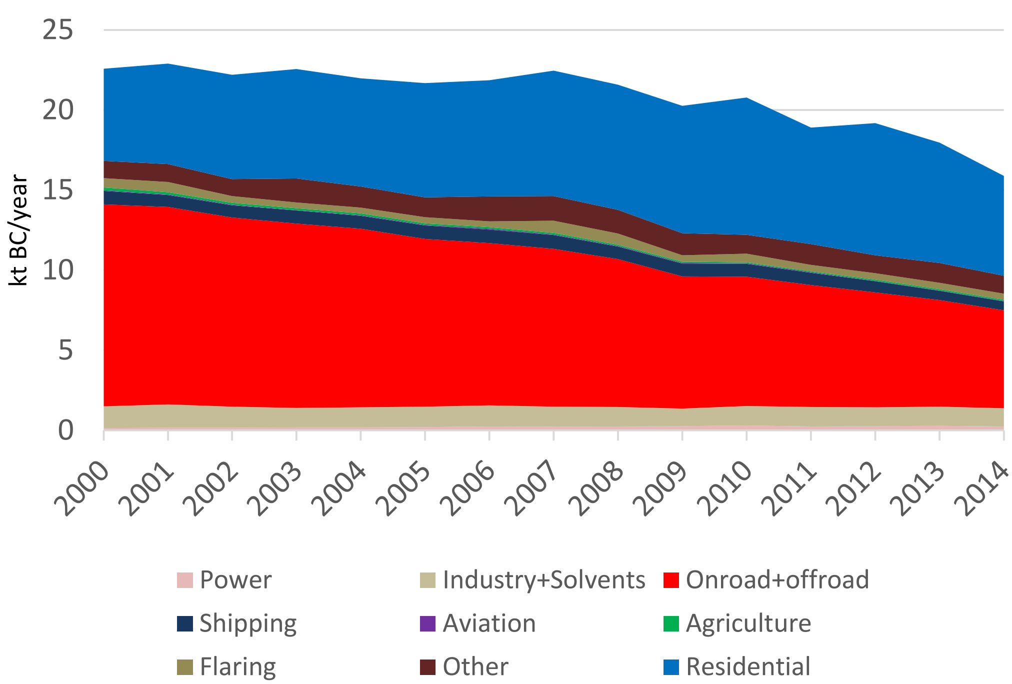


Table 2 shows that Arctic States are expected to reduce their black carbon emissions by 24 percent from 2013 levels by 2025. It should be noted that black carbon emission *projections* for 2025 were in some cases based on older inventory methodologies, or on different sectoral aggregations, and are therefore not necessarily consistent with the latest 2013 *inventories* reflected in this document. Moreover, projections from some States only take into account policies that were enacted before the projection was calculated, whereas others take into account policies still being developed. The projected total black carbon emissions for Arctic States was calculated by assuming no change in emissions in States that did not provide projections.

Table 2: Black Carbon projections, kt/year			
	2013 inventories	2025 projections	%decrease
Canada	45	31	30%
Denmark	4.5	3.4	26%
Finland	5.8	3.6	39%
Iceland	0.28	Not available	NA
Norway	3.8	3.6	5%
Russian Federation	360	Not available	NA
Sweden	3.9	2.8	28%
US	310	160	49%
Total[62]	730	560	24%

