No. E0038
April 2021

Elements in the policy landscape for action on black carbon in the Arctic

Supporting material to the EUA-BCA report Enhancing the reduction of black carbon emissions to protect the Arctic: Mapping the policy landscape of national, regional and international actions

Stefan Åström, Mikael Hildén, Bradley Matthews

Funded by the European Union

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of IVL, UBA and SYKE and do not necessarily reflect the views of the European Union.

ivl

SYKE

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Funded by
the European Union

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of IVL, UBA and SYKE and do not necessarily reflect the views of the European Union.

Author: Stefan Åström, Mikael Hildén, Bradley Matthews
Funded by: European Union
Report number E0038
ISBN 978-91-7883-279-8
Edition Only available as PDF for individual printing

IVL Swedish Environmental Research Institute Ltd.
P.O Box 210 60, S-100 31 Stockholm, Sweden
Phone +46-(0)10-7886500 // www.ivl.se

This report has been reviewed and approved in accordance with IVL's audited and approved management system.

Preface

This technical report constitutes the deliverable wp4.i of the EU-funded Action on Black Carbon in the Arctic (EUA-BCA) (EU grant contract PI/2017/392-687). It provides a detailed description of the information collected during the work leading up to the forthcoming publication of the indicative EUA-BCA report *Enhancing the reduction of black carbon emissions to protect the Arctic: Mapping the policy landscape of national, regional and international actions* (deliverable wp4.ii).

The EUA-BCA provides inputs to processes aimed at reducing black carbon emissions from major sources (gas flaring, domestic heating, transport, open burning and maritime shipping), and also strives to enhance international cooperation on black carbon policy development in the Arctic region – with a special focus on supporting the work of the Arctic Council, the Convention on Long-range Transboundary Air Pollution and other national and international initiatives, as well strengthening collaboration with EU strategic partners.

There are four major areas of work in EUA-BCA:

- improving the knowledge base on black carbon emissions,
- increasing awareness and sharing knowledge,
- preparing technical advice documents and scenario analyses, and
- providing support in mapping the policy landscape for enhanced international cooperation on black carbon.

This technical report provides support to the fourth work area above.

This report is a part of the EUA-BCA final deliverables series including several reports and digital products in support of policy actions and increasing national/international cooperation with the ultimate target of reducing negative impacts from black carbon emissions in the Arctic. The present report explores possible policy actions to reduce black carbon emissions across prioritised areas and serves as a support for the EUA-BCA Policy landscape report, which provides suggestions for the implementation of relevant actions and stresses the role of enhanced cooperation in progressing with the actions. The policy landscape report is also informed by the EUA-BCA Stakeholder analysis which provides an indicative analysis on the importance of different organisations and groups for the policy actions and cooperations discussed in the EUA-BCA Policy landscape report. The EUA-BCA Policy landscape report summary is a brief for policymakers on the most important conclusions of the policy landscape report. There is also a digital version of the policy landscape available on a EUA-BCA project webpage and aimed at visualisation of policy actions, potential involvement of relevant stakeholders in their practical implementation, and the timeline with specific milestones on the way to reduce black carbon emissions in the next decade. The EUA-BCA Policy landscape report summary and a print version of the EUA-BCA Policy landscape report are also available in Russian.

The report has been produced with the active support from the entire EUA-BCA project team, and it has undergone several rounds of improvement thanks to constructive input from reviewers of draft versions. The authors of the report are grateful for the constructive input from Susanne Lindahl, Helena Laakso at the European Commission, Norah Foy, Chelsea Kealey, Diane de Kerckhove, Heather Morrison, Dominique Pritula at Environment and Climate Change Canada, and Seita Romppanen at the University of Eastern Finland. Any errors are the responsibility of the authors.

Table of contents

Summary

Black carbon is a short-lived climate forcer that, being a component of $PM_{2.5}$, also affects human health, contributing to respiratory diseases and reduced life expectancy. Black carbon pollution in the Arctic results from emissions that occur in the entire Northern Hemisphere. Actions to tackle black carbon emissions can therefore be taken on sub-national, national and international levels. Solutions to reduce emissions are available, but to be effectively implemented, they often require coordinated policy actions.

The aim of this report is to summarise information about relevant policy actions to reduce black carbon emissions from key polluting sectors, as well as options to better monitor how different initiatives affect black carbon emissions and their environmental and health effects. Several relevant policy areas are identified – *In situ observations of black carbon in the Arctic*, black carbon *emission inventories, Gas flaring*, *Small-scale domestic heating*, *Shipping*, *On-and off-road engines*, and *Open biomass burning*. Within these areas, possible actions are described in detail and presented in terms of their time horizon, societal impact, jurisdictional scope and relevant policy fora.

Actions within the areas *In situ observations of black carbon in the Arctic* and black carbon *emission inventories* are aimed at improving monitoring of the effectiveness of policies and measures to reduce emissions of black carbon and reduce subsequent impacts on the Arctic. To improve the number and the quality of black carbon *emission inventories* and to ensure their inter-comparability, the relevant actions include capacity-building activities, improved methodological guidance, harmonisation of the reporting formats between different reporting systems, inclusion of black carbon in Nationally Determined Contributions under the United Nations Framework Convention on Climate Change Paris Agreement, enhanced in-depth review mechanisms for reported black carbon emissions, and dialog on black carbon inventories with countries that are neither EU Member States nor Parties to the Air Convention of the United Nations Economic Commission for Europe. In the Area *In-situ observations of black carbon in the Arctic*, key actions are establishing and sustaining more observation stations in the Arctic, harmonisation of measurement methods, and developing solutions and opportunities for data sharing.

For *Gas flaring*, three actions are identified – defining common environmental standards for gas flares (including black carbon emissions), promoting research of actual black carbon emission rates for different types of flares, and monitoring of progress of the World Bank's Zero Routine Flaring by 2030 initiative.

In the Area *Small-scale domestic heating*, a range of actions of different character are recognised. A replacement of oil or coke-fuelled boilers used for heating or district heating would reduce emissions of both black carbon and CO_2. Spreading information on the benefits and techniques to "burn right" can be effectively combined with economic incentives to replace old equipment. Energy efficiency improvements of both burning appliances and buildings in general can reduce need for burning and therefore emissions. More stringent actions include consideration of bans on certain types of equipment that do not meet emission standards.

Emission reductions from *Shipping* are relevant for regulation on the international level – in particular, through the work of the International Maritime Organization, where development of a standardised black carbon sampling, conditioning and measurement protocols and legal regulations to reduce black carbon emissions are currently under discussion. National and sub-national

authorities could also contribute to black carbon emission reductions by e.g. setting limits on emissions, implementing fuel switching policies, mandatory shore power requirements, etc.

Actions in the Area *On-and off-road engines* are focused on enhanced implementation of stricter emission standards for vehicles, as well as on harmonisation of the standards used in the Arctic countries, and the ways to assure that vehicles actually meet the set requirements (by e.g. annual exhaust maintenance testing, or emission measurements at alternative test-driving cycles). Other relevant actions are stricter regulation of international trade of second-hand vehicles that significantly contribute to black carbon emissions in the Arctic region and banning use of AdBlue emulators and chip engine tuning equipment.

To reduce black carbon emissions from *Open biomass burning*, two actions are identified – one addresses mitigation of open burning on cropland, while the other is focused on managing risks of wildfires on forest and peatland. Since the cause of fires vary, the management of open burning on croplands is subject to regular and strong policy interventions whereas wildfires are only partly manageable through policy interventions.

The presented actions can act as a reference list of options for interested policymakers, synthesising existing knowledge about relevant policy actions rather than giving prescriptive recommendations on which of them to implement.

This report serves as a background document to the EUA-BCA Policy landscape report that informs on possible ways to implement these actions in practice and clarify how enhanced international cooperation would contribute to actions in the key areas.

List of abbreviations

AC	Arctic Council
AMAP	Arctic Monitoring and Assessment Programme
CAP	Common Agricultural Policy
CCAC	Climate and Clean Air Coalition
CEIP	UNECE Air Convention Centre on Emission Inventories and Projections
EGBCM	Arctic Council Expert Group on Black Carbon and Methane
EMEP	UNECE Air Convention Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe, unofficially European Monitoring and Evaluation Programme
EUA-BCA	EU-funded Action on Black Carbon in the Arctic
GAW	Global Atmosphere Watch
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
MEPC	IMO Marine Environment Protection Committee
MPG	Modalities, Procedures and Guidelines
NDC	Nationally Determined Contribution to achievement of the UNFCCC Paris Agreement
NECD	National Emission Reduction Commitments Directive
PAME	Arctic Council working group for Protection of the Arctic Marine Environment
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than 2.5µm
SLCF	Short-Lived Climate Forcers
TFEIP	UNECE Air Convention Task Force on Emission Inventories and Projections
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WTO	World Trade Organization

The context of this technical report

Black carbon – a climate change forcer and driver of poor human health

Climate change is having profound effects on the Arctic. In the Arctic, the rate of warming is currently at least twice as fast as the global average (in some regions as high as three times): the Arctic amplification. The Arctic climate plays a strong role in the global climate system and impacts of climate change on the Arctic cryosphere will have implications for other regions of the world through, for example, sea level rise and increased frequency of extreme weather events.

In adopting the Paris Agreement, to "*limit warming to well below 2°C above pre-industrial levels …*", the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) recognised that reductions in the emission of carbon dioxide (CO_2) are the backbone of any meaningful effort to mitigate climate forcing. However, in order to slow the pace of warming over the next two to three decades, both globally and in the Arctic, countries must also reduce emissions of short-lived climate forcers (SLCFs) such as black carbon and methane. Short-lived climate forcers are gases and particles that contribute to warming but have lifetimes in the atmosphere of a few days to a few decades - much shorter than that of carbon dioxide. The shorter the lifetime, the more quickly atmospheric concentrations can be reduced by lowering emissions to provide climate mitigation benefits in the short term. The focus of EUA-BCA is on black carbon (commonly known as soot) - a component of fine particulate matter ($PM_{2.5}$) emitted from the incomplete combustion of fossil fuels and biomass.

In the studies by Quinn et al. (2008), Bond et al. (2013), and Sand et al. (2020), the overarching message is that the warming effect of black carbon takes multiple routes. One route is that black carbon in the atmosphere absorbs sunlight, which increases warming. Another route is that once black carbon is deposited on snow or ice, it reduces the Arctic snow/ice ability to reflect incoming sunlight, which can cause increased warming and snow/ice melting. In addition, black carbon in the atmosphere outside the Arctic, even when not physically transported to the Arctic, can induce transfer of warm air to the Arctic, which then again induces warming. Black carbon also affects cloud formation (as do all particles), but whether this induces warming or cooling depends on when, where and how high the clouds are. For all the above effects on Arctic warming it is also important at what time of the year that the emissions occur.

Black carbon is composed of small particles which are a component of $PM_{2.5}$ and are therefore linked to severe effects on human health such as respiratory diseases and reduced life expectancy. Although the final numbers vary between studies and methods, a ballpark assessment is that human exposure to $PM_{2.5}$ around 2010 was linked to ~3-4 million preterm fatalities each year globally (World Health Organization 2014, Lelieveld et al. 2015), of which in Europe ~400 000 – 500 000 (World Health Organization 2014, European Environment Agency 2015, Lelieveld et al. 2015). There are even indications that black carbon might be more toxic than other $PM_{2.5}$ components (Janssen et al. 2011, WHO 2012, Grahame et al. 2014).

Black carbon pollution is transported to the Arctic notably from countries throughout the Northern Hemisphere, including Russia, the US, Canada, the EU and Asia; however, per tonne emitted, emissions sources within or in close proximity to the Arctic are of particular interest. Addressing

emissions of short-lived climate forcers such as black carbon is therefore a problem that often requires local, national and international solutions and response.

Current and future impact and emissions

Globally, emissions of black carbon have been estimated to be 9.5 million tonnes in 2010 (Klimont et al. 2017) and 6.6 million tonnes in 2015 (CCAC 2020). Regionally, emissions from the Arctic Council (AC) countries have been reported to be 730 thousand tonnes in 2013 (Arctic Council 2019). Recent modelling undertaken within the EUA-BCA project shows that emissions from the Arctic Council countries were some 450 thousand tonnes in 2015 (IIASA 2021). Most of the gap between the estimates for 2013 and 2015 is caused by different issues related to what type of particles that are considered as black carbon and geographical coverage of the estimate. For the Arctic Council Observer countries (5 Asian countries including China and India as well as 8 European countries), 2015 emissions are modelled to be some 2.5 million tonnes (IIASA 2021). Emissions are generally considered to be declining, although the trend varies between regions and sectors. Globally, without further policy interventions, black carbon emissions can be expected to decrease to 6.2 million tonnes by 2030 (CCAC 2020). For the Arctic Council countries that report emission projections, emissions are projected to decline with 46% of 2013 levels by 2025. According to model estimates that include all Arctic Council countries, emissions are projected to go down from 450 to 325 thousand tonnes by 2030 (28% reduction from 2015). For the observer countries, emissions are projected to decrease by 39% based on 2015 emission levels, down to 1 500 thousand tonnes by 2030 (IIASA 2021).

The role of different black carbon sources in the Arctic warming impact varies between regions. In the Arctic Council countries, Arctic warming impact of 2010 black carbon emissions are driven mainly by grass and forest fires as well as gas flaring, while in East and South Asia, fuel burning by households and the energy/industry sectors are the largest contributors. For the other non-European countries, grass and forest fires as well as fuel burning by households are most important. On a per tonne emitted basis, emission reductions in the Arctic Council region have higher effect on the Arctic warming than emission reductions in other regions (Sand et al. 2016). A similar picture is shown for future scenarios and the projected region-specific technical emission reduction potentials (Kühn et al. 2020). Regarding transport emissions, it has been shown that in 2010, on-road diesel black carbon emissions from Europe were most important for Arctic warming, while Russian black carbon emissions had the highest warming impact per tonne emission. However, scenario analysis indicates that by 2050 on-road diesel black carbon emissions from East Asia and the Middle East can become the most important with respect to their impact on Arctic warming (Lund et al. 2014).

Shifting perspectives from warming impact to emissions in absolute values, the EUA-BCA analysis[1] shows that in 2015 the most important emitting sectors in the Arctic Council countries are road transport, households, gas flaring and non-road transport. For the Arctic observer countries, the most important emitting sectors are households, energy/industry and road transport. By 2030, it can be anticipated that road and non-road transport emissions will decrease significantly in the Arctic Council countries. In the Arctic Council observer countries, also household emissions will decrease

[1] It should be noted that the GAINS model used for scenario analysis currently has a restricted definition of anthropogenic grass and forest fires: it includes burning of agricultural waste but does not explicitly include savannah and forest fires. This might lead to lower perceived importance of grass and forest fires for BC emissions than in other studies. For the importance of forest fires, see for example van Marle, M. J. E., et al. (2017). "Historic global biomass burning emissions for CMIP6 (BB4CMIP) based on merging satellite observations with proxies and fire models (1750–2015)." Geoscientific Model Development **10**(9): 3329-3357 10.5194/gmd-10-3329-2017.

significantly. The sectors with highest remaining emissions in 2030 are expected to be households and gas flaring in the Arctic Council countries, and households and waste treatment in the Arctic Council observers (IIASA 2021).

