CARBON LIMITS

Accelerating SLCP emissions reduction in the Arctic

Report for the Norwegian Ministry of Climate and Environment

This report was prepared by Carbon Limits AS.

Project title:
Accelerating SLCP emissions reduction in the Arctic

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Report title:	Accelerating SLCP emissions reduction in the Arctic
Finalized:	02/02/16

This report presents a summary of the study focused on methane and black carbon emission status and abatement potential of Arctic States, as well as the key findings for the major contributing sectors. The analysis involved reviews of emission levels and trends for methane and black carbon in Arctic States, as made public by national authorities and independent institutions. Implemented or announced mitigations actions have also been investigated with the objective to contribute to insight into the progress currently made in emission reductions. An overview of further emissions reduction potential is presented on the basis of available information.

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Carbon Limits is a consulting company with long standing experience in supporting energy efficiency measures in the petroleum industry. In particular, our team works in close collaboration with industries, government, and public bodies to identify and address inefficiencies in the use of natural gas and through this achieve reductions in greenhouse gas emissions and other air pollutants.

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Glossary

ACAP	Arctic Contaminants Action Program
AMAP	Arctic Monitoring and Assessment Program
APG	Associated petroleum gas
BAU	Business as usual
BC	Black carbon
CH_4	Methane
CLRTAP	Convention on Long-range Transboundary Air Pollution
CBM	Coalbed methane
CMM	Coal mine methane
CO_{2e}	Carbon dioxide equivalent
GAINS	The Greenhouse gas and Air pollution Interactions and Synergies (model)
GHG	Greenhouse gas
EPA	(US) Environmental Protection Agency
IIASA	International Institute for Applied Systems Analysis
kt	kilo tonnes (thousand tonnes)
Mt	mega tonnes (million tonnes)
PM	Particulate matter
SLCF	Short lived climate forcers
t	tonne
UNFCCC	United Nations Framework Convention on Climate Change
US / USA	United States of America

1. Background and objective

This report summarizes results from a study which has reviewed emission levels and trends for methane and black carbon in Arctic States, as made public by national authorities and independent institutions. Implemented or announced mitigations actions have also been scrutinized with the objective to contribute to insight into the progress currently made in emission reductions. An overview of further emissions reduction potential is presented on the basis of available information.

The Ministerial meeting of the Arctic Council in April 2015 was an important event for international cooperation on efforts to reduce emissions of short lived climate pollutants (SLCP). The meeting decided to establish a framework for action on black carbon and methane emissions (Arctic Council Framework). The Arctic Council Framework commits the parties to provide National Reports to the Arctic Council Secretariat in support of the common vision for enhanced action to reduce emissions of black carbon and methane emissions. The National Reports should include information on current emission levels and future projections (if available), and summarize national actions and strategies and further highlight best practices, relevant projects and lessons learnt.

By January 2016 all Arctic States had submitted their National Reports to the Arctic Council Secretariat. This information together with a number of other public sources has been thoroughly reviewed as part of this project. There are important difference in emission levels estimates and projections presented by various sources, caused by differences in the use of primary data sources and methodologies, and for projections also due to use of different assumptions for factors that drive emissions developments (e.g. economic factors, development in policies & regulation and technologies).

Data quality is important in the assessment of progress in emission reductions, but the purpose of this project has not primarily been to explain these discrepancies, but rather to use data from different sources to establish a good understanding of what emissions sources and sectors are particularly important in the context of enhanced efforts to reduce emissions. It is the hope that this review and analysis will provide insight of relevance for further efforts to improve data and the reporting format needed for the future review of progress in actions and results of emission reductions efforts.

2. Sources of information

The National Reports to the Arctic Council Secretariat will be of key importance for the work under the Framework. All the submitted reports have been thoroughly reviewed as part of this project. As prescribed by the Arctic Council Ministerial Meeting of April 2015, the National Reports should include:

1. Summary of back carbon emissions reported under reporting requirements of the Convention on Long-Range Transboundary Air Pollution (CLARTAP) and, if available, future projections.
2. Summary of methane emissions reported under reporting requirements of under the United Nations Framework Convention of Climate Change (UNFCCC), and, if available, future projections.
3. Summary of National Actions, National Action Plans, or Mitigation Strategies by sector.
4. Highlights of best practices or lessons learnt from key sectors
5. Projects relevant for the Arctic
6. Other information if available (.e.g. climate health, environmental, economic effects of emissions and mitigation).

The coverage and quality of these submissions are presented in Table 1 below and can be summarised as follows:

- **Inventories:** All countries have reported methane data, for the most part time series from 1990 to 2013, in line with UNFCCC guidelines. Black carbon data are reported by most

countries in line with CLARTAP guidelines for the year of 2013 (with an exception of the US data, reported for 2011). Black carbon inventories are for most countries newly established and years and sectors covered vary. Canada, the United States and Russia use different categorization of the emission sources, with North American categories comparable with GNFR[1] format. This constrains the analysis of impacts of actions and climate change impacts of black carbon emissions.

- **Projections:** Denmark, Finland, Norway, Sweden and USA have reported emissions projections, either to 2025, 2030 or 2035**.** The sectoral details vary, and underlying assumptions differ and/or are not transparent. Cross country comparisons are therefore not possible.
- **Action plans:** Canada, Denmark, Finland, Sweden and USA report the most detailed action plans. Information is for a large part qualitative, but also to some extent quantitative in terms of expected or targeted effects on emissions reductions (particularly USA). Iceland has not reported action plans.
- **Best practices and lessons learned:** Information reported by Canada, Denmark, Finland and USA presents specific projects and initiatives that proved to be effective in addressing national methane and black carbon emissions. For certain projects, a qualitative evaluation of the program impacts is provided.
- **Projects relevant for the Arctic and other information:** Ongoing projects of particular importance to the Arctic region are presented by most countries, among which monitoring & measurement activities, research, financial support mechanisms and international cooperation initiatives are highlighted.

Table 1: Summary of National reports of Arctic States submitted under the Arctic Council Framework for Action

Country	Methane			Black carbon			Best practices & lessons learned	Projects relevant to Arctic	Other
	Inventory	Projections	Action plan	Inventory	Projections	Action plan			
Canada	1990-2013	No	Detailed action plan per sector.	2013, (different categorization)	No	Detailed action plan per sector.	Specific actions/lessons identified	Presented	
Denmark	1990-2013	Up to 2035	Detailed action plan per sector.	1990-2013	Up to 2030	Detailed actions for PM and BC reduction	Specific actions/lessons identified	Presented	
Finland	1990-2012	Up to 2030	Major climate strategy, detailed action plan for waste, agriculture, energy	2000-2013	Up to 2030	Detailed action plan for transport and residential	Specific actions/lessons identified	Presented	National studies of PM effects on health, BC effects on Arctic climate
Iceland	1990-2012, 3 sources only: agriculture, waste & other	Not presented		1990-2013, 3 sources only: aluminium, ferroalloy production & smoking	Not presented		Not presented		
Norway	1990-2013	Up to 2030	Reference to the detailed National action plan on SLCF, no specific sectoral actions	1990-2013	Up to 2030	Reference to the detailed National action plan on SLCF, no specific sectoral actions	Not presented		
Russia	2013 (different categorization), focus on Arctic zone	No	Overall strategy for GHG emissions, remediation measures in the Arctic, no specific sectoral actions	2013 (different categorization), focus on Arctic zone	No	Overall strategy for GHG emissions, remediation measures in the Arctic, no specific sectoral actions	Not presented	Presented	
Sweden	1990-2013	Up to 2035	Cross-sectoral policy instruments, detailed action plan per sector	2000-2013	Up to 2030	Cross-sectoral policy instruments, detailed action plan per sector	Not presented	Presented	Clean Air & Climate Program – focus on health effects
USA	1990-2013	Up to 2030	Very detailed sectoral actions (both regulatory and voluntary)	2011, (different categorization), incl. emissions north of 40th parallel	Up to 2025	Very detailed sectoral actions (both regulatory and voluntary)	Specific actions/lessons identified	Presented	

[1] National gridded data of emissions by source category (GNFR)

The other main source of information for this project, and the principal source for all work on SLCP under the Arctic Council, are the reports from the Arctic Monitoring and Assessment Program (AMAP) of which the reports published on respectively methane (AMAP Assessment 2015 for methane[2]) and black carbon (AMAP Assessment 2015 for black carbon[3]) are of key importance. The AMAP Assessment reports compile results and make their conclusions based on a large number of studies on methane and black carbon developments and related policies and actions. The two most important institutions having conducted analysis of methane and black carbon relevant here are:

- **IIASA (International Institute for Applied Systems Analysis)**. The Greenhouse gas and Air pollution Interactions and Synergies (**GAINS**) model is the principal analytical tool for presenting emission levels and analyzing emission trends and mitigation opportunities. Different versions of the model and model results have been published over the last few years.
- **US EPA (United States Environmental Protection Agency**) has conducted several analyses of methane and black carbon emissions with a broad coverage of countries, sectors and including future projections and review of historical trends. Research institutions and consultancies have made important contributions to the work.

In addition to these sources, there are a number of research papers and other public sources that shed light on methane and black carbon emissions levels and trends, as well as on mitigation actions.

As will be presented in detail below, data sources show large differences both in estimates of emission levels and in emission projections. This is partly because the quality of primary data sources is weak, and because different aggregation levels and methodologies are being used when estimates are made. For projections there are often different analytical approaches, and the underlying assumptions that drive emission developments further complicate comparisons and interpretation of results.

Nevertheless, there are developments which eventually will lead to convergence in estimates and improve the basis for a coherent assessment of progress in emission reduction efforts. Many initiatives are ongoing which will help improve national inventories and this is in turn should lead to an improved empirical basis for analysis of future developments such as those having been conducted by IIASA and US EPA.

Improved national inventories are essential for creating a good basis for the review and assessment of progress in mitigation actions. US EPA, IIASA and other research institutions will play a key role in the quantitative analysis of progress through presentation of comparable projections of future emissions, specified by country and sectors. In addition to emissions data, such analysis relies on accurate and realistic information on planned action, best practices and lessons learnt (as requested for in the National Report submissions). It is therefore particularly important that the National Reports are being improved by providing better and more uniform information of this sort.

3. Methane emissions

3.1 Emission levels and trends

About 1/5 of global anthropogenic methane emissions come from Arctic States, of which emissions in USA and Russia dominate. The oil and gas sector is the principal source contributing 44% to Arctic States methane emissions[4]. Agriculture and waste sectors emit about 20% each and coal mining takes the major part of remaining methane emissions with about 9% of the total. The oil and gas sector is also the most important in terms of expected growth in emissions, though forecasts vary. IIASA-GAINS predicts emissions to grow by 7% from 2015 to 2030, while US EPA for the same period has a growth

[2] AMAP (2015) *AMAP Assessment 2015: Methane as an Arctic climate forcer.* http://www.amap.no/documents/doc/AMAP-Assessment-2015-Methane-as-an-Arctic-climate-forcer/1285
[3] AMAP (2015) *AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers.* http://www.amap.no/documents/doc/AMAP-Assessment-2015-Black-carbon-and-ozone-as-Arctic-climate-forcers/1299
[4] Sectoral shares here are based on 2012 UNFCCC national submissions.

estimate of 22%. For other sectors US EPA has small changes in methane emissions development, considering Arctic States as a whole, while IIASA-GAINS predicts coal mining to grow by significant 25% with the remaining sectors changing only marginally. In aggregate, therefore, methane emissions are estimated to increase from 2015 to 2030, but only by a significant volume if there is growth in oil and gas sector activities and regulations and policies are unable to counteract this effect. The divergence in the projections reflects the great uncertainty of oil and gas sector development and of efforts to reduce emission intensities.