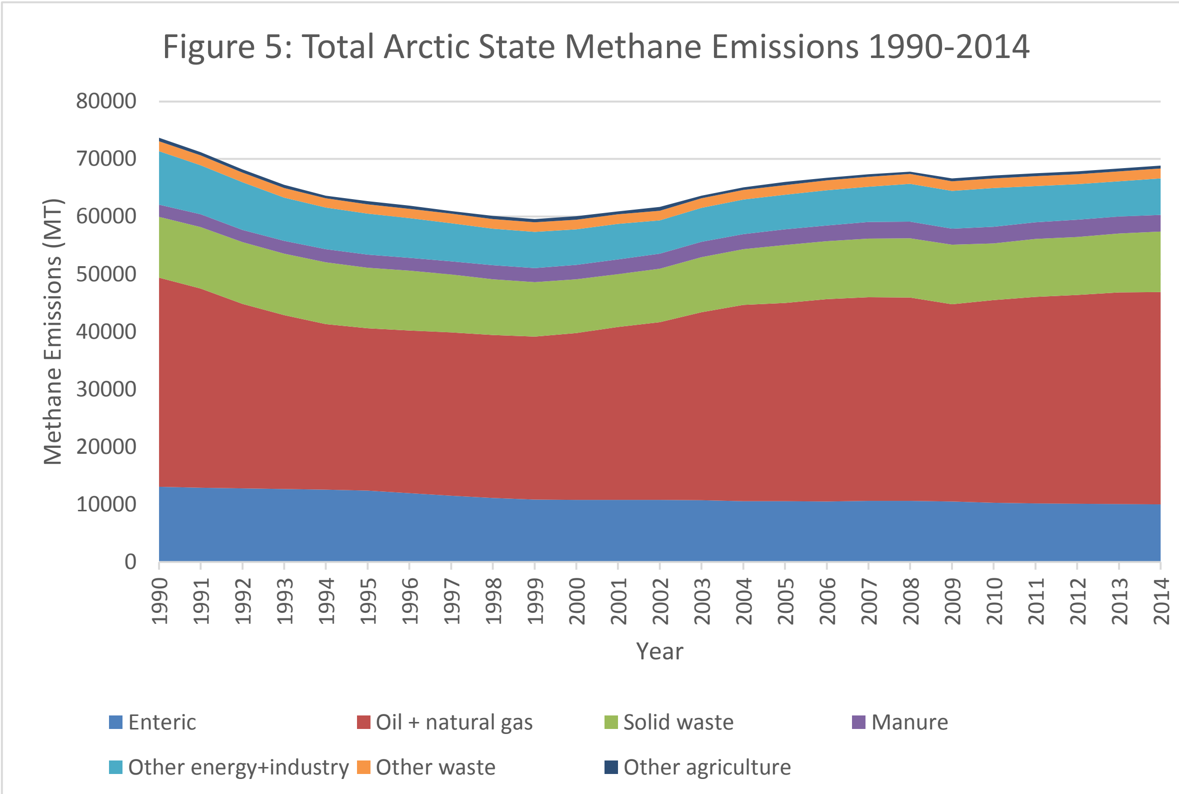
Summary of Current Methane Emissions and Projections for Arctic and Observer States

The inventories reported here are drawn from States' 2016 inventory submissions to the UNFCCC, which contain data from 1990 through 2014 emissions. Oil and natural gas, enteric fermentation (i.e., methane releases from digestive tracts of ruminants such as cattle), solid waste, and manure were the largest emission sectors in 2013. Methane inventories are developed annually and continuously improved as new data become available. Estimates presented here may change over time as countries review new data and recalculate emissions estimates.

Methane Emission Inventories

Methane emissions inventories have a long history due in large part to methane-reporting requirements under the UNFCCC. Figure 5 shows total Arctic State emissions by sector from 1990 to 2014. Overall, Arctic State methane emissions are 7 percent lower than their 1990 levels, though the trend over time is complicated by the temporary decline in methane emissions from the Russian Federation in the 1990s after the dissolution of the Soviet Union.

[62] The total projected emissions and the percent decrease for the total Arctic emissions from 2013 are both calculated under the assumption that any nation that did not report projected emissions will have emissions in 2025 equal to their emissions in 2013. All numbers in this table were rounded to two significant figures: as a result, totals may not sum exactly.



Figures 6 and 7 show current methane emissions by State and sector. Total emission from the Nordic States are a fraction of that produced by other Arctic States, and are therefore presented in both aggregate alongside Canada, the Russian Federation and the United States to understand scale in Figure 6, as well as broken out individually in Figure 7. Note the corresponding figures have separate vertical-axis scales, reflecting different magnitudes of emissions among countries.