Emissions from shipping are of particular interest in the Arctic (especially in countries such as Russia, Denmark, Canada, Norway, and the US) as melting sea ice is expected to increase shipping in the area and hence local emissions in the Arctic, which may aggravate the long-range pollution that global shipping causes. Black carbon emissions from shipping in the Arctic was about 1 000 tonnes in 2004 (Corbett et al. 2010), 1 500 tonnes in 2015, or some 0.7% to 1.1% of anthropogenic black carbon emissions in 2015 (Comer et al. 2017, ICCT 2017). The emissions are expected to be in the range of 1 500-2 100 tonnes in 2025 (ICCT 2017). Older estimates indicated a growth in emissions from 1 000 tonnes in 2004 to 2 000 tonnes in 2030 and 3 000 tonnes in 2050 (Peters et al. 2011).

In 2017, 165 900 tonnes of black carbon were emitted from open burning on croplands in the Northern Hemisphere (AMAP Forthcoming). In the EU27 plus the United Kingdom, open burning emitted 6 100 tonnes of BC. India (25 700 tonnes), China (23 400 tonnes), the Russian Federation (15 500 tonnes), Ukraine (7 600 tonnes), and the US (5 300 tonnes) are also leading emitters of black carbon from open burning (Figure 1). By 2099, approximately 76% of the boreal zone will have adequate growing degree days for crop production, compared to roughly 1/3 now (Hannah et al. 2020), favourable to wheat and maize production even in parts of West Siberia (Parfenova et al. 2019). Future emissions from open burning in the Northern Hemisphere will likely increase with climate change if burning practices are not curtailed. Open burning of agricultural residues is banned in the EU; in the US and Canada there are limits on open burning derived from policies to improve and manage air quality as well as wildland fire risk. Open burning is also banned in Russia and Ukraine (Hall et al. 2016), but it is not enforced. Adapting and/or enforcing current legislation to incentivise reduction of open burning will need to be central to solutions for this source of black carbon.

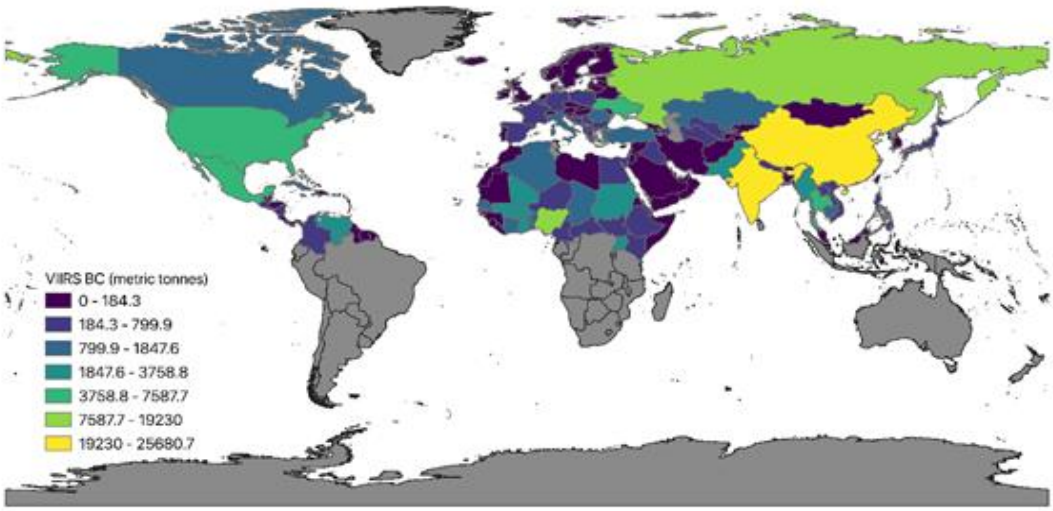

Figure 1: Black carbon emissions in 2017 estimated from 375 m Visible Imaging Infrared Radiometer Suite active fire detections for the countries in and spanning the Northern Hemisphere.

Solutions are available to reduce emissions

Even though emissions from the Arctic Council countries and observer countries are projected to go down significantly from 2015 to 2030, there will remain a technological potential to cut 2030 emissions by more than half. For the Arctic Council countries, the largest technical potential is found for household fuel combustion, gas flaring and agricultural burning. For the observers, the largest technical potential can be found for household solid fuel consumption (cooking and heating) and waste management (IIASA 2021). More specifically, the technical potential for households in the Arctic Council countries pertain mostly to using newer stoves and when applicable wood pellet stoves and boilers. For larger boilers used in the service and other sectors even electrostatic particle filters can be applied. A report prepared by Carbon Limits for the EUA-BCA, which will be published in 2021, gives more details on solutions available to reduce emissions from household fuel combustion. Other analysis shows that a full implementation of these advanced technologies in the 15 European countries can reduce the Arctic warming induced by household wood combustion by 85% compared to 2016 (Seay et al. 2020). Reducing emissions from gas flaring can be undertaken by reusing gas to produce electricity instead of flaring. A recent report produced by Carbon Limits for the EUA-BCA gives more details on best available technologies to reduce emissions from gas flaring (Saunier et al. 2019).

For the Arctic Council observer countries, the most effective technologies relate to speeding up the introduction of clean-burning coal and fuelwood stoves. Examples are fan-assisted wood cooking stoves, new efficient clean burning heating stoves, and pellet heating stoves and boilers. To reduce emissions from waste, the main solution is to improve waste management schemes (collection, recycling and composting) and to reduce uncontrolled open waste burning so that only non-recyclable materials are incinerated in well-controlled waste incineration plants.

Emissions from open burning of agricultural residues could be reduced by introduction of new equipment, agricultural extension services, market development for excess straw and residues, and financing for transition to fire-free agriculture. Reducing and potentially eliminating open burning means that farmers would be improving air quality, reducing climate impacts, and being good neighbours – a strong message for public outreach and agricultural education and extension campaigns. A combination of technological, management and practice, and policy changes can reduce open burning emissions while also building a narrative of farming communities contributing to solutions for reducing black carbon.

Engaging the public-private sector partnerships that target producer and consumer behaviour can reduce burning practices. For example, organic certification processes[2] could be expanded to include prohibition of crop residue burning, providing a market-based incentive to reduce burning and a third-party certification process for farmers to plan alternatives to burning integrated with organic farming practices. Similarly, labelling foods that have been produced "fire-free" would align with current global consumer preference for labelling genetically modified foods (Wunderlich and Gatto 2015). Labelling "fire-free" foods does not cost farmers (unlike potentially organic certification) and would be a low-cost burden on food companies, distributors, and/or grocery stores.

There are several options to reduce black carbon emissions from shipping in the Arctic. Some of the options include fuel shifts from heavy fuel oil to either distillate fuels or to the even cleaner liquid natural gas, using diesel particulate filters or electrostatic precipitators to clean engine exhaust, or

[2] Such as European Council Regulation (EC) No 834/2007, Commission Regulations (EC) No 889/2008 and No 1235/2008

using battery technologies or hydrogen fuels to avoid combustion completely (IMO 2015, ICCT 2019). The reduction potential strongly depends on the adopted technology mix. A switch to natural gas and use of scrubbers are the main solutions using currently available technology (Kuittinen et al. 2021). Some of the solutions can reduce black carbon emissions from an individual ship by 90% or more. But there are risks for trade-offs attached to some solutions, such as the fuel shift to liquid natural gas, which with current technology is associated with increasing methane emissions.

Earlier studies have been pointing to the transport sector among primary reduction targets (e.g. Bond (2004), UNEP and WMO (2011), Shindell et al. (2012)), specifically diesel engines. While this sector is still an important source of BC, the existing legislation in most Arctic Council as well as Observer countries requires application of diesel particulate filters on both cars and heavy-duty trucks leading to effective reduction in the next decade. However, diesel particulate filters requirements are not yet as widespread for non-road machinery. In several countries such legislation is not in place yet, offering an effective mitigation opportunity since the technology is well established. Another black carbon reduction strategy for diesel engines is elimination of so called "high-emitting" vehicles that represent a small fraction of the fleet but a major part of emissions. Introducing regular inspection and maintenance programmes and ensuring their strict enforcement, including pulling over of vehicles that smoke, would offer important reductions.

Thousands of diesel generator sets are in use across the Arctic (used in households, commercial entities, as electricity generators in communities not connected to the grid) and especially in South Asia where individual households, as well as commercial and public companies, own millions of them. Knowledge about the absolute numbers, their capacity utilisation, fuel consumption, and black carbon emissions, is incomplete. While stationary generators do not represent a large share of total black carbon emissions at a large regional scale, they are important contributors locally and thus have important health implications.

All in all, there are ample opportunities to reduce black carbon emissions affecting Arctic warming, and if doing so, human health would be significantly improved. If the Arctic Council countries would implement best available technologies to reduce black carbon emissions by 2030, the number of annual premature deaths due to $PM_{2.5}$ exposure could be reduced by 329 000, approximately 9% of the global total (Kühn et al. 2020).

International engagement with the challenges

There are several international initiatives that in one way or another address black carbon emission. The Arctic Council has agreed on an indicative non-binding target to reduce emissions. The United Nations Economic Commission for Europe (UNECE) Air Convention (official name: Convention on Long Range Transboundary Air Pollution – CLRTAP) and its Gothenburg Protocol include binding commitments to reduce emissions of black carbon as part of $PM_{2.5}$ emission reduction commitments. The Climate and Clean Air Coalition (CCAC) and several other transboundary organisations have identified the reduction of black carbon emissions as a priority.

The Arctic Council is an international forum promoting cooperation in the Arctic consisting of eight Arctic states as members (Canada, Denmark (including Greenland and Faroe Islands) Finland, Island, Norway, Sweden, Russia, and the US); six associations of indigenous peoples as permanent participants; 13 non-Arctic states as observers (eight European countries (six of which are EU-

member states), and five Asian countries which include China, India, South Korea, Japan, and Singapore) as well as intergovernmental and non-governmental organisations. Decisions are taken by consensus and the chairmanship circulates every two years between the Arctic member states.

The UNECE Air Convention is the first broad international treaty to deal with the transboundary environmental problems associated with air pollution. In addition to participants from almost all European states USA, Canada, Russia and Turkey participate in the Convention. It was originally focused on acid rain but over the years, through the establishment of eight protocols, expanded to also cover eutrophication, nitrogen management and ground-level ozone, heavy metals, persistent organic pollutants, $PM_{2.5}$, biodiversity, and human health. The Gothenburg Protocol is the first and, so far, the only international agreement with strict targets that explicitly addresses black carbon emissions.

In 2012 the governments of Bangladesh, Canada, Ghana, Mexico, Sweden and the US together with UNEP formed the Climate and Clean Air Coalition. The CCAC is a voluntary partnership of governments, intergovernmental organisations, businesses, scientific institutions and civil society organisations. Today the CCAC consists of 69 state and 77 non-state partners. The overarching objective of the partnership is to improve air quality and reduce climate change by encouraging actions to reduce emissions of short-lived climate forcers, including black carbon, with an emphasis on developing countries.

The issue of black carbon in the Arctic and its impact on climate change and human health has been a key topic for the Arctic Council. In April 2015 the Ministers of the Arctic Council adopted a framework titled *"Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action"* that outlined approaches for national and collective action to reduce black carbon and methane emissions. The Arctic Council members are committed to report on existing and planned actions to reduce black carbon and methane emissions, on countries' national inventories of these pollutants and, if available, on projections of future emissions. In the 2017 meeting, the Ministers of the Arctic Council member states adopted an expert group report that recommended a collective, aspirational goal to further reduce black carbon emissions by 25-33% relative to 2013 levels by 2025. Observer States have been invited to join the Arctic States in efforts to reduce emissions of black carbon and methane and to submit similar reports on their progress.

The Arctic Council Expert Group on Black Carbon and Methane (EGBCM) reviews, analyses, and assesses progress toward the common vision of the Framework based on a compilation of national reports, relevant output of Arctic Council Working Groups and other information. In its latest report, EGBCM put forward 22 recommendations that, if implemented, would speed up the mitigation of SLCF emissions (Arctic Council 2019). See Appendix for a short summary of the recommendations. Nineteen of these recommendations are directly aimed at black carbon. Further, many of the working groups under the Arctic Council are collecting, summarising and producing state-of-the-art knowledge with respect to black carbon emissions and potential actions to reduce emissions. For example, the Arctic Monitoring and Assessment Programme (AMAP) is producing a SLCF assessment report, including black carbon, by May 2021, which the EUA-BCA is contributing to with scenario analyses. In addition, several of the working groups are participating actively in other international initiatives to provide input and support to their initiatives to reduce black carbon emissions – for example, the working group Protection of the Arctic Marine Environment (PAME) attends meetings of the International Maritime Organization (IMO) and the Arctic Contaminants Action Program (ACAP) has initiated actions for piloting emission reductions in many locations and organised discussions on policies aiming at sector specific reduction of emissions.

The Air Convention's approach to black carbon is based on parties prioritising $PM_{2.5}$ emission reduction that result in large concomitant reductions of BC. One of the pollutants regulated in the amended Gothenburg protocol is $PM_{2.5}$, and in the protocol, it is expressed that national efforts to reduce emissions of $PM_{2.5}$ should give priority to measures that also reduce emissions of black carbon. In 2019 the fifth joint session of the Steering Body of the Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) and the Working Group on Effects (WGE) arranged a joint thematic session on black carbon in inventories, monitoring and modelling. To support the parties with prioritising $PM_{2.5}$ emission reduction that also reduce BC, two guidance documents have been prepared by experts and submitted to the Air Convention for adoption in December 2021.[3] The documents have been produced by the Air Convention Task Force on Techno-Economic Issues, Task Force on Integrated Assessment Modelling and the Task Force on Reactive Nitrogen. Input has also been provided by the International Cryosphere Climate Initiative and fire experts.

The CCAC initiatives to reduce emissions of black carbon are less formalised than those of the Arctic Council. The primary focus can be said to lie on expanding the knowledge base regarding black carbon and supporting actions in developing countries (Khan and Kulovesi 2018). Beginning in 2015, CCAC-funded demonstration projects in India and Peru led to community-level reduction of open burning from farmer-led initiatives.[4] The CCAC scientific advisory panel in 2018 recommended developments of black carbon emission inventory guidance and emission inventory databases, as well as support and coordination of inventories and research.

This section has focused on the Arctic Council, the CCAC and the Air Convention; however, there are other types of initiatives that should be mentioned. Although characterised as a National authority in this report, the European Union with its revised National Emission reduction Commitments Directive (EU NECD) has adopted the same focus as the Air Convention on black carbon and has set stricter $PM_{2.5}$ emission reduction commitments from 2030 and beyond, which should lead to emission reduction of BC. These commitments are set for the EU-states but have wider impact as cooperation activities with accession countries in western Balkan support fulfilment of EU-law.

The World Bank is an international financial institution made up of 189 member countries. With traditional loans, interest-free credits and grants to developing projects and governments of low- and middle-income countries, the World Bank aims to reach two goals: to end extreme poverty and to promote shared prosperity in a sustainable way. The World Bank is via the engagement in the Zero Routine Flaring by 2030 Initiative under the Global Gas Flaring Reduction partnership also engaged in controlling black carbon emissions.

The Intergovernmental Panel on Climate Change (IPCC) is the scientific body summarising existing knowledge on climate change and providing decision support material to the UNFCCC. In May 2019 the IPCC decided to establish methodologies for emission inventories of short-lived climate forcers including black carbon. The 2015 UNFCCC Paris Agreement includes the obligation to report nationally determined contributions (NDCs). Since it is possible to report emission reductions of black carbon as means to reach the Paris Agreement, it is possible for Parties to strengthen global action to enhance black carbon emission reductions with benefits to the Arctic region through the Paris Agreement.