For individual countries trends differ greatly and different sources show significant discrepancies in emission level estimates. UNFCCC data for 2010 show methane emissions in the oil and gas sector of Russia to be twice the level of USA. According to IIASA-GAINS, the level in Russia is five times higher than in USA. While this is an extreme difference in estimates, it illustrated the uncertainty that exist on emission levels and the different views that prevail on emission factors that should be used in calculating emissions. According to UNFCCC data, Russia and USA account for 91% of oil and gas sector methane emissions, combined[5]. Over twelve years until 2012 the Russian share increased by 7 percentage points to 61% while that of USA for the same period went from 36% to 30%.Assuming continued growth in oil and gas production, US EPA predicts stronger growth by Russia and USA in emissions of this sector from 2015 until 2030, 22% and 21% respectively. However, taking into account a decisive shift in policies and regulations in the US with the "US Methane Strategy", announced in 2015, the country's emissions are expected by the authorities to go down by 40-45% from 2012 levels by 2025, resulting in USA share of Arctic States' methane emissions from this sector decreasing to 15%, whereas Russia's contribution increasing to 72%[6].

Methane emissions from agriculture are also dominated by Russia and USA, but USA in this case being the larger emitter with 72%, against 16% for Russia. Changes in emissions are for a large part determined by activity levels (e.g. number of cattle), rather than emission control measures. For this reason emission levels are expected to change moderately and there appears to be much less uncertainty related to projections than for the oil and gas sector. Emissions from waste have increased sharply in Russia from 2000 to 2012 according to UNFCCC data. This reflects strong economic growth over the same period (80% accumulated growth in GDP) and lack of investment in modern waste management systems. This is in contrast to the development of Nordic countries for the same period in response to strict waste management regulations being imposed.

3.2 Abatement potential and actions

Estimates of abatement potentials used in this report are primarily from one source; the US EPA Global mitigation of non-CO_2 greenhouse gases assessment[7] which includes both calculations of maximum technical potentials and calculations of reductions than can be achieved economically at different levels of carbon prices. The EPA estimates suggest that the greatest potential for inexpensive abatement measures is in the oil and gas sector. According to EPA, oil and gas sector emissions in 2030 can be reduced by 31% without incurring any additional costs to the investor[8] (carbon price=0). With a carbon price of 20 US$/ton CO_{2eq} this potential is increased to about 42% of the predicted emission level for 2030. Similar estimates exist for agricultural, waste and coal mining sectors, and they are as shown in Table 2.

[5] In 2012.
[6] This is not accounted for in US EPA projections that were estimated in 2012, i.e. prior to announcement of the Methane Strategy.
[7] http://www3.epa.gov/climatechange/EPAactivities/economics/nonco2mitigation/execsumm/index.html
[8] Emission reduction investments will have an economic return of at least 10%.

Table 2: Abatement costs per sector based on carbon price

Sector	0 $/tCO$_{2eq}$	10 $/tCO$_{2eq}$	20 $/tCO$_{2eq}$	Max potential
Oil and gas	-31%	-39%	-42%	-56%
Agriculture	-4%	-6%	-8%	-23%
Waste	-3%	-13%	-16%	-37%
Coal mining	-8%	-40%	-46%	-52%

In relative terms the abatement potential in coal mining is almost as large as in the oil and gas sector, but in absolute volume the abated emissions would only be about 15% of oil and gas sector emissions. Agriculture has the smallest potential with the waste sector being better, but still closer to agriculture than to oil and gas.

Mitigation actions that are in progress or have recently been announced are summarized here, based on information from the National Reports to the Arctic Council Secretariat, other public sources and information Carbon Limits has acquired through other project assignments. These include various legislative requirements, voluntary programs and agreements, as well as economic incentives.

Oil and gas sector actions

For several years Russia has had in place regulations of flaring and methane emissions from oil and gas sector installations and transport systems. Flaring and emissions that exceed specific limits set in the regulations are subject to fines and these fines have been increased significantly over the past few years. There are clear indications that enforcement of regulations has reduced flaring while the effect on other sources of methane is largely uncertain. The Russian National Report to Arctic Council Secretariat does not contain any specific information on new policies and regulations or enforcement measures.

The voluntary Natural Gas Star program in USA has been important for creating awareness and promoting action on methane emissions reductions. A mandatory regulation was passed in 2012 covering various equipment and new measures are now in the process of being developed as a follow up to the target of reducing methane emissions by 40% from 2012 to 2025. EPA estimates suggest that this can be achieved at relatively low net costs to the industry[9]. Canada has different types of regulations at the provincial level and it can be expected that new regulatory measures will be imposed in line with those being implemented in USA. Norway has strict regulations and low emission intensities for methane. There is however uncertainty with respect to the actual level of emission and work is ongoing to gain better knowledge.

Agricultural sector actions

Most of the ongoing and planned mitigation actions in this sector are voluntary in nature, with several countries providing economic incentives for biogas generation from manure (e.g. the Nordic countries) and other agricultural methane mitigation projects (Canada). USA voluntary AgSTAR program aims at promoting and providing support for recovery of biogas from livestock with 247 operational projects[10] that resulted in 3 $MtCO_{2e}$ of avoided greenhouse gases in 2014. In Canada, besides the Federal Agricultural GHG Program that finances relevant mitigation projects, several provincial-level offset protocols address methane emissions from anaerobic digestion and manure storage. There is little available information on ongoing mitigation activity in the Russian agricultural sector.

Waste sector actions

There are stringent EU regulations with regards to landfill deposing of organic waste, recovery of landfill gas and quality of wastewater treatment. All of the Nordic countries comply with these regulations, significantly limiting their emissions from this source. US EPA has similar guidelines for

[9] Similarly, ICF International estimates that approximately 40% of the US onshore oil and gas methane emissions can be reduced at zero abatement cost by 2020 (https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf)
[10] As of March 2015.

new and existing landfills, establishing requirements for emission control and gas recovery. In addition, a voluntary Landfill Methane Outreach Program promotes collection and utilization of landfill gas. In Canada, provincial regulations that require flaring/utilization of landfill gas are complimented with a number of voluntary programmes that encourage recycling, organic processing and gas utilization.

The Russian waste sector emissions have only marginally been addressed in legislation. However, there is currently growing concern with regards to waste management which resulted in several laws being passed in 2014-2015. Their focus is on economic incentives for recycling/waste utilization, upgrading existing infrastructure and developing legal instruments for control of emissions.

Coal mining sector actions

Coalbed methane emissions are subject to regulations in Canada, Russia and USA in relation to mining safety. These are supplemented by economic incentives for recovery and utilization of coalbed methane (a royalty incentive program in British Columbia, renewable energy incentive in Russia, tax credits for "unconventional" sources of natural gas in USA). In addition, US EPA runs a Coalbed Methane Outreach Program promoting profitable recovery of coal mine methane that has resulted in cumulative reductions of 140.2 $MtCO_{2e}$ since the start of the program in 1994[11].

4. Black carbon emissions

4.1 Emission levels and trends

It is only recently that Arctic States have started preparing inventories for black carbon emissions. The US inventory is for 2011, while the other countries have prepared data for 2013. These data are included in the National Reports to the Arctic Council Secretariat. Various other institutions and research groups have made independent estimates of black carbon emissions by country and sectors, which for a large part are presented in the AMAP Assessment 2015 for black Carbon[12]. Generally the national inventories show higher level of black carbon emissions than the independent estimates. This may be caused by the differences in emission sources covered by the inventories and the emission factors applied.

A broad comparison, by country and sector, of black carbon emissions is not possible using only data from national inventories, due to differences in data specification. However, a comparison has been made as part of this review using a variety of sources, including also national inventory data[13]. Estimates are shown for five broad sector categories:

i) **Transport**, currently the most important source accounting for approximately 40% of estimated emissions in Arctic States as a whole. Emissions in USA are by far the largest.
ii) **Residential**, which, similar to transport, consists of millions of individual emission sources, accounts for around 15% of Arctic States black carbon emissions. In relative terms, the Nordic countries have large emissions from this sector (40% of their black carbon emissions).
iii) **Flaring,** which represents a relatively small number of point sources, with Russia dominating both in terms of emissions and the remaining abatement potential (the volume of gas flared in Russia accounted for ¾ of all the gas flared by Arctic States in 2012).
iv) **Power and industry** emissions account for slightly over 10% of the total and are relatively evenly distributed between countries.
v) **Open burning** from agriculture and forestry is possibly a major emission source but the reporting practices are very different among countries and a direct comparison is not possible.

[11] Data for 1994-2012.
[12] AMAP (2015) AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers. http://www.amap.no/documents/doc/AMAP-Assessment-2015-Black-carbon-and-ozone-as-Arctic-climate-forcers/1299
[13] Further details including documentation of sources are presented in the main part of this report.

Data are not presented in National Reports from Russia and Canada. The US estimates are high and accounts for over 25% of the country's total black carbon emissions[14].

Another potentially important emission source is from wild fires. They are not included in open burning category, but are partly linked to it since many of the forest fires originate from open burning practices[15]. Related to this is the question whether and/or to what extent to consider wild fires as anthropogenic emissions. An adequate coverage of open burning and an eventual inclusion of wild fires would significantly reduce share of total black carbon emissions caused by the first four categories presented above.

Projections of black carbon emission development to 2030 are presented in the AMAP Assessment 2015 for black carbon. The information is derived from the ECLIPSE project conducted using the IIASA-GAINS model[16]. Results presented in the sectoral analysis of black carbon emissions are based on the ECLIPSE *baseline scenario* which includes all presently agreed legislation and adopted policies affecting air pollutant emissions. This information has been combined with data from other sources where AMAP Assessment 2015 for black carbon and ECLIPSE results do not provide the needed specification of emission levels by country and sector.

The ECLIPSE analysis suggests a reduction in transport sector emissions of around 60% from 2010 to 2030, in response to stricter regulations of PM emissions. USA is currently responsible for over 2/3 of transport sector black carbon emissions and it is estimated that the country will account for almost 80% of the reduction. All Arctic States will see a decrease in transport sector emissions, but Russia is expected to lag somewhat behind other countries due to a slower pace in implementation of new regulations.

For the residential sector, a significant increase of almost 50% is projected, first of all in Russia and Canada, while a smaller increase is foreseen for power and industry (≈10%) driven by a notable growth in Russian emission, which is only partly offset by reductions in the other countries. The reductions outside Russia are driven by assumed changes in regulations and policies.

Since 75% of black carbon emissions related to flaring originates from Russian oil production developments, the country's flare reduction policies and regulations are decisive for future emission development. It is predicted that emissions in Russia will be reduced, but only moderately. Still, this contrasts with the increase predicted for Russian oil and gas methane emissions driven by the assumed increase in oil production. In the case of black carbon, therefore, it is expected that the parity in the development of oil production and emissions will be broken.

For open burning, only minor reductions in USA and Canada are predicted under the *baseline scenario*.

4.2 Abatement potential and actions

The ECLIPSE project also estimates abatement potentials by sector, calculated as the difference in emissions between the *baseline scenario* and the *mitigation scenario*[17]. Unlike the US EPA analysis for methane, indications of abatement costs are not given, but it appears that the *mitigation scenario* represents a radical reduction in emissions which may entail high abatement costs.

