CARBON LIMITS

Reporting and regulation of black carbon and methane in the Arctic

A study supported by the Ministry of Climate and Environment and financed by the Ministry of Foreign Affairs in Norway

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Reporting and regulation of black carbon and methane in the Arctic

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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.

Content

List of acronyms

AMAP	Arctic Monitoring and Assessment Programme under the Arctic Council
AD	Activity Data
BC	Black carbon
BrC	Brown carbon
CCAC	Climate and Clean Air Coalition
CEC	Commission for Environmental Cooperation
CEIP	Centre on Emission Inventories and Projections
CH4	Methane
CLRTAP	Convention on Long-range Transboundary Air Pollution
DOE	Department of Energy in USA
EC	Elemental Carbon
EEA	European Environment Agency
EF	Emission Factor
EFDB	Emission Factor Database under the IPCC
EMEP	European Monitoring and Evaluation Programme
EPA	US Environmental Protection Agency
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies model developed by IIASA
GHGRP	The Greenhouse Gas Reporting Program
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IIR	Informative Inventory Reports, submitted to EMEP
IPCC	Intergovernmental Panel on Climate Change
IVL	Swedish Environmental Research Institute
NEI	National Emissions Inventory of the USA prepared EPA
NILU	Norwegian Institute for Air Research
NIR	National Inventory Report,
NOAA	National Oceanic and Atmospheric Administration in USA
NPRI	National Pollutant Release Inventory
OC	Organic carbon
OM	Organic mass
PM	Particulate Matters
RWB	Residential wood burning
SLCP	Short Lived Climate Pollutants
SNAP	Supporting National Action Planning on Short-Lived Climate Pollutants
SYKE	Finnish Environment Institute
TFEIP	Task Force on Emission Inventories and Projections
TFI	Task Force on National Greenhouse Gas Inventories
TSP	Total Suspended Particles
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

1. EXECUTIVE SUMMARY

Radical reductions in emission of black carbon and methane can significantly halt climate change in the Arctic. Arctic countries are considering new policies and measures to reduce emissions, among others through cooperation in the Arctic Council. The Ministerial meeting of the Council will most probably in April of this year establish an Expert Group to help implement a Framework for actions on black carbon and methane emissions. A common vision for emission reductions will be established, together with a process of national reports on emissions and progress in reduction efforts. The Expert Group will support in implementing the Framework through a two-year iterative process.

The aim of the work presented in this report is to provide information of relevance for implementation of the Framework, and for the efforts of other initiatives such as the Climate and Clean Air Coalition (CCAC). A review is conducted of current status for reporting and inventories as well as for regulations in various sectors. In addition, a number of other international and national initiatives to improve reporting and regulations are identified and discussed.

Inventories

Almost all Arctic States are either in in process of or have finalised black carbon inventories. These inventories present important sources of uncertainties due to, amongst others, the lack of good data sources for emission factors.

Inventories of methane emissions are more mature and international procedures for reporting of the data to the United Nations Framework Convention on Climate Change are well established, including international review processes. Nevertheless, quantitative assessments suggest large uncertainties for some methane emission sources, particularly within oil and gas and waste management sectors.

A number of international initiatives make independent estimates of emissions based on their own methodologies. Being based on the same “bottom-up” approach as the work with national inventories, results from several of these estimations have highlighted the sensitivity of results to variable methodologies being used internationally. Estimations can also be checked against “top-down” methods that calculate emissions from measurements of atmospheric black carbon concentrations. This type of approach has improved emission inventories.

Policies and regulations

The review of policies and regulations is focused on sectors and countries that are large sources of black carbon and methane emissions. The oil and gas sector is the most important both for methane and black carbon, the latter being significant primarily because of large amounts of gas being flared in the northern part of Russia. The oil and gas sector is also important because emissions are expected to increase, while the costs of abatement are generally low. Regulatory approaches, including enforcement mechanisms, vary greatly. The efficiency of regulating oil and gas sector emissions is hampered by an intrinsic “information bias” to the disadvantage of the regulator, which is largely caused by the complexities of oil and gas activities and dispersed emission sources (for methane).

Transport is an important source of black carbon emissions. Emissions are expected to decline in line with stricter vehicle and fuel standards. Black carbon emissions from international shipping, currently small, may increase as traffic in Arctic waters increase. These emissions are for a large part outside national jurisdiction but are dealt with by committees under the International Marine Organization, which so far has not implemented specific measures that will affect future black carbon emissions in the Arctic.

Other important sectors are agriculture and forest burning and waste management. Regulations and mitigation costs vary, as do monitoring and reporting requirements, but perhaps with some convergence in approaches.

Recommendations for Arctic Council follow up on inventories

The Arctic Council, primarily through the Arctic Monitoring and Assessment Programme (AMAP), is playing a key role in providing knowledge on emissions and inventory work and should continue to do so in close collaboration with the Expert Group, and also in coordination with other international initiatives. Five specific recommendations are suggested for Arctic Council bodies to follow up:

i. *Cooperation between different organisations and initiatives*. Many initiatives provide knowledge relevant for inventories, but there is duplication of efforts. The Arctic Council could engage in coordination and sharing of information.

ii. *Black carbon emission reporting grid*. There is no agreed global or Arctic grid for reporting black carbon emission. Given the importance of such information for impact assessments it is recommended that AMAP or other relevant bodies work on developing this.

iii. *International database for emission factors*. Several databases exist for emission factors but a comprehensive international database is lacking. The Arctic Council could encourage to improvement of existing databases (as opposed to creating new databases).

iv. *Uncertainty assessment for black carbon*. Quantitative uncertainty assessments are not yet part of black carbon inventories. The Arctic Council could encourage Arctic States to include such assessments in inventories.

v. *Uncertainty for methane emission in oil and gas and waste sectors*. Although more mature than black carbon, large uncertainties remain for methane inventories, particularly oil and gas and waste sector emissions. The Arctic Council could encourage international efforts to improve these, for example through measurements which leads to better emission factors in the oil and gas sector.

Recommendation for Arctic Council follow up on enhanced action

The iterative process of the Expert Group can give important impetus to enhanced action, partly by spurring national policies and measures, and more indirectly by ensuring that the Arctic dimension is properly covered in relevant international initiatives. Four recommendations are made for r Arctic Council bodies:

i. *Convergence.* For the relevant sources of emissions, the Arctic Council could explore further what seems to be a trend towards convergence in reporting requirements and on technical standards among Arctic States and on this basis identify ways in which further convergence can be promoted.

ii. *Elements of best practise regulation.* In the oil and gas sector regulations differ greatly by countries and differences will probably to a large extent prevail. Nevertheless, there seem to be an interest in most countries to learn from others. The Arctic Council could initiate a forum for exchange of experiences and views among regulators of Arctic States, and when relevant also involve the (regulated) companies.

iii. *Promote public private partnerships and international cooperation.* The knowledge gap on emissions and challenges with imposing efficient regulations call for collaboration between authorities and oil and gas companies, both at the national and international level. The CCAC has established public private partnerships dealing both with black carbon and methane emissions and the Arctic Council could interact with CCAC to see that the Arctic issues are addressed under these partnerships.

*Identifying gaps and avoiding overlaps***.** Some 50 international initiatives are engaged in black carbon and methane emission reduction efforts, inevitably with the result that there is duplication of efforts. Many initiatives are linked to CCAC which gives it great convening powers. The Arctic Council could collaborate with CCAC to contribute to better coordination and communication between initiatives and also spot gaps where addition efforts are needed.

2. Introduction

2.1 Context and objective of the project

Following the Arctic Council Ministerial meeting in Tromsø in 2009 a "Task Force on Short-Lived Climate Forcers" (TF SLCF) was established. In its final report TF SLCF concluded that the Arctic Council could contribute inter alias in three ways:

- Encourage the sharing of knowledge and data.
- Facilitate collaboration and collective action among Arctic State.
- Incentivize sustained action to reduce emissions of black carbon and methane.

The report further stated that the Arctic Council "... can also facilitate the pursuit of common objectives among Arctic Nations". In 2013, the Task Force on Black Carbon and Methane (TFBCM) was established and has a mandate to develop a Framework for Enhanced Action to Reduce Black Carbon and Methane, and report to the next Ministerial meeting in 2015. The final results from the work of TFBCM are not known but a draft text of the Framework exist which represent a political commitment, but not a binding obligation under international law, to reduce emissions. The Framework includes wording on a common vision for emission reductions and outlines a process of national reporting on emissions and progress in reduction efforts. An Expert Group will support implementation of the Framework through a two-year iterative process.

This is the context for this report from Carbon Limits titled "Reporting and regulation of black carbon and methane in the Arctic" where the focus is to review and compare emission reporting systems and regulation (including policies) in the Arctic States. The task was commissioned to Carbon Limits by the Ministry of Climate and Environment and financed by the Ministry of Foreign Affairs in Norway.

The aim of the work and the report is to provide information of relevance for implementation of the Framework, and further to be of use for other initiatives engaged with black carbon and methane emissions that impact on the climate in the Arctic.

In the report, an overview of current status for reporting and inventories as well as for regulations in various sectors is covered. In addition, a number of other international and national initiatives to improve reporting and regulations are identified and discussed.

Where applicable some recommendations which might be useful in the context of the Framework to prioritize specific actions within each sector are suggested. These recommendations are discussed with reference to categories of actions/initiatives:

1. How the Arctic Council can support enhanced understanding of magnitude of emissions in the Arctic States
2. How the Arctic Council can contribute to more active, effective and cost efficient regulations and policies being implemented at the national level
3. How the Arctic Council working groups and related financing instruments (e.g. the PSI) can contribute directly to emission reduction efforts
4. How the Arctic Council and Arctic States can interact and support other international initiatives in order to avoid duplication of efforts and further strengthen the "Arctic dimension" of the international initiatives

2.1 Methodology and approach

The analysis presented in this report is based on extensive literature studies, previous work by Carbon Limits on black carbon and methane and a number of interviews with relevant stakeholders.

Policies and regulations play an essential role in triggering abatement measures and a review of existing regulatory practises in the different Arctic States for the key emissions sectors has thus been an important part of the analyses. An important specificity when comparing regulation related to black carbon is that hitherto countries have normally not had specific regulation for black carbon but only for Particulate matter (PM)[1] and precursors of PM.

Methodologies used to calculate and report emissions in Arctic States vary between sectors and have been reviewed and compared within each sector (e.g. oil and gas, agriculture, etc.).

Many international initiatives are engaged in efforts to encourage and trigger emission reductions. These initiatives were also reviewed and classified as part of the presented analysis.

Interviews and communications have taken place with a number of institutions, comprising regulatory authorities, researchers, international organisations and members of the different Arctic Council bodies. The interviews were conducted with the aim of enhancing our understanding of planned improvements and interactions between the different institutions. This information was compared with other sources to get the fullest picture and overview of what is going on in the field.

These analyses and reviews have led to suggested recommendations for how Arctic Council bodies more efficiently can contribute to a better understanding of the emissions, and enable acceleration of emissions reductions in the Arctic States.

2.2 Report Structure

Chapter 3 gives an overview of black carbon and methane emissions in the Arctic addressing the specific nature of these emissions as well as possible climate impact.

This is followed by a review of the emission inventories and of other existing initiatives to better understand the magnitude of emissions in Chapter 4, identifying gaps and overlaps as well as offering some recommendations for how to mitigate these.

In Chapter 5 we analyse the national regulation and policies as well as some international initiatives and give some ideas as how to capture synergies between national and international actions and policies.

The appendix outlines in more details an overview of sectorial inventories and regulations and the challenges associated with these.

[1] Particulate Matter: A complex mixture of extremely small particles and liquid droplets suspended in the atmosphere. Particulate matter (PM) is made up of a number of components, including acids (such as nitrates and sulphates), organic chemicals, metals and soil or dust particles.

3. Black carbon and methane emission - Context

3.1 Overview of the black carbon and methane emissions in the Arctic States[2].

Black carbon emissions and abatement potential in the Arctic States

The two largest sources of black carbon emissions in Arctic are the transport sector (on-road and off-road) and open biomass burning (grass, forest and agricultural burning). The US emissions are primarily in transport, while Russia has the largest share of black emissions from agriculture and forest burning. Total emission in Arctic States energy & industry and the residential sector are about equal in size.

Since climate impacts are sensitive to the location of black carbon emissions it is useful to explore what sources are the most important in northern latitudes. The figure below shows that flaring of gas associated with oil production becomes increasingly important as one move northward. Agricultural and forest burning and wildfires are the other important sources in the Arctic, and these together with flaring dominate as emission sources north of $62^{0.}$ The importance of flaring for the Arctic is also documented by an recent analysis which estimate flaring to contribute 44% to surface black carbon concentration in the Arctic (2) (3).