[3] Available at https://unece.org/environmental-policy/events/working-group-strategies-and-review-fifty-ninth-session
[4] https://ccacoalition.org/en/resources/addressing-agricultural-sector-open-burning-results-and-lessons-learned-ccac-no-burn

One of the specialised agencies of the United Nations, it is also important to note the IMO. The IMO is responsible for measures to prevent pollution from ships beside the responsibility to improve the safety and security of international shipping. Within the IMO, the Marine Environment Protection Committee (MEPC) deals with all issues on marine environment protection related to shipping, and the Sub-Committee on Pollution Prevention and Response reports to the MEPC. The IMO in the Sub-Committee on Pollution Prevention and Response is currently discussing options to reduce black carbon emissions from shipping.

Finally, there are several states with national programmes to reduce emissions of short-lived climate forcers, including black carbon.

The aim of the work leading to this report

Given the variability of ways to reduce emissions and existence of national and international organisations that can drive policies, it is appropriate to focus on how to move forward and increase the efforts to reduce black carbon emissions affecting the Arctic. The objective of the work leading to this technical report on actions to reduce black carbon emissions, and the connected EUA-BCA Policy landscape report, is to ensure the greatest possible uptake of the EUA-BCA output to support policy initiatives under relevant national and international initiatives, including future work to continue action on black carbon. Here we present relevant and ambitious ways to reduce emissions and to monitor the effects of initiatives.

We have strived to expand on existing recommendations from reports and other literature and make the description of actions transparent with respect to *why* the action is worth considering, *what* the action entails (mainly from a technical/scientific perspective), *who* the stakeholders with agency over the action are and *when* in time the action is applicable. To a minor extent we've also tried to identify barriers and opportunities for the actions and the agenda items. This report is thereby primarily a support document to the EUA-BCA Policy landscape report but should also be a suitable support to discussions on ways forward for Arctic black carbon policies between technical experts of the Arctic Council, the Air Convention, the CCAC, the European Union, national governments and other international initiatives.

From technical actions to mapping the policy landscape

The work leading up to this report has consisted of three main parts. The first part has been to identify actions available to reduce black carbon emissions with high effect on the Arctic, including actions required to verify effects of policy initiatives. This has been done partly through our own earlier studies within the project and partly by literature review. The second part has been to identify key policy-oriented questions that need to be answered in order to qualify how the actions can be part of a policy landscape. This has been done mainly via informal interviews with stakeholders and by studying the format of other similar documents. The third part of the work has consisted of arranging stakeholder consultations throughout the project duration. The first scoping workshop was arranged in Stockholm in October 2019 and the second in a web-format in June 2020. Prior to finishing the EUA-BCA Policy landscape report, we presented the summary of this technical report and the policy landscape work at the Northern Dimension forum in November 2020 and submitted

an informal document for comments to the Air Convention Working Group on Strategies and Review that met in December 2020.

The work presented here and in the EUA-BCA Policy landscape report, has focused on identifying ways to reduce effects of black carbon in the Arctic, not to make recommendations on which ways that are better than others. The actions and mapped policy landscape are thereby to be considered as indicative, and the report serves more as a glossary or guidebook for interested policymakers and technical experts.

Delimitations of this report

Compiling and synthesising useful information on actions that directly or indirectly would reduce the problem with black carbon in the Arctic requires framing of information and delimitation of scope. The information presented on the actions is not exhaustive. First, the report is not based on a SWOT[5] analysis or an analysis of barriers and opportunities. This implies that political, economic, administrative, or even public opinion obstacles to implementing the actions often remain to be analysed.

Second, when presenting actions, the report mainly focuses on physical, technical and policy aspects. Legal and economic aspects are not in focus for this report. In order to be realised, several of these actions do require legislative action, but changing law is a subsequent step of implementing these actions, a step that in cases might be facilitated by increased coordination between stakeholders.

In this report the geographical / jurisdictional scope generally ranges between international and national. How to define the jurisdictional scope of organisations based on cooperation between countries is not self-evident and we haven't been able to disaggregate these further in this report. As examples, the Arctic Council is an international organisation but has a geographically determined membership structure, whilst the IMO is an international organisation that nevertheless allow some member countries enforcing stricter rules on international waters in their immediate proximity. We recognise that large countries such as Canada, the Russian Federation, and the United States of America are constituted of Provinces/Okrugs/States with varying degrees of jurisdictional autonomy, including over environmental legislation. Also, in smaller countries, sub-national regions and municipalities may have some independent regulatory power in terms of pollution control. When we have indications on actions being suitable for provinces/okrugs/state jurisdiction we indicate this by the term 'sub-national'. Further, the jurisdictional scope of the EU is in this report considered to be 'national'.

The cost-effectiveness of the options is for many actions already assessed with the GAINS model analysis made elsewhere in the EUA-BCA project. For other actions it might be necessary to conduct complementary economic analysis. Finally, the target years for the actions vary, which is only natural given the wide variety in the nature of the actions.

[5] Strengths, Weaknesses, Opportunities, Threats

Description of possible actions

Given the varying nature of the action areas and the need for structure we have developed report-specific terms to facilitate understanding. Each area of action is composed of separate actions which in turn may be composed of components. Further, the actions are characterised by type of intervention, time horizon, jurisdictional scope, primary policy forum, societal impact, and degree of evidence.
We consider six different types of interventions:

- *Non-binding/diplomatic policy statements* that guide actors on future goals. This type of intervention includes soft measures such as formulating ambitions, strategies and recommendations without necessarily making legal requirements.
- *Regulation/legislative proposals* that put demands on actors to make technical improvements. This second intervention includes development of national legislation on technical standards or emission limit values as well as establishment of international agreements of some sort. These agreements can be in the shape of technical annexes to existing protocols, amendments of existing agreements, etc.
- *Economic incentives* for forerunners / disincentives for laggers. This group includes all types of economic instruments available to steer desirable behaviour. Examples are investment subsidies, emission taxes, tax rebates for frontrunners, etc.
- *Information and guidance* to change practice. This group contains soft interventions such as information campaigns, information videos, education opportunities, etc.
- *Funding of research, independent analysis and innovation*. This intervention relates to steering research funds into the direction needed to reduce emissions or facilitate improved coordination of black carbon action in the Arctic and emission reductions.
- *Establishment and improvements of monitoring and inventories* that strengthen the knowledge base. This final group of interventions includes actions and components that serve to improve the understanding of the problem and the solutions available mainly through collection of data/information (as in contrast to group 5, where both methodology, methods and data might be missing).

These interventions can differ in jurisdictional scope: international, national or sub-national. The classification of actions per jurisdictional scope is just indicative given the varying organisation of the countries included in the analysis. Related to this, the actions can vary with respect to whether they are especially suited for one specific policy forum or several. The actions can be achievable within two different time horizons: after five years (short-term) or after a longer period (medium-term, long-term). They can also have small or large societal impact: either implying large structural changes in society (such as abandoning the use of combustion technologies for electricity production and mobility). When this is the case, the action is classified as having transformative societal impact, when not – as having incremental societal impact. Finally, there are differences in the amount of studies available that focused on the impact of the considered action on black carbon in the Arctic. We indicate the degree of evidence with reference to key literature supporting the action. If there are no such studies, we use the term Not Estimated (N.E.). If the action can't be analysed with existing science for impact assessments, we indicate this with the term Not Applicable (N.A.).

Several of the actions presented here are closely linked to recommendations proposed by the EGBCM in 2019 (Arctic Council 2019), see Appendix 1. When this is the case, we indicate the EGBCM recommendation number. For these actions the ambition is that our descriptions of the actions are

more detailed than in Arctic Council (2019), thus facilitating potential uptake of ideas presented both by EGBCM and in this report.

The rest of this chapter presents the results for the areas of action in the following order: In situ observations of black carbon in the Arctic, Black carbon emission inventories, Gas flaring, Small-scale domestic heating, Shipping, On- and off-road engine and Open biomass burning. There are some actions that are presented within an emission sector area of action while having a general policy nature. This placement in the text is due to readability.

During spring 2021 we aim to update the project web site so that these actions can be filtered based on type of intervention, time perspective and applicable policy fora. Please see the project website by the end of May 2021 (https://eua-bca.amap.no/).

Area of Action 1 - *In situ* observations of black carbon in the Arctic

Monitoring of black carbon in the Arctic ambient air is extremely important in the implementation of policies and measures seeking to curb the Arctic impacts of this pollutant. Measurements of black carbon in ambient air and black carbon deposition not only allow monitoring of how much black carbon ultimately reaches the Arctic, but also provide an independent dataset, with which black carbon emissions and atmospheric transport can be inversely modelled. Given that ambient levels of black carbon are generally below what can be reliably monitored via satellite-based remote sensing, in-situ measurement stations are crucial to monitor the spatial and temporal trends across the Arctic domain.

The EUA-BCA technical report *Review of Observation Capacities and Data Availability for Black Carbon in the Arctic Region* (EUABCA 2019a) provided a basis for the development of this area of action. The report indicated that *in situ* monitoring of ambient air black carbon in the Arctic is restricted by a number of factors such as intermittent station/measurement operations, lack of stations (particularly in Russia), and insufficient data sharing and coordination.

The four actions identified within this area of action (Table 1) identify opportunities through which black carbon monitoring in the Arctic can be improved. From an Arctic perspective, the ultimate long-term goal to be strived for is: Regular sharing/reporting of black carbon measurement data from an adequate number of Arctic monitoring stations which apply: consistent maintenance and calibration programmes, consistent/ comparable measurement techniques, and data quality control routines.

Action 1.1 highlights paths along which sustainability of existing Arctic stations can be enhanced and through which new stations can be established and sustained. Actions 1.2 to 1.4 have been developed to improve international coordination of black carbon measurements and increase sharing of observation data.

Table 1: Actions within the area In situ observations of black carbon in the Arctic

Action id	**Short Action description**
1.1	International stimulus to mobilise processes at the national level of the Arctic countries to establish and sustain observation stations measuring BC
1.2	Promote further harmonisation of measurement methods and QA/QC procedures applied at long-term stations observing black carbon in the Arctic and the lower latitudes
1.3	Operationalise data sharing, review and dissemination of data from long-term stations measuring BC
1.4	Further incentivise sharing of data from ad hoc /campaign black carbon measurements in the Arctic

Action 1.1: International stimulus to establish and sustain Arctic observation stations measuring BC

Measurement stations located in the Arctic are resource-intensive to establish, operate and maintain. As follows from the technical report (EUABCA 2019a), lack of stations and issues in terms of station sustainability are key factors that restrict black carbon monitoring in the Arctic.

Commitments to international agreements that include requirements or obligations on monitoring, or at least formal encouragement for monitoring, is seen as the best way to secure long-term operation of Arctic monitoring sites. As an example, all Arctic countries are Parties to the Air Convention; however, the protocol concerning EMEP monitoring within the Air Convention applies only to the European countries. This means that the US, Canada and a large part of Russia (east of Ural) are exempt from the EMEP monitoring requirements. Only a part of the Arctic region (Arctic parts of the Nordic countries and European Territory of Russia) is contained within the EMEP domain. As set out in the 2020-2029 EMEP Monitoring strategy (Decision 2019/01),[6] measurements of black carbon at EMEP monitoring stations are mandatory; however, black carbon is listed as a level 2 variable, meaning that *"it is to be measured at a (undefined) subset of sites"* with measurements made at least at one site per country.

It is worth mentioning measurements at background rural locations under the EU Ambient Air Quality Directives, AAQD (Directives 2004/107/EC[7] and 2008/50/EC,[8] Implementing Decision 2011/850/EU[9] and amendments under 2015/1480/EU[10]). Under Article 6, paragraph 5 of 2008/50/EC, it states that *measurements shall be made, at rural background locations away from significant sources of air pollution, for the purposes of providing, as a minimum, information on the total mass concentration and the chemical speciation concentrations of fine particulate matter ($PM_{2,5}$) on an annual average basis* and that *where appropriate, monitoring shall be coordinated with the monitoring strategy and measurement programme of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)*. Under Annex IV of this directive, it clarifies that to characterise $PM_{2,5}$ chemical composition at background rural sites, measurements of elemental carbon (EC) shall be included. While relevant, it should be noted that this legislation (and any future amendments thereof) only applies to EU MS and that *in situ* monitoring of BC in the Scandinavian Arctic is rather conducted by scientific institutions at background stations for the purpose of climate research rather than air quality assessments as per the EU AAQD.

All Arctic countries are also members of the World Meteorological Organization (WMO). The WMO Global Atmosphere Watch (GAW) strategy defines monitoring requirements for a range of species. A key topic for WMO-GAW is aerosols, and most Arctic stations are currently reporting their black carbon data to GAW and making them available through the GAW-World Data Centre for Aerosols.[11]

So, integration areas for enhanced international cooperation and action on black carbon monitoring in the Arctic exist. However, the multi-pollutant character and specific geographical scopes of the Air Convention-EMEP, the EU AAQD and WMO-GAW can limit the required focus on the Arctic

[6] https://www.unece.org/fileadmin/DAM/env/documents/2019/AIR/EB_Decisions/Decision_2019_1.pdf
[7] https://eur-lex.europa.eu/eli/dir/2004/107/oj
[8] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008L0050
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011D0850
[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2015_226_R_0002
[11] https://www.gaw-wdca.org

and on BC. New impulses beyond these programmes will be required to improve the state of in situ black carbon monitoring in the Arctic.

The Arctic Council is the most obvious forum for enhancing international cooperation on Arctic black carbon observations. It is in the territories of the AC Member countries where the extent and sustainability of in situ black carbon monitoring needs to be increased. Under AC, the AMAP has the mandate and responsibility for monitoring and assessing environmental pollution issues, using obtained information to provide scientific input to policymaking. The AMAP working group could therefore be key to enhancing black carbon monitoring in the Arctic.

At present, although the AMAP monitoring programme coordinates Arctic monitoring of greenhouse gases and air pollutants in the atmosphere, assessment of these data is conducted only periodically. This lack of regular review of Arctic observation data means that during the intervals between assessments, coordinated long-term monitoring effort in the Arctic region relies mainly on national activities and on voluntary data reporting to programmes such as EMEP, GAW and AMAP. Work under the EUA-BCA has illustrated that this can lead to a situation where reported data quality control is not sufficient, and thus the data may be unsuitable for inter-comparisons and as supporting material for policy initiatives.

An extension and enhancement of the existing AMAP monitoring activities to include, e.g. a regular update of data products summarising the results of long-term Arctic monitoring for BC, may provide impetus for a more coordinated monitoring effort in the Arctic region and improved quality assurance of available data. Implementing such an initiative would be consistent with the AMAP's current strategy, AMAP Strategic Framework 2019+,[12] and would also support implementation of the AC's *Framework for Enhanced black carbon and methane emissions reductions: An Arctic Council Framework for Action*. The Arctic Council's Framework text[13] reflects the Arctic states' intention *"to sustain and, as appropriate, expand their own existing activities and capabilities to monitor levels of black carbon and methane in the Arctic"*. Implementing the AC Framework is in the mandate of the EGBCM that was established with the inception of the Framework. Nevertheless, there is scope for AMAP to contribute to this aspect of the Framework as well, given AMAP's overall monitoring mandate within the Arctic Council.