Figure 1 presents the sectors where major emission reductions can be achieved in the mitigation scenario as compared to the baseline scenario. Flaring and open burning can be eliminated, while the abatement potential in the transport sector in relative terms are more modest (50%). However it should be kept in mind that the transport in the baseline scenario is expected to be reduced by more than half due to regulation already being implemented. In terms of volume, the greatest abatement potential is in

[14] Excluding wildfires.
[15] For instance, in Russia, from 30% to 90% of forest fires are said to stem from burning of arable land (http://www.nefco.org/sites/nefco.viestinta.org/files/ICCI%20SLCP%20and%20Agricultural%20Burning_20150814.pdf).
[16] AMAP (2015) AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers. http://www.amap.no/documents/doc/AMAP-Assessment-2015-Black-carbon-and-ozone-as-Arctic-climate-forcers/1299
[17] The mitigation scenario assumes "full implementation of a portfolio of measures by 2030 and 2050 to achieve large reductions in temperature response in the short term at the global scale". See AMAP Assessment 2015 for Black Carbon for more details.

the residential sector, followed by flaring and open burning. As stated before, however, these estimates are uncertain given the limited knowledge that exits about black carbon emission levels.

Figure 1: The additional abatement potential under *mitigation scenario* per sector

Transport sector actions

Transport is currently by far the most regulated sector when it comes to particulate matter (and thus, black carbon) emissions. Stringent standards on the amount of allowed emissions for new engines exist in all European states (Euro 6 standard for both light- and heavy-duty vehicles), USA (Tier 3 being implemented for on-road vehicles and Tier 4 for off-road engines) and Canada (emission standards aligned with the US regulations). In addition, there are mandated reductions of sulphur contents in fuel in these countries. Russia is also on the way of adopting the European standards, with Euro 5 planned to be introduced in 2016.

USA has a number of voluntary retrofit programs (Clean Diesel Campaign, SmartWay Transport Partnership) aiming to replace/upgrade older generations of engines with cleaner technologies. Similarly, Canadian programs ecoTechnology and Fleetsmart, together with smaller provincial level initiatives, are designed to verify and implement new technologies and improve fuel efficiency.

In Denmark and Finland economic incentives are introduced to encourage filter retrofit and car fleet exchange. In addition, the Nordic countries have environmental zones in their largest cities that help limit the amount of emissions.

Residential sector actions

There are a number of EU regulations with impacts on black carbon emissions from residential combustion, namely the EU Ecodesign Directive and the EU Energy Performance of Buildings Directive. They limit allowed emissions from boilers and heaters and set maximum allowed heat consumption levels for new buildings. In Denmark, Norway and Sweden, national legislation sets particulate matter emission limits for new stoves and boilers. In addition, Norway encourages upgrade of existing appliances by offering financial incentives, while Finland provides information campaigns and guidance on sustainable operation of heating equipment.

USA and Canada are introducing similar regulations for new residential wood-burning appliances. Canada provides economic incentives for utilizing cleaner wood stoves in some provinces, while USA facilitates replacement/retrofitting of old units through EPA's Burn Wise program.

There is no available information on the current ongoing or planned activities in Russia in relation to black carbon emissions from residential combustion.

Power and industry sector actions

Similarly to emissions from the transport sector, power and industry are highly regulated through air quality standards. In the EU, 3 Directives influence emissions from large industrial combustion: Large Combustion Plant, Incineration of Waste and Integrated Pollution Prevention and Control directives. Thus, the Nordic countries are subject to these regulations (except Norway, where industries are regulated through facility-specific emissions permits).

In both Canada and USA, the air quality standards set PM emission limits or permitting requirements for different industrial sources. Russian black carbon emissions from large industrial combustion are regulated through air quality standards.

Flaring reduction efforts

Whilst associated petroleum gas (APG) production in Russia has steadily grown over the last decade, there is also a more recent but clear trend of higher utilization of APG in Russia as a result of a more stringent and effectively enforced gas flaring regulation. The combination of these trends has led to stable flaring volumes until a clear downward trend started in 2012. Nevertheless gas flaring may still represent the largest source of black carbon emission in the Russian Arctic. Medium term prospect for APG utilization is uncertain as low oil prices and existing sanctions undermine the companies' abilities to undertake even previously economically feasible flare reduction opportunities. In addition, many of the new field developments are in remote/isolated areas and the remaining gas flares in mature oil areas tend to be smaller. In both Canada and the Unites States there are no federal regulations on gas flaring. However, state- or province-specific regulations define applicability, gas flaring exemptions and reporting procedures. In Alberta for example, companies are required to recover associated gas subject to an economic test. In addition, there are also a number of economic incentives/penalties for gas utilization in Canada, such as a royalty waiver or revenue neutral carbon tax on flared gas.

Among the Nordic countries, Norway and Sweden have limited flaring to technical, safety and emergency reasons only. Norway assesses application on a case-by-case basis. In addition, the EU ETS and CO_2 tax incentivize further gas utilization.

Open burning reduction efforts

The scope of ongoing actions with regards to open burning (agricultural, waste residues, forestry) is rather limited in some of Arctic States. In the Nordic countries, agricultural burning is prohibited, thus, limiting emissions from this source to minimum. In USA, the Department of Agriculture provides technical and financial assistance for prescribed burning. Similarly, several provinces in Canada offer educational and incentive programs aiming at better crop residue management, and corresponding agricultural waste regulations control time of the year when it is allowed, impacts on visibility.

In Russia, where a significant share of forest fires that destroy hectares of land annually stem from agricultural burning, the need for better regulation of agricultural burning is well understood. In 2015, a law prohibiting agricultural residues burning was passed.

5. Concluding remarks

Data quality is essential in order to assess progress of methane and black carbon emission reduction in Arctic States. Reporting of methane emissions according to UNFCCC guidelines are well established, while black carbon emission reports under the CLRTAP have just recently started. For both sources there is major scope for improvement both in terms of emission factors being used and level of specification (especially sector and spatial coverage for black carbon). There are a number of international initiatives ongoing which will lead to improved knowledge of emission levels and trends and further lead to improved quality of the National Reports to the Arctic Council Secretariat.

Assessing progress also requires information on ongoing and planned actions and mitigation strategies. There are requirements for such information to be included in the National Reports, but

currently without any specific guidelines for formats to be used. The content and format of information of actions and strategies vary greatly in the first submissions of the National Reports by Arctic States. Some reports are brief and general while others are detailed and with quantitative estimates of how actions and mitigation strategies are expected to impact emissions trajectories. Different bodies of the Arctic Council, as well as other initiatives engaged in methane and black carbon emission reductions efforts, would benefit significantly if this information in the National Reports were given in a common format, comparable among countries.

Independent research institutions have an important role to play in predicting emissions development, including analysis of how policies and regulations might impact emissions, and identifying cost efficient abatement opportunities. As pointed out in this report, the empirical foundation for such analysis is inadequate. In addition to the uncertainty of emission levels (at sufficiently detailed sectoral and spatial level), information on abatement opportunities and costs are poorly known. Improvements will take time, but priorities should be set such that improved knowledge first come in areas where the opportunities for effective and cost-efficient abatement seem to be the greatest.

The review made as part of this project suggests that improved knowledge is particularly important for the following emission sources and sectors:

Methane emissions in the oil and gas sector: By far the most important sector of methane emissions and, in the absence of stricter regulations, emissions will continue to increase. At the same time, there is large abatement potential which entails low or no net cost. Emissions and abatement potential estimates are highly uncertain.

Methane emissions in the waste sector: Emissions estimates from the waste sector vary significantly between different sources reflecting uncertainty in the emission level. Current estimates indicate that the overall abatement potential is relatively limited compared to the oil and gas sector.

Black carbon emissions from open burning: Scale of emissions is poorly known, but effects of open burning (and the wildfires that often stem from it) in the Arctic region are very significant and abatement could be achieved at relatively low cost.

Black carbon emissions from flaring: Largely confined to Russia, scale of the problem and abatement costs poorly known. A few large point sources dominate.

The analysis also shows that, though the Arctic States have developed actions plans targeting SLCF emissions, these are presented in different formats and it is difficult to assess their impacts and make cross country comparisons. More uniform reporting should be a priority particularly for sectors where there is a believed to be a large abatement potential and/or where limited action is ongoing.

References in the following sections of the report are marked with round brackets ( ). Corresponding sources can be found on page 27.

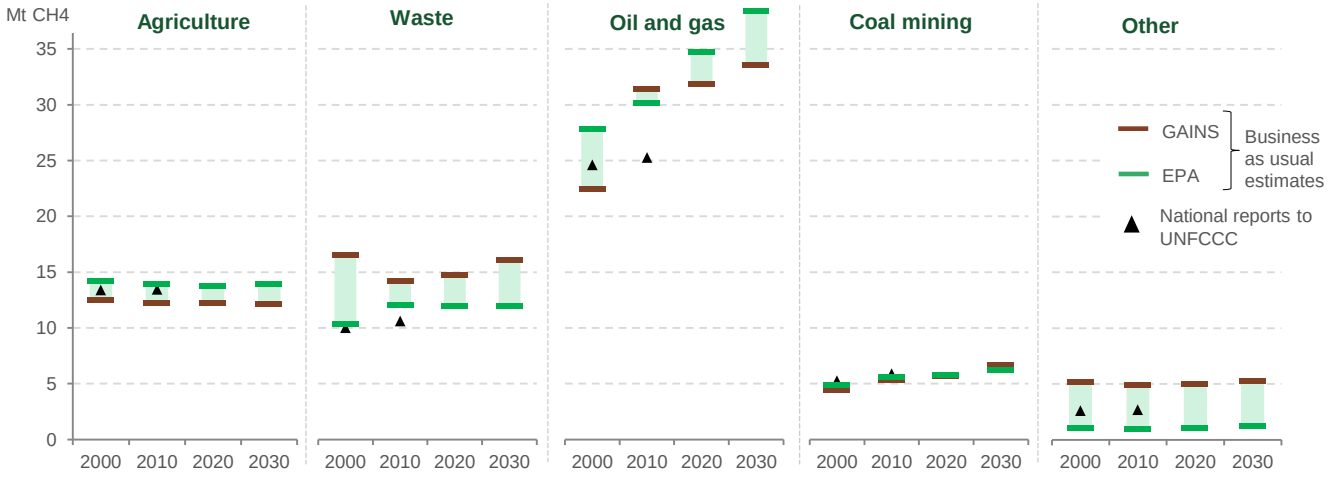
Anthropogenic methane emissions in Arctic States