Black Carbon emissions are expected to decline by about 25% by 2020 due to current air pollution legislation; in particular the tightening of emission standards in the transport sector (4). Important incremental emission reduction could be achieved in the residential, agricultural, oil and gas sector and from transportation (4). Current black carbon emission estimates are, however, subject to major uncertainties due to knowledge gaps on emissions factors as well as activities data (4)

Figure 1: Black carbon emission per country and per sector (4)

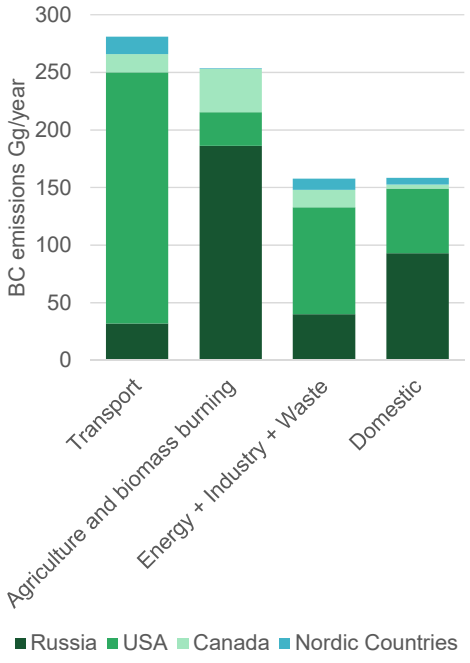
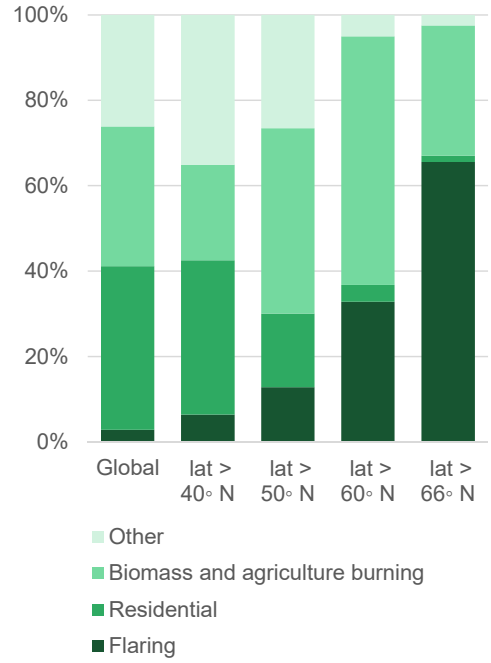


Figure 2: Black carbon emissions for the year 2010 depending on the latitude (3)



Methane emissions and abatement potential in the Arctic States

In 2012, according to national inventories, the Arctic States emitted about 1200 Mt CO_2eq of methane (equivalent to more than two times the CO_2 emissions of Canada[3]). The oil and gas sector represents

[2] AMAP will in 2015 publish two reports which will describe in details the status of the knowledge on these questions

by far the largest source of emission. Since Russia, USA and Canada all are significant oil and gas producers on a global scale, these emissions also represent a notable share of global methane emissions from oil and gas operations (39%[4]). Norway is a also a relatively large oil and gas producer, but its reported methane emissions are significantly less than those accounted for by the three large Arctic States. Agriculture and the waste management sector follows thereafter as important sources with methane emission in the US being the highest. Mines are the fourth important sources with about 10% of the total

Methane emissions are projected to increase by about 12 % between 2015 and 2030 (18), with the oil and gas sector representing the largest source of future emission growth. The oil and gas sector also has the largest abatement potential in the Arctic States (Figure 2). There are substantial uncertainties in the existing figures due to the limited number of measurements performed outside North America.

Figure 3: Emissions of methane per sector and per country (1)

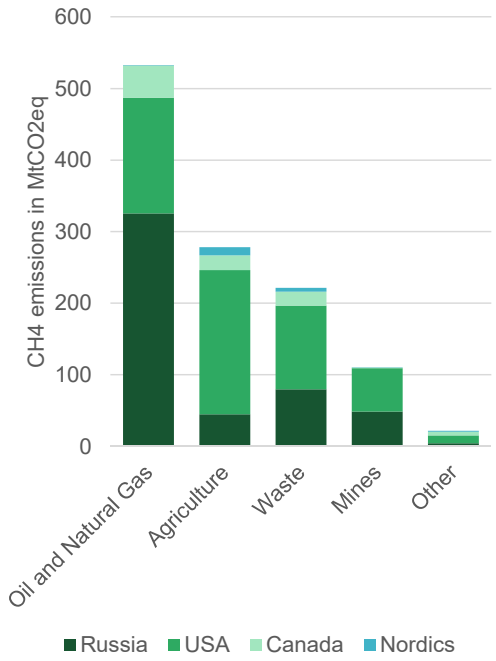
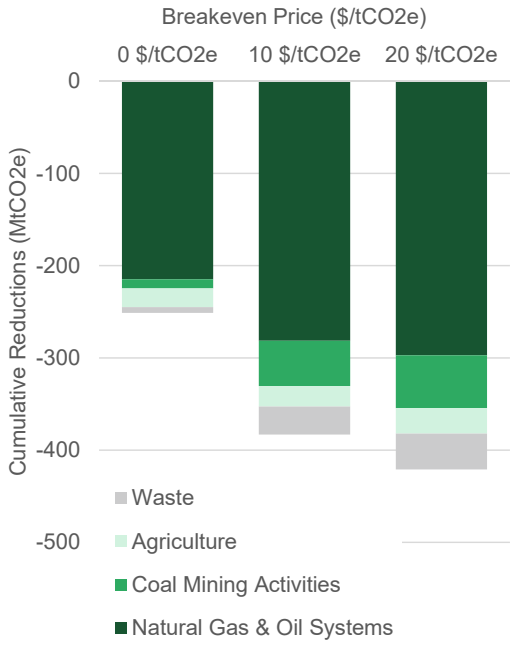


Figure 4: Abatement potential in USA, Canada and Russia in 2020[5]



3.2 Characteristics of black carbon and methane emissions and measurements

Methane and black carbon emissions present characteristics and challenges which have significant impact on how these sources can be monitored, reported and mitigated.

[3] In 2012.
[4] EPA 2012 data, 2015
[5] Analysis by Carbon Limits using data from EPA 2014 (2)

Definitions (from (15) (16))

Particulate Matter: A complex mixture of extremely small particles and liquid droplets suspended in the atmosphere.
Three different fractions of particulate matter:

- TSP: total suspended particles
- PM10: Particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometres.
- PM2.5: Fine particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometres.
-

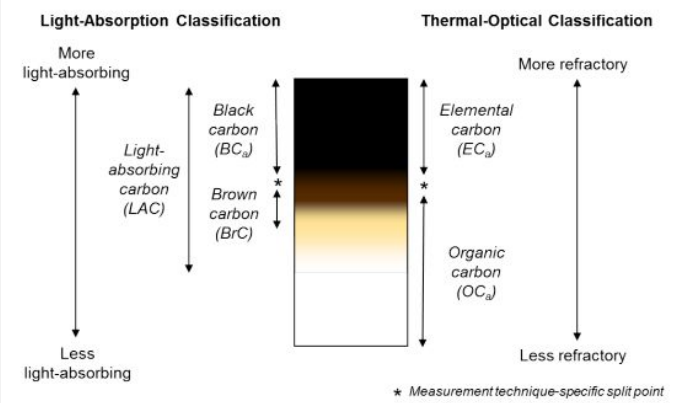
Black carbon (BC) Black Carbon is the dark, light absorbing part of the particles. BC absorbs solar radiation (light) at all wavelengths. BC is the most effective form of PM, by mass, at absorbing solar energy, and is produced by incomplete combustion. BC is considered as a share of PM2.5.

Elemental Carbon (EC) Elemental carbon (EC) refers to all carbon in elemental form. The term EC is often used with thermal analysis to indicate the carbon that does not oxidize below a certain temperature or which is not extractable with, e.g., hydrogen peroxide or benzene. EC is often used as a synonym for black carbon.

Organic mass (OM) refers to the non-carbonate carbonaceous particles other than black or elemental carbon and it includes numerous organic compounds. OM is also considered as a share of PM2.5.

Organic carbon (OC) actually refers to the content of carbon in the organic mass compounds.

Figure 5 Definitions and measurement of the Carbonaceous Components of Particles. Source: U.S EPA



Impact of black carbon and co emitted species emissions on climate change is complex
Black carbon emissions have complex impact on global warming with three distinct effects: (i) a direct warming effect on the atmosphere (ii) a cloud indirect effect and (iii) a snow/ice albedo effect (5). As black carbon remains in the atmosphere for only a few days to weeks, the climatic effects depend on the location of the emissions and how these emissions are transported (4) (3). The seasonal black carbon emission variation impacts the climate due to the variation of snow coverage (6) (3). It is important to note that the health effect of black carbon obviously also depends on the location of the emission.
Sources that emit black carbon also emit other short-lived species that may either cool or warm climate. The net climate forcing of black carbon-rich emission sources depends on the effects of co-emitted species, such as organic carbon, sulphate, and gaseous constituents. The uncertainties on net climate forcing from black-carbon-rich sources are substantial (5)

Black carbon emissions are difficult to measure and emissions are highly variable
Black carbon has historically been defined as the fraction of the carbonaceous aerosol with large capacity to absorb visible light. Despite ongoing research and definition refinement, there is currently no unique methodology (and thus terminology) available for quantifying black carbon emission. Definitions used in the scientific literature refer to a specific property of the respective carbonaceous fraction or to the measurement method.[6] Current inventory guidelines do not reflect which measurement methods are used for the proposed Emission Factors (EF[7]).

[6] There are three main class of measurement/definition: (i) optical or light absorption method (measuring the light absorption properties) (ii) thermal-optical method (measurement of the thermal and chemical stability) and (iii) microscopy methods (measuring the morphology and the microstructure). (12)
[7] But in general, it is Elemental carbon

The quality of the fuel consumed, the air-fuel ratio, the flame temperature, the combustion conditions, and the use of cleaning technologies[8] all have significant impact on black carbon emissions. For example, emissions from wood combustion can vary by order of magnitude depending on how the stove is operated. In addition, these parameters though they greatly influence black carbon formation, are not generally recorded and reported and thus increasing the overall uncertainties

Methane emissions depend on several factors and are highly fragmented
Unlike carbon dioxide, where emissions are mainly estimated from well-tracked energy statistics, many sources of methane depend heavily on parameters not systematically tracked by statistics agencies. For example, methane emissions from enteric fermentation depend on factors including the average weight gain per day, the quality of the pasture, the milk production, the slaughter age. As a result, methane emissions are difficult to predict and can vary significantly between regions or countries and EFs measured on one set of conditions are not easily applicable to others.
Methane emissions are spread across more than hundred thousand locations globally and millions of emission points. In the oil and gas sector, each well site, each compressor station, each gas plant, each pipeline segment may include a few to several hundred emissions points (7) (8). In the agricultural sector, each animal represents an emission point. As a result, emissions of methane are highly spread geographically and are difficult to measure and to mitigate[9].

4. Black carbon and methane emissions inventories

4.1 Objective and approach

This section provides an overview of current activities to enhance understanding of the magnitude of emissions of methane and black carbon in Arctic States. The focus is on developing and improving national inventories, but other initiatives are also summarized, starting with how the specificities of black carbon and methane emissions influence emissions reporting and inventories followed by the status in terms of national reporting. Other initiatives, which complement national inventories, are then described and main findings and gaps are identified together with some recommendations at the end.

4.2 Methane and black carbon emissions inventories

As noted in section 3.2, black carbon and methane have characteristics which represent challenges in the design and the preparation of the inventories.

[8] The black carbon formation process is very complex, involving several steps of chemical and physical particle growth and then destruction. There is an extensive work on soot formation mechanisms performed, among others by F. Mauss (Lund Univ), M. Frenklauch (Univ of Calif-Berkely), and R. Lindstedt (Imperial College)
[9] http://www.npl.co.uk/carbon-measurement/european-consortium-to-combat-methane-emissions , http://www.edf.org/energy/natural-gas-policy/methane-detectors-challenge

Table 2: Overview of the key characteristics of methane and black carbon emissions and how they influence emissions inventories

	Characteristics of methane and black carbon emissions	Impact on inventory design and preparation	Key GHG principles impacted
black carbon	The impact on global warming and health depends on the location (and the time) of the emission	Inventory needs to be developed to allow for the geographical (and the seasonal) distribution of the emissions estimates	Cost efficiency
	Emissions vary highly depending on a number of factors (not necessary reported)	EFs developed for a set of conditions are not necessarily applicable to others. Existing EF may not be representative of a population of emission sources. Additional research is required on some emission factors to reflect the variety of practices in different countries.	Accuracy Cost efficiency (Comparability)
		There are important sources of uncertainties on some estimates (including activity data)	
	Co emitted species also impact the climate	Ideally, co-emitted species should be quantified along black carbon emission to assess the overall climate impact on a measure	Cost efficiency
	There is not currently one standardized definition	There are challenges to compare the EF from different sources as the underlying definition may differ	Accuracy Comparability
Methane	Emissions vary highly depending on a number of factors (not necessary reported)	EF developed for a set of conditions are not necessary applicable to others. Existing EF may not be representative of a population of emission sources. Additional research is required on some emission factors to reflect the variety of practices in different countries.	Accuracy Cost efficiency (Comparability)
		There are important sources of uncertainties on some estimates (including activity data)	

The specificities of black carbon and methane affects the quality of GHG inventories, in particular the accuracy[10] and the comparability[11] of the inventories as defined by the UNFCCC (9)[12]. In addition, the characteristics of the SLCP also impact the time and resource required to develop an inventory.