Through *Annex A – Two-year iterative process to enhance implementation*, a continuous assessment process is formally in place for the EGBCM (potentially supported by relevant bodies of the Arctic Council) to review progress made under the Framework. Furthermore, it could be assumed that a follow-up aspirational goal will be proposed for the post-2025 period once the 2025 target expires. Therefore, there is scope for AMAP to consider cooperation with the EGBCM and in 2021-2025 to begin to lay foundations for enhanced Arctic in situ monitoring of black carbon and methane. Such groundwork could be elaborated into a detailed gap analysis (highlighting the importance of monitoring, lack of stations, and critical assessment of AMAP's monitoring implementation strategy) and provide recommendations for enhanced implementation of the Framework. Recommendations could define inter alia an explicit coordinating role of AMAP within the Framework in terms of in situ Arctic monitoring.

Beyond the Air Convention-EMEP, WMO-GAW and AC, enhanced international cooperation through bilateral partnerships and possible EU-funded initiatives could play a significant role in

[12] https://www.amap.no/documents/download/3362/inline

[13] https://oaarchive.arctic-council.org/bitstream/handle/11374/610/ACMMCA09_Iqaluit_2015_SAO_Report_Annex_4_TFBCM_Framework_Document.pdf?sequence=1&isAllowed=y

capacity building that benefits Arctic in situ monitoring by enhancing observation systems and securing reporting of associated data.

National initiatives are also worth noting. Especially critical is lack of observations in the Russian Arctic and mid-latitude parts of the country. One of the key elements within this action is therefore mobilising processes at the national level in Russia to establish and sustain observation stations measuring BC. Russian authorities have drafted plans for increasing national monitoring capability in the Arctic. Also, initiatives under the Russian Academy of Sciences have resulted in new black carbon monitoring activities in the Russian Arctic in recent years. Together, and if realised, these national activities form a basis for filling some of the identified (geographical) gaps in black carbon monitoring networks in the Arctic. However, for this action to maximise circumpolar monitoring, it is crucial that AMAP as far as possible reviews and coordinates the national programmes as set out in AMAP's 2019+ Strategic Framework.

The Russian Chairmanship of the Arctic Council in 2021-2023 may present a timely opportunity for the country to take further action on enhancing black carbon observation stations in the Arctic and sub-Arctic areas. It may further provide a stimulus for continuing leadership on black carbon within the Arctic Council building on the momentum developed under the Finnish and Icelandic AC Chairmanships. The Action *International stimulus to mobilise processes at the national level of the Arctic countries to establish and sustain observation stations measuring black carbon* is summarised in Table 2.

Table 2: Summary information for the Action International stimulus to mobilise processes at the national level of the Arctic countries to establish and sustain observation stations measuring BC

Area of Action	*In situ* observations of black carbon in the Arctic
Action	International stimulus to mobilise processes at the national level of the Arctic countries to establish and sustain observation stations measuring BC, starting with an investigation of the options though which in situ monitoring of black carbon can formally be enhanced within the AC framework
Type of intervention	Information and guidance
Time perspective	Long-term with preparatory work in short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International Air Convention: EMEP centers and task forces AC: AMAP and EGBCM
Evidence	N.A.

Action 1.2: Harmonise measurements and procedures for stations observing black carbon in the Arctic

Methodological comparability between stations within and outside the Arctic is fundamental. Establishing monitoring infrastructures requires significant resources, and there is a need for knowledge transfer and scientific collaboration to secure adequate observational data and interpretation of results. European scale infrastructure efforts like the Aerosol, Cloud, Trace gases Research Infrastructure would be highly relevant.

If AMAP enhances its role as coordinator of Arctic black carbon measurements, it may consider strengthening working relationships with EMEP Task Force on Measurements and Modelling (TFMM), WMO and the Aerosol, Clouds, Trace Gases Research Infrastructure in terms of quality and inter-comparability of black carbon observation data. Such cooperation is indeed explicitly stated in the current strategy documents of AMAP and EMEP and could ensure consistent operating and reporting recommendations. Furthermore, cross-programme cooperation could allow promotion and utilisation of the reporting and data structures already in place within the EMEP TFMM and the WMO – this would prevent a scenario where data have to be reported twice. The Action *Promote further harmonisation of measurement methods and QA/QC procedures applied at-, and subsequent data sharing from long-term stations observing black carbon in the Arctic and the lower latitudes* is summarised in Table 3.

Table 3: Summary information for the Action Promote further harmonisation of measurement methods and QA/QC procedures applied at long-term stations observing black carbon in the Arctic and the lower latitudes

Area of Action	*In situ* observations of black carbon in the Arctic
Action	Promote further harmonisation of measurement methods and QA/QC procedures applied at-, and subsequent data sharing from long-term stations observing black carbon in the Arctic and the lower latitudes through enhanced cooperation between EMEP TFMM, WMO GAW, the Aerosol, Clouds, Trace Gases Research Infrastructure and AMAP on harmonisation of black carbon measurement methods and promotion of data reporting to existing programmes
Type of intervention	Information and guidance
Time perspective	Long-term with preparatory work in short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International AC: AMAP; UNECE Air Convention: EMEP, TFMM; WMO: GAW; EU
Evidence	N.A.

Action 1.3: Operationalise data synthesis, review and dissemination of BC-data from Arctic

Experience shows that attention to data quality is closely linked to efforts associated with data submission, and to the prospects that the data will be subject to external review and synthesis for data interpretation and assessment to further inform policymaking.

AMAP's currently irregular assessment process means that Arctic data reported largely through existing international programmes and/or national initiatives are not subject to regular review or quality assurance at the international level. Data review is conducted within EMEP, though only a subset of Arctic monitoring stations is operating within EMEP's geographical domain.

AMAP could consider, in the mid- to long-term, producing annual data products, for example web-based summaries of data coverage and general statistics/trends. This could better engage the Arctic monitoring community, as well as secure and improve data management efforts (including work at data centres) to ensure availability of data suitable for supporting science-driven policy initiatives. The Action *Operationalise data synthesis, review and dissemination of data from long-term stations measuring black carbon* is summarised in Table 4.

Table 4: Summary information for the Action Operationalise data sharing, review and dissemination of data from long-term stations measuring black carbon

Area of Action	*In situ* observations of black carbon in the Arctic
Action	Operationalise data synthesis, review and dissemination of data from long-term stations measuring black carbon through establishment of a regular AMAP programme for the review and assessment of black carbon measurements in the Arctic
Type of intervention	Information and guidance
Time perspective	Long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International AC: AMAP
Evidence	N.A.

Action 1.4: Further incentivise sharing of data from campaign black carbon measurements in the Arctic

The EU-funded technical report *Review of Observation Capacities and Data Availability for Black Carbon in the Arctic Region* (EUABCA 2019a) highlights differences between observations conducted as part of long-term sustained monitoring systems and those resulting from measurement campaigns and ad-hoc research projects. The potential utilisation of data from the research projects can be compromised by lack of incentive for project coordinators and co-researchers to share data and to

make them available for purposes beyond the immediate objectives of the research project. Research data publication in e.g. journal articles can involve significant delays to data availability, and typically data are reported in an aggregated form that is not suitable for other purposes (such as combining data from different sources).

AMAP could consider exploring mechanisms that incentivise and stimulate data sharing. By formally committing to share the data, researchers proposing relevant Arctic measurements would improve their chances to secure funding. To implement this, AMAP may consider a proposal endorsement mechanism that is contingent on subsequent data sharing and/or working with relevant national and international funding agencies to explore how explicit data sharing instructions could be included in the funding requirements. In addition to stimulating data sharing, proper coordination of shared data is essential. AMAP could therefore consider how the above options can explicitly encourage the use of existing data sharing databases and initiatives (e.g., EBAS)[14] to ensure that collected data are available, shared and inter-comparable. The Action *Further incentivise sharing of data from ad hoc /campaign black carbon measurements in the Arctic* is summarised in Table 5.

Table 5: Summary information for the Action Further incentivise sharing of data from ad hoc /campaign black carbon measurements in the Arctic

Area of Action	*In situ* observations of black carbon in the Arctic
Action	Further incentivise sharing of data from ad hoc /campaign black carbon measurements in the Arctic through AMAP project endorsement at proposal stage to secure sharing of the data in future
Type of intervention	Information and guidance
Time perspective	Long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International AC: AMAP
Evidence	N.A.

[14] http://ebas.nilu.no/

Area of Action 2 - Black carbon emission inventories

Monitoring of emissions constitutes a fundamental element in the implementation of climate change and air pollution abatement policies and measures. Emissions inventories and systems that facilitate and ensure reporting of national inventory data provide both a baseline for developing emissions reduction targets and a transparent gauge for monitoring individual and collective progress toward those targets.

The EUA-BCA technical report *Review of Reporting Systems for National Black Carbon Emissions Inventories* (EUABCA 2019b) provided a basis for the development of this area of action. The report highlighted that many EU-, Arctic Council- and Air Convention countries are reporting national black carbon emissions. While the level of emission reporting is encouraging, the report concluded that there is substantial room for improvement. Several potentially significant emitters, whose emissions impact the Arctic, do not report black carbon emissions data to the respective institutions of the Air Convention and the Arctic Council. Furthermore, the report identified transparency, consistency, comparability, completeness and accuracy issues in the inventories that have been reported.

The six suggested actions identified within this area of action (Table 6) identify opportunities through which the international exchange of national black carbon emissions inventories can be improved. From the perspective of the Arctic, the ultimate long-term goal to be strived for in terms of black carbon emissions reporting is: Regular compilation and reporting of national black carbon inventories which are of high quality in terms of transparency, consistency, comparability, completeness and accuracy by all countries whose black carbon emissions (significantly) impact the Arctic.

Actions 2.1 to 2.3 highlight paths along which the number of countries that compile and report black carbon emissions inventories can be increased, while Actions 2.4 to 2.6 have been developed to increase transparency, consistency, comparability, completeness and accuracy of reported black carbon inventories. It is, however, important to note that certain components may contribute to more than one action and thus contribute to both increasing the number of countries reporting black carbon and increasing the quality of reported emissions.

Table 6: Actions within the area black carbon emissions inventories

Action id	Short action description
2.1	Mobilise further voluntary compilation and reporting of black carbon inventories under EU NECD, AC Framework and the Air Convention
2.2	Mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE
2.3	Lay foundations for potential future changes in black carbon emissions reporting requirements
2.4	Improve methodological guidance and external support for black carbon inventories
2.5	Promote further harmonisation of black carbon emissions reporting formats
2.6	Enhance in-depth independent review mechanisms for reported black carbon emissions

Action 2.1: Mobilise further voluntary compilation and reporting of black carbon inventories in EU, AC and UNECE

The technical report on emissions reporting (EUABCA 2019b) highlighted that a large number of countries are reporting black carbon emissions inventories to the EU, AC and/or the Air Convention – however, not all. As of 1 June 2020, Albania, Austria, Bosnia and Herzegovina, Liechtenstein, Luxembourg, Russia, and Turkey have not yet reported estimates of national black carbon emissions under the Air Convention.[15] Furthermore, as documented by annual Centre on Emission Inventories and Projections (CEIP) reviews,[16] several of the Air Convention Parties are not reporting their black carbon inventories regularly.

Under this action, mobilising voluntary black carbon reporting by Russia under AC Framework and the Air Convention should be prioritised, given the country's proximity, scale of black carbon emissions (estimated independently, e.g. Klimont et al. (2017)) and geopolitical influence. To date, Russia has only reported black carbon emissions during one reporting cycle of the AC Framework. Under the Air Convention, no black carbon emissions from Russia have been reported so far. To improve frequency and quality of black carbon emission inventories in countries like Russia, capacity-building activities, addressed in Component 7.1a, are crucial. Another important issue is dialogue with Asian countries (China, India and Singapore) regarding barriers they face in reporting national black carbon emissions – this aspect is considered in Component 2.1b.

Component 2.1a. Emission inventory capacity-building

Often, non-reporting or irregular reporting indicates a lack of capacity in the respective countries, an issue that could be addressed via capacity-building endeavours. A number of Western Balkan-

[15] https://emep.int/publ/reports/2020/EMEP_Status_Report_1_2020.pdf

[16] https://www.ceip.at/ceip-reports

and EECCA[17] countries do not report black carbon emissions under the Air Convention or do so irregularly. However, capacity-building to enhance general implementation of the Convention does take place,[18] and in the 2010 the Executive Body Decision 2010/17 established a specific Coordinating Group to help foster implementation of the Convention in the EECCA countries.[19] The overall framework for capacity-building (tasks and responsible legal bodies (i.e. the Working Groups, Centres and Task Forces of the Convention)) are agreed upon at the Executive Body meetings and outlined in the work plan for implementation of the Convention. The critical issue of resources is agreed between the UNECE Secretariat, the EECCA Coordinating Group and, crucially, the donating Parties.

Providing support to emission reporting through international workshops or in-country assistance has been one of three main activities undertaken by the Convention's capacity-building programme[20] and could be potentially used to improve the level and quality of black carbon emissions inventories reported under the Air Convention. According to the Convention's Long-term strategy for 2020-2030,[21] *"capacity-building under the Convention should be enhanced"* and *"mutual outreach to and information-sharing with organisations such as CCAC, the Arctic Council"* should be built upon by *"continuing to leverage synergies between their work and the work of the Convention"*. There is therefore scope for cooperation between the Air Convention, Arctic Council and the CCAC on capacity-building to help establish and improve national black carbon emissions inventories, should resources be made available.

With respect to Western Balkan and EECCA countries, there is also scope for the EU to intervene via IPA[22]/TAIEX[23] capacity building instruments that aim to help the beneficiary countries in compiling national greenhouse gases and air pollution inventories. Future tenders could be designed so that greenhouse gases and air pollutant inventories are integrated and include black carbon submodules. Opportunities also exist for strengthening international and bilateral cooperation on emissions inventories undertaken by Parties to the Convention/AC Member and Observer Countries (however, sometimes de facto independent from the top-down impetus of the respective fora). For example, Sweden and Russia are planning to commence a joint project to develop a complete Russian particulate matter and black carbon inventory system, within long-term bilateral cooperation under the Air Convention.[24] The timing of this initiative could be significant given that in 2021 Russia will take over the Arctic Council chairmanship. This may provide a stimulus for renewed Russian reporting under the AC and compilation of black carbon emission inventories under the Air Convention.

Another incentive to increase the reporting of black carbon emission inventories can be to integrate requirements of emission inventories in investment support schemes. For example, the fulfilment of such reporting can be viewed as a criterion when priorities for location of new Arctic Council pilot projects are set. Linking the fulfilment of reporting tasks to decision-making processes on localisation of funding and pilot projects may as well generate new Arctic Council working groups and make

---

[17] EECCA (Eastern Europe, Caucasus and Central Asia) includes the following 12 countries: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan. All of them except three countries (Tajikistan, Turkmenistan and Uzbekistan) ratified the Air Convention.
[18] http://www.unece.org/environmental-policy/conventions/envlrtapwelcome/capacity-building.html
[19] http://www.unece.org/fileadmin/DAM/env/documents/2010/eb/eb/eb%20decisions/Decision_2010.17.e.pdf
[20] http://www.unece.org/fileadmin/DAM/env/lrtap/Publications/20191003-CAPACITY-BUILDING-DIGITAL-PAGE-EN.pdf
[21] http://www.unece.org/fileadmin/DAM/env/documents/2018/Air/EB/correct_numbering_Decision_2018_5.pdf
[22] Instrument for Pre-Accession Assistance (IPA), https://ec.europa.eu/regional_policy/en/funding/ipa/
[23] the Technical Assistance and Information Exchange instrument of the European Commission (TAIEX), https://ec.europa.eu/neighbourhood-enlargement/tenders/taiex_en
[24] https://www.rusaco.se/

existing groups to even better coordinate and support each other's work. The Component *Emission inventory capacity-building* is summarised in Table 7.