Anthropogenic methane emissions in Arctic States: OVERVIEW

CARBON LIMITS

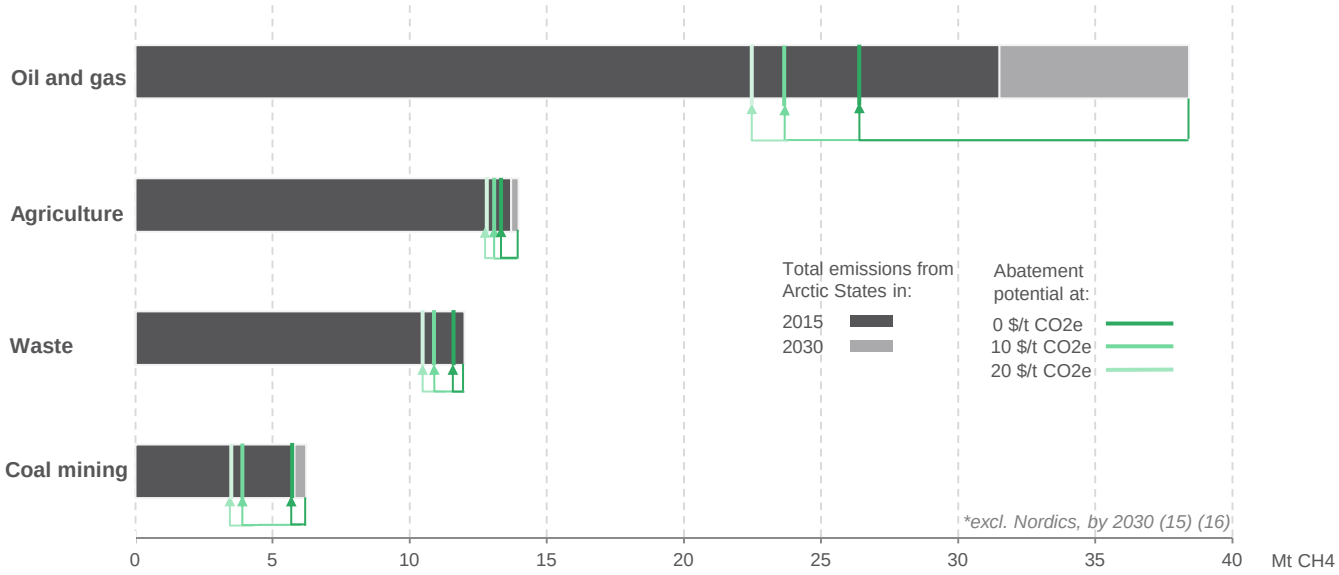
Arctic States are responsible for **20% of global anthropogenic methane** emissions and have the **largest technical abatement potential** of any major world region for reducing emissions (4).

Mitigation potential by 2030 at **$0/tCO2e** amounts to **13 500 kt** of methane (**≈20%** of the total 2030 emissions of the Arctic States under the baseline scenario), at **$10/tCO2e ≈ 20 000 kt** (**≈30%** of the forecasted emissions) (16).



The oil and gas sector dominates with respect to current and projected future emissions of methane. Agriculture and waste are predicted to remain significant as well. Discrepancies in estimates are particularly large for the oil and gas and waste sectors.

Sector contribution to the total emissions of Arctic States and abatement potential*



Possible mitigation measures

Oil and gas	Extended utilization of associated gas; improved control of unintended fugitive emissions; replacement of equipment
Agriculture	Farm-scale anaerobic digestion of manure
Waste	Separation and treatment of biodegradable waste; landfill gas collection for utilization; Improving wastewater treatment to recover gas
Coal mining	Extended pre-mine degasification and recovery of methane from ventilation air in coal mines

Summary

- Projection are uncertain (important differences depending on the methodology).
- Oil and gas sector is by far the largest contributor to Arctic States methane emissions and is projected to grow in the future under the business as usual scenario. However, it also presents the largest abatement potential.
- Agriculture and waste constitute approximately1/5 of the total methane emissions each, with limited abatement potential.

Source: (19) (25)

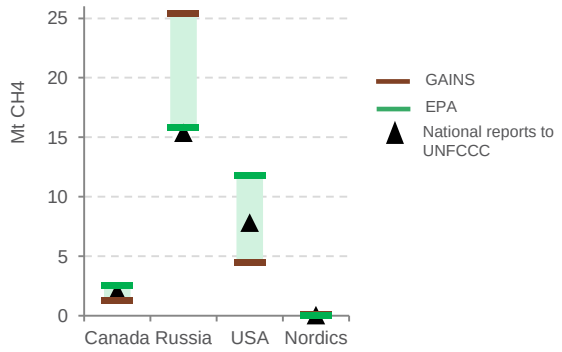
Methane emissions: OIL AND GAS

CARBON LIMITS

Oil and gas sector is the **single** largest source of emissions for Arctic States (dominated by the US and Russia) (10).

Methane emissions from oil and gas in 2010

Uncertainty in emissions estimations due to the complexity of the sector , lack of data and differences in methodologies being applied



Country	Mitigation actions*	
	Implemented	**In progress**
Canada	Alberta, British Columbia, Newfoundland, Saskatchewan, New Brunswick have requirements to limit flaring / venting. Some of the provinces require e.g. mandatory LDAR, dehydrator mitigation measures, and reporting of emissions. Carbon tax on natural gas flaring in British Columbia.	Intent to develop regulations to reduce emission from oil & gas sector in line with US 2015 Methane Strategy
Russia	Associated gas utilization requirement of 95%. The operator must ensure monitoring and repair of natural gas leaks. Purchase of permits is required above agreed Emission Limit Value.	Not available
USA	Voluntary program Natural Gas Star. Regulation in 2012 covering a number of equipment including e.g. new pumps and pneumatic controllers, new tanks.	Target to reduce emissions by 40% from 2012 levels by 2025. New set of measures announced: capture gas from the completion of hydraulically fractured wells, leaks repairs, low bleed pneumatic devices.
Denmark	Not available	
Finland	Not applicable	
Iceland	Not applicable	
Norway	Venting is prohibited but permits are given annually on case-by-case basis. Flaring only allowed with specific government permits. Emissions measurement and reporting mandatory onshore.	Ongoing analysis and studies to identify mitigation options.
Sweden	Not applicable	

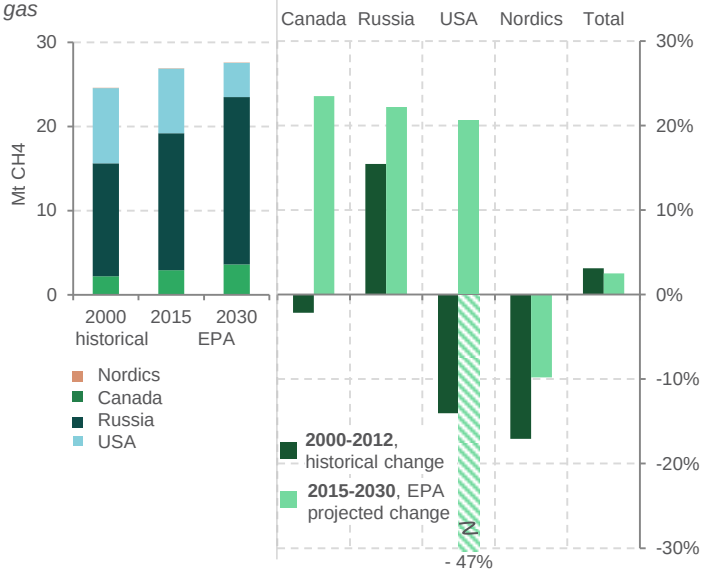
**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Methane emissions from oil and gas per country*

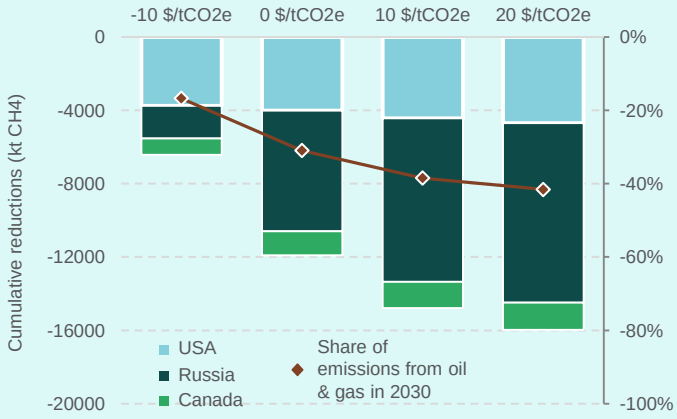
**US projections with and without adjustment for the US Methane Strategy (40% reduction from 2012 levels by 2025) (8)*

Country contribution to CH4 emissions from oil & gas

Change in emissions 2000-2012 (UNFCCC) and 2015-2030 (EPA)



Abatement potential in the oil and gas sector



Abatement potential of Arctic States (excluding Nordics) by 2030 (additional to BAU): absolute reduction in kt (left) and share of the projected 2030 emissions reduced through mitigation measures (right)(16)

Summary

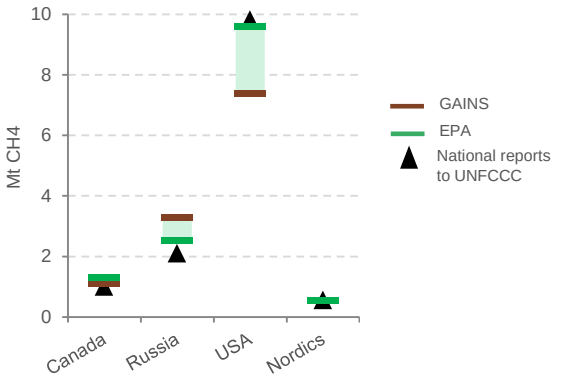
- Methane emissions in the oil and gas sector represent the largest abatement potential in the Arctic region (16).
- Significant reductions can be achieved at negative abatement costs (with economic benefit for the companies) (16).
- There is important ongoing effort in USA, Norway and, more recently, in Canada to reduce this emission source.
- Russia is both the largest emitter and the biggest potential emission reduction.

Methane emissions: AGRICULTURE

CARBON LIMITS

Methane emissions from agriculture in 2010

GAINS and EPA estimates significantly differ for USA. This country is by far the leading contributor to methane emissions from agriculture.



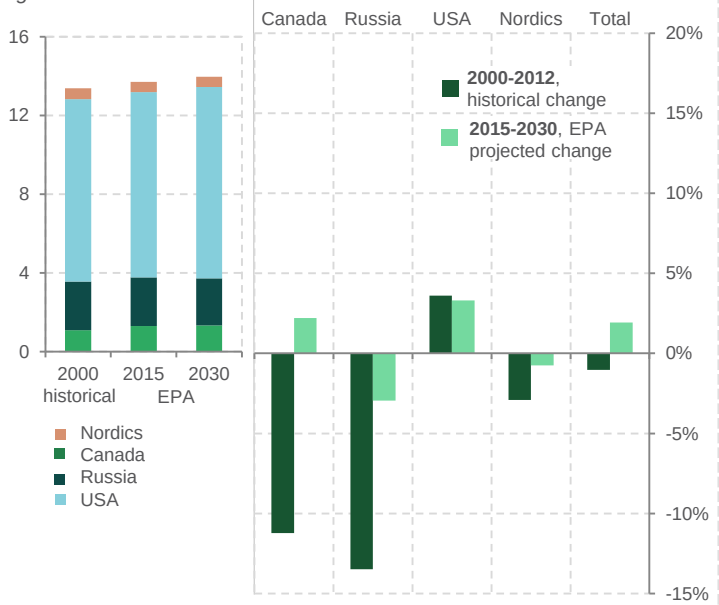
Agricultural sector is the **second** largest source of emissions for Arctic States.