4.3 Review of National Inventories

This section reviews the status of methane and black carbon emissions in the Arctic States and provides a general overview of the methodologies used for these inventories. More details on the methodology used for each sector are provided in the Appendix.

Black carbon national inventories

All the Arctic States have ratified the Convention on Long Range Transboundary Air Pollution (CLRTAP). As such, they are invited every year to report emission data for particulate matter (TSP, PM10, and PM2.5[13]). Black carbon is not part of the mandatory reporting, but parties can include black carbon reports on a voluntary basis from 2015[14]. Most of the Arctic States either have black carbon inventories published or have started work on an initial black carbon emission report. Black carbon emission inventories are less mature than other existing GHG inventories. The table below shows the status for each of the countries.

[10] Accuracy means that emission estimates should be accurate in the sense that they are neither systematically over nor under true emissions, as far as can be judged, and that uncertainties are reduced as far as practicable.
[11] Comparability means that estimates of emissions reported by different nations in their inventories should be comparable.
[12] or the EEA/EMEP guidebook (11)
[13] TSP: total suspended particles TSP include PM 10, PM10: Particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometres. PM10 includes PM2.5. PM2.5: Fine particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometres.
[14] The TFEIP supports Parties in the reporting of official air pollutant emissions and projections data to the Convention (37). As described above the EEA/EMEP guidelines for emission reporting (including BC) was published in 2013 (11). The current guidelines are planned to be updated next year. As part of the update, the differences between EC/BC EF are expected to be targeted.

Table 1: Black carbon emission inventory in Arctic States - PM reporting under EMEP

Country	Name	Comment
USA	EPA report to Congress on black carbon emissions (10)	The EPA report to congress on black carbon emissions was published in 2012 and includes a detailed emission inventory which is based on the US National Emissions Inventory (NEI) of PM. EPA publishes the SPECIATE database which includes all the speciation factors[15].
Canada	Canada's First Black Carbon Inventory	Canada has developed and published its first black carbon inventory in February 2015.
Russia		A number of Russian institutions have started working on a black carbon inventories. The first official BC emissions report should be published in the next few months.
Norway	Norwegian black carbon inventory (11)	The first Norwegian black carbon inventory was prepared in 2013 for the year 1990-2011. Black carbon report has been submitted for the first time to the LRTAP in February 2015.
Sweden	Swedish Informative Inventory Report (IIR)	Black carbon report has been submitted for the first time to the LRTAP in February 2015.
Denmark	Danish IIR	The first inventory for Denmark was published in 2011. LRTAP inventory has been submitted in 2015..
Finland	Finish IIR	An initial black carbon inventory for 2000-2012 was included in the EMEP inventory submission in February 2014. A first official report has been submitted in February 2015
Iceland	Iceland IIR	Black carbon will not yet be included in the national inventory report. Iceland is a very small source of emissions with limited resources to prepare inventories. [16]

For most of the emissions sources, black carbon emission estimates are based on a bottom-up approach, applying a speciation factor[17] to PM2.5 emission estimates for each emission source or emission source category[18].

$$BC\ emission = Activity\ Data_{PM\ 2.5} * \ EF_{PM2.5} * Speciation\ factor$$

Activity data are country specific and gathered through different processes depending on the countries and on the sector (described in more details in the annex). Emission factors and speciation factors are generally obtained through measurements for a sample of emission sources and/or derived from modelling. Existing literature highlights that EF and speciation information are scarce for a number of emissions sources. Historically, EF has been shared between different countries; though country specific practices can influence the applicability (e.g. residential heating practices and systems are very different between the Arctic countries or regions).

Though sources of uncertainties are often described, quantitative uncertainty assessments are not yet part of the existing black carbon inventories[19]. As black carbon emissions estimate are generally based on PM inventories, the black carbon uncertainties is a combination of the PM estimates uncertainties and the speciation factor uncertainty.

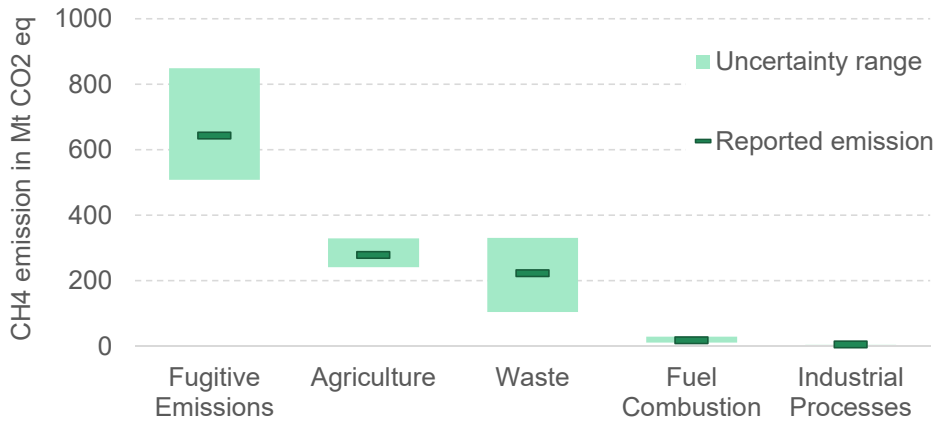
[15] http://www.epa.gov/ttn/chief/software/speciate/speciate_version4_4_finalreport.pdf, http://www.epa.gov/ttnchie1/software/speciate/
[16] Source: interviews
[17] Definition: weight fractions of different species (e.g., BC and OC) for specific emission sources.
[18] For a few sources, emission factors are available for BC directly (e.g. gas flaring in Norway).
[19] In the Norwegian inventory and in the US report to congress, key sources of uncertainties are briefly listed. In the Finnish inventory, it is mentioned that "An uncertainty and a key source analysis for black carbon emissions will be carried out for the submission in February 2015"

Methane national inventories[20]

All the Arctic States submit inventories of national emissions of greenhouse gases every year, including methane, to the United Nations Framework Convention on Climate Change (UNFCCC). Methodologies, approaches, emission factors applied and uncertainty analyses for all the Arctic States are available in details in the National Inventory Report (NIR) (1). Methane emissions inventories are more mature (and thus more sophisticated) than currently available black carbon inventories. The 1996 and 2006 IPCC Guidelines for National Greenhouse Gas Inventories provide the methodologies for GHG emission (including methane) reporting[21]. These range from the use of default global or regional factors (Tier 1) to an extensive use of country-specific information to estimate emission (Tier 2 and Tier 3). The selection of the relevant tier and the level of aggregation in the inventories depend on the availability of relevant activity data and emissions factors in the different countries.[22]

Contrary to existing black carbon inventories, all the NIR include quantitative uncertainty analysis. Such uncertainty analysis provides important information to help prioritize the effort in terms of inventory improvements. Although the approaches and the level of details are different between NIRs, the uncertainty analyses of the different Arctic States have been compiled and summarized in Figure 6, where the dark green dot represents the reported emission while the lighter green bar reflect the current range of uncertainty as reported by the countries.

Figure 6: Quantitative uncertainty analysis for methane inventories in the Arctic States (Carbon Limits analysis based on the NIR)



Though each Arctic State has specific challenges for emission reporting, fugitive emissions are clearly the largest source of uncertainty (and in particular for USA and Russia[23]) followed by waste. The agriculture sector represents a large source of uncertainty in USA only[24]. It is important to highlight that there are important differences between emission factors for different countries. These differences can be partially explained by differences in practices and technologies but also reflects the important uncertainties on the EF (e.g. in the oil and gas sector).

[20] This section is based on the NIR for the Arctic States as published in the UNFCCC website: (5)

[21] According to the IPCC, to keep the validity of the 2006 IPCC Guidelines, there are certain refinements that may be required, taking into account scientific advances since 2006. As a result, a technical assessment of the need and the feasibility of methodological development/refinement is planned to be carried out in 2015.

[22] Note: In US, two different inventory systems co-exists (25).

- The Greenhouse Gas Inventory (GHGI) which is reported under the UNFCCC by EPA[22]
- The Greenhouse Gas Reporting Program (GHGRP), a congressionally mandated EPA program requiring large emitters from many sectors to report their emissions to EPA.

Methane data are now available in GHGRP for several sectors[22] and generally consistent with the GHGI, although more analysis is planned (25).

[23] In absolute terms

[24] In absolute terms

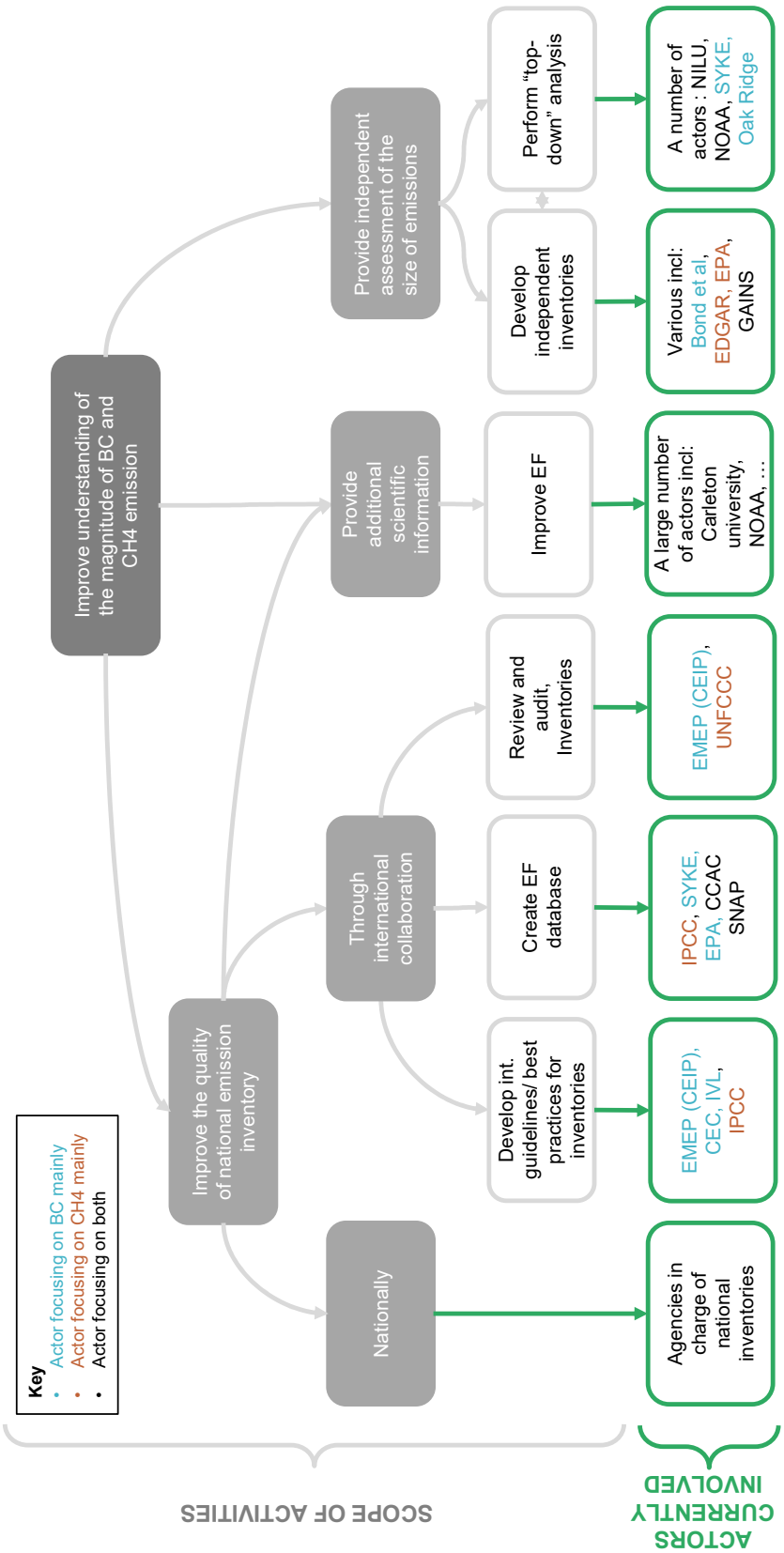
4.4 Other initiatives to improve understanding of emissions

In addition to national inventories, there are many other initiatives to improve the understanding of both methane and black carbon emissions. These initiatives complement the work on the national inventories by:

- Improving the quality of national emission inventory through international collaboration.
- Providing additional scientific information necessary to build inventories.
- Providing independent assessment of the size of emissions.