Table 7: Summary information for the Action Mobilise further voluntary compilation and reporting of black carbon inventories under EU NECD, AC Framework and the Air Convention, Component Emission inventory capacity-building

Area of Action	BC emissions inventories
Action	Mobilise further voluntary compilation and reporting of black carbon inventories under EU NECD, AC Framework and the Air Convention
Component	Emission inventory capacity-building
Type of intervention	Establishment and improvements of monitoring and inventories Information and guidance
Time perspective	Short-term (ongoing capacity building)
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National EU, AC, CCAC, UNECE Air Convention, national environmental authorities
Evidence	N.A.

Component 2.1b. Dialogue with China, India and Singapore on barriers to reporting national black carbon emissions

It is worth to note that some of the AC observer countries are neither Parties to the Air Convention nor Member States of the EU. Reporting of black carbon emissions by China, India, Japan, Singapore and South Korea is thus only recommended under the AC Framework. So far, only Japan and South Korea have reported black carbon emissions estimates in their summary reports to the AC secretariat. The Arctic Council's EGBCM may thus wish to engage, e.g. through its working and expert groups, with China, India and Singapore in order to identify the barriers currently stopping these countries from reporting black carbon emissions under the AC Framework. The Component *Dialogue with China, India and Singapore on barriers to reporting national black carbon emissions* is summarised in Table 8.

Table 8: Summary information for the Action Mobilise further voluntary compilation and reporting of black carbon inventories under EU NECD, AC Framework and the Air Convention, Component Dialogue with China and India on barriers to reporting national black carbon emissions

Area of Action	BC emissions inventories
Action	Mobilise further voluntary compilation and reporting of black carbon inventories under EU NECD, AC Framework and the Air Convention
Component	Dialogue with China, India and Singapore on barriers to reporting national black carbon emissions
Type of intervention	Establishment and improvements of monitoring and inventories Information and guidance
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International AC: EGBCM, national authorities among AC Observer countries
Evidence	N.A.

Action 2.2: Mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE

BC emissions from countries outside the EU, AC and UNECE have an impact in the Arctic as well. Furthermore, with black carbon being a significant SLCF, it can be argued that beyond international air pollution agreements, black carbon should be embedded within the UNFCCC/Paris Agreement. Potential inclusion of black carbon in NDCs submitted under the Paris Agreement is considered in Component 2.2a. Component 2.2b highlights need for continued scientific synthesis of climate impacts of BC.

Component 2.2a. Inclusion of black carbon in NDCs submitted under the Paris Agreement

Within the UNFCCC, the landmark agreement on combating climate change is the Paris Agreement, reached at Conference of the Parties COP 21 in 2015.[25] At COP 24 in 2018 in Katowice, a decision on the modalities, procedures and guidelines (MPGs) for the transparency framework for action and support referred to in Article 13 of the Paris Agreement[26] was agreed. This decision with a purpose to establish a robust reporting and review system, made no mention of black carbon; thus, potential reporting of black carbon under the Paris Agreement is currently not foreseen. However, the Paris

[25] https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf
[26] https://unfccc.int/sites/default/files/resource/CMA2018_03a02E.pdf

Agreement and the so-called enhanced transparency framework will develop over time, and therefore this component may lay foundations to enable formal black carbon emissions reporting under the Paris Agreement in the future (after 2030).

As an international agreement, the Paris Agreement is built as a bottom-up system in certain important aspects. The submission of the NDCs reflects this, as the agreement does not prescribe these contributions for each Party in a top-down approach. NDCs, where Parties describe the effort, they offer to contribute to the collective response to climate change, are prepared, communicated and maintained by the Parties themselves. A small number of countries included black carbon to different extents in their first NDCs. Countries may continue and further elaborate black carbon issues in upcoming NDCs.[27] If indeed a substantial number of countries are seeking to make their climate change mitigation contribution through black carbon emissions reductions and communicate this action in their NDCs, these countries may exercise the potential option of including black carbon emission trends in their Biennial Transparency Reports.

Since recently agreed MPGs made no mention of BC, it is not possible for the Parties to include black carbon emissions data in their annually/biennially[28] submitted National Inventory Documents or accompanying Common Reporting Tables. However, there will probably be scope for Parties to report trends in national total black carbon emissions within so-called tracking of progress tables foreseen as part of Biennial Transparency Reports (to be submitted every two years starting at the latest at the end of 2024). Some further clarity can be expected with a COP decision on the Common Tabular Format tables for tracking progress in implementing and achieving NDCs. Such a decision is anticipated in November 2021 at COP 26. Any potential voluntary reporting of black carbon mitigation action and emissions in NDCs as well as Biennial Transparency Reports will be driven by the Parties to the Paris Agreement themselves. Support and coordinated impetus to this process could be provided by international networks of governments and organisations such as CCAC. Within the UNFCCC-PA forum, CCAC has become an influential voice advocating the inclusion of action on SLCFs in NDCs. CCAC undertakes capacity-building missions and has helped several countries to develop national black carbon inventories.

In the UNFCCC negotiations, the details for reporting in the enhanced transparency framework are currently being discussed. In the new transparency framework, all Parties will have to use the 2006 IPCC Guidelines for estimation of their emissions in the inventories. In 2019 the IPCC approved a refinement of the guidelines. Neither of these two documents provides guidance for estimation of black carbon emissions. In the negotiations of the reporting tables, possible inclusion of the 2019 IPCC Refinement is getting pushed back by some Parties. It seems unlikely that there will be great enthusiasm among Developing Country Parties for expanding reporting requirements, even if non-mandatory, to other climate-relevant air pollutants in the near future. The first review of the MPGs (including the reporting tables and methodology) will happen in 2028, and no regular MPG review schedule is agreed so far.

---

[27] NDCs have to be updated every five years and have to represent a progression over time, as specified in Decision 1/CP.21 (https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf). Parties with a time horizon until 2025 (2021-2025) in their first NDCs are requested to communicate a new NDC by 2020 and to do so every 5 years thereafter. Parties with a time horizon until 2030 (2021-2030) are requested to communicate a new or updated NDC by 2020 and to do so every 5 years thereafter.

[28] Annex I Parties under the UNFCCC and the Kyoto Protocol have the obligation to continue to submit annual GHG inventories, regardless if they are Parties or non-Parties to the Paris Agreement. Parties to the PA must use the MPGs for reporting. Developing country Parties submit their inventory together with their BTR biennially. Several flexibilities are granted to those developing countries that need it in the light of their capacities. Furthermore, least developed countries and small island developing states are offered additional discretion in reporting.

In the methodological support of black carbon emission reporting within UNFCCC, IPCC work is crucial. The IPCC's Task Force on National Greenhouse Gas Inventories was in 2020 about to commence preparatory work to develop an IPCC Methodology Report on SLCFs. Due to the COVID-19 pandemic, the expert meetings had to be rescheduled to 2021. The establishment of the expert group on SLCFs and its work on SLCF inventory methodologies over the coming years is very important in terms of providing methodological guidelines for Parties. Necessity of such guidelines will be more obvious if reporting of black carbon emissions becomes an issue of negotiations and is encouraged to be reported under the Paris Agreement transparency framework. As the SCLF expert group is still in the process of being established, drafting of inventory guidelines will not commence until the next IPCC cycle (after 2022). Depending on the IPCC internal elections and on the risk of further delay caused by COVID-19, the Methodology Report can cautiously be estimated to be approved in 2025/2026.

There are several steps and preparatory work before even negotiating the inclusion of black carbon under the reporting of the UNFCCC. The IPCCs AR6[29] and Methodology report on SLCF are important cornerstones on this way in the coming years. The Component *Inclusion of black carbon in NDCs submitted under Paris Agreement* is summarised in Table 9.

Table 9: Summary information for the Action Mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE, Component Inclusion of black carbon in NDCs submitted under PA

Area of Action	BC emissions inventories
Action	Mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE
Component	Inclusion of black carbon in NDCs submitted under PA
Type of intervention	Regulation/legislative proposals (National climate policy)
Time perspective	Short- to long-term: 2020, 2025 and 2030 are the next rounds of submission
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National National authorities, UNFCCC-PA, CCAC
Evidence	N.A.

Component 2.2b. Scientific synthesis of climate impacts of BC

In the quest to mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE, the importance of the IPCC work should be highlighted. The IPCC assessment reports have provided the guiding science on which climate policy is based, and the subsequent assessment reports (e.g. AR6 Synthesis Report due in 2022) will continue to quantify inter alia the radiative forcing of SLCFs including BC. Here it is possible to improve the knowledgebase through

[29] Assessment Report

funding of research. The Component *Scientific synthesis on climate impacts of black carbon* is summarised in Table 10.

Table 10: Summary information for the Action Mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE, Component Scientific synthesis on climate impacts of BC

Area of Action	BC emissions inventories
Action	Mobilise voluntary compilation and reporting of black carbon inventories beyond EU, AC and UNECE
Component	Scientific synthesis on climate impacts of BC
Type of intervention	Funding of research, independent analysis and innovation Establishment and improvements of monitoring and inventories
Time perspective	Ongoing and future assessment cycles of IPCC
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International IPCC
Evidence	N.A.

Action 2.3: Lay foundations for potential future changes in black carbon emissions reporting requirements

Reporting of national black carbon emissions inventories is not legally required under any international treaty/legislation. Compiling and reporting black carbon inventories is formally encouraged under the Air Convention and AC while under EU NECD the reporting of black carbon inventories is conditionally mandatory – i.e., the reporting of black carbon emissions is compulsory if national black carbon inventories are available.

A process towards potential mandatory black carbon reporting would be long. To lay foundations for potential changes in the future, a good starting point would be evaluation of whether the desired level of black carbon reporting is reached within the existing (even though non-mandatory) reporting schemes – under the Gothenburg Protocol (Component 2.3a) and under EU NECD (Component 2.3b).

Component 7.3a. Evaluate whether the amended Gothenburg Protocol produced the desired level black carbon reporting

High level of black carbon emissions reporting has been achieved with international agreements that encourage, rather than oblige, compilation and sharing of the respective data - such as the Gothenburg protocol within the Air Convention. The Convention's Working Group on Strategies and Review will review the amended Gothenburg Protocol, which could in principle initiate a process whereby subsequent draft revisions are developed. These could include specific proposals

for changes in black carbon reporting requirements that build upon suggestions submitted by the Convention's policy review group report during the development of the 2020-2030 Convention strategy.

Even if the amended Gothenburg Protocol would be revised and such a revision enter into force (beyond 2030), any potential change in black carbon reporting requirements would only apply to the Parties that have ratified the revised Protocol. Only a decision by the Executive Body on minimum reporting obligations could facilitate a change of Convention-wide reporting requirements. Such Executive Body decisions normally require consensus among the Parties. Increased capacity-building to enable voluntary reporting of black carbon (Actions 2.1 and 2.2) will be vital in generating consensus on this issue. The Component *Evaluate whether the current Gothenburg Protocol amendments produced the desired level black carbon reporting* is summarised in Table 11.

Table 11: Summary information for the Action Lay foundations for potential future changes in black carbon emissions reporting requirements, Component Evaluate whether the current Gothenburg Protocol amendments produced the desired level black carbon reporting

Area of Action	BC emissions inventories
Action	Lay foundations for potential future changes in black carbon emissions reporting requirements
Component	Evaluate whether the current Gothenburg Protocol amendments produced the desired level black carbon reporting
Type of intervention	Establishment and improvements of monitoring and inventories
Time perspective	Ongoing until 2022
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International UNECE Air Convention: Working Group on Strategies and Review
Evidence	N.A.

Component 2.3b. Evaluate whether EU NECD has produced the desired level of black carbon reporting by EU Member States

Under EU NECD, black carbon emissions reporting is compulsory if national black carbon inventories are available. While the level of reporting is high, as of 2020, Austria and Luxembourg remain the two EU countries yet to report black carbon emissions. The 2025 evaluation of the EU NECD thus provide an opportunity for the European Commission to investigate whether the current legislation is producing the desired level of black carbon reporting by EU Member States. The Component *Evaluate whether EU NECD has produced the desired level of black carbon reporting by EU Member States* is summarised in Table 12.

Table 12: Summary information for the Action Lay foundations for potential future changes in black carbon emissions reporting requirements, Component Evaluate whether EU NECD has produced the desired level black carbon reporting by EU MS

Area of Action	BC emissions inventories
Action	Lay foundations for potential future changes in black carbon emissions reporting requirements
Component	Evaluate whether EU NECD has produced the desired level of black carbon reporting by EU Member States
Type of intervention	Establishment and improvements of monitoring and inventories
Time perspective	Short-term: 2025
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National EU
Evidence	N.A.

Action 2.4: Improve methodological guidance and external support for black carbon inventories

Within this action focused on methodological guidance and external support for the inventories we have identified two components. Component 2.4a addresses potential improvements in the existing guidance documents under the Air Convention and UNFCCC, relevant for black carbon emission inventories. Component 2.4b highlights the need for external support for national experts in applying these methodologies while compiling the emission inventories.

Component 2.4a. Methodological guidance for black carbon emissions inventories

The EUA-BCA technical report on emission inventories (EUABCA 2019b) highlighted deficiencies in the 2016 EMEP/EEA[30] Air Pollutant Emission Inventory Guidebook and the reporting guidelines - such as lack of higher Tier inventory methodologies and outright lack of Tier 1 emission factors for some source sectors. The lack of a clear working definition for black carbon is also an important issue to resolve.

The EMEP/EEA Air Pollutant Emission Inventory Guidebook is normally updated every 3 years; the last update happened in 2019. Impetus from the EMEP is likely needed to give the Task Force on Emission Inventories and Projections (TFEIP) the mandate and allocate resources for substantial updates and improvements in black carbon inventories. Such action will likely need to be elaborated first in proposals for the Air Convention 2-year work plans. An expert group on black carbon within

[30] European Environment Agency

TFEIP has, however, been set up to review current EMEP/EEA Air Pollutant Emission Inventory Guidebook with respect to BC, and to identify priority areas for improvement.

The establishment of the IPPC expert group on SLCFs and its work on SLCF methodologies (see Action 2.2) is also highly relevant. The synthesis of methods applicable outside of Europe will be essential if reporting black carbon emissions, to begin within the UNFCCC-PA forum. Cross-convention collaboration between TFEIP and the IPCC expert group on SLCFs has already been initiated and can be maintained and enhanced. These groups can work in close collaboration to develop a technical consensus on some priority issues (e.g. working definition of BC), and to agree upon the best approach in terms of emission factors (e.g. whether black carbon coefficients should be expressed as fractions of $PM_{2.5}$ emissions or as explicit emissions factors in units of black carbon mass per unit activity data). In this regard, it may also be beneficial for this cross-convention cooperation to include a link to the ongoing methodological work under the IMO with respect to the monitoring of black carbon emissions from shipping (see Area of action *Shipping*). The Component *Improve and develop methodological guidance for black carbon emissions inventories* is summarised in Table 13.

Table 13: Summary information for the Action Improve methodological guidance and external support for black carbon inventories, Component Improve and develop methodological guidance for black carbon emissions inventories

Area of Action	BC emissions inventories
Action	Improve methodological guidance and external support for black carbon inventories
Component	Improve and develop methodological guidance for black carbon emissions inventories
Type of intervention	Establishment and improvements of monitoring and inventories Information and guidance
Time perspective	Medium- to long-term: 2020-2030
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International UNECE Air Convention: TFEIP, IPCC: The IPCC's Task Force on National Greenhouse Gas Inventories, IMO
Evidence	N.A.