The largest sources of agricultural methane emissions are: **enteric fermentation** and **manure management** (10)**.**

Methane emissions from agriculture per country

Country contribution to CH4 emissions from agriculture

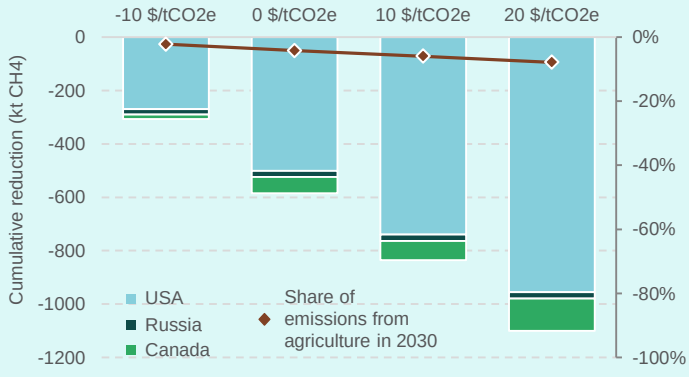
Change in emissions 2000-2012 (UNFCCC) and 2015-2030 (EPA)



Country	Mitigation actions*	
	Implemented	**In progress**
Canada	Federal: Agricultural GHG Program provides funds for mitigation projects Provincial programs: • Ontario: voluntary program enables farmers to learn and implement best management practices • Alberta & Quebec: GHG offset protocols address methane emissions, project funding	Not available
Russia	Not available	
USA	AgSTAR program (247 operating projects in 2015): • Encourage use of anaerobic digestion techniques • Address barriers to installation of biogas recovery devices	Biogas Opportunity Roadmap (developed in August 2014): • Supports voluntary goal of US dairy's sector to reduce GHG by 25% by 2020
Denmark	National law on promoting renewable energy includes subsidy on biogas generated from manure	Not available
Finland	Rural Development Plan 2014-2020 for Finnish Agriculture (approved in 2014) is enforced by a number of decrees: actions promoting energy efficiency and renewables in farming	Climate Program developed by the Finnish government in 2014: • Energy efficiency measures and use of renewables in farm production • Dietary changes for cows
Iceland	Not applicable	
Norway	Not available	National Action plan for SLCF includes: transition from red to white meat, and phasing in biogas from manure on buses
Sweden	From January 2015, support to biogas production by anaerobic digestion of manure: • Maximum 20 cents/kWh produced biogas	Rural Development Program 2014-2020: support for investment, capacity building

**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Abatement potential in the agricultural sector



Abatement potential of Arctic States (excluding Nordics) by 2030 (additional to BAU): absolute reduction in kt (left) and share of projected 2030 emissions reduced through mitigation measures (right)(16)

Summary

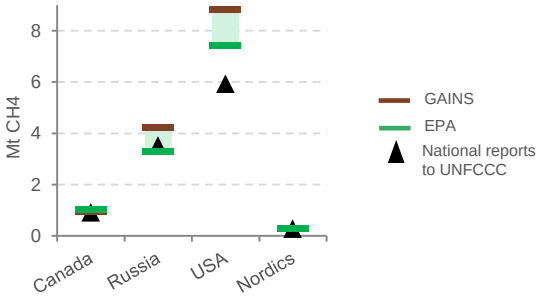
- Major source of methane: slurry-based manure management (tenfold higher compared to solid storage / pasture).
- Historical decrease in some countries due to reduction in number of cattle (e.g. Russia, Finland) (6) (7).
- Opportunities for reducing emissions from enteric fermentation are not well understood (8).
- Mitigation actions are widely discussed, but only limited number of measures is implemented (23).
- Overall mitigation potential is limited (21).

Methane emissions: WASTE

CARBON LIMITS

Methane emissions from waste in 2010

GAINS and EPA estimates significantly differ for USA. USA and Russia are the major countries contributing to methane emissions from waste

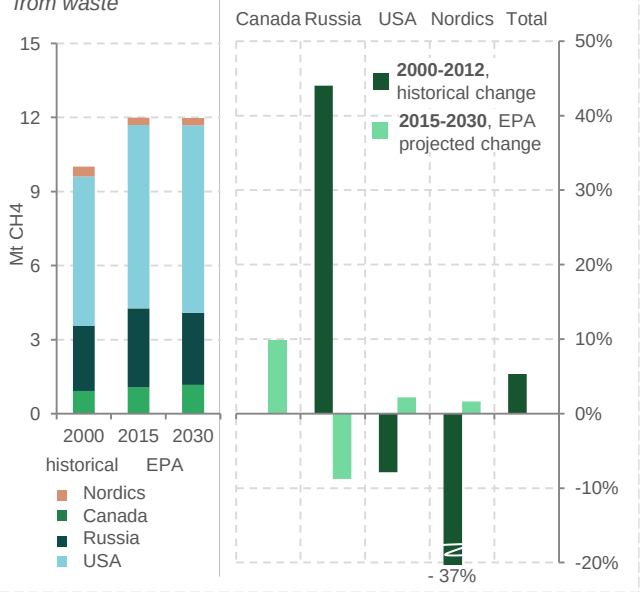


Waste (solid waste and wastewater) is the **third** largest source of emissions for Arctic States (10).

Methane emissions from waste per country

Country contribution to CH4 emissions from waste

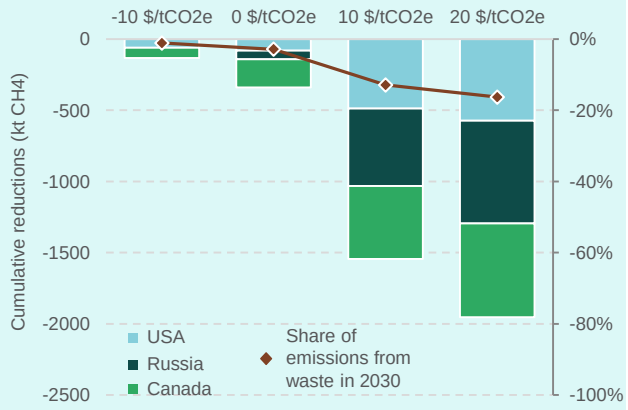
Change in emissions 2000-2012 (UNFCCC) and 2015-2030 (EPA)



Country	Mitigation actions	
	Implemented	In progress
Canada	Most provinces require utilization / flaring of landfill gas (s.t. facility age, size), stricter requirements for larger facilities. Ontario offers feed-in tariff for landfill gas. As of 2014, over 30 extended producer responsibility programs significantly increase the recycling rate. Funding programs to promote recycling, organic processing (e.g. Gas Tax fund, Green infrastructure fund, ecoENERGY)	Not available
Russia	Strategy for handling solid waste (2013) proposes the development of infrastructure for separate collection, recycling, utilization of waste; introduction of economic and legal instruments for regulation of waste utilization. Federal law on production and consumption waste (2014/15) incorporates economic incentives for recycling / waste utilization. From 2016, regional authorities will be responsible for collection and utilization of solid waste, allowing for economies of scale.	Not available
USA	EPA's 1996 emission guidelines for existing landfills and 1996 New Source Performance Standards for new landfills set requirements for gas emissions control and collection. Landfill Methane Outreach Program (since 1994) encourages voluntary recovery and use of landfill gas as an energy resource (focus on smaller landfills not covered by the regulations and larger ones that flare gas)	EPA (2015) proposed lower thresholds for active landfills.
EU	EU Landfill Directive: landfill disposal of biodegradable waste reduction targets + compulsory recovery of landfill gas (2009) EU Waste Management Framework Directive: recycling and composting must be preferred to energy recovery. EU Urban Wastewater Treatment Directive: appropriate infrastructure must be in place by 2005, quality objectives on receiving waters.	
Denmark	Landfill deposing of organic waste is prohibited (1997). Tax on landfilling and incineration (1987). Strategy for waste prevention (2015-2027) includes 72 specific initiatives to reduce generation of waste.	
Finland	Landfill deposing of organic waste is prohibited (2016) + additional targets for recycling / recovery of certain waste Landfill gas recovery regulations encourage recovery of gas.	Not available
Iceland	Not applicable	
Norway	Landfill deposing of organic waste is prohibited (2004).	Not available
Sweden	Landfill deposing of organic waste is prohibited (2005). Combustible waste banned from landfilling since 2002. The same ordinance regulates collection and disposal of gas from landfills. Tax on waste disposed to landfills (since 2000).	Not available

**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Abatement potential in the waste sector



Abatement potential of Arctic States (excluding Nordics) by 2030 (additional to BAU): absolute reduction in kt (left) and share of the projected 2030 emissions reduced through mitigation measures (right) (16)

Summary

- Russia is behind Western countries when it comes to waste management (less than 5% is processed) (24)
- Emission reductions can be achieved at relatively low cost (≤10$/tCO2e)(16)
- Emissions from Russia are expected to decrease slightly due to development of waste legislation (11). Emissions from other Arctic States are forecasted to increase (economic abatement measures already implemented) (3).

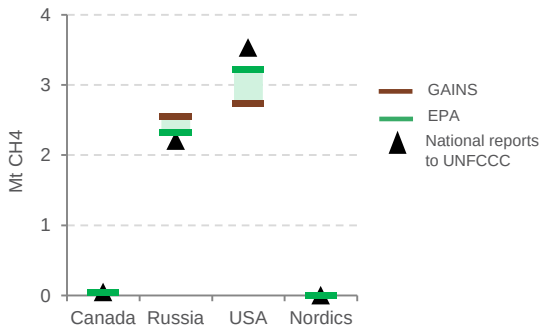
Methane emissions: COAL MINING

CARBON LIMITS

Coal mining presents the 4th largest source of emissions for Arctic States (dominated by USA and Russia) (10).

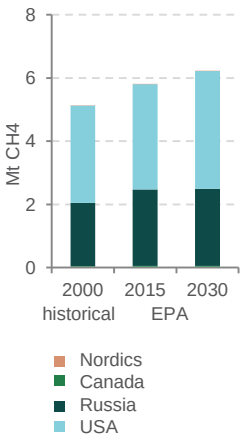
Methane emissions from coal mining in 2010

EPA estimates are consistent with national submissions to UNFCCC

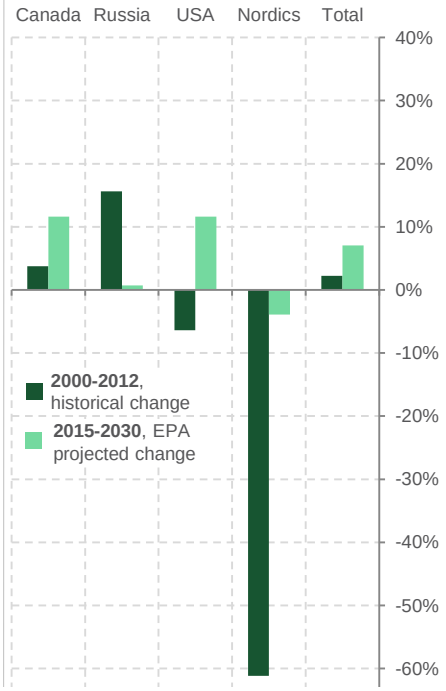


Methane emissions from coal mining per country

Country contribution to CH4 emissions from coal mining



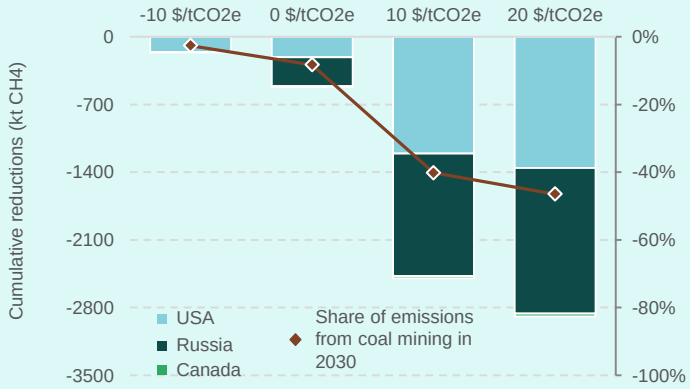
Change in emissions 2000-2012 (UNFCCC) and 2015-2030 (EPA)