Oil and natural gas methane emissions are the largest emission sector across the Arctic States, accounting for more than half of all methane emissions in 2013, though Nordic nation emissions are dominated by enteric fermentation. Manure emissions have been on average the fastest growing sector since 1990 (34 percent growth over that time period, though representing only 4 percent of emissions in 2013) and other energy and industry emissions have decreased the most over that time period on average (a 34 percent decline, now representing 9 percent of total emissions).

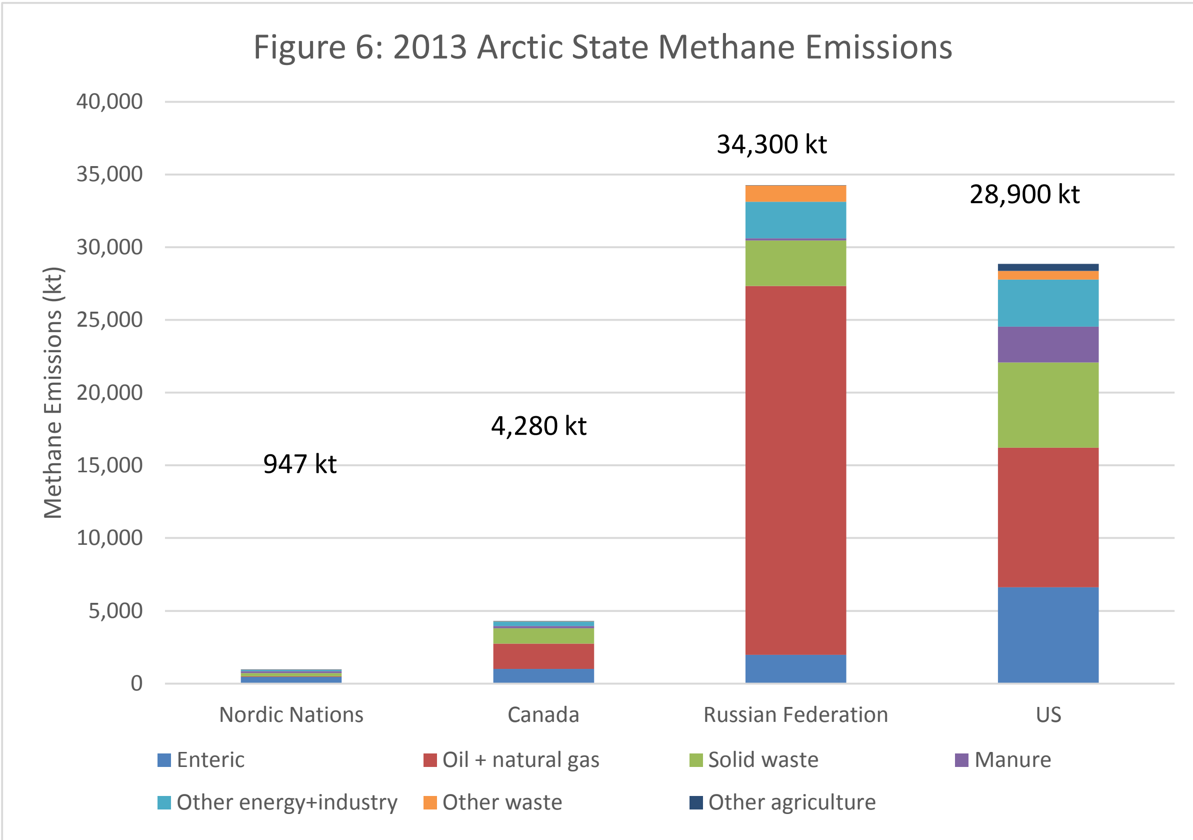


Figure 6: 2013 Arctic State Methane Emissions
Methane Emissions (kt)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
947 kt
4,280 kt
34,300 kt
28,900 kt
Nordic Nations
Canada
Russian Federation
US
Enteric
Oil + natural gas
Solid waste
Manure
Other energy+industry
Other waste
Other agriculture