Component 2.4b. Emissions inventory capacity-building

While improvements in methodological guidance are important, the availability of adequate emission factors per se do not guarantee high rates and good quality of black carbon emission reporting. National circumstances can restrict the establishment, maintenance, and improvement of national inventory systems for BC. Capacity-building focused on development of national black carbon emission inventories is very relevant here. For more details on current and potential capacity-building activities concerning emission inventories and the ways they are organised and supported see information on Action 2.1. The Component *Emissions inventory capacity-building* within the Action

Improve methodological guidance and external support for black carbon inventories is summarised in Table 14.

Table 14: Summary information for the Action Improve methodological guidance and external support for black carbon inventories, Component Emissions inventory capacity-building

Area of Action	BC emissions inventories
Action	Improve methodological guidance and external support for black carbon inventories
Component	Emissions inventory capacity-building
Type of intervention	Establishment and improvements of monitoring and inventories Information and guidance
Time perspective	Short-term (ongoing capacity building)
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national UNECE Air Convention, EU, national authorities
Evidence	N.A.

Action 2.5: Promote further harmonisation of black carbon emissions reporting formats

Comparable reporting of source-sector level of emissions is important for monitoring emissions in different countries. Between the Air Convention, AC and EU NECD, reporting of black carbon is to a large extent harmonised. The reporting templates (i.e. the spreadsheets containing the national totals and source-sector level emissions) of the Air Convention and EU NECD are identical, and AC recommends the use of the same reporting template. However, to date the US and Russia have reported black carbon emissions using different source sector splits at a more aggregated level.

Under the Air Convention, not all Parties are obliged to use the current NFR14[31] reporting format. In fact, only the EMEP countries are obliged to use this reporting template, while non-EMEP countries – the US and Canada – are encouraged (but not obliged) to do so. Starting from 2020, Canada does use the NFR14 reporting format for reporting of its air pollutant emissions including BC. The US on the other hand reports only its national total air pollution emissions in the reporting template, with source-sector level black carbon emissions reported at a different and aggregated level in a separate document. Recent discussions with representatives of the US Environmental Protection Agency indicate that the US have been working on a cross-walk system between their inventory system and the NFR sector-split, so that emissions of all air pollutants including black carbon can soon (2021/2022) be reported using the Air Convention reporting format.

[31] Nomenclature For Reporting

Recommendations for the reporting of black carbon under the AC framework are somewhat brief, and the EGBCM of the Arctic Council may wish to examine whether the black carbon reporting guidelines set out in the AC *Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions*[32] could be refined or elaborated. Given the framework's existing reliance on parallel reporting of its Members and Observers under the Air Convention, the EGBCM may explore the possibility of more explicit reporting recommendations that encourage its Members and Observers to submit their summary reports to the AC secretariat, while the full emissions inventory data would be submitted to CEIP using the Air Convention reporting templates. Such an action could be explored in collaboration with CEIP and EMEP given that it would potentially mean the acceptance of emissions data from the Arctic Councils non-EU Observer countries that neither are parties to the Air Convention. If considered beneficial and receives support from the respective institutions of the Air Convention (EMEP Steering Body, the Executive Body) the action could be explored and further developed into a recommendation by the EGBCM through the 2-year iterative process to enhance implementation (the process that allows the EGBCM to continuously assess the implementation of- and progress under the AC Framework). Indeed, the preliminary action described above is consistent with the EGBCM's 2017 recommendations to the AC Member and Observer countries to follow the Air Convention guidelines, or comparable methodology, when developing black carbon inventories and projections.[33] Collaboration with EMEP centres and Task Forces of the Air Convention has been identified by the EGBCM as an opportunity to propagate best practises for black carbon inventories,[34] and reciprocally, cooperation with the Arctic Council is explicitly mentioned in the Convention's Long-term strategy for 2020-2030 as something that should be built upon to leverage synergies in respective implementation work. The Action *Promote further harmonisation of black carbon emissions reporting formats* is summarised in Table 15.

.

[32] https://oaarchive.arctic-council.org/bitstream/handle/11374/610/ACMMCA09_Iqaluit_2015_SAO_Report_Annex_4_TFBCM_Framework_Document.pdf?sequence=1&isAllowed=y

[33] https://oaarchive.arctic-council.org/bitstream/handle/11374/1936/EDOCS-4319-v1-ACMMUS10_FAIRBANKS_2017_EGBCM-report-complete-with-covers-and-colophon-letter-size.pdf?sequence=5&isAllowed=y

[34] https://oaarchive.arctic-council.org/bitstream/handle/11374/2411/Expert%20Group%20on%20Black%20Carbon%20and%20Methane%20-%20Summary%20Progress%20and%20Recommendations%202019.pdf?sequence=1&isAllowed=y

Table 15: Summary information for the Action Promote further harmonisation of black carbon emissions reporting formats, Component Review of AC framework reporting recommendations

Area of Action	BC emissions inventories
Action	Promote further harmonisation of black carbon emissions reporting formats
Component	Review of AC framework reporting recommendations
Type of intervention	Establishment and improvements of monitoring and inventories Information and guidance
Time perspective	Short-term (EGBCM Meetings)
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International AC: EGBCM, UNECE Air Convention: EMEP Steering Body & CEIP
Evidence	N.A.

Action 2.6: Enhance in-depth review mechanisms for reported black carbon emissions

The in-depth review processes under the Air Convention, EU NECD, and UNFCCC, whereby independent experts audit the submitted emission reports/data and provide the respective countries with feedback and recommendations, is an important component of these respective emissions reporting systems. Such reviews help to maintain standards and stimulate improvements in the reported inventories in terms of transparency, consistency, comparability, completeness, and accuracy.

The AC Framework does not provide a formal review mechanism for submitted black carbon emission inventories. Furthermore, until very recently, submitted emissions of black carbon had not been thoroughly assessed during the independent expert reviews under EU NECD review or the stage 3 reviews under the Air Convention - due to resource prioritisation and black carbon status as pollutant reported on a voluntary basis. The national black carbon emissions reported by the EU Member States are scheduled to be centrally examined in the in-depth NECD review during 2021. Up to and including 2018, the stage 3 reviews under the Air Convention concentrated solely on the emissions of mandatory pollutants.

However, plans to devote more attention to black carbon within the scope of the in-depth reviews under the Air Convention and EU NECD are being gradually developed and implemented. Since 2017, initial (stage 1) and extended (stage 2) controls[35] performed by CEIP/EMEP have been expanded to cover reported black carbon emissions. In 2018, the Air Convention Executive Body Decision (2018/01) on Updated methods and procedures for the technical reviews of air pollutant

[35] https://www.ceip.at/status-of-reporting-and-review-results/2020-submissions

emission inventories reported under the Convention[36] reaffirmed that CEIP stage 3 reviews would continue to focus on the mandatory pollutants; however, the Decision also stated that other non-mandatory pollutants including black carbon *"shall also be reviewed as resources allow"*. Since this decision, stage 3 reviews of 11 Parties in 2019 and 2020 have indeed examined national black carbon emissions reported by the respective countries,[37] and reviewers provided the Parties with explicit recommendations on methodological improvements in key categories (i.e. significant source sectors).

The above developments with respect to inventory reviews under the Air Convention and EU NECD indicate notable progress and should be monitored closely over the next years. Given that black carbon is a non-mandatory pollutant, the review findings and recommendations under the Air Convention cannot be enforced; however, they would increase the transparency of the reporting systems and may stimulate improvements of the inventories at the national level. Under EU NECD, the inventory review results in recommendations and sometimes technical corrections enforced in the EU Member States reporting BC.

The degree to which reviews will help to improve reported black carbon emissions will depend on whether this initial review effort can be sustained and enhanced. For the EU NECD inventory review, a follow-up review to assess the implementation of the recommendation for black carbon inventories is at least planned for 2022 and 2023. Under the stage 3 reviews of the Air Convention, it would be useful to monitor whether resources allow for further reviews of black carbon inventories, and to follow-up whether the initial recommendations have been implemented. The EMEP Steering Body (the Air Convention) and European Commission may consider further coordination of black carbon review where CEIP dedicates its attention to the non-EU Parties to the Convention and rely upon EU NECD review process for the EU Member States. Furthermore, TFEIP may consider options to enhance review focus on black carbon when the Task Force reviews and potentially proposes updates to the 2018/01 Executive Body Decision on Updated methods and procedures for the technical reviews of air pollutant emission inventories reported under the Convention.

Improvements brought by sustained and enhanced reviews of black carbon under the Air Convention and/or EU NECD, would also translate into improved data for monitoring black carbon emissions under the Arctic Council Framework, given that all Arctic Council Member countries are Parties to the Air Convention and/or Member States of the EU. It can therefore be considered that ECBCM follows developments on this front and investigates how the review results (e.g. the publicly available review reports)[38,39] may be used to assess progress of the implementation of AC Framework. The Action *Enhanced in-depth review mechanisms for reported black carbon emissions* is summarised in Table 16.

.

[36] https://www.unece.org/fileadmin/DAM/env/documents/2002/eb/air/EB%20Decisions/Decision_2018_1.pdf
[37] https://www.ceip.at/review-of-emission-inventories/in-depth-review-of-ae-inventories
[38] https://ec.europa.eu/environment/air/reduction/implementation.htm
[39] https://www.ceip.at/review-of-emission-inventories/in-depth-review-of-ae-inventories

Table 16: Summary information for the action Promote further harmonisation of black carbon emissions reporting formats

Area of Action	BC emissions inventories
Action	Enhanced in-depth review mechanisms for reported black carbon emissions
Type of intervention	Establishment and improvements of monitoring and inventories Information and guidance
Time perspective	Short-term (EMEP Steering Body Meetings)
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International UNECE Air Convention: EMEP, EU, AC
Evidence	N.A.

Area of action 3 - Gas flaring

Klimont et al. (2017) estimates global black carbon emissions from gas flaring at 270 kt in 2005 and 210 kt in 2010. The share of gas flaring in the total global black carbon emissions is small (about 3%); however, it is a significant emission source in the areas near and within the Arctic. Being a large oil and gas producer, Russia has the largest volumes of flared gas in the world (Evans et al. 2017) and consequently large emissions – e.g. Huang et al. (2015) gives an estimate of 81 kt black carbon emitted from gas flaring in the country in 2010. Black carbon emissions from gas flaring in Russia are the second-largest source contribution to warming in the Arctic (Sand et al. 2016).

There are three actions identified within the Area of action *Gas flaring* (Table 17). One of them – Define common environmental standards for gas flares, including black carbon emissions – was included in the EGBCM recommendations (Arctic Council 2019). The other two concern research of actual black carbon emission rates for flares, and monitoring of progress of the World Banks Zero Routine Flaring by 2030 initiative.

Table 17: Actions within the area Gas flaring

Action id	**Short action description**	**Similar EGBCM (2019) recommendation**
3.1	Promote R&D into field measurement data on actual black carbon emission rates for a diverse range of flares relevant for the Arctic	-
3.2	Close monitoring and reporting of progress including independent research within the Zero Routine Flaring by 2030 initiative	-
3.3	Define common environmental standards for gas flares, including BC	2b

Action 3.1: Gas flare research and development

A number of studies have been performed over the last 10 years which have enabled a better understanding of the challenges with emissions from gas flaring (Stohl et al. 2013, Conrad and Johnson 2017, Cho et al. 2019), but a number of questions remain open on the black carbon yield depending on the type of flare, the rate of gas flaring, the composition of the gas and the weather conditions.

Gas-flaring-related black carbon emission rates are currently only estimated from a generic database on emission factors and flaring volumes. Therefore, further quantitative understanding and in-depth assessments of gas-flaring-derived black carbon in the Arctic region is important and could be enhanced through the promotion of new field measurement studies.

One of the relevant further actions is to incentivise, promote, or encourage performing new on-site field measurements of black carbon emission rates (and flare gas volume-specific black carbon yields) for a diverse range of flares relevant for the Arctic region. Using established techniques, such as the sky-LOSA[40] optical measurement techniques, could be suitable - in harmony with comprehensive Monte Carlo-based uncertainty analysis. The measurements campaigns could be combined with measurements of combustion efficiency to gain in parallel a better understanding of the methane emissions depending on various parameters.

As black carbon flare gas volume-specific yields have shown to be strongly correlated with flare gas heating values (i.e.: higher BC yields at higher gas heating values - from natural gas liquids still entrained in the flare gas), a particularly useful strategy when undertaking new measurements could include parallel on-site measurements of flare gas flow rates as well as analysis of the gas composition. This could enable the establishment of a more comprehensive dataset relevant for Arctic flares. New field measurements could furthermore be performed at a subset of locations across order to enable direct measurements of "fuel-specific BC yields" from flares under Arctic field conditions.

A potentially enabling mechanism for such R&D efforts is to utilise the Arctic Council mechanisms of investing in pilot projects as showcases to develop and enhance knowledge build-up. If the work with tailoring and making use of pilot projects can be further strengthened, it could be an important step to build up knowledge around gas flaring emission reductions. Pilot projects could then be pooled together by forming long-term strategies for information sharing between different projects, strategies on how to build knowledge based on the results of the projects and how to follow the projects for a longer period. Issues of how to apply different actions and technology changes in local areas deserves deeper analysis enabled by pilot projects. Further coordination between the Arctic Council working groups and efforts to cooperate with the research and innovations funds of the AC-states, as well as coordination with the CCAC and the World Bank Zero Routine Gas Flaring initiative, may facilitate such enhanced effort. The Action *Promote R&D into field measurement data on actual black carbon emission rates for a diverse range of flares relevant for the Arctic region* is summarised in Table 18.

[40] Line-of-sight attenuation using skylight

Table 18: Summary information for the Action Promote R&D into field measurement data on actual black carbon emission rates for a diverse range of flares relevant for the Arctic region

Area of action	Gas flaring
Action	Promote R&D into field measurement data on actual black carbon emission rates for a diverse range of flares relevant for the Arctic region
Type of intervention	Primary: Funding of research, independent analysis and innovation Secondary: Information and guidance for policy makers
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, National AC: AMAP; CCAC; World Bank; EU: national research funding authorities, universities and research groups, the Global Gas Flaring Reduction Partnership, oil and gas associations, owners of flaring test facilities (typically gas flare technology providers)
Evidence	N.A.

Action 3.2: Close monitoring and progress reporting within the Zero Routine Flaring by 2030 initiative

The Zero Routine Flaring by 2030[41] is a World Bank led initiative endorsed by all the oil and gas producing countries in the Arctic region (Canada, Denmark, Norway, Russia, and the US). Several EU Member States (e.g. France, Germany and the Netherlands) have also endorsed it. According to the initiative text:

> *"Governments that endorse the Initiative will provide a legal, regulatory, investment, and operating environment that is conducive to upstream investments and to the development of viable markets for utilization of the gas and the infrastructure necessary to deliver the gas to these markets. This will provide companies the confidence and incentive as a basis for investing in flare elimination solutions. Governments will require, and stipulate in their new prospect offers, that field development plans for new oil fields incorporate sustainable utilization or conservation of the field's associated gas without routine flaring. Furthermore, governments will make every effort to ensure that routine flaring at existing oil fields ends as soon as possible, and no later than 2030."*

This initiative has the potential to substantially reduce black carbon emissions from gas flaring in the Arctic and beyond. Unfortunately, though important progress has been achieved in some countries (e.g. Kazakhstan, Nigeria),[42] gas flaring volumes have also increased in some parts of the world. Careful monitoring of progress towards the 2030 zero routine flaring target is thus required.