The graph below provides an overview of different types of such initiatives.

Figure 7: Overview of the different initiatives to improve understanding of methane and black carbon emissions



Improve methodology quality

Internationally, important effort is undertaken to improve methodologies for estimating black carbon and methane emissions and harmonise national inventories of which some initiatives aim at improving inventory methodologies for both methane and black carbon.

For methane, the IPCC Task Force on National Greenhouse Gas inventories is in charge of reviewing the GHG reporting guidelines. For black carbon, the EMEP/EEA Air Pollutant Emission Inventory Guidebook (12) provides expert guidance on how to compile an atmospheric emissions inventory. In 2013, this document was updated to include guidance and emission factors for black carbon[25]. The Commission for Environmental Cooperation (CEC)[26] is also developing North American black carbon emissions estimation guidelines.

Additionally, a number of organisations publish or are developing emission factor databases for both black carbon and methane emissions. Some are national (e.g. SPECIATE from the EPA) while others are more international (CCAC, IPCC).[27]

Finally, existing inventories are reviewed and audited: The UNFCCC has developed and implemented a review process for all GHG emissions inventories including methane (13). The EMEP CEIP has also a detailed review process for the inventories submitted (14) which should eventually be applied to black carbon.

Additional scientific information– emission factor improvements

According to existing literature, emission factors represent a large source of uncertainty for the emission estimates. Important work is initiated at many different levels to improve the understanding of current emission factors, but a detailed review of ongoing efforts and possible gaps is outside the scope of this project. It is interesting, however, to note that this effort involves different type of entities:

- Universities and Institutes: Carleton University is e.g. performing work to improve the understanding on black carbon emission factors for gas flaring. NOAA recently led some work on shipping emissions (15)
- NGO: The Environment Defend Fund led a unique partnership including the University of Texas and participating companies to measure methane emissions in the oil and gas sector. (16)
- National agencies: The National pollution agency of Norway e.g. commissioned SINTEF to develop new EF for wood stoves (17)

Independent assessment of the size of emissions

Global and regional bottom-up inventories of both black carbon and methane have been published by several organisations over the years. These inventories contribute to enhance the understanding by enabling independent assessment of emissions[28]. For methane, the main global inventories published

[25] The guideline will again be updated in 2015

[26] In 2013, The CEC commissioned a team led by Eastern Research Group, Inc. (ERG) to develop guidelines for estimating BC emission inventories for USA, Canada and Mexico. The project involves three main tasks: (i) Literature review and synthesis of current BC emission inventories and initial recommendations for the inventory development guidelines. (ii) A series of consultations with experts on emission inventories and (iii) the development of a Black Carbon Emissions Estimation guideline.

[27] Databases include

- The Task Force on National Greenhouse Gas inventories (TFI) has developed an Emission Factor Database (EFDB) that includes CH4 EF (40). According to the progress report of Oct 2014, the TFI plans to continue its efforts to maintain improve and promote the EFDB.
- The Finnish Environment Institute publishes a database of EF including BC (41).
- EPA publishes its SPECIATE database (42) which includes detailed PM speciation profiles. EPA has ongoing plans to improve the database in particular to improve the understanding of BC versus EC.
- As part of the project “Supporting National Action Planning (SNAP) on SLCP, CCAC has plans to develop an EF database. It is not clear whether this database will be fully public.

[28] Methodologies and assumptions vary between the different authors. Some inventories use national inventories for historical years when possible, whilst other use a consistent approach for all countries, leveraging international statistics such as IEA fuel use statistics Those inventories have the advantage of consistency compared to aggregation of national inventories as they estimate the emissions in a consistent manner across a variety of countries, but are based on rougher activity data.

include US EPA (18), GAINS (19) (used in AMAP reports), and EDGAR (20). In the same way, international inventories exist for black carbon, including Bond et al. (21) and GAINS (22). Some of the literature compare black carbon inventories (23) (10)[29] and have found large uncertainties on some of the estimates due to the high level methodologies applied [30]

"Bottom-up" greenhouse gas inventories (as described above) can be complemented by "top-down" methods that infer emissions from measurements of atmospheric methane or black carbon concentrations. Top-down approaches are traditionally used for independent validation of emission inventories. Atmospheric methane and black carbon concentrations are sampled by a variety of instruments on towers, ships, and aircraft but also by satellites. (24). Snow can also be collected and melted to analyse black carbon concentration. (4) It is interesting to note that longer time-series of black carbon information only is available for a few stations in the Arctic.

Models allow the comparison of bottom-up inventories with atmospheric and snow measurements, ultimately supporting improvements of emission estimates by providing an independent assessment of the emissions (4) (25) (2). "Top-down" approaches have significantly improved the quality of emission inventories over the last five years[31]

Summary of international initiatives

Three main conclusions can be drawn from the review of the effort to improve the understanding of emissions.

- There are many initiatives ongoing to improve the quality of national and international emission inventories
- There are some overlaps between the activities of different actors. This is not surprising as it is part of a normal learning process for a relatively new issue (black carbon) and as each region has its specific and unique challenges.
- While a number of processes are currently centralized and harmonised globally for methane, it is not yet clear how, if (and by whom) processes will be centralized and harmonised for black carbon.

4.5 Gaps- and overlaps

The table below provides an overview of gaps and overlaps between different initiatives. The ongoing initiatives are linked to the emissions related challenges identified in section 4.2 and then concrete recommendations for the Arctic Council are proposed.

[29] In addition. some authors have focused on assessing and improving the understanding of the emissions for one specific sector: Corbett et al. for example (32) published some work on Arctic shipping inventories, while the CCAC Oil and Gas initiative is working on a map of BC emissions from gas flaring (33)

[30] The following initiatives are not directly linked to the black carbon and methane inventories but contribute to improve the understanding the magnitude of emissions by providing independent assessment of emissions. The objective of this section is not meant to be exhaustive or to provide a status of the science on these issues, but rather to provide an overview of the type of past and current initiatives and provide some illustrating examples. It is important to note that AMAP will be publishing in 2015 two reports which review and cover in details current work on inter alia: (i) the atmospheric concentrations and (ii) transport or inverse modelling

[31] CIENS Seminar -24/11/2014 "what is the role of black carbon for climate change? "

Table 2: Overview on how the current initiatives address the challenges summarized before.

		Impact on inventory design and preparation (as per section 4.2)	**Summary of national and international actions** (based on section 3.3 & 3.4)	**Gaps identified** (based on section 3.3 & 3.4)
black carbon	**The impact on global warming and health depends on location and time of emission**	Inventory needs to allow for geographical and seasonal distribution of the emissions estimates	Spatial distribution done under EMEP (Europe and West of Russia) program and by US EPA.	There is no black carbon emission reporting grid covering all the Arctic States[32]
	Emissions depend on several factors (not necessarily reported)	A large number of emission factors are often required in order to adequately capture the different conditions that impact emissions Additional research is required	Important work ongoing to better understand links between activity data and emissions, hence reducing the uncertainty in a number of sectors.[33]	There are no comprehensive international black carbon emissions factors databases
		There are major sources of uncertainty on some of the estimates (including activity data)	Ongoing "top down" analyses provide valuable independent assessments of emission inventories[34]	Quantitative uncertainty assessment is not part of existing black carbon inventories
	Co emitted species also impact the climate	Ideally, co-emitted species should be quantified along black carbon emission to assess the overall climate impact on a measure	Co emitted species are not reported systematically in inventories	
	There is not currently one standardized definition	There are challenges to compare the emission factors from different sources as the underlying definition may differ	Work plan both in US EPA and at EMEP to improve the understanding between EC and black carbon in existing guidelines or EF database	
methane	**Emissions depend on a number of factors**	A large number of emission factors are often required in order to adequately capture the different conditions that impact emissions Additional research is required	Important work ongoing to understand EF and to reduce the uncertainty in a number of sectors.	There are no comprehensive international methane EF databases
		There are important sources of uncertainties on some of the current estimates (including on activity data)	Quantitative uncertainty assessment performed in NIR	Important remaining uncertainties in particular in the oil and gas and the waste sectors

Summary of the findings and recommendations

Based on the analysis above, four key findings have been identified and summarized. Each finding has been paired with an associated recommendation for the Arctic Council. The first recommendation is a general conclusion based on the review of the ongoing initiatives. The next recommendations aims at addressing the gaps identified in the table above.

[32] In addition, temporal distribution is currently not a standard.
[33] A detailed review of the completeness of the work ongoing on EF improvement is out of the scope of this project
[34] A detailed review of the completeness of this work is out of the scope of this project

Finding 1: There are many initiatives to understand the magnitude of black carbon and methane emissions

Many ongoing international and national initiatives to improve understanding of black carbon and methane emissions in the Arctic States. These initiatives involve many actors and there are some overlaps

→

Recommendation 1: Encourage collaboration between organisations to maximise synergies

The results of the different initiatives should effectively be shared and duplications avoided. Increased collaboration between key actors could capture synergies and tackle key issues. For example, the AMAP (Arctic Monitoring and Assessment Program) could organise an annual meeting with amongst others EMEP (European Monitoring and Evaluation Programme), CCAC (Climate and Clean Air coalition)) and CEC (Commission for Environmental Cooperation).

Finding 2: No black carbon emission reporting grid covering all Arctic States

Given the specificities and the complexity of black carbon impact on climate change as well as on health, information regarding geographical distribution should be made available.

There is no agreed common global or Arctic grid to report geographically the emission in Arctic States.

→

Recommendation 2: Develop an international black carbon emission reporting grid covering the Arctic States

A black carbon emission reporting grid could be developed based on the existing EMEP grid and in close cooperation with the national inventory teams in particular in USA, Canada and Russia[35][36]. Two options could be considered:

- AMAP in collaboration with EMEP and the national inventories teams could develop a grid covering the Arctic Stations regions.
- A grid could also be developed globally under the auspice of UNEP or CCAC

Finding 3: No comprehensive international EF database exists

The review has highlighted that no comprehensive international black carbon or methane EF databases exist. Lack of EF data is a key source of uncertainty for a number of sectors.

Sharing existing emissions data would improve the quality of different national inventories

→

Recommendation 3: Improve methane and black carbon emission factors databases

Given the number of existing initiatives, the Arctic Council could encourage Arctic States to strengthen existing initiatives so as to contribute to existing databases (IPCC CH4 EF database, SYKE or CCAC EF database)

An EF database should be as exhaustive as possible covering the best data available for all the emissions sectors. Given the important scientific work in this field, a mechanism should also be developed to ensure that the database is updated regularly as and when new knowledge is available.

Finding 4: Quantitative uncertainty assessment is not part of black carbon inventories

Though sources of uncertainty are often described, quantitative uncertainty assessment is not yet part of the existing black carbon inventories. This may stem from the immaturity of the existing black carbon inventories.

→

Recommendation 4: Encourage black carbon emissions uncertainty assessment in future national inventories

Understanding the impact on the emission quantification would help prioritize the effort. The Arctic Council could encourage the Arctic States to include such assessment in future national black carbon inventories.

Finding 5: There are important remaining uncertainties on methane estimates

Thanks to the existing NIR, main sources of uncertainties have been identified. For the Arctic States as a whole, the Oil and Gas sector represents the largest source of uncertainty, followed by the waste sector

Recommendation 5: Increase effort to characterize these emission sources

The Arctic Council could encourage the development of initiatives to increase the understanding of the magnitude of these two emissions sources. For example, measurements of EF in the oil and gas sector[37] could help reduce existing uncertainty ranges

[35] existing national processes should be leveraged to minimise the incremental effort required
[36] As most of the Arctic deposited BC is a result of long-range transport from source regions on the fringes of or outside the Arctic (5), such a grid should include regions outside the Arctic
[37] Outside the USA

5. Enhanced action on emission reductions

5.1 National regulations and policies - Black carbon

Differences in targets and regulatory approaches

Black carbon is a new and yet somewhat contentious issue in relation to climate change policy. Impacts of emissions are sensitive to the spatial and time dimensions, and the lack of scientific certainty on climate impacts represent a challenge in formulation of regulations and policies. It is also noted that there is no internationally agreed definition of black carbon. Measures to mitigate black carbon emissions are being discussed in Arctic States, but generally countries are not yet putting in place coherent and specific policies for this pollutant.

Still, there are policies and measures that affect black carbon emissions, primarily through direct regulations of particular matters (PMs) and PM precursors such as NOx and SO2. Well established emission targets and regulatory measures exist for these pollutants, and with the new Gothenburg Protocol adopted in 2012 all Arctic States are obliged to impose policies and measures to meet ambitious emission targets by 2020.