Country	Mitigation actions*	
	Implemented	In progress
Canada	British Columbia has a royalty incentive program to encourage production of coalbed methane (CBM).	Not available
Russia	As of 2008, 7 coal mine methane (CMM) projects in Russia provide boiler fuel or power generation. Promotion of CBM recovery projects by providing assistance; CMM qualifies for renewable energy incentive under 2009 Decree. The Decree on payments for emissions of pollutants (2003) sets out reginal emissions limits and payment amounts for charging companies that emit methane.	Long-term Program for development of the coal sector (2012) was developed to promote modernization of production facilities, improving ecological safety and reducing industry's energy intensity.
USA	Voluntary Coalbed Methane Outreach Program (since 1994) aims at promoting profitable recovery and utilization CMM: 26 operating projects (as of 2012). Tax credits are used to encourage production of "unconventional" sources of natural gas (including CMM).	Not available
Denmark	Not applicable	
Finland	Not applicable	
Iceland	Not applicable	
Norway	Not applicable	
Sweden	Not applicable	

**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

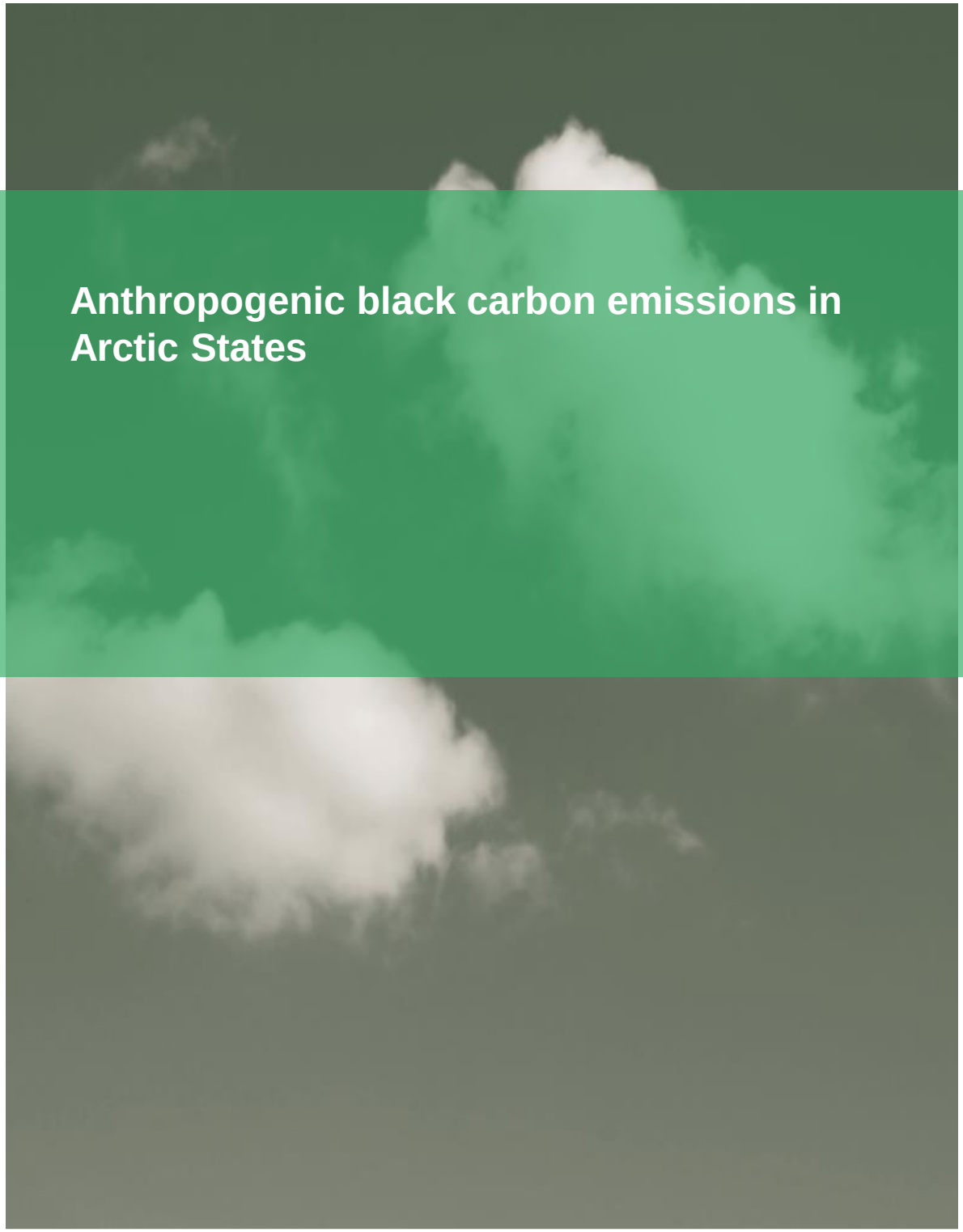
Abatement potential in the coal mining sector



Abatement potential of Arctic States (excluding Nordics) by 2030 (additional to BAU): absolute reduction in kt (left) and share of the projected 2030 emissions reduced through mitigation measures (right)(16)

Summary

- Methane emissions from coal mining have been gradually increasing, driven by growth in Russia and Canada.
- Emissions growth is expected to continue, largely due to Russia and the US (CL analysis based on (15)).
- At low gas and electricity prices, expanded coalbed methane recovery is economically unfeasible (current situation in Russia) (20).
- Significant mitigation potential exists at relatively low abatement cost (≤$10/tCO2e), both in Russia and USA (16).

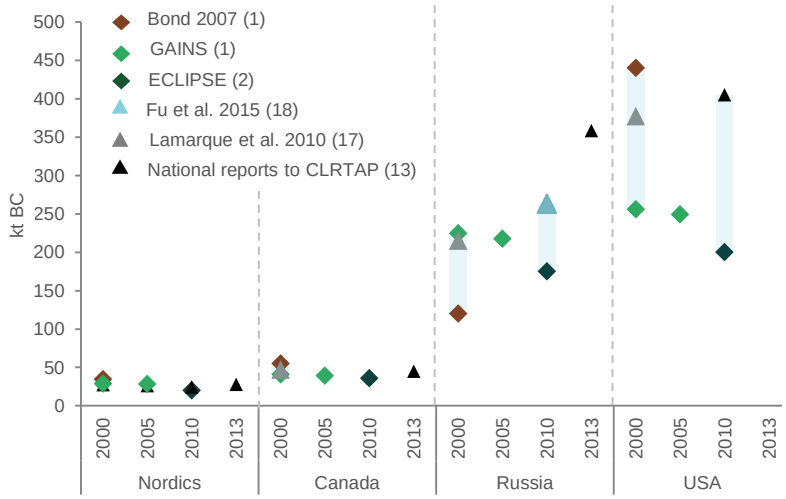


Anthropogenic black carbon emissions in Arctic States

Anthropogenic black carbon emissions in Arctic States: OVERVIEW

CARBON LIMITS

Comparison of various emission inventories of black carbon



There are important differences in international inventories of black carbon, especially for Russia and USA. The major source of uncertainty are emissions from flaring and open burning.

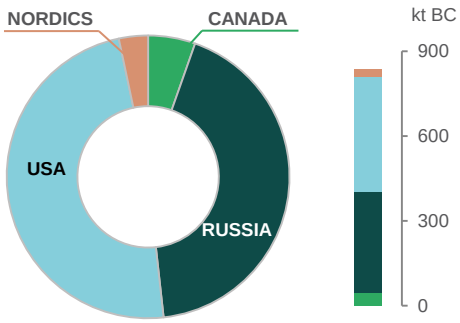
Arctic States are responsible for **10% of global black carbon** emissions. However, the Arctic **climate effect per unit of emissions** from these countries is likely to be higher due to their proximity to the Arctic.

Major emissions **sources** for the Arctic States are: **surface transportation**, as well as **residential and commercial combustion**.

There is significant uncertainty regarding current and future black carbon emissions from open burning and gas flaring.

Source: (2) (9) (10)

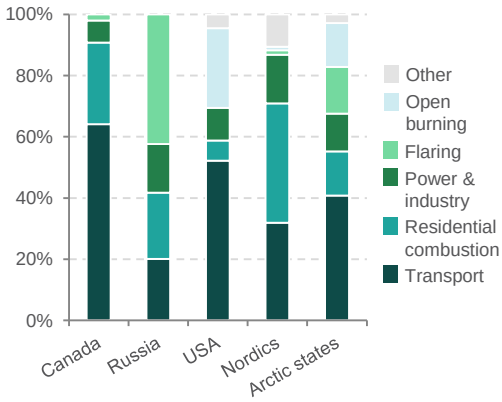
National contribution to total black carbon emissions of Arctic States



US is the largest contributor to Arctic States' black carbon emissions, followed by Russia.

Source: 2013 data, for Nordics, Canada, US – (13) (2011 for US, excl. wildfires); for Russia – (7)

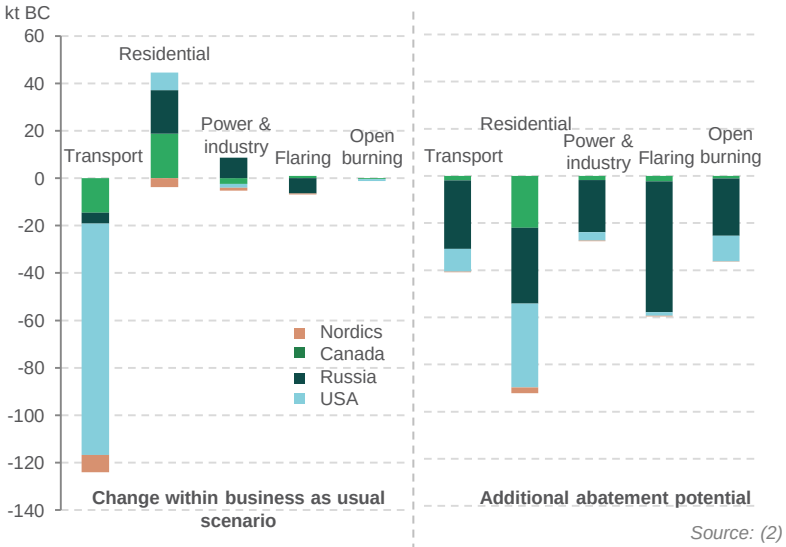
Share of major sources of black carbon emissions of Arctic States in 2013



Major source of black carbon emissions in North America is transport, in Russia – flaring, in Nordic countries – residential combustion.

Source: For Nordics, Canada, US – (13) (2011 for US, excl. wildfires); for Russia – (18); excl. Iceland

Black carbon forecasted change and abatement potential until 2030



Source: (2)

Emission projections

- Up to ¾ of global anthropogenic black carbon emissions can be eliminated by 2030 if new legislation is enforced (2).
- Given efficient enforcement of current legislation, black carbon emissions from Arctic States are projected to continue to decrease by up to 35% over the next couple of decades (10).
- AMAP analysis suggests that overall black carbon emissions reduction will be driven by transport sector that is projected to decrease significantly, while emissions in other sectors may remain roughly constant or even increase in the future (9).
- Gas flaring in Russia and residential heating in all Arctic States represent the largest potential for abatement (2).