The World Bank already reports progress on the Annual Upstream Flare Volumes by the endorser (self-reported).[43] In addition, independent assessment of the volume of gas flared by countries, or operators are crucial to ensure that progress towards targets is credible. Monitoring can be performed e.g. using satellite data[44] or aerial surveys. The National Oceanic and Atmospheric Administration has published annual flare specific and country wide estimates of the volume of gas flaring,[45] providing an important insight in the progress made by the countries. According to this data, in 2018 about 38 billion m^3 of gas was flared in the Arctic Council states.

A couple of the remaining challenges should be highlighted:

- There are some challenges in reconciling data between different sources of information;
- Reporting of routine flaring implies that an operator reports the cause of the flaring (and not only the volume). Though splitting gas flaring by root cause is possible,[46] in practice, most international reports will focus on the volume of gas flared irrespectively of whether the flaring is considered "routine" or "non routine";
- Unlit and malfunctioning flares[47] can represent a significant source of methane and non-methane volatile organic compound emissions that are not always or poorly detected by some gas flaring remote monitoring techniques. It is thus critical that the monitoring programme is designed to estimate also the volume of gas vented, combining black carbon

[41] https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030#
[42] https://www.canadianenergycentre.ca/wp-content/uploads/2020/06/CEC-Project-38-FS-10-Gas-Flaring-FINAL.pdf
[43] https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030#5
[44] https://skytruth.org/viirs/
[45] https://viirs.skytruth.org/apps/heatmap/flarevolume.html
[46] For example https://www.carbonlimits.no/project/assessment-of-flare-strategies-techniques-for-reduction-of-flaring-and-associated-emissions-emission-factors-and-methods-to-determine-emissions-to-air-from-flaring/
[47] https://www.permianmap.org/flaring-emissions/

and methane detection and quantification technologies with technologies to quantify amounts of flared and vented gas.

The Action *Close monitoring and reporting of progress including independent research within the Zero Routine Flaring by 2030 initiative* is summarised in Table 19.

Table 19: Summary information for the Action Close monitoring and reporting of progress including independent research within the Zero Routine Flaring by 2030 initiative

Area of action	Gas flaring
Action	Close monitoring and reporting of progress including independent research within the Zero Routine Flaring by 2030 initiative
Type of intervention	Primary: Funding of research, independent analysis and innovation Secondary: Information and guidance (for policy makers)
Time perspective	Long-term; annual between 2020 and 2030
Structural change	Incremental (build on existing work)
Jurisdictional scope & **Policy forum**	International (countries endorsing the initiative) The World Bank, national authorities, oil and gas associations
Evidence	NOAA estimates[48]

Action 3.3: Common BC-standards for gas flares

BC formation can be caused by several factors including wind, water, impurities in the fuel, or poor mixing with air. Therefore, deploying appropriate flare systems or technologies - for the appropriate conditions - is vital to reducing the emission of black carbon. Emissions can be reduced by ensuring that flare technologies are appropriately designed, constructed, maintained, and operated.

Even when routine flaring has been eliminated, flaring of gas does occur for safety reasons (for example, flaring in safety burner pilots), during well testing and start-up of operations, for any unavoidable technical reasons (such as purge venting), or for the case of the onset of emergencies (emergency production stops). By setting common standards for black carbon emissions, newly designed flare stacks could serve the potential for reducing black carbon formation, regardless of routine flaring or intermittent flaring.

This action could include, in a sequential manner:

- Step 1: Develop testing procedures for gas flares to allow comparison of performance in terms of black carbon emissions and emissions of other air pollutants from different types

[48] The National Oceanic and Atmospheric Administration https://viirs.skytruth.org/apps/heatmap/flarevolume.html

of flares. Currently there is no selected common procedure for testing and comparing a flare performance from a black carbon perspective;

- Step 2: Develop environmental standards for flares, regulating inter alia black carbon emissions. This standard, leveraging existing work performed by research groups and flare technology providers, should build on existing low emissions standards and provide a consistent framework, including testing procedure and measurement technology. A common environmental standard for flares would allow comparison of performance of different types of flares in terms of emissions and verification that a flare is "low emissions";
- Step 3: Encourage (regulate) flare technology providers to comply with the low emission standard when designing new models;
- Step 4: Encourage operators to deploy low emission gas flares. For example, the permission for implementing a new flare with a low emission standard could be a part of the operating rights granted to operators under production licenses (or contracts) or field development plan approvals.

The Action *Define common environmental standards for gas flares, including black carbon* is summarised in Table 20.

Table 20: Summary information for the Action Define common environmental standards for gas flares, including BC

Area of action	Gas flaring
Action	Define common environmental standards for gas flares, including BC
Type of intervention	Primary: Regulation/legislative proposals (on technical standards) Secondary: Economic incentives
Time perspective	Medium-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International (Arctic Council countries) Arctic Council and/or the World Bank
Evidence	N.E.

Area of action 4 - Small-scale domestic heating

Small-scale domestic heating has been estimated to be the most important source of BC-related problems in the Arctic in 2010 (Sand et al. 2016). There are six actions identified within the Area of action *Small-scale domestic heating* (Table 21). Common themes, for the actions aiming at reducing black carbon emissions are improved operational behaviour when burning wood (information, education), and accelerated deployment of cleaner and more efficient heating sources (promote modern technologies and energy efficiency actions). The latter may also include technology development in local district heating networks.

Table 21: Actions within the area Small-scale domestic heating

Action id	Short action description	Similar EGBCM (2019) recommendation
4.1	Information on the benefits and techniques of "burn right"	3a
4.2	Economic incentives to replace old and inefficient wood burning equipment and appliances fuelled by oil or hard coal	3b
4.3	Economic incentives coupled with information.	(3a)
4.4	Energy efficiency improvements	3c
4.5	Disincentivise the second-hand market for wood burning equipment that does not meet requirements for new stoves and boilers	3b
4.6	Disincentivise the use of stoves and boilers that do not meet (national) requirements	(3b)

Action 4.1: Information on the benefits and techniques of "burn right"

The burn-from-the-top technique, considered to reduce black carbon emissions from ovens and stoves, is still recent knowledge, and more information activities are needed for it to reach the general population using wood stoves and to result in behavioural changes. Attempts have been done – a good example is the Finnish actor Roman Schatz teaching Fins how to light and maintain their sauna stoves,[49] but more and innovative educational efforts are needed.

New measures to reach the target audience may include:

[49] https://www.youtube.com/watch?v=ZYDrl_Y8d_s

- 'Fireplace consultants' coming to people's homes and spreading information about "burning right". For this to be not too expensive measure it should be coupled with other services such as fire safety inspections. This type of consulting can also be performed by chimney sweeps or educated volunteers, e.g. representing national stove & fireplace expert associations or non-government organisations.
- Targeted information through wood providers. Pamphlets with step-by-step guides to burn-right could be enclosed in wood fuel sold to population.
- The stove/fireplace providers could be obliged to teach people who buy a fireplace how to burn right in that particular fireplace. For example, the fireplace provider Nordpeis has a model-specific information video on how to burn right.[50]
- International exchange of experience on effective means to provide information on 'burn right'.

The Action *Information on the benefits and techniques of "burn right"* is summarised in Table 22.

Table 22: Summary information for the Action Information on benefits and techniques of "burn right"

Area of action	Domestic heating
Action	Information on the benefits and techniques of "burn right"
Type of intervention	Information and guidance
Time perspective	Short-term, ongoing
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National & Sub-national National authorities (e.g. those responsible for fire safety and/or environmental protection), associations of producers and providers of heating equipment
Evidence	N.E.

Action 4.2: Economic incentives to replace old heating equipment

Old wood burning equipment has in general been shown to have higher or much higher emissions than modern equipment. There is also a significant number of old oil-fuelled heaters and local oil-fuelled district heating boilers that cause black carbon emissions. Replacement of these older, high-emitting stoves and boilers would reduce emissions considerably.

National initiatives/programmes for subsidies (or other economic incentives) have been initiated (Levander and Bodin 2014) with the aim of accelerating the replacement of old wood burning

[50] https://www.youtube.com/watch?v=7r4eGvqZ9FE&feature=youtu.be

equipment with cleaner technologies. There are also national programmes for replacing oil burning in individual houses or local district heating boilers with cleaner technologies.

The programmes need rules and policies identifying the requirements for eligibility of subsidy, as well as requirements for the replacement technology. It is worth noting, however, that national perspectives here vary. Economic incentives have previously been considered in Canada where it was deemed not feasible due to high costs, while the Danish experience points towards the incentive having effect and they are used in the EU. In Finland a national programme aims at supporting a switch away from oil burning,[51] and in Russia actions have been initiated to replace old polluting local district heating boilers (Salonen 2020). Although not targeting domestic heating per se, Norway has banned the use of fossil oil to heat buildings utilised in the construction sector, starting from the 1st of January 2024.[52] All these initiatives aim at improving local air quality and health benefits as well as climate impact. Again, and of importance given the current disparity in national experiences, it is useful with international exchange of experience. The Action *Economic incentives to replace old equipment and appliances fuelled by oil or hard coal* is summarised in Table 23.

Table 23: Summary information for the Action Economic incentives to replace old equipment and appliances fuelled by oil or hard coal

Area of action	Domestic heating
Action	Economic incentives (subsidies for new equipment or scrapping bonuses) to replace old equipment and appliances fuelled by oil or hard coal through national initiative/programme for
Type of intervention	Economic incentives
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National National authorities (e.g. those responsible for fire safety and/or environmental protection)
Evidence	N.E.

Action 4.3: Economic incentives coupled with information for all appliances

Economic incentives alone may accelerate replacement of old wood burning appliances – but replacement rates could be further enhanced by combining incentives and replacement programmes with targeted information to the general public regarding benefits of the new burning technologies – health-related, environmental and economic. New equipment is not only less emissive – it is also

[51] https://ec.europa.eu/energy/sites/ener/files/documents/fi_final_necp_main_en.pdf
[52] https://www.regjeringen.no/no/aktuelt/forbod-mot-bruk-av-mineralolje-til-byggvarme-pa-byggjeplassar-fra-2022/id2828714/

most often more efficient at proper operation and maintenance. Active spreading of information among the stove users about cost-efficiency of replacement old stoves and fireplaces with new, cleaner technologies, could encourage more people to use the economic incentives provided within on-going replacement programmes. For example, the Norwegian public fund Enova does this seemingly successfully: they prepare fact sheets with a clear overview of the size of the subsidy, how to obtain the subsidy, how the technology works and what you may gain economically in energy savings.[53] The Action *Economic incentives coupled with information* is summarised in Table 24.

Table 24: Summary information for the Action Economic incentives coupled with information

Area of action	Domestic heating
Action	Economic incentives to owners of wood burning equipment for accelerating deployment of cleaner and more efficient heating sources coupled with: Information and education on economic and health savings from installing cleaner and more efficient heating sources and to promote proper operation and maintenance, including storage and treatment of fuels
Type of intervention	Economic incentives, Information and guidance
Time perspective	Short- to long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National National authorities (e.g. those responsible for fire safety and/or environmental protection), associations of producers and providers of stoves and fireplaces
Evidence	N.E.

Action 4.4: Energy efficiency improvements

Energy efficiency actions to reduce the need for heating can rely on regulatory measures, such as building regulations and/or economic incentives to accelerate improved energy efficiency of buildings, more efficient heating technologies, or installation of accumulator tanks with wood boilers that facilitate efficient use of wood. An example here is the European Structural and Investment Fund (ESIF) of the EU.

Measures to improve energy efficiency of buildings include, for instance, insulation and glazing. According to Dubey et al. (2019), energy efficiency in the building stocks is improving – to some extent due to subsidised loans, tax incentives, and energy efficiency funds used to intensify implementation of these measures for privately owned buildings. Insulation and glazing of public buildings are most often regulated via the state. In Russia there is a requirement to perform a

[53] An example can be found here: https://www.enova.no/privat/alle-energitiltak/varmepumper/luft-til-vann-varmepumpe/

specified number of annual insulation and glazing projects for public and multi-family residential buildings, and to have dedicated budget for this included in the municipality budgets. Overall, countries with comprehensive and stringent building standards have higher implementation rates of energy efficient technologies. Regarding measures for existing buildings – to accelerate retrofitting for better energy efficiency energy performance, certificate systems seem to be one of the effective ways (Dubey et al. 2019).

Regulations and development of engineering solutions that improve energy efficiency are not always directly driven by black carbon emission concerns but rather by energy savings. Nonetheless, highlighting the positive effect of energy efficiency improvements in residential dwellings on black carbon in the Arctic could enhance implementation of relevant policy actions and stimulate further development and research on this issue. The Action *Energy efficiency improvements* is summarised in Table 25.

Table 25: Summary information for the Action Energy efficiency improvements

Area of action	Domestic heating
Action	Energy efficiency improvements by promoting enhanced energy efficiency in residential dwellings reducing the need for heating
Type of intervention	Regulation/legislative proposals, Economic incentives
Time perspective	Short- to long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National National authorities, producers of heating equipment
Evidence	N.E.

Action 4.5: Disincentivise the second-hand market for worst polluting stoves and boilers

To implement policies that discourage certain types of stoves and boilers on the second-hand market, legislation on emission limit values for new equipment needs to be in place. For EU Member States the Ecodesign Directive sets emission limits for new wood burning equipment to be placed on the market. Restrictions on the second-hand market for e.g. equipment that do not meet the same requirements would accelerate phasing out of potentially high-emitting legacy equipment from continued use. Based on these requirements, a national list of preferred wood burning equipment on the second-hand market could be compiled.

To assess whether the specific stove or boiler meets the requirements and is allowed on the second-hand market or not, standardised testing and certificates showing emission performance for each model of equipment would be needed. The Nordic Ecolabelling gives a review of European and other certification schemes' threshold values that can serve as a reference. The Nordic Ecolabelling certification scheme sets the limit for particulate matter at 15 mg/m^3 of flue gas for pellet stoves (Nordic Ecolabelling 2018). There are however some well recognised obstacles to this action – in

particular, it would require amendments to existing legislation in many countries and can cause resistance among population. The mere suggestion of the action caused strong public protests in Sweden 2018.[54] The Action *Disincentivise the second-hand market for stoves and boilers that do not meet the requirements for new stoves and boilers* is summarised in Table 26.

Table 26: Summary information for the Action Disincentivise the second-hand market for stoves and boilers that do not meet the requirements for new stoves and boilers

Area of action	Domestic heating
Action	Disincentivise the second-hand market for stoves and boilers that do not meet the requirements for new stoves and boilers
Type of intervention	Regulation/legislative proposals
Time perspective	Short- to long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national National authorities, EU
Evidence	N.E.

Action 4.6: Disincentivise stoves and boilers that do not meet (national) requirements

Policies setting requirements on emission performance would be one way to accelerate the phase out of high-emitting, already installed wood burning equipment (not only the equipment re-entering market again, as in Action 4.5).

For such a policy to become reality, emission limit values targeting already installed wood burning equipment in use is needed, most likely through national legislation. In connection with this policy, rules and regulations for retirement and eventually prohibiting the use of stoves and boilers that do not meet those requirements have to be developed. As an example, in Germany there are rules stipulating transitional periods allowed for shutting down and/or exchange of equipment depending on age and performance of the installed equipment, also taking into account if wood burning is the primary heating source (Gustafsson and Kindbom 2019).