Primary or secondary legislation typically include specific air quality targets or emission limits. They differ by country, sector and also by location (e.g. for large cities), and actual regulatory measures to achieve the targets and ensure compliance show large variations. Differences will prevail, but there is a trend towards convergence in awareness, political priority and in regulatory measures. Environmental impacts are increasingly recognized as Transboundary and global and technical standards are being imposed on internationally traded machinery and equipment.

In Russia, for example, most air emissions have traditionally been regulated through specific emission limits derived from environment quality standards. This is gradually changing with new regulations based on “best available technology”. In the same way as the EU, under its Industrial Emissions Directive, Russia develops a series of reference documents for use of “best available technology”[38].

In the Nordic counties EU environmental legislation is the dominant factor affecting regulation of black carbon and methane emissions and technical standards are not only important in the industry sector, but also in transportation,for burning of biomass and diesel in the residential sector. The regulatory requirements are primarily directed by health considerations but climate change is increasingly a factor in setting targets and imposing policy measures.

There are differences in air quality and technical standards in the US and Canada, but generally they are relatively well aligned in the two countries, particularly for transport. In both countries the state and provincial governments have considerable authority in setting standards for air quality and emissions and in imposing specific regulatory measures.

Sector specific regulations

Transport vehicles, primarily diesel trucks, are the principal sources of black carbon emissions and at the same time have the clearest downward trend in emissions. This is not because of lower transport volume but due to more effective regulation. All Arctic States have technical standards for vehicles and also fuel quality standards. The degree of economic incentives being applied (e.g. fuel and vehicle taxes, incentives for retrofitting/refurbishment) vary. Some countries have Low Emission Zones, but not specifically for the Arctic region. A good dialogue between regulatory authorities and the dominant vehicle manufacturers and transport fuel producers makes it possible to achieve a steady reduction in emissions from transport.

Dialogue between industry and public authorities of Arctic States is even more important in the case of *international marine transport* since it is not under the jurisdiction of individual states. Black carbon

[38] These are referred to as BREF documents.

emissions from ships are currently small in the Arctic, but may grow as the Arctic becomes more accessible as shipping routes. There are well established institutions and processes that deal with emissions from international marine transport, but as of now with limited tangible results on air emission restrictions in the Arctic. For example, the Arctic is not defined as a Emission Control Area under the regulations of MARPOL[39], unlike what is the case for the coastal waters of North America, the North Sea and the Baltic Sea.

Flaring of associated gas, of which a large share is from oil production sites in northern latitudes of Russia, may have a significant Arctic climate impacts. Flaring is resource waste and has primarily been regulated from a resource management perspective, hence with focus on minimizing flare volumes. Russia has relatively ambitious targets for flare reduction; 95% associated gas utilization by 2012 announced by the President already in 2007. The current utilization rate is probably less than 80%[40]. Improved effectiveness of Russian regulation and enhanced action by oil companies are therefore important determinants for future black carbon emissions in the Arctic. But reduced flare volumes is not the only way to achieve it; removing liquid components from the flare gas stream and improving the quality of the flare system are potentially also effective measures.

Agricultural burning and wildfires are important sources of black carbon emissions in eastern Siberia, Alaska and several provinces in Canada. Agricultural burning is for the most part regulated and monitored at the regional and local level. Agricultural waste burning is either banned or strictly regulated in all Arctic States, however the enforcement vary significantly. Wildfires are often caused by careless human activity, which requires specific responses from authorities. Monitoring of wildfires is of variable quality across the Arctic.

Energy use (biomass and diesel) in the *residential sector* is the fourth important black carbon emission source. It receives quite a bit of attention in Nordic countries, not so much because the magnitudes for the Arctic as a whole, but rather because it represent a large share of these countries black carbon emissions. There are specific regulations for biomass burning in stoves, ovens etc, less strict in Finland than in the other Nordic countries, but a new Eco-Design Directive from the EU gradually may help realign regulatory requirements and impact importantly on emissions through technical standards.

5.2 National regulations and policies - Methane

Anthropogenic methane emissions originate from several quite diverse activities. Accordingly, policies and regulations as well as their motivation differ. Possible damages from emissions cover safety hazards (methane can be highly explosive), local environmental impacts and climate change. Methane concentrations in the air (globally) has contributed half a degree Celsius to Arctic temperature increase since pre-industrial times, according AMAP, and Arctic States are particularly well placed to contribute to global reductions om methane emissions.

The *oil and gas sector* stands out as particularly important, with about half of total methane emissions in Arctic countries and with an even larger share of low cost emission reduction opportunities. In the US there has been little regulation of methane emissions at the federal level but a long history of regulating Volatile Organic Compounds (VOC) which typically are related to methane emissions Canada, Norway, Denmark and Russia have also regulations on VOC emissions due to obligations under the Gothenburg Protocol. Russia has relatively high emission fees for methane releases above permissible levels, and if emissions are not monitored and/or calculated through third party verification default emissions factors are used. In such cases, which are quite common, companies do not have incentives to reduce emissions since the fee is unrelated to actual emissions but determined by the default emission factor. In the US, Canada and Norway two types of technical standards/requirements are common: technical standards in the gas supply chain and requirements for performing leak

[39] International Convention for the Prevention of Pollution from Ships under the International Maritime Organization (IMO)
[40] Associated Petroleum Gas Flaring Study for Russia, Kazakhstan, Turkmenistan and Azerbaijan. http://www.ebrd.com/downloads/sector/sei/ap-gas-flaring-study-final-report.pdf

detection and repair programs. Regulations in the US and Canada are primarily formulated and enforced at the state and province level and partly as federal standards. There is now a very clear trend towards tightening of the standards and process to establish voluntary schemes for cutting oil and gas sector methane emissions in the US[41].

Agriculture is the second largest emitter of methane in Arctic States with 24% of emissions. Emission sources show great variations in applicable mitigation strategies, and generally there is not a great potential low cost reduction options. Technical standards are in place for the agro-industry in most countries but voluntary measures are also important.

Emissions from waste management sites accounts for 19% of total methane emissions in Arctic States. Regulations are strict in Nordic countries where depositing of organic waste at landfills is prohibited. In North America different approached apply covering both voluntary partnership programs and mandatory requirements for use of landfill gas at state and provincial levels. In Russia there is currently no legislation specifically for landfills, but landfill gas is to some extent used for energy purposes locally.

Methane emissions from coal mines are primarily from the US and Russia, and only the Russian sites are in northern latitudes. Although some coal mine methane projects are underway in Russia, regulations are reported as being inadequate, resulting in relatively large methane releases and also fatal accidents.

5.3 International initiatives

In addition to regulatory and corporate measures spurred at the national level, international institutions and initiatives (hereafter called initiatives) can make a significant contribution to enhanced action for emission reductions. Many initiatives (here excluding Arctic Council bodies, which will be discussed in the next section) have been reviewed for the work with this report. They can be placed in four categories, with the most important being specifically mentioned:

1) **International public private partnerships**: Climate and Clean Air Coalition (CCAC), Global Methane Initiative (GMI), Global Gas Flaring Reduction Partnership (GGFR)
2) **International development agencies and banks**: World Health Organisation of the United Nations (WHO), Food and Agriculture Organisation of the United Nations (FAO),United Nations Environment Program (UNEP). Multilateral Development Banks, particularly the World Bank (WB), the European Bank for Reconstruction and Development (EBRD) and the Nordic Environment Finance Cooperation (NEFCO).
3) **Industry associations**: Oil and gas industry associations such as the International Organisation of Oil and Gas Producers (OGP), the global oil and gas industry association for environmental and social issues (IPIECA) and the International Solid Waste Association (ISWA).
4) **Environmental non-governmental organisations (NGOs) and research institutions** such Bellona, Clean Air Task Force, Environmental Defence Fund, Earth Justice, International Cryosphere Institute, International Council on Clean Transport, World Wide Fund for Nature.

The listed initiatives are all considered relevant for Arctic States black carbon and methane emission reduction efforts. Their current operations cover a broad range of activities, some which already are highly relevant and others with an undeveloped potential to spur enhanced action. Several NGOs and research institutions target emissions in the Arctic and in Arctic States, typically through demonstrating and advocating best practises and pilot projects. Industry associations also have some focus on black carbon and methane emissions, but oil and gas and shipping associations engage primarily on global issues and less on an the Arctic..

[41] See web site of the US Environmental Protection Agency (www.epa.gov)

But the industry does not only work through their respective industry associations, they are also directly engaged through public private partnerships such as CCAC, GMI and GGFR. We consider CCAC as particularly important, for two reasons:

a) All Arctic States, with the exception of Iceland, are partner countries of CCAC, and USA, Canada, Sweden and Norway are leaders in activities of particular relevance for the Arctic. Russia became a partner country in 2014. Government officials and civil servants active in CCAC are to a large extent the same persons as those dealing with black carbon and methane emission issues within the bodies of the Arctic Council, and they are often key personnel in the formulation and design of national environmental policies.

b) Most of the initiatives mentioned above, plus large industry companies in oil and gas and other sectors and the EU Commission, are connected to CCAC either as partners or in other ways.

This puts CCAC in a unique position to secure coordination and prevent duplication of efforts among initiatives and, more importantly, identify where there are gaps in joint efforts to reduce emissions. CCAC has the potential to be an important platform for initiating broad and voluntary actions to reduce back carbon and methane emissions. Key players within the oil and gas sector, in manufacturing industries and providers of technology are partners or can be recruited as partners to CCAC, hence this can become a forceful means both for initiating action and for sharing information and views on best practises and on policy and regulatory approaches.

CCAC and GMI have a number of activities relevant for black carbon and methane in the Arctic. They are shown in the table below which also lists other initiatives considered particularly important

Figure 8: List of the main initiative and their relevance to the Arctic

	Initiative – Stakeholders	Activity (brief summary)	Relevance to Arctic States (currently)
Oil and gas	CCAC	Methane Partnership: Partner companies commit to report on emission and implement mitigation	US in lead. No specific Arctic focus, no Russian companies partners.
	CCAC	The Technology Demonstration Component: Focus on back carbon emissions from flaring. Emission estimates, mitigation pilots and sharing of information.	Canada in lead. Arctic component under consideration.
	GMI	Promote best available technologies and finance pilots.	US led. Has had cooperation with Russian institutions, stalled for political reasons.
	GGFR	Promote flare reduction through best practices and policy-regulatory improvements. Voluntary target	Active in measurement of black carbon emissions from flaring. Most activities outside the Arctic. Khanty Mansiysk a partner but not the Russian Federation or Russian companies.
	Industry associations	OGP Committee on Arctic matters IPIECA work on black carbon specifically	Russian companies not members of these associations.
Agriculture & Fires	CCAC	Agriculture and open burning: Share and implement best practices: methane from agriculture and black carbon from open agricultural burning.	No activities yet in Arctic countries (but in Himalaya). Russia and Norway not active but several institutions who do work in the Arctic
	FAO	Engage with stakeholder, develop pilots and promote emission reduction	The program Mitigation of Climate Change in Agriculture, for example, does not target the Arctic.
	GMI	Agriculture: Promote best available technologies and finance pilots	Very few projects in the Arctic

	Global Fire Monitoring Centre (GFMC)	Support development of long-term strategies or policies for wild fire management	No specific focus on the Arctic, although much activity in the US and Canada
Waste	**CCAC**	Municipal waste management in large cities	No cities in or near the Arctic participate
	International solid waste association	Convey the message that sustainable waste management should be included in future international agreements	Waste associations of a number of Arctic States are part of the International solid waste association
	GMI	Capacity building and promotes the development of sanitary landfills and methane recovery.	Active in Russia in the past
Transport incl. Shipping	**CCAC**	Heavy-Duty Diesel Vehicle and Engines Initiative: Catalyze adoption of vehicle and clean fuel regulation.	Not active in the Arctic
	IMO - Environmental Protection Committee	Work on measurements and control options for black carbon emissions	Focus on the Arctic, safety and accidents but also air emissions
Residential	**CCAC Household Cooking and Domestic Heating (CCAC**	High-level advocacy, standards, new finance mechanisms and research.	Not active in the Arctic

As this overview shows few of these initiatives have focus on emissions in the Arctic (or Arctic States). Still, the initiatives are relevant in an Arctic climate change context, even without targeting Arctic emissions specifically. Methane emissions have Arctic climate impacts independent of where emissions take place and black carbon emissions, whose impacts are site specific, have in many cases impacts on the Arctic also if emissions are far from the Arctic (e.g. in South and South East Asia).