Black carbon emissions: TRANSPORTATION

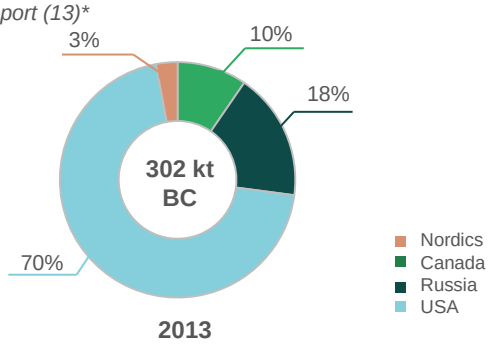
CARBON LIMITS

Transport presents the largest black carbon emission source for Arctic States as a whole (≈40% with onroad and off-road transport accounting for relatively similar shares) (2).

USA is the major contributor to the BC emissions from this sector (13).

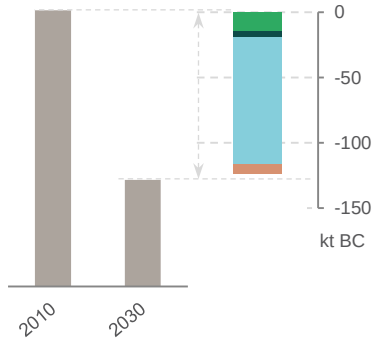
BC emissions from transportation per country

*Country contribution to the total BC emissions from transport (13)**



*Estimates for Russia: (18)

Country contribution to change in emissions from transport in 2010-2030 (ECLIPSE estimates from (2))

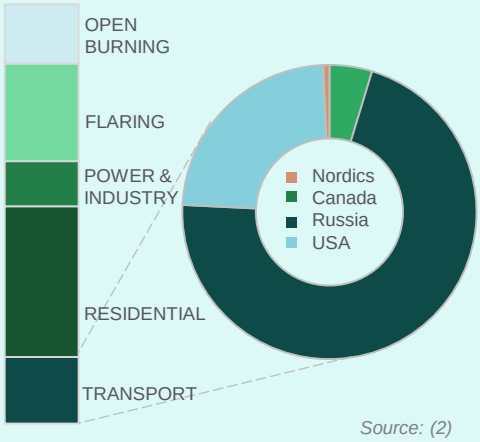


Country	Mitigation actions	
	Onroad	Off-road
Canada	Since 2015, stringent emission standards for light vehicles post-2017, as well as heavy-duty vehicles and engines post-2018 aligned with US Tier 3 regulations.	Since 2011, emission standards aligned with the US EPA Tier 4. 2011-2015 governmental program to reduce emissions from locomotives. Marine: vessel pollution regulations & North American Emission Control Area
	Voluntary programs: ecoTechnology and Fleetsmart - improving fuel efficiency and verifying new technologies. Provincial programs: vehicle anti-idling, scrappage, retrofit	
Russia	Vehicle emissions are restricted by Technical Regulation No. 609. The Euro standards adopted with later implementation (Euro IV – 2013, Euro V – 2016). Municipal air quality controls: e.g. in Moscow trucks <Euro III are prohibited in the city centre.	Not available
USA	Two primary mechanisms: - Emissions standards for new engines: • Tier 3 starting in 2017 for passenger / light-duty vehicles (PM ≤ 0.003 g/mile) • Tier 4 for off-road engines from 2004 • New locomotive engines standards from 2015, marine vessels - from 2014 • Mandated (since 1995) reductions in sulphur contents in gasoline / diesel - Retrofit programs for in-use mobile diesel engines: • Clean Diesel Campaign (since 2008): >73 000 upgraded / replaced vehicles • SmartWay Transport Partnership: development and deployment of new technologies and finance strategies + Department of Transport's Congestion Mitigation and Air Quality Programs.	
EU	Euro exhaust emission standards: • light-duty vehicles – Euro 6 standard, in force since 2014 (2015 for heavier vehicles), PM ≤ 0.005 g/km; • heavy-duty engines – Euro VI standard from 2014 (PM ≤ 0.01 g/kWh).	Directive 97/68/EC (agricultural and forestry since 2001). Implemented in steps (currently Step III B) s.t. engine power. Ongoing review to harmonize with US Tier 4 (≈2020).
Denmark	Environmental zones in four largest cities. Economic incentives for PM filter retrofit (tax on cars without filters) and car fleet exchange.	Electrification of railways. Sulphur requirements for marine vessels.
Finland	Environmental strategy for transport (2013-2020) includes: promoting the use of alternative fuels and low-emissions vehicles; scrappage program (€3 M allocated in 2015); improving energy efficiency.	Not available
Norway	Subject to EU exhaust emission standards. Significant economic incentives for electric vehicles.	Not available
Sweden	Diesel is subject to energy tax raised in 2011 & 2013 Since 1998, municipal air quality controls in 6 cities. Congestion tax in Stockholm, Gothenburg.	Not available
	Procurement requirements (on fuel, age, emission control equipment) applied by the some governmental bodies and municipalities.	

*Colour indicates: *mandatory (legislations, binding targets)*, *voluntary actions*, and *economic incentives*

Abatement potential

Abatement potential of Arctic States by 2030 (additional to already adopted measures): sector contribution to total possible abatement (left) and country share of the projected emissions reduced from transport through mitigation measures (right)



Source: (2)

Summary

- Most Arctic States have PM control measures for new vehicle engines that are already in effect or will come to power by 2020, off-road transport emissions are less regulated.
- This sector is expected to show the largest reduction in BC emissions under the business as usual scenario (driven by stringent US, Canadian and EU PM limits), and significantly less abatement potential beyond it.
- There is additional potential in efficient retrofitting programs (example of USA), retirement of old engines / vehicles / machinery that might be more difficult in some countries (e.g. Russia) due to lack of necessary financing of relevant economic sectors (9) (17).

Black carbon emissions: POWER & INDUSTRY

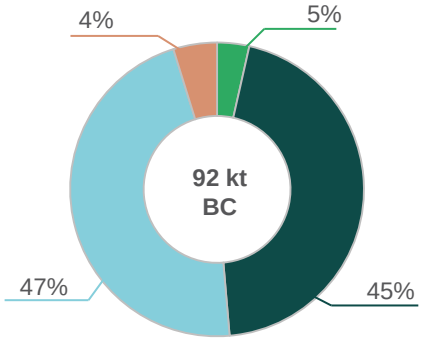
CARBON LIMITS

Power and industry emission source includes industrial combustion that occurs throughout different manufacturing processes, as well as emissions from production of electricity.

The largest contributors are USA and Russia, with the latter presenting the highest abatement potential (2) (13) (18).

BC emissions from power & industry per country

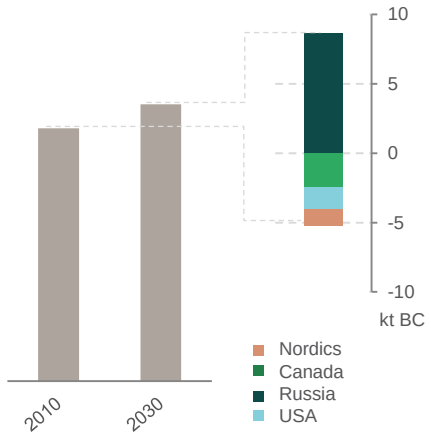
*Country contribution to the total BC emissions from power & industry (13)**



2013

**Estimates for Russia: (18)*

Country contribution to change in emissions from power & industry in 2010-2030 (ECLIPSE estimates from (2))



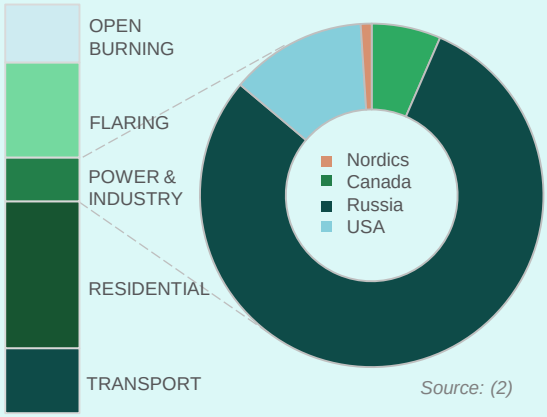
Russia and USA contribute approximately equal shares to the total black carbon emissions from power & industry sector. Under the current legislation scenario, the sector is expected to grow only moderately , with Russia's increase in emissions being offset by reductions in all other Arctic States.

Country	Mitigation actions*
Canada	Federal: Reduction of CO2 emissions from coal-fired generation regulations (2012) indirectly impacting black carbon emissions. Ambient Air Quality Standards to become more stringent from 2020. Regulated by provinces and/or territories through permitting requirements for specific industries, applying a cap on emissions from electricity generation.
Russia	Not available
USA	Air quality standards (NAAQS) set PM emission limits for >40 categories of industrial sources (e.g. coke ovens, cement plants, industrial boilers, stationary diesel engines) through utilizing fabric / diesel particulate filters, electrostatic precipitators.
EU	Large industrial combustion regulated in 3 EU Directives: the Large Combustion Plant Directive (2001/80/EC), Directive 2000/76/EC on the Incineration of Waste and Directive on Integrated Pollution Prevention and Control (2008/1/EC). PM emissions further restricted by Directive 2010/75/EC on industrial emissions (limit reduced by half).
Denmark	Subject to EU regulations.
Finland	Subject to EU regulations.
Norway	Industries regulated through facility-specific emissions permits.
Sweden	Subject to EU regulations. Since 2011, energy tax on fossil fuels used in heating and industrial manufacturing levied according to energy content.

*Colour indicates: *mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Abatement potential

Abatement potential of Arctic States by 2030 (additional to already adopted measures): sector contribution to total possible abatement (left) and country share of the projected emissions reduced from power & industry through mitigation measures (right)



Source: (2)

Russia 's additional abatement potential is by far the largest among Arctic States. Few measures have been introduced for power & industry particulate matter reduction to date.

Summary

- Russia and USA are the largest contributors to the Arctic black carbon emissions from power & industry.
- Due to adopted legislation, US and Canada and the Nordics are expected to significantly reduce their emissions from this sector.
- Most of the remaining abatement potential is presented by Russia.

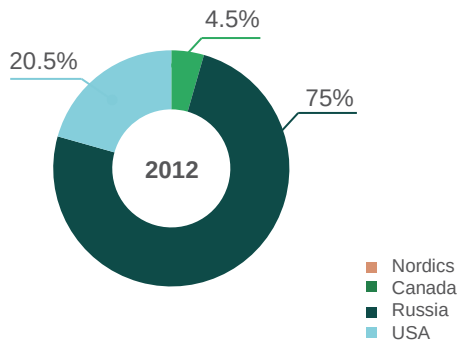
Black carbon emissions: FLARING

CARBON LIMITS

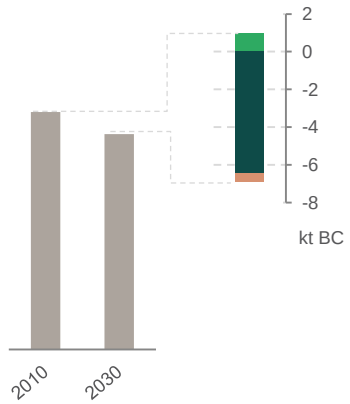
Flaring is potentially a very large source of emissions at high latitude, with Russia being the main contributor. However, the amount of emissions and their future projections are largely uncertain.