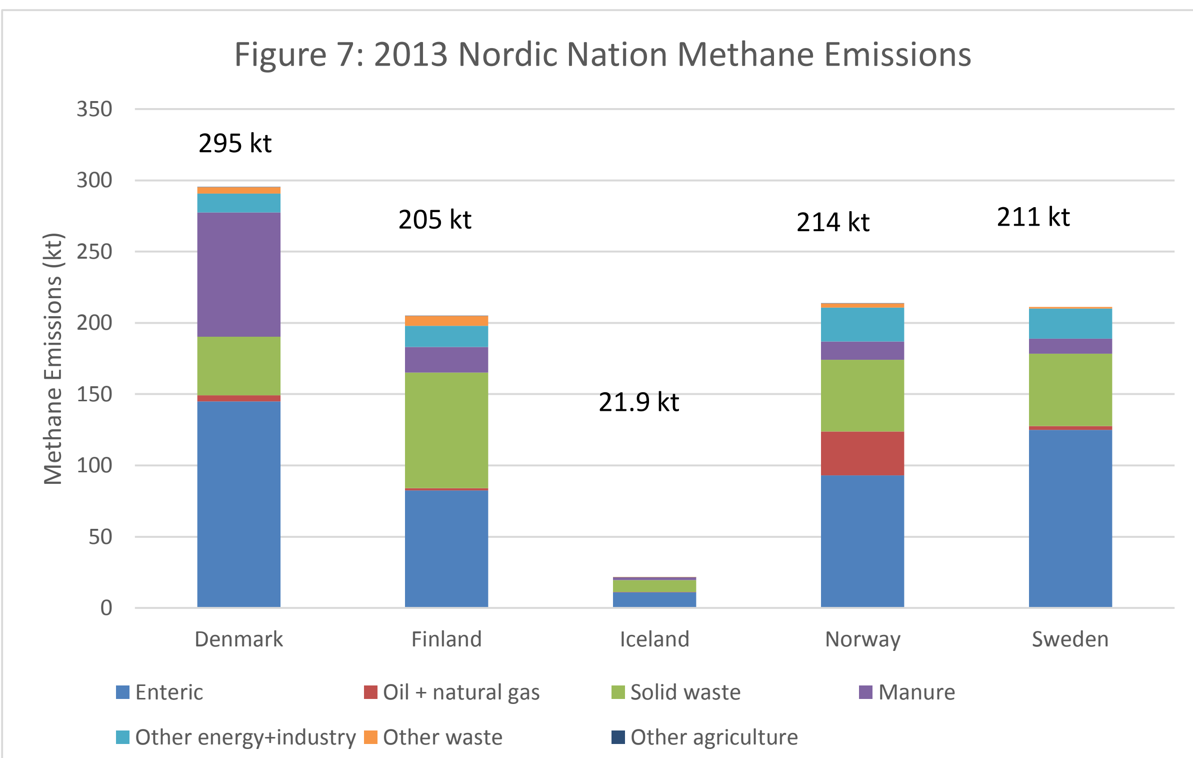
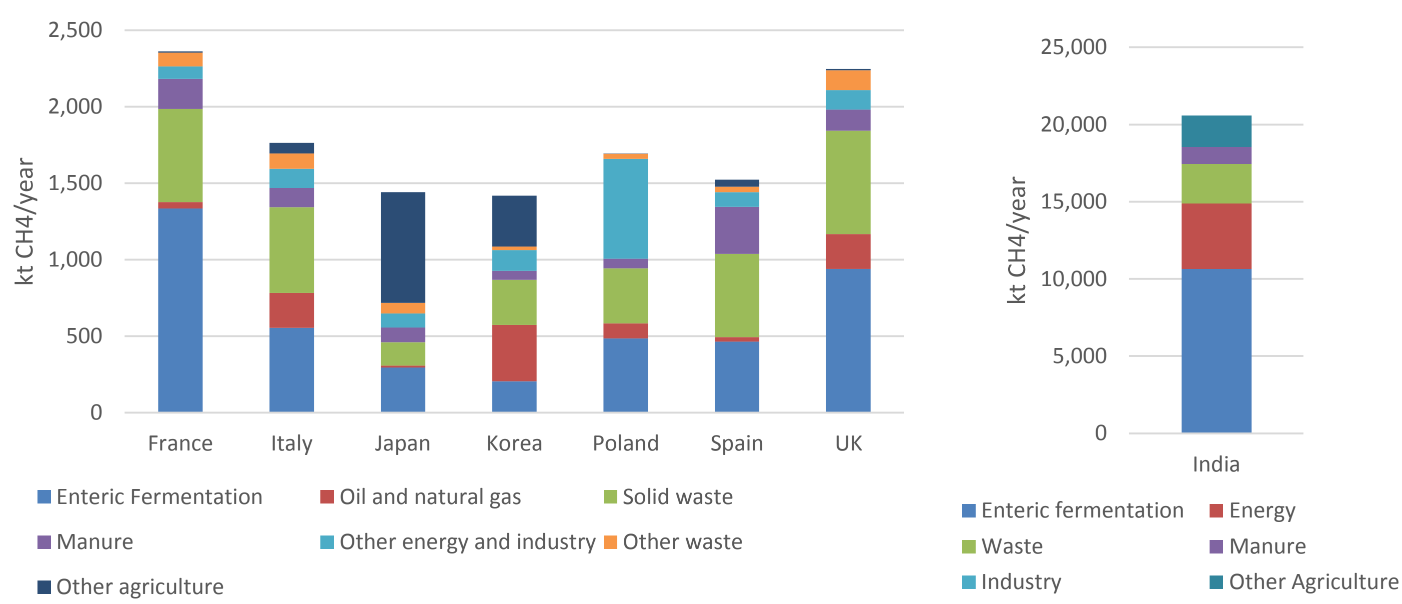