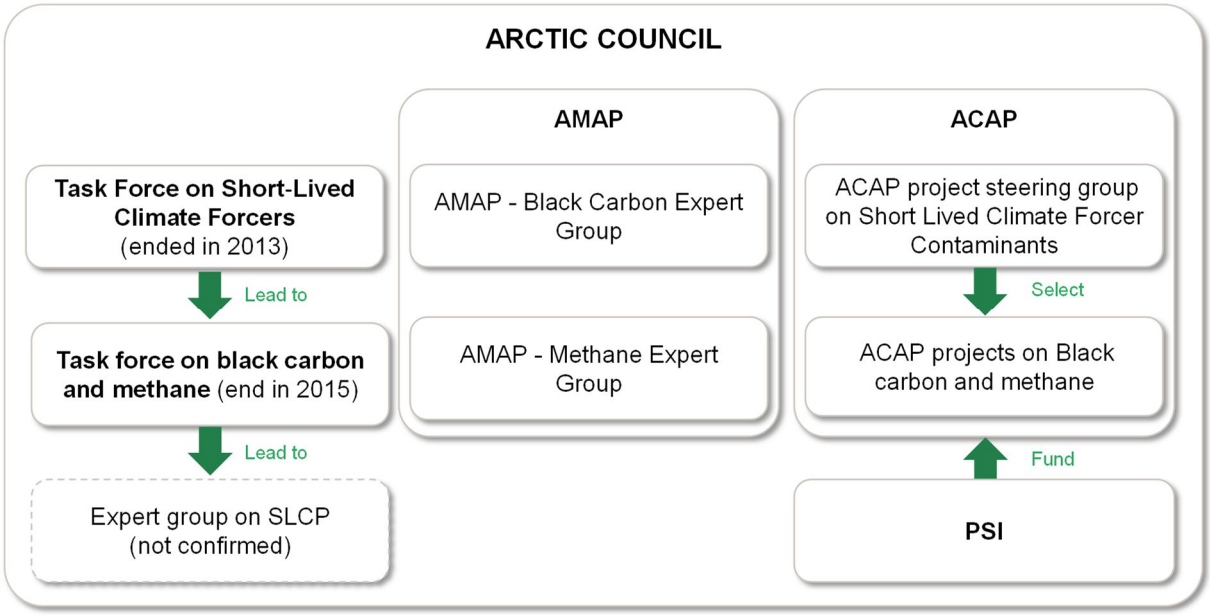
Several of the CCAC initiatives have the potential of becoming more effective if Arctic dimensions are added and/or Arctic States and companies operating in the Arctic are encouraged to take active part. Arctic States themselves will have to initiative this, but Arctic Council bodies should also communicate with CCAC, GMI, GGFR and other relevant initiatives.

Some 50 NGOs and research institutes and programs reviewed for this report, have numerous activities, some which overlap and where coordination and communication could be better. Many programs focus on best practises and pilot projects and there is room for considerable improvement in disseminating results in order not to duplicate efforts and for the purpose of creating synergies.

5.4 Arctic Council bodies

A number of bodies of the Arctic Council deal with black carbon and methane emission issues. An overview is presented in the figure below.

Figure 9: Overview of the Arctic Council bodies on SLCP



A task force on short-lived climate pollutants (TF SLCF) was established following a decision at the Arctic Council in 2009. This marked the start of black carbon and methane emissions being a priority by the Council.

Subsequently, after the Ministerial meeting in May 2013 a new task force "Task Force for Action on Black Carbon and Methane" (TFBCM) was established. TFBCMs mandate was to development a Framework for Enhanced Action to Reduce Black Carbon and Methane, and report to the next Ministerial meeting in 2015. As noted in Section 2 TFBCM will be followed by an Expert Group to assist in implementation of the Framework. The terms of reference for the Experts will be decided by the 2015 Ministerial meeting,

Two expert groups under the Arctic Monitoring and Assessment Programme (AMAP) have had the mandate to *"monitor and assess the status of the Arctic region with respect to pollution and climate change issues and to produce sound science-based, policy-relevant assessments products"*. AMAP has published an assessment on black carbon in 2011 and is preparing an assessment for black carbon and methane for 2015[42]. The reports conclude that large reduction of SLCPs can significantly reduce temperature increases in the Arctic. As for sectors, the reports particularly highlights the opportunities for reductions in the oil and gas, waste management and mining sectors for methane emissions, and for black carbon reduced use of diesel fuels, biomass burning and flare elimination[43].

The Arctic Contaminants Action Program (ACAP) was set up to address Arctic pollution sources identified through AMAP, and to strengthen and support national action. Black carbon and methane was adopted as part of ACAPs mandate by establishment of the Project Steering Group for Short lived Climate Forcers and Contaminants (PSG SLCFC) in 2010. The mandate of PSG SLCFC is to facilitate projects with an initial focus on black carbon emission reductions. It has supported mitigation projects related to diesel and residential wood combustion, but the project portfolio has been limited due to relatively modest funds being available. With the Project Support Instrument (PSI), which is an instrument for financing prioritized Arctic Council projects, being operational from 2014 (with NEFCO as fund manager) this situation will improve. Arctic States have pledged 15 million Euros to PSI, of which 10 million Euros come from Russia. Only a part of the PSI funds will be allocated to black

[42] Source: AMAP website
[43] Ref to BC and M reports

carbon and methane projects and given the current emphasis on enhanced actions on these pollutants Arctic States could see additional funds allocated to PSI as one of several means to achieve this. Over the course of almost six years the Arctic Council has created several bodies dealing with different aspects of promoting action for black carbon and methane emission reductions. The AMAP expert groups have presented invaluable knowledge as a basis for action, and progressively the task forces (TF SLCF and TFBCM) have become more action oriented. With PSI now being operational, ACAP is also likely to become more important in facilitating projects that reduce black carbon emissions.

5.5 Findings and recommendations

Although policies and regulatory approaches differ among countries the review and analysis of this project suggest there is a certain trend towards convergence among Arctic States. The Arctic Council may give further impetus to this process especially through adoption of the Framework Document which is expected to results in a common vision and policy recommendations for dealing with black carbon and methane emissions. Other international institutions and initiatives can also play an important role in strengthening efforts to reduce emissions. Public private partnerships, such as the CCAC, can have large impact because they bring together relevant public authorities and key actors from the industry. CCAC, in particular, also has great convening powers since most institutions with a mandate to work for reduction of black carbon and methane emission reductions are partners to CCAC. There is always a risk of duplication of efforts with so many institutions being involved in one subject matter. But at the same time there are opportunities for synergies to be made if communication is managed well. The Arctic Council and CCAC could take the initiatives to establish web sites and organize events to facilitate sharing of information on ongoing and planned efforts.

Some sectors are more important than others when prioritizing enhanced action. Key findings and recommendations are presented for the following sectors:

Oil and gas sector

The oil and gas sector has the potential to deliver the largest reductions of methane emissions in Arctic States. Technology standards can help reduce emission. Operational practices are also important, and specifically for methane emissions can be difficult to detect and measure. This creates challenges for regulations, and often an “information bias” to the disadvantage of the regulators. Effective and cost efficient measures to reduce emissions therefore depend on a good dialogue and cooperation between the major industrial players and authorities. The fact that a relatively small number of companies contribute a large share of the emissions is an additional argument for cooperation being an effective approach to regulation.

Public private partnerships, both at the national and international levels, are responses to consider and develop. They have with success been used in the US (for methane) and Canada (for methane and flaring) and can be developed further. Moreover, international public private partnerships, such as CCAC, GMI and GGFR, have an untapped potential to promote enhanced action in Arctic States. However currently few companies, and no Russian companies, are active in these initiatives. Authorities and other stakeholders should engage in getting oil companies to join public private partnerships and other voluntary schemes to reduce black carbon and methane emissions.

Transport

Technical standards and fuel standards have been effective measures to reduce emissions of PMs and there is a considerable international momentum in further improvements both through regulatory pressures and through measures taken by vehicle producers and fuel suppliers. Transport sectors emissions are therefore expected to decrease but there is scope for enhanced action, for example through establishment of Low Emission Zones in Arctic areas. Such measures must be incorporated into national legislation, but Arctic Council bodies and other international initiatives can play a role in encouraging such measures being implemented.

A sub-committee under the Marine Environment Protection Committee (MEPC) of the IMO deals with black carbon emissions in Arctic waters from international shipping. Technical measures being considered are closely related to definition of black carbon which is not clarified. Hence work of the sub-committee seems to have progressed slowly and for this reason black carbon was not incorporated in the Polar Code of the IMO adopted at the end pf 2014. Clearly more progress in work of the MEPC is important in order to avoid black carbon being a large source of emissions once shipping Arctic water becomes significant.

Agriculture and forest

Agriculture burning seems have adequate regulations in terms of bans and restrictions, but often have insufficient monitoring and reporting processes with regulatory enforcement. Also for wildfires is there a need for improved monitoring and reporting and clear and predicable regulatory responses. For both, the use of modern technologies (e.g. through satellite images) help in the monitoring, and CCACs Agriculture and Open Burning Initiative and the Global Fire Monitoring Centre can play a role. Nevertheless, it is the capacity and capability of national regulatory authorities that by far matters the most.

The residential sector

Regulation of these sectors is often a challenge because there are numerous emission sources. Technical standards for energy appliances can effective but may need may need to be supplemented with economic incentives. There should be further room for international coordination of technical standards, while other instruments such as economic incentives or bans/restriction would have to be locally or nationally determined.

The role of Arctic Council bodies

Arctic Council bodies, dealing with black carbon and methane, seem to have distinct and clearly defined mandates without ambiguity about their respective roles and responsibilities. However during interviews with stakeholders for this report, it has become clear that communication between relevant bodies can be improved. Synergies through effective communication have to some extent remained untapped, for example when one body has communicated findings and progress to other bodies inadequately or late. Good communication will become even more important now that the work is entering a more operational phase. The Expert Group, expected to be established after the Ministerial meeting in April 2015 to help implement the Framework, should play an important role in sharing of knowledge and coordinating activities targeted at enhanced action.

Moreover, the iterative two-year process of implementing the Framework gives the Expert Group a central role in promoting enhanced action for emission reductions Based on the review and analysis of this report we would make the following recommendations for the Arctic Council follow up (normally acting through the Expert Group, but not necessarily always):

1. **Convergence of national regulations**

   For some emission source, there seems to be a trend towards convergence both on reporting requirements and on technical standards among Arctic States. The Arctic Council could review and analyse this process and identify ways in which it can contribute to further convergence.

2. **Elements of best practise regulations**

   In some sectors convergence in regulatory approaches may be more difficult to achieve. Regulation of oil and gas sector activities, for example, is firmly rooted in the legal and regulatory traditions and structure. Still there are elements of “best practices” that are relevant for all countries, and there seems to be an interest between to learn from each other on complex issues such as regulation of flaring (including black carbon emissions) and methane emissions in the oil and gas sector. The fact that there often is an “information bias” to the disadvantage of the regulator makes it even more important to establish good international

cooperation, and an atmosphere of trust and cooperation between the regulator and companies at the national level. The Arctic Council could initiate a forum of exchange of experiences and views among regulators of Arctic States, and when relevant also involve the (regulated) companies.

3. **Promoting public private partnerships and international cooperation.**

   Collaboration between authorities and companies is also important at the international level. Public private partnerships involving the oil and gas industry is particularly important, due to their large share of back carbon and methane emissions with Arctic impacts and because relatively few actors are responsible for a large share of the emissions. The Oil and Gas Initiative of CCAC has started activities that are highly relevant but which still lack an Arctic focus. The Arctic Council could work with relevant parts of the CCAC to rectify this. Further, international shipping may become an important black carbon emission source in the Arctic. The primary international body to address this is the Marine Environment Protection Committee (MEPC) of the IMO. The Arctic Council could work with the MEPC to explore whether more specific and ambitious targets or requirements for Arctic black carbon emission can be incorporated under IMO regulations.

4. **Identifying gaps and avoiding overlaps**

   As noted in this report a large number of initiatives are engaged in efforts to reduce black carbon and methane emissions, some with specific focus on the Arctic. Duplication of work and lack of communication between initiatives have been identified, for example activities on best practises and pilot projects. In other cases initiatives covering back carbon and methane have little or no focus on the Arctic. Given CCACs convening power it can play an important role in spotting duplication and poor communication, and the Arctic Council in collaboration with relevant initiatives of the CCAC can identify gaps where international efforts can be important, and get them get started.

6. Appendix - Sector specific review

6.1 Oil and Gas sector

Black carbon inventories
The main potential sources of black carbon in the oil and gas sector are:

- Gas flaring
- Stationary combustion from diesel generators, gas turbines, and mobile sources

Activity data is either directly measured or estimated by companies using gas oil ratio and reported to the regulator. However, black carbon estimates are considered uncertain due to both the uncertainty of the activity data (e.g. how much gas is flared) and the uncertainty on the emission factors (27). There is indeed currently very few measurements of black Carbon emissions from gas flaring. Existing measurements have been performed by Carleton University, Aerodyne, and University of Illinois.