BC emissions from flaring per country

Country contribution to the volume of gas flared by Arctic States (excluding Nordics, (14) for Russia and USA, (26) (27) (28) for Canada)



Country contribution to change in emissions from flaring in 2010-2030 (ECLIPSE estimates from (2))



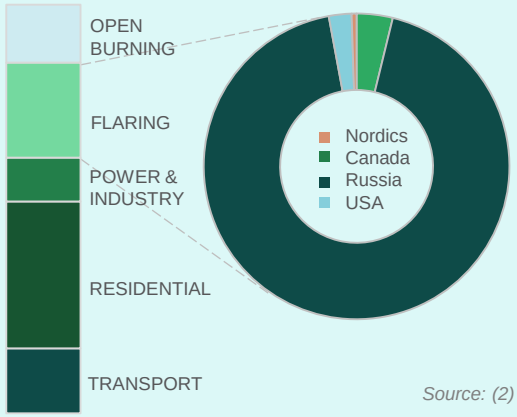
Due to differences in reporting of black carbon emissions from flaring, there is significant disparity between national estimates and it is problematic to compare the different inventories. The graph above (left) presents the country contribution to gas flaring volume based on (14).
Under the business as usual scenario emissions from flaring are expected to decline marginally, driven by reductions mostly in Russia.

Country	Mitigation actions*
Canada	No Federal regulations. A number of provinces have regulations applying to flaring or to CO2 emissions. For instance, in Alberta companies flaring gas are required to recover the gas subject to an economic test. Companies have also overall CO2 emission reduction targets. Royalty waiver can also be applicable to some of the utilized gas. When natural gas is flared in British Columbia, it is subject to a revenue neutral carbon tax.
Russia	Target utilization of associated gas set at 95%. Payment system (with a multiplying factor) for exceeding the APG flaring limit (2015).
USA	No federal regulation on gas flaring but companies have to report CO2 emissions. Specific regulation for each state defining applicability, gas flaring authorization procedures and exemptions.
Denmark	Limited flaring only for technical or safety reasons. The Danish Subsoil Act regulates the volumes of gas flared. EU ETS incentivize further gas utilisation.
Finland	Not applicable
Norway	Associated gas routine flaring is prohibited but permits are given annually on a case-by-case basis for technical, safety or emergency reasons. Permit is normally given with specific gas volume targets. EU ETS and CO2 tax incentivize further gas utilisation.
Sweden	Not applicable

**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Abatement potential

Abatement potential of Arctic States by 2030 (additional to already adopted measures): sector contribution to total possible abatement (left) and country share of the projected emissions reduced from flaring through mitigation measures (right)



Source: (2)

Though flaring in Russia has already been reducing, the abatement potential remains significant. The abatement cost for gas flaring reduction is site specific and highly variable.

Summary

- There is currently large uncertainty regarding the magnitude of black carbon emissions from gas flaring due to limited number of field measurements. Existing studies show important variations in the emission factors.
- Gas flaring has been reducing in Russia over the last few years.
- Gas flaring in Russia represents about 1/5 of the overall black carbon abatement potential in the Arctic (2).

Black carbon emissions: RESIDENTIAL

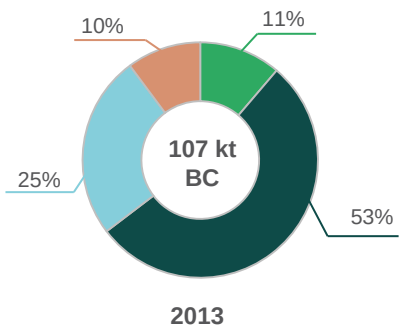
CARBON LIMITS

Residential and commercial combustion represents around 15% of black carbon emissions of Arctic States.

In the Nordic countries residential and commercial combustion represents approximately 40% of the BC emissions (13).

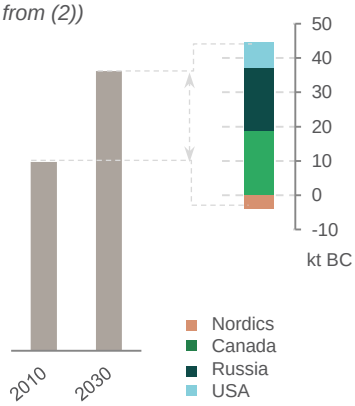
BC emissions from residential and commercial combustion per country

*Country contribution to the total BC emissions from residential and commercial combustion (13)**



**Estimates for Russia: (18)*

Country contribution to change in emissions from residential combustion in 2010-2030 (ECLIPSE estimates from (2))



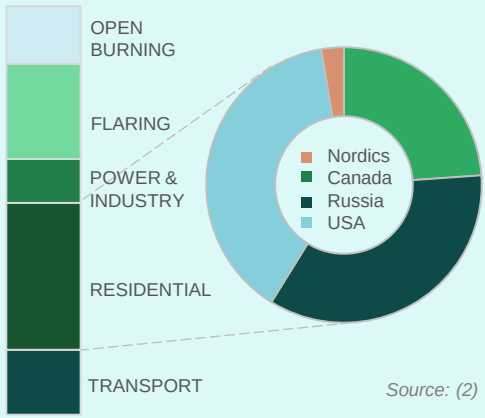
Russia contributes over half of total emissions from residential combustion. The US contributes about a quarter of sector's emissions.
Under the current legislation scenario, significant increase is expected for all of Arctic States, except the Nordics that are projected to reduce their emissions from this source.

Country	Mitigation actions*
Canada	Provincial and municipal regulations: • new wood-burning appliances need to meet PM standards; • wood stove change-out programs; • regulated codes of practice, operating conditions, phase-out dates. Federal educational programs on wood burning and incentives for cleaner wood stoves (through 2012 Code of Practice for Residential Wood Burning Appliances).
Russia	Not available
USA	Stringent rule on maximum achievable technology for commercial boilers (from 2011). Standards for new residential wood heaters strengthened from 2015 (new categories of heaters included, PM limits reduced by ≈2/3). EPA's Burn Wise voluntary program facilitates replacement and retrofitting of old units.
EU	EU Ecodesign Directive (2009/125/EC) limits emissions from solid fuel boilers and room heaters. Stricter limit values agreed upon, taking effect in 2020 for new boilers, in 2022 for space heaters. EU Energy Performance of Buildings Directive sets maximum consumption levels for new buildings, reducing need for fuel heating. A new Medium Combustion Plant Directive agreed upon provisionally in 2015.
Denmark	Revised Statutory Order on Wood-Burning Stoves tightens PM emission requirements for new wood stoves (from 2015) and straw fired boilers (from 2018).
Finland	Information campaigns (2007-2013, "Burn right") raising awareness about PM and providing guidance on correct stove operation.
Norway	Since 1998, regulations for new wood stoves, offering financial reimbursement for upgrading new stoves and setting PM emissions limit.
Sweden	Boilers' Swan eco labels set air quality requirements for boilers (in all Nordic countries). Construction industry legislation sets maximum energy consumption level. New biofuelled boilers and stoves need approval from the National Board of Housing.

**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Abatement potential

Abatement potential of Arctic States by 2030 (additional to already adopted measures): sector contribution to total possible abatement (left) and country share of the projected emissions reduced from residential combustion (right)



Source: (2)

The additional abatement potential is significantly higher for residential combustion than for any other sector. The US constitutes the largest share of the potential, with Russia and Canada following closely.

Summary

- Switching to cleaner fuels (e.g. natural gas) is a feasible mitigation measure that can reduce emissions from this sector drastically (9).
- Retrofitting old appliances and change-out programs might have significant abatement potential (9).

Black carbon emissions: OPEN BURNING

CARBON LIMITS

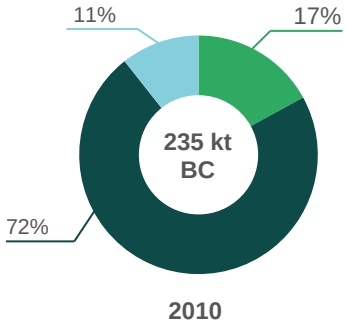
Global estimates of open burning vary from 30% to 45% of total BC emissions and present potentially the biggest source of emissions. It is also said to be a primary source of black carbon emissions in the Russian and Canadian Arctic. In addition, a large share of wildfires is claimed to originate from burning of arable land (up to 90% in Russia).

At the same time, reduction of agricultural burning is one of the most cost-effective mitigation options compared to other black carbon reduction measures.

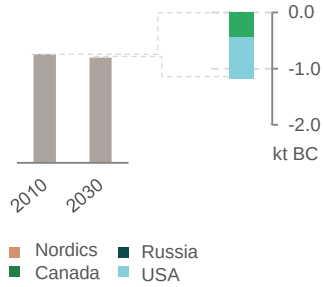
Source: (1) (12) (22)

BC emissions from open burning per country

Country contribution to the total BC emissions from open burning (including agriculture and forestry sectors) (22)



Country contribution to change in emissions from open burning in 2010-2030 (ECLIPSE estimates from (2))



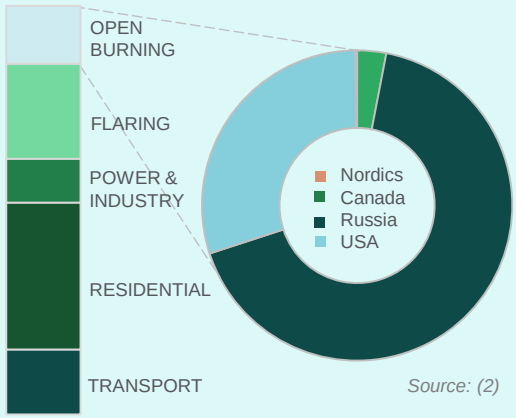
National inventories for BC emissions from open burning are either not reported (Russia, Canada) or characterised by striking discrepancies in the reporting approach. While some countries only include agricultural waste burning in this category, others also incorporate other types of open burning and wildfires (the case of the US – wildfires are excluded from this analysis).

Country	Mitigation actions*
Canada	On provincial level: • Agricultural waste control regulation in British Columbia establishes relevant management practices (limiting time of the year, impacts on visibility), • Open burning of waste is prohibited / is being phased out (Yukon, Northwest Territories), • Educational and incentive programs promoting investments in crop residue management (Quebec), forest protection / fire management legislation that control air quality, • Forest protection and fire management legislation
Russia	Agricultural burning and burning of dry grass in proximity to roads, highways, pipelines is banned (from November 2015)
USA	2015 National Cohesive Wildland Fire Management Strategy aims at responding more effectively to wildfire. The US Department of Agriculture provides direct technical and financial assistance for prescribed burning.
Denmark	Agricultural burning prohibited since 1992. Many municipalities have a ban on open biomass burning.
Finland	Not available
Norway	Not available
Sweden	Not available

**Colour indicates: mandatory (legislations, binding targets, etc.), voluntary actions, and economic incentives*

Abatement potential

Abatement potential of Arctic States by 2030 (additional to already adopted measures): sector contribution to total possible abatement (left) and country share of the projected emissions reduced from open burning through mitigation measures (right)



Source: (2)

Russia accounts for almost ¾ of the total abatement potential within open burning.

Summary

- The amount of emissions from open burning and its future projections are largely uncertain due to differences in inventories across countries, as well as challenges in determining the source of fires (anthropogenic vs natural).
- Ban on agricultural burning, micro-financing assistance for use of no-burn methods or improved fire prevention and management practices (better timing location, control) have large abatement potential in Arctic States (9).

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