Figure 7: 2013 Nordic Nation Methane Emissions
Methane Emissions (kt)
350
300
250
200
150
100
50
0
295 kt
205 kt
21.9 kt
214 kt
211 kt
Denmark
Finland
Iceland
Norway
Sweden
Enteric
Oil + natural gas
Solid waste
Manure
Other energy+industry
Other waste
Other agriculture

Figure 8 shows that enteric fermentation and the solid waste sector are generally the largest sources of methane emissions in Observer States[63]. Note that the chart of India's emissions has a different vertical-axis scale and legend.

Figure 8: 2013 Observer State Methane Emissions



Methane Projections

Methane projections captured in Tables 3 and 4 below were derived from States' Biennial Report submitted to the UNFCCC. Those projections may not reflect recent actions, and may be based on older figures rather than those in the most-recent UNFCCC inventory submissions. Thus, although these projections show little change in the total methane emissions across all Arctic States between 2013 and 2030, significant additional emission reductions could occur over the next one to two decades. For example, the U.S. and Canada jointly committed in March 2016 "to reduce methane emissions by 40-45 percent below 2012 levels by 2025 from the oil and gas sector, and explore new opportunities for additional methane reductions."[64]

[63] Emissions from the Republic of Korea are for 2012 from their 2014 Biennial Update Report to the UNFCCC http://unfccc.int/resource/docs/natc/rkorbur1.pdf. Indian emissions are from their national report to the Expert Group (https://oaarchive.arctic-council.org/bitstream/handle/11374/1169/EDOCS-3137-v1-India_2016_Black_Carbon_Methane_National_Report.PDF?sequence=26&isAllowed=y).