Black carbon regulations
Black carbon from gas flaring is not regulated directly[44] (although visible smoke emissions from gas flaring are often regulated) they are, however, part of broader regulatory frameworks. Flare reduction and increased associated gas utilization has gained considerable political attention as a resource waste and environmental problem. Regulation of flaring is therefore an important means for reduced emissions of black carbon emissions for the oil and gas sector. Gas flaring has received important political attention and is regulated through several mechanisms e.g. (i) Gas flaring limits (e.g. in Russia) or ban of routine flaring (e.g. in Norway) (ii) economic incentives (e.g. in Alberta and in Norway) and (iii) negotiated agreements (e.g. in Norway)

Installations in USA, Canada and Norway must report flaring volumes monthly and there are requirements for metering equipment and accuracy of measurements. Russia also has mandatory reporting of flaring volumes but these are not always based on measurements or verified. Exploration activities are usually exempt of some or all of flaring reduction mechanisms.

Methane inventories
Methane (CH_4) is emitted to the atmosphere during the production, processing, storage, transmission, and distribution of natural gas. Production, refining, transport, and storage of crude oil are also sources of methane emissions. Emission sources are normally categorised as either venting or fugitive emissions.

The inventories for venting in upstream O&G in Canada, Norway and US use emission factors for unreported venting (i.e. under the reporting threshold) and reports are submitted yearly. Denmark does not estimate venting in upstream O&G because it is assumed that all systems are connected to flares. For non-venting emissions from natural gas production and processing, the calculation is either based on company reported information (Norwegian onshore gas terminals measure and report emissions regularly) or on activity data (number of compressors, number of pneumatic devices etc…) and EF.

For fugitive emissions from natural gas transmission and distribution systems, Canada, US and Norway[45] use emission factors, whereas Denmark and Finland base their calculations on yearly measurements of leaks, reported by operators of gas networks. Over the past few years, there has

[44] Though visual smoke is for example in USA:
[45] In Canada and US, the emission factors used come from national expertise (CAPP 1999 in Canada, GRI 1996 in the US, decreased to account for voluntary emission reductions) and are Tier 3. In Norway, emission factors are taken from an Austrian study (2010).

been an important focus on methane O&G sources and a large number of studies have been published in particular in North America to improve the inventories.

Methane regulations
Historically methane emissions mitigation (and regulation) has been driven by safety and health risks consideration and local and regional impacts of co-emitted Volatile Organic Compounds (nmVOC),

Regulatory requirements include (i) emission permits/ limits (e.g. in Alberta and in Norway), (ii) technical standards (e.g. in USA), (iii) LDAR requirements (e.g. in Colorado), (iv) payment of emission charges or fines (e.g. in Norway), (v) and/or as positive incentives through tax rebates, investment support or emissions offset schemes (e.g. in Alberta) Since methane emissions in the oil and gas sector cut across many different production segments with a considerable diversity in emission sources, several regulatory approaches may be applied.

A number of countries in the Arctic (including Norway, USA and Canada) are working on developing further the understanding of the magnitude of the emissions, the emission reduction potential and developing new regulation to address this source of emissions.

International initiatives[46]
Over the last two decades, a number of national and international initiatives have been launched to address the specific challenges of methane and black carbon emissions (or gas flaring) in the Oil and Gas sector. Since 1993, the Natural Gas STAR has provided a framework to encourage companies to implement methane emissions reducing technologies first in USA and then internationally. The Global Methane Initiative, launched in 2004, have been central in sharing experience and building capacity globally in the oil and gas sector. Since 2002, the GGFR public-private partnership supports the efforts of oil producing countries and companies to increase the use of associated natural gas. More recently, the CCAC has created a voluntary initiative to reduce methane emissions in the oil and gas sector: the CCAC Oil & Gas Methane Partnership[47], which provides companies with a credible mechanism to systematically and responsibly address their methane emissions. The CCAC has also a black carbon component: the “Technology Demonstration and Evaluation for the Recovery of Hydrocarbon Liquids” initiative. (26)

A number of NGOs (e.g. Environment Defend Fund, Natural Resources Defense Council, Skytruth, Sierra Club and Clean Air Task Force) have also led some important research and analytical work to raise awareness and promote new regulations in particular in USA. Finally, industry associations have also been active in this area: IPIECA[48] e.g. provides best practice documents (e.g. for flare management), CAPP[49] supported the development of EF, and OGP[50] has an Arctic Committee to develop a long-term strategy to address the key upstream arctic issues.
mention the Arctic Economic Council (AEC)

6.2 Agriculture (including enteric fermentation)

Methane[51] Inventories
Domestic livestock such as cattle, buffalo, sheep, goats, and reindeer produce CH_4 as part of their normal digestive process (enteric fermentation). CH_4 is also produced when animals' manure is stored or managed. In the emission inventories of the Arctic States, Tier 2 approach is usually used for the most important sources of emission (e.g. dairy cattle) while Tier 1 is used for lesser sources of

[46]For all the paragraphs on initiatives: The objective of the paragraphs is to map the type of current initiatives and provide an overview of the activities ongoing. The list of initiatives provided do not aim at being exhaustive.
[47] The founding companies are: BG-Group, Eni, Pemex, PTT, Southwestern Energy, Total and Statoil
[48] International Petroleum Industry Environmental Conservation Association
[49] Canadian Association of Petroleum Producers
[50] International Association of Oil & Gas Producers
[51] category 4A and 4B in IPCC

emissions (e.g. horses) . In terms of uncertainty, the uncertainty for the count of population is generally low (5 to 10%) for the main animal categories. A large part of the uncertainty in the emission estimate is associated with the EF (Uncertainties from emissions factors range from 20 to 250%). Other factors such as methane conversion rate (Ym) and net energy used for maintenance (NEm) also contribute to the overall uncertainty.

Methane regulation

Regulatory efforts in the Arctic States has been targeting increasing productivity (extended productive lifetime, forage and space optimization, production efficiency and breeding[52]) and other environmental policies (e.g. nitrates pollution control) that may also reduce methane emissions[53].

On the other hand, the combination of technology development in the rural sector, support from voluntary programs (e.g. AgStar Program in U.S) and economic incentives (project financing, tax relief, feed-in-tariffs, power purchasing agreements for renewable energy generation…) has been successful at enabling a large number of biogas projects already.

Further mitigation strategies e.g. feed additives are being researched (by e.g. Agriculture and Agri-Food Canada AAFC)[54], but it is unclear if they will ever be part of the regulatory framework. For instance, in Europe, forage supplements are restricted and the legislation does not allow most of these substances to be used routinely in forage[55]

Current initiatives

A number of actors have been active to promote and demonstrate livestock emissions reduction best practices in a manner that also enhances food security and livelihoods. International collaborations such as GMI, UN Food and Agriculture Organization (FAO) [56] and CCAC have a leading role in this process. A number of other organizations (e.g. CGIAR (CCAFS, CIAT), CATIE, GRA, ICCI, ILRI, ICIMOD, IRRI, LPELC, and USDA) are also active in increasing awareness and lifting implementation barriers, in particular project financing barriers[57]. Some development banks (e.g. World Bank, EBRD) have financed projects to reduce methane emissions in diverse countries. Most of the initiatives currently focus mainly on developing countries. Canada, the EU and USA are however lead partners in the agriculture initiative of CCAC and are partners of the GMI initiative on agriculture.

6.3 Waste Sector

Methane Inventories

Methane generation and emissions from landfills are a function of several factors, including: (i) the total amount of waste-in-place[58], (ii) the characteristics of the landfill receiving waste (e.g., composition of waste-in-place, size, climate, cover material); (iii) the amount of CH_4 that is recovered[59] and; (iv) the amount of CH_4 oxidized as the landfill gas passes through the cover material into the atmosphere.[60]

The different countries used First Order Decay models to estimate the emissions: The method assumes that the degradable organic carbon in waste slowly decays over many years following its deposition, thus producing methane and carbon dioxide emissions. The decomposition time varies

[52] Nordic initiatives to abate methane emissions: a catalogue of best practices. By Cajsa Hellstedt, Jenny Cerruto, Maria Nilsson, Michael McCann
[53] https://www.globalmethane.org/documents/EC_GMI_reduction_actions.pdf
[54] http://www.agr.gc.ca/eng/science-and-innovation/science-publications-and-resources/technical-factsheets/reducing-methane-emissions-from-livestock/?id=1305058576718
[55] Nordic initiatives to abate methane emissions: a catalogue of best practices. By Cajsa Hellstedt, Jenny Cerruto, Maria Nilsson, Michael McCann
[56] Mitigation of Climate Change in Agriculture (MICCA) Programme
[57] Through e.g. AID and carbon financing mechanisms.
[58] Total waste landfilled annually over the operational lifetime of a landfill
[59] either flared or used for energy purposes
[60] Source: NIR of the Arctic States

from material to material[61]. Data on the amount of different waste materials is usually compiled using a range of information sources including special surveys (e.g. in USA) and reported data from local authorities or by waste operators (e.g. in Denmark). The emissions estimates are currently considered as highly uncertain, both due to uncertainty on the activity data (in particular on waste composition) and on the emissions factors[62]. The time dependency in methane production makes the model estimate further dependent on assumptions of waste management from earlier years[63].

Methane Regulation

Most Arctic States have regulations, guidelines and targets pertaining to the recovery of methane from landfills waste. These vary substantially but usually include (i) flaring (instead of venting) requirement for the produced gas (ii) bans or restrictions for landfilling of organic waste, (iii) required landfill gas (LFG) collection and upgrading, including development of landfill gas projects (large biogas plants, low tech bio-cover systems, micrometeorological methods, low methane content feed to Stirling engines, …) and (v) available financing/soft loan schemes and development projects (e.g. Joint Implementation of the Chelyabinsk LFG to energy between the Russian Federation, companies of the Baltic Sea Region Testing Ground Facility (TGF) and the Danish Environmental Protection Agency[64]).

In Europe, it is expected that the EU Landfill Directive will target elimination of landfilling for all untreated waste and organic waste and requiring landfill gas (LFG) projects at landfills. Binding the target into legislation is expected to further reduce methane emissions[65]. Landfill depositing of organic waste is prohibited in all the Nordic countries, and existing organic content will just decompose reducing emissions over time. More than regulations, the focus is on developing relevant projects across the different countries. In fact, there is a large number of facilities with biogas recovery systems in all Arctic countries.

The increased awareness and availability of cost-effective and efficient technologies has been key to the reduction of emissions in the later years. However, increasing volumes of waste will make effective combination of voluntary programs, stream-lined financing opportunities and clear power purchasing agreements/carbon credits more critical. In the Arctic, on the other hand, small volumes of waste and cold temperatures[66] make this source less relevant for arctic-specific regulations.

Current initiatives

A large number of actors[67] are involved in technical assistance, capacity building, and awareness-raising to increase emissions reductions from solid waste landfills. The CCAC Municipal Solid Waste Knowledge Platform (27) e.g. provide an extensive tool to share and exchange information on solid waste emissions. Some actors (e.g. international solid waste association and C40 Cities Climate Leadership Group) are working on best practice adoption through engagement of stakeholders (cities) and development of project financing frameworks (NAMAs[68]).

Waste management regulations and standards also receive attention by a number of organisations. In the Arctic, USA, Canada and Sweden are partners of the CCAC Municipal Solid Waste and Russia has a number of projects featured on GMI website (28).

[61] Easy degradable waste (food, etc.) has shortest decomposition time, while wood waste has the longest decomposition time. Other materials do not emit methane at all, either because they are inorganic (metal, glass, etc.) or because they break down extremely slowly (plastic)

[62] Combined uncertainties of DOC (degradable organic carbon), DOCf (Fraction of DOC that can decompose), MCF (Methane correction factor for aerobic decomposition) and F (Fraction of methane in generated landfill gas).

[63] Activity data estimates are generally much more uncertain in past years (before 2000 or before 2005) than in recent years.

[64] From Landfill Gas to Energy: Technologies and Challenges
By Vasudevan Rajaram, Faisal Zia Siddiqui, Mohd Emran Khan

[65] https://www.globalmethane.org/documents/EC_GMI_reduction_actions.pdf

[66] Heat enhance methane release from waste

[67] international solid waste association, C40 Cities Climate Leadership Group, International Council for Local Environment Initiatives (ICLEI), Institute for Global Environmental Strategies (IGES), Center for Clean Air Policy (CCAP), United Nations Centre for Regional Development (UNCRD), Landfill Methane Outreach Program (LMOP) and TERRE Policy Centre.

[68] Note that three CDM methodologies already exists for emissions reductions in waste management AM0083 AM0093 ACM0001

6.3 Industry and energy production

Black Carbon inventories
Emissions from stationary combustion in industry (power, process industry, other combustion) are either reported directly by the facilities, or estimated for small industries using energy statistics. Reports are in most countries collected by local environmental protection agencies and forwarded to the national agency. Nordic countries, U.S and Canada include PM in their reporting protocol but not black carbon, whereas Russia includes soot as a reported pollutant.