[64] U.S. – Canada Joint Statement on Climate, Energy and Arctic Leadership. March 10, 2016. Available at https://www.whitehouse.gov/the-press-office/2016/03/10/us-canada-joint-statement-climate-energy-and-arctic-leadership

Table 3: Arctic State Methane Projections[65]				
kt CH_4	2013 (Annual Inventory)	2013 (Biennial Report)	2020	2030
Canada	4,280	4,280	4,120	4,160
Denmark	295	277	280	285
Finland	205	242	159	137
Iceland	21.9	17.8	14.6	13.9
Norway	214	217	213	200
Russian Federation	34,300	19,600	21,200	22,800
US	28,900	25,200	26,400	26,900
Sweden	211	221	191	169
Total	68,400	50,100	52,600	54,700

Table 4: Observer State Methane Projections				
kt CH_4	2013 (Annual Inventory)	2013 (Biennial Report)	2020	2030
France	2,360	2,420	2,350	2,290
Italy	1,760	1,770	1,630	1,480
Japan	1,440	1,440	1,360	1,260
Poland	1,690	1,690	1,890	1,820
Spain	1,370	1,530	1,520	1,480
UK	2,250	2,260	1,920	1,810
Total	10,900	11,100	1,070	10,100

[65] Methane projections are derived from Table 6(a) of the Biennial Report CTF submission workbook as provided to the UNFCCC (http://unfccc.int/national_reports/biennial_reports_and_iar/submitted_biennial_reports/items/7550.php). The Biennial Update Reports did not have sectoral level detail for methane emissions projections. The emission totals do not include land use, land-use change, and forestry emissions. The Biennial Report emissions estimates for 2013 may differ from the emissions estimates for 2013 from the most recent emissions inventories submitted to the UNFCCC in the previous section, and therefore both the Biennial Report estimates and the UNFCCC annual inventory estimates for 2013 methane emissions are included in the projection tables. Norway reported 2011 emissions but not 2013 emissions in Table 6(a), and therefore the 2011 figures are included here. Emission estimates have been rounded to three significant figures.

Recommendations for Improving the Technical Basis of the Expert Group's Work

The adoption of the Framework and this first convening of the Expert Group led several countries to develop black carbon inventories or emission projections for the first time. Some countries are continuing to improve their inventory, and explore emission projections with the aim of providing robust data for the next reporting cycle. The Expert Group recommends three actions to improve the technical foundation of the Expert Group's work:

Recommendation A1: Follow Convention on Long-Range Transboundary Air Pollution guidelines, or comparable methodology, when developing black carbon inventories and projections

All Arctic States should submit black carbon inventories that follow CLRTAP guidelines, or a comparable methodology, including the categorization of emissions sources, in order to enable the aggregation and comparison of data across Arctic States. Inventories should be specific to black carbon, and should be generated for each country in its entirety to provide a more accurate and comprehensive understanding of emissions sources and possible mitigation measures. Observer States are invited to apply the same standards to their black carbon inventory.

Recommendation A2: Convene a workshop with the Convention on Long-Range Transboundary Air Pollution to propagate best practices for black carbon inventories

Arctic States should convene a workshop with CLRTAP to build capacity in those countries that need assistance in developing robust black carbon inventories and emission projections. Countries that emit significant quantities of black carbon that is subsequently transmitted to the Arctic should particularly be encouraged to participate, as black carbon disproportionately contributes to warming of the Arctic. (Participation should not be geographically restricted, however, as all black carbon emissions contribute to overall warming of the planet, including the Arctic). Observer States are encouraged to provide black carbon inventories and to participate in the workshop.

Recommendation A3: Approach the Convention on Long-Range Transboundary Air Pollution to consider further specifying source categories

Arctic States should discuss with their representatives in CLRTAP whether it would be feasible and desirable to further break down source categories to enable better identification and mitigation of emissions sources. The Expert Group found that data on some emissions sources, such as heating appliances, were not specific enough to fully understand the specific emitting technologies and associated reduction opportunities. Better information on this topic would enable future Expert Groups to develop better-tailored recommendations in the future.