Black carbon regulations
The main regulatory focus is on dust and particulate matter control on stationary power generating plants and industrial plants (e.g. cement production) through:

- Environmental permits, sometimes facility-specific (e.g. in Norway)
- Exhaust thresholds using filtering technology (e.g. in European directives)
- Technology standards, including for example high temperature combustion (e.g. super-critical coal), and BAT for new installations or for retrofitting (e.g. Best Available Retrofitting Techniques in U.S)
- Economic incentives: Pollutant taxes can be found in Russia if surpassed the Emission Limit Values (ELV) in tonnes of CO_2eq.

Usually different types and sizes of plants have different thresholds or standards of operation for each country, which makes the comparison between industries much more challenging.

6.4 Residential and Domestic heating

Black carbon Inventories
Residential wood burning is emphasized among residential heating sector as wood burning appliances[69] emit much more particles than gas or oil heaters and as the wood consumption estimate are more uncertain than gas or oil consumption (i.e. wood can be directly collected in the forest without being traded).

Wood consumption estimates rely on surveys completed every few years and extrapolated for other years. Studies have been conducted in Scandinavia and Finland to measure the EFs for several types of burners (29). EF from residential wood burning are still considered uncertain, due to the high variability of the EF reported depending on a number of factors (technology, fuel type and condition etc...). The Swedish Environmental Research Institute (IVL) is currently conducting some work on on EF improvement as part of a project commissioned by the Nordic Environmental Ministers.

Black carbon regulations
We can classify the efforts done by regulators into (i) mandatory regulation (e.g. EcoDesign directive in Europe), (ii) manufacturing standards / BAT (e.g. Nordic Swan), (iii) economic incentives (e.g. stove changing campaigns, scrapping premium or investment grants to shorten turn-over time), (iv) limits on information campaigns (e.g. in Denmark and Finland), (v) environmental classification of boilers and stoves combined with a differentiated environmental fee.

Nordic countries have the regulatory tools necessary to intervene when wood burning results in poor local air quality, but their application varies and these measures have little effect on the regional emission reductions (30). In general, countries find that manufacturing standards plus consumer recognition of appropriate labels and standards are central to the solution. Most countries (except Russia) also have some form of subsidy or scrapping premium. These are expensive and punctual but somewhat effective measures to speed development and adoption of black carbon reducing

[69] Wood boilers, pellet boilers/burners, kitchen stoves, coke furnaces, wood stoves, fireplace inserts, tiled stoves and masonries as defined by the Eco-design Directive (July 2013 proposal).

measures. It is also unclear the impact of information campaigns on the user's skill to burn a fire. Finally, development of recognised protocols for testing black carbon emissions is a prerequisite to the development of a number of black carbon specific regulatory tools[70]. (31)

Current initiatives
A number of national and international initiatives have the potential to reduce the environmental impact of residential heating in the Arctic States. Some initiatives are focusing on sharing information and best practices such as the BurnWise partnership of US EPA. Several organizations provide financial support for projects, e.g. Alaska has implemented different mechanisms to encourage and fund the replacement of diesel systems with renewables projects. Some NGOs (e.g. Alliance for green heat, International Cryosphere Institute, CATF) promote further actions and regulations.

There is currently no ambitious international standard/label for domestic heating which covers black carbon, however existing standard/label (e.g. The Nordic Swan[71]) could be improved to include black carbon considerations.

6.5 On– and off–road transport

Black carbon inventories
On-road transportation: The approaches to estimate black carbon/PM emissions from on-road transportation are relatively similar in the different inventories. The activity data are collected from road administration and include number of vehicles, fuel consumption or mileage per vehicle type (Depending on fuel type, vehicle type, engine size). Emission factors for PM and black carbon are generally available for the different vehicle categories. This sector is complex and thus specific software tools are often used to estimate the emissions[72]. In Russia, the government agency in charge (Rosprirodnadzor) must report estimated data on emissions from mobile sources annually.

Off-road mobile combustion: The overall approach to estimate emission from off-road transport is similar to the on-road transportation sector. The activity data is however less certain and is estimated based on a number of sources (sales of equipment, existing databases, fuel sales etc.) and based on assumptions (share of the fuel consumed off road, utilisation rate etc.). PM and black carbon emission factors are less available for off road transport than for on-road transport and thus black carbon emissions factors from on-road transport are often used. Different countries apply different methodologies: In the Russian greenhouse gas inventory, off-road mobile combustion is not accounted as one separate category. In USA, emissions are calculated as a function of the vehicle type, engine size, engine load and utilisation rate using a detailed model[73].

Black carbon regulations
The EU has the strictest standards on both on-road and non-road vehicles, while USA and Canada have also their own, less strict manufacturing standards. Russia follows older EU standards. These standards, like the EURO series, set emission limits for NO_x, unburnt hydrocarbons (HC), CO and PM for most vehicle types, both on-road and off-road vehicles. Fuel quality directives can also have an impact on the level of these emissions.

[70] Note that the Household Cooking and Domestic Heating initiative of CCAC is planning to "develop standards and testing protocols to provide clear criteria for evaluating emission reductions of black carbon, PM and other SLCP."
[71] The Nordic Swan is a voluntary eco-labelling system for a number of product including stoves is well known and highly accepted among both producers and consumers in the Nordic countries. The Nordic Swan does not currently include requirements for black carbon.
[72] COPERT (computer programme to calculate emissions from road transport) in Europe MOBILE6,2 in Canada and MOVES (motor vehicle emissions simulator) in the US.
[73] For off road emissions, the models are EPA's NONROAD and EEA's COPERT Off-road

Economic incentives are also common and can be classified into (i) refurbishing and retrofitting campaigns and programmes (more common in U.S and Canada), (ii) congestion taxes, (iii) tire wheel taxes and (iv) air pollution taxes.

Finally several other types or measures and regulations apply for this sector like (i) low emission zones, (ii) anti-idling regulations, (iii) speed limits, (iv) mandatory road cleaning to remove dust, (v) lower taxes and free tolls for electric vehicles and (vi) application of salt to roadways instead of sand.

Current initiatives
A number of actors have been active to promote further emissions reductions from both on and off road transportation. The different initiatives provide technical support and best practice information (e.g. The Institute for Transportation and Development Policy, International Council on Clean Transportation), supports retrofit programs (e.g. US EPA, NEFCO), environmental performance standard (e.g. Smart Way, VERT) or promote action and new regulations (e.g. smart freight centre, CCAC Heavy Duty Diesel Vehicles initiative[74]). Despite the number of ongoing programs, large-scale substitution remains slow.

Overall, most of the international effort focuses on the large cities in developing countries. Over the last few years, the US EPA “Black Carbon Diesel Initiative in the Russian Arctic” has engaged with a number of stakeholders to target emissions (32).

6.6 Shipping

Black Carbon inventories
Emissions are calculated using data from air and maritime agencies combined with information from airports and maritime ports. International and domestic transport is generally differentiated. Emission factors are available for different ship/plane types, and engine size.

Black carbon regulation
International Maritime Organization (IMO) is the international body responsible for international marine standard and in particular for negotiating the new International Code for Ships Operating in Polar Waters (Polar Code) to govern shipping traffic in the Arctic Ocean. This November, the Polar Code was adopted (33). However, this code does not contain any measure to limit black carbon emissions. The IMO is planning to conduct a second phase of Polar Code negotiations in the next few years (34) In addition; IMO Marine Environment Protection Committee is evaluating options to address the impact in the Arctic of black carbon emissions from ships.
The establishment of Emission Control Areas (ECAs) under the MARPOL Protocol is the main instrument for pollution control. Currently, there are several ECAs, some of them only limit SO_x like Baltic Sea area and the North Sea areas, while the North American and the United States Caribbean Sea areas also include NO_x and PM emissions. However, there is no ECA for the Arctic region or Russia despite the increasing traffic of the arctic route[75] and oil and gas activities.

In addition, emission reduction is achieved through increasing (i) standards for shipping including limits on air pollution, including PM, from ship exhausts, (ii) economic incentives targeting fuel efficiency (soft loans to retrofit old vessels) (e.g. in Greenland) , (iii) voluntary commitments and environmental guidelines[76].

Figure 10: Emission Control Areas (ECA) as defined by MARPOL. Source: DNV. Horizontal line marks the Arctic Circle.

[74] Canada, USA and Sweden are partners of the CCAC Heavy Duty Diesel Initiative
[75] http://www.spiegel.de/international/world/russia-moves-to-promote-northeast-passage-through-arctic-ocean-a-917824.html
[76] Association of Arctic Expedition Cruise Operators

Current initiatives
Other actors in this area include the International Council on Clean Transportation (ICCT), Clean Shipping Coalition (CSC)[77], Bellona, Cicero, Oceana, Transport and environment (T&E), and CATF. These organisations are leading a number of activities including emission assessment, promotion of policy, evaluation of the abatement technologies and costs, and market-based mechanisms development. Individual ports also lead some emission reduction initiatives (e.g. World Ports Climate Initiative – WPCI)

6.7 Open burning

Black carbon inventories
Today's open fire inventories are often derived by combining satellite remote sensing information with modelling (4). In the EMEP guideline, emission factors are either given as an average of residue burnt (Tier 1) or for each type of crop or forest burnt (Tier 2) (12). This emission source is not accounted for in the Russian, Finnish and Swedish inventories. In the US, the estimation is the result of the combination of a satellite measurement of burnt areas[78] with on-the-ground information collected by different state agencies (35). Overall, the emissions estimates for this sector are still considered highly uncertain.[79]

Black carbon regulations
In the sector, the main instruments to reduce black carbon or its precursor pollutants are (i) general bans, (ii) permits that can be permanent or seasonal, (iii) delegation of the decision to farmers (iv) specific banning (e.g. petroleum-based products) or (v) regulating slash-and-burn clearing of forests and Arctic tundra.

While for some countries banning agricultural waste burning is the solution (in Denmark, Norway and Greenland), for others permitting (in the U.S) or delegating the decision to farmers (e.g. Saskatchewan province in Canada) is the preferred approach. In Alaska, petroleum-based materials burning require a black smoke approval permit and burning of piles and yard requires a permit from the DNR Division of Forestry[80]. Also, open burning is prohibited in areas where an Air Quality Advisory is occurring[81] (i.e.

[77] A global international environmental organisation that focuses exclusively on shipping issues. Members includes AirClim, Bellona, CATF, EDF, Transport and Environment, Oceana, Seas at Risk, Stichting de Noordzee
[78] Using MODIS satellite.
[79] Due to likely underestimation of area burnt in many regions, an over- or underestimation of combusted biomass, and use of emission factors that do not distinguish smoldering from free-burning fire. (5)
80 http://forestry.alaska.gov/burn/
81 https://myalaska.state.ak.us/dec/air/airtoolsweb/AirQualityAdvisories/Advisories.aspx

PM pollution is higher than threshold), during Forestry Burn Suspensions and Closures and local government burning suspensions[82]. They also have advised burning practices83. Canada delegates to each province the regulatory efforts. In Russia, several oblasts have enacted bans on open burning[84] with mixed results, especially poorer results in isolated areas. There seems to be no clear definition of public reponsability between the different states. There is also no local or federal system for controlled burning permits for crop residues or other trash and waste[85]. This is further complicated as agricultural burning is recognised as the main source of wildfires[86]. Some research has been undertaken on how to enable better procurement processes and support for technology implementation in Russia[87].

Current initiatives (34)
A number of collaborative efforts are ongoing to share best practices and promoting reduction of open burning. Global Fire Monitoring Center (GFMC) supports local, national and international entities to develop long-term strategies or policies for wild land fire management and serve as advisory body to the UN.

A number of NGO are also working on educating the public and promoting mitigation for open burning (e.g. Pacific environment, Greenpeace, ICCI, Bellona). The U.S. Forest Service's International Program, as a part of the Arctic Black Carbon Initiative, has also implemented a number of projects efforts in Russia. ICCI and Bellona Russia continue to address open burning in Russia in all its aspects—by analysing and promoting legislation (the Rostov legislation was a direct result of ICCI/Bellona efforts); educating farmers, scientists and the general public; working with local and regional officials; and finding ways to support equipment needs[88]. Finally, the CCAC agriculture initiative has open agricultural burning as one of the main components. Despite these, adoption of best practice presents significant challenges including low public (farmers) awareness.

82 http://www.dnr.state.ak.us/forestry/fire/current.htm or http://fire.ak.blm.gov/
83 Open burning policy and guidelines. State of Alaska. Department of Environmental Conservation. Division of Air Quality. Air Permits Program. AC 50.065 https://dec.alaska.gov/air/ap/docs/obrguide.pdf
84 Overview of current environmental legislation in the framework of the project "Air pollution and the Arctic climate" By Juliya Ukupova, St. Petersburg, Russia, 2013. ICCI and Bellona Russia http://iccinet.org/wp-content/uploads/2012/03/UpkunovaENGlegislationanalysis2013.pdf
85 http://iccinet.org/june-2014
86 Mapping and fighting short lived climate forcers in the arctic - Bellona
87 http://iccinet.org/wp-content/uploads/2012/03/FinalReportProcurement12-27-2012.pdf
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