In order to follow up and enforce the policy, a system for regular equipment performance control is needed. This could build on certificates from standardised testing of the specific equipment model (from manufacturer) which must be presented upon request. Alternatively, a national list of accepted models (built on certificates from manufacturers) could be compiled. The enforcement issue can be considered as one of the most important obstacles to this action, especially in large sparsely populated countries.

[54] https://www.svt.se/nyheter/lokalt/smaland/efter-vedspisupproret-nu-far-vedspisen-gront-ljus-igen

If a certificate is not available, emission measurements to check compliance by chimney sweeps (or fire inspectors, or other certified personnel) could be an additional, although more expensive, way. In Germany emission measurements for compliance are performed, and time intervals between measurements are given.

In Sweden there are examples of local regulations (from air quality and health perspective) where the local authority may define areas within densely populated areas where the use of wood burning equipment is prohibited (or intermittently prohibited), also taking equipment standard into account (Kindbom et al. 2018). This kind of local regulations would, however, most likely have small or negligible effect on black carbon in the Arctic. The Action *Disincentivise the use of stoves and boilers that do not meet (national) requirements* is summarised in Table 27.

Table 27: Summary information for the Action Disincentivise the use of stoves and boilers that do not meet (national) requirements

Area of action	Domestic heating
Action	Disincentivise the use of stoves and boilers that do not meet (national) requirements through policies targeting the use of already installed and existing wood burning equipment
Type of intervention	Regulation/legislative proposals
Time perspective	Long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National National and local authorities
Evidence	N.E.

Area of action 5 - Shipping

PAME's Arctic Shipping report[55] shows an increase in shipping activities in the Arctic region from 2013 to 2019. The number of vessels increased by 25%, and distance sailed by 75%. The increase coincided with diminishing sea ice in the Arctic and increasing natural resource extraction. According to some estimates, shipping was responsible for 0.7% to 1.1% of anthropogenic black carbon emissions in 2015 (Comer et al. 2017). Between 2015 and 2019 the black carbon emissions from shipping in the Arctic increased with 85%.[56] Given the increase in shipping, black carbon emissions from the sector is of interest in the Arctic.

One of the two actions identified within the Area *Shipping* (Table 28) concerns emission reductions at the national and sub-national levels while the other one focuses on the international level of activities, where the key operator regulating shipping emissions is the IMO. Other key organisations working with black carbon emissions from international shipping are the Arctic Council (PAME, EGBCM), CCAC and ICCT. PAME is actively engaged in the black carbon work, including the identification of actions for the revision of the Arctic Council Arctic Marine Strategic Plan extending until 2025. EGBCM has a recommendation to *"work to accelerate efforts under the International Maritime Organization to mitigate black carbon from international shipping"* (Arctic Council 2019). The work of the international organisations is complemented by efforts of the national and local authorities to reduce black carbon emissions on the respective level.

Table 28: Actions within the area Shipping

Action id	Short action description	Similar EGBCM (2019) recommendation
5.1	Emission reductions through the IMO	1d
5.2	Emission reductions through national and sub-national actions	1a, 1b

Action 5.1: Emission reductions through the IMO

The IMO is the main policy forum for global measures to reduce pollution from international shipping. The Action *Emission reductions through the IMO* is divided into two main components. Further develop a standardised black carbon sampling and measurement protocol (Component 5.1a) is a prerequisite for practical implementation of black carbon regulations and policies for international shipping (Component 5.1b).

The IMO's MEPC has been considering the impact on the Arctic of black carbon emissions from international shipping since 2011, assigning its Sub-Committee on Pollution Prevention and Response to carry out a work plan in this area. The work plan was most recently renewed at 74th session of MEPC[57] and includes the following:

[55] Arctic Shipping Status Reports
[56] https://theicct.org/sites/default/files/Arctic-HFO-ban-Fact-Sheet_sept2020.pdf
[57] https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MEPC-74th-session.aspx

i) consider regulating or otherwise directly controlling black carbon emissions from marine diesel engines to reduce the impact on the Arctic of black carbon emissions from international shipping,

ii) further consider the recommended black carbon measurement methods to be used in conjunction with i),

iii) develop a standardised black carbon sampling, conditioning and measurement protocol,

iv) submit a report to the 77th session of MEPC in 2021.

Component 5.1a. Further develop a standardised black carbon sampling, conditioning and measuring protocol

Some black carbon control policies, like those involving an emissions limit, require a black carbon measurement method to confirm compliance. As the IMO considers regulating or otherwise directly controlling black carbon emission from international shipping, work is underway to advance the development of a standardised black carbon sampling, conditioning and measurement protocol that will provide comparable and reliable measurements of black carbon from marine diesel engines. Such work is currently ongoing in the IMO. In February 2020 at the 7th session of the Sub-Committee on Pollution Prevention and Response, a Correspondence Group was established to advance the development of a standardised black carbon sampling, conditioning and measurement protocol and to investigate the linkages between the measurement systems and policy options (IMO 2020). At their 8th session in March 2021, the Sub-Committee suggested to the MEPC that the terms of reference for how to develop the standardised sampling, conditioning and measurement protocols should be made at the 79th session of MEPC. The Component *Further develop a standardised black carbon sampling, conditioning and measurement protocol* is summarised in Table 29.

Table 29: Summary information for the Component Further develop a standardised black carbon sampling, conditioning and measurement protocol

Area of action	Shipping
Action	Emission reductions through the IMO
Component	Further develop a standardised black carbon sampling, conditioning and measurement protocol
Type of intervention	Establishment and improvements of monitoring and inventories
Time perspective	Short- to intermediate term (5+ years)
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International IMO
Evidence	N.A.

Component 5.1b. International regulations reducing black carbon emissions from shipping

Over the years the MEPC's Sub-Committee on Pollution Prevention and Response has been investigating appropriate control measures to reduce the impact of black carbon emissions from

international shipping on the Arctic and has developed documentation highlighting technical solutions to reduce black carbon emissions (IMO 2015). To enhance deployment rates of available solutions, there is a need for policy instruments that set emission limits, restrict certain types of fuels, provide economic incentives for cleaner technologies or in other ways regulate shipping emissions on the international level.

MEPC 75 has approved draft amendments to MARPOL Annex I[58] to introduce a prohibition on the use and carriage for use of heavy fuel oil as fuel by ships in Arctic waters on and after 1 July 2024,[59] with exemptions and waivers for some ships until 1 July 2029. The exemptions and waivers result in only an expected 5% reduction in BC emissions from Arctic shipping, when a full prohibition would cut emissions with 30%.[60] Waivers can for example be issued by ships under the flag of a state operating in Arctic waters. According to IMO's definition of Arctic waters, countries able to issue waivers are therefore Russia, Canada, the United States, Denmark and Norway. In addition, the 8th session of the MEPC Sub-Committee on pollution prevention recommended that the MEPC should start developing guidelines on which black carbon emission control measures that should be used to reduce the impact on the Arctic.

International regulations on black carbon emissions would have a long-term effect on the development of shipping and ship propulsion technologies. They would provide a minimum standard for technological development and would gradually lead to phasing out of more polluting ships. Here, endorsement of control measure guidelines and of suggestions to prohibit heavy fuel oil use can be important to reduce the impact of black carbon on the Arctic. There is, however, opposition to black carbon emission reduction decisions, and some parties are waiting to see how the global sulphur cap and the forthcoming heavy fuel oil prohibition in the Arctic affect black carbon emissions. The Component *Advancing international regulations reducing black carbon emissions* is summarised in Table 30.

.

[58] MARPOL – International Convention for the Prevention of Pollution from Ships. MARPOL Annex I regulates prevention of pollution by oil - https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

[59] https://theicct.org/sites/default/files/publications/Arctic-HFO-ban-sept2020.pdf

[60] https://theicct.org/blog/staff/imo-draft-hfo-ban-2020

Table 30: Summary information for the Component International regulations reducing black carbon emissions

Area of action	Shipping
Action	Emission reductions through the IMO
Component	Advancing international regulations reducing black carbon emissions
Type of intervention	Regulation/legislative proposals, Economic incentives
Time perspective	Intermediate-long term
Structural change	Incremental, with transitional potential
Jurisdictional scope & **Policy forum**	International IMO
Evidence	N.E.

Action 5.2: Emission reductions through national and sub-national actions

Regulation and development of standards for international shipping can be supported by national and sub-national actions. Such actions, including local measures such as port restrictions, would reduce emissions from both international and in-country shipping (Arctic Council 2019), curbing a development that would otherwise be likely to increase emissions in the Arctic. An example is a declaration[61] of the Nordic Council of Ministers aimed at increased use of port electricity (instead of on-board diesel generators) by cruise ships for fulfilling their energy needs when at berth. The Component *National and sub-national regulations and policies* is summarised in Table 31.

.

[61] https://www.regeringen.se/pressmeddelanden/2020/10/nordiska-ministrar-vill-minska-utslapp-av-luftfororeningar-fran-kryssningsfartyg-i-hamn/

Table 31: Summary information for the Action Emission reductions through national and sub-national actions

Area of action	Shipping
Action	Emission reductions through national and sub-national actions: such as setting limits on black carbon emissions, fuel switching policies, mandatory shoreside power requirements, etc.
Type of intervention	Regulation/legislative proposals, Economic incentives
Time perspective	Short- to intermediate term
Structural change	Incremental with contribution to transitional change
Jurisdictional scope& **Policy forum**	International, National, Sub-national National and local authorities, international organisations and initiatives
Evidence	N.E.

Area of action 6 - On- and off-road transport and stationary engines

Land transport emissions in 2010 has been estimated to be the third most important source of BC-related problems in the Arctic (Sand et al. 2016). Most of these emissions originate from on- and off-road diesel engines. Emissions from diesel transport, especially in Europe and Russia, have strong effect on arctic warming (Lund et al. 2014). Recent estimates show that Russian on-road transport black carbon emissions can be expected to go down with some 25-30% between 2010 and 2030, and that off-road vehicles currently are the largest source of black carbon emissions in the Russian Arctic (Kholod and Evans 2016a, Kholod and Evans 2016b).

There are four actions identified within the Area of action *On- and off-road engines* (Table 32). As a common theme, the key to this area of action is changing local practices (technical specifications) to optimise engine performance and thereby reduce black carbon emissions.

Table 32: Actions within the area On and off-road engines

Action id	**Short action description**
6.1	Annual engine exhaust maintenance testing
6.2	Stricter regulation of international trade of second-hand vehicles
6.3	Encourage countries to control and stop use of AdBlue emulators and chip engine tuning equipment
6.4	Harmonisation and enforcement of engine emission standards in the Arctic region

Action 6.1: Annual engine emission testing

One way to get rid of "high-emitting" vehicles is to measure black carbon emissions in regular schemes for testing of environmental performance during motor vehicle inspections – with the important action of banning the use of the vehicle until the engine exhaust system meets certain black carbon emission standards. Alternatively, one could add control of black carbon emissions as a part of the manufacturer's engine maintenance programmes or engage in a roadside engine exhaust campaign. An example is recent vehicle inspection initiative recently in Spain following evaluation and testing of the Spanish case.[62] The Action *Annual engine exhaust maintenance testing* is summarised in Table 33.

[62] https://www.europol.europa.eu/print/newsroom/news/haulier-in-spain-caught-cheating-emission-regulations-designed-to-prevent-air-pollution

Table 33: Summary information for the Action Annual engine exhaust maintenance testing

Area of action	On- and off-road engines
Action	Annual engine exhaust maintenance testing with focus on national $PM_{2.5}$ emission standards on exported/imported vehicles
Type of intervention	Regulation/legislative proposals (on standards)
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national UNECE, EU, national authorities
Evidence	N.E.

Action 6.2: Stricter regulation of international trade in second-hand vehicles

In 2014 the top-five exporting countries in the world exported used vehicles to a value of ~18 billion US$, and 20% of all these vehicles ended up in low or lower-middle income countries (Coffin et al. 2016). In effect, the Action *Stricter trade regulation* would operate via export/ import restrictions on vehicles in accordance with their $PM_{2.5}$ emissions. Two components of this action can be considered. First, national export/import regulations can add requirements on $PM_{2.5}$ emissions (Component 6.2a). Second, steps can be taken to initiate an international agreement on international trade of second-hand vehicles (Component 6.2b).

Component 6.2a. National $PM_{2.5}$ standards in export/import regulations

National export/import regulations would mean that vehicles with the best available emission reduction technology should be incentivised. The strictest version of this would be to demand functioning emission control systems and installed diesel particulate filters, while softer versions would be to implement stronger Euro-differentiated export/import taxes/tariffs on vehicles or to apply allowable quotas of total second-hand import. As diesel vehicles are more significant in terms of black carbon emissions than gasoline vehicles, the regulations suggested above would be more effective if targeting diesel engines in the first place. $PM_{2.5}$ standards in import/export regulations could be relatively easily and quickly introduced given that many countries already have regulations on trade of vehicles (UNEP and UNECE 2017). Even though this component is aimed at national governments with large import of second-hand vehicles, an endorsement from international fora such as the Arctic Council or the UNECE could provide further motivation.

There is some evidence of the effects from export/import restrictions on emissions. Davis and Kahn (2010) find that the trade in used vehicles between the US and Mexico increases total emissions of CO_2 while decreasing total emissions of local pollutants such as particles. This variance should be due to differences in national emission regulations in the countries at the time of the study. A US-Mexico second-hand vehicle trade scenario analysis made by the Global Fuel Economy Initiative (Macias et al. 2013) indicated that if 15% of the current trade would be impeded due to environmental

requirements, the Mexican emissions of $PM_{2.5}$ from light-duty vehicles would go down with some 3.4%. On a global level Coffin et al. (2016) show that an extensive import ban from 140 countries would reduce second-hand vehicle imports by 76% while tariff-based solutions would reduce second-hand vehicle import by 38%.

Russia is a large importer of second-hand vehicles. In 2017, the country introduced a vintage-based import-tax scheme on second-hand cars (UNEP and UNECE 2017). This scheme can be complemented with $PM_{2.5}$ requirements to avoid higher $PM_{2.5}$ emissions from imported pre-Euro 6 diesel and gasoline cars. The Component *National $PM_{2.5}$ emission standards on exported/imported vehicles* is summarised in Table 34.

Table 34: Summary information for the Component National $PM_{2.5}$ emission standards on exported/imported vehicles

Area of action	On- and off-road diesel engines
Action	Stricter regulation of international trade of second-hand vehicles
Component	National $PM_{2.5}$ emission standards on exported/imported vehicles
Type of intervention	Primary: Regulation/legislative proposals Secondary: Non-binding/diplomatic policy statements
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national UNEP, UNECE, EU, national tax authorities
Evidence	Davis and Kahn (2010), Macias et al. (2013), Coffin et al. (2016), UNEP and UNECE (2017)

Component 6.2b. Initiate international agreement on international trade

Given the risk of trade moving to other geographical regions in response to unilateral initiatives there are also reasons to contemplate larger international agreements. The process of creating an international agreement on the trade of second-hand vehicles can therefore be considered a second component of the Action *Stricter regulation of international trade of second-hand vehicles*. Today there is no existing second-hand vehicle trade agreement to build upon (UNEP and UNECE 2017). The World Trade Organization (WTO) member states could investigate the possibility to address their country representatives at the WTO Committee on Trade and Environment to start discussions on this. This component is a long-term endeavour with multiple preparatory steps required, and there is to this date no related evidence presented. The Component *Initiate international agreement on international trade of second-hand vehicles* is summarised in Table 35.

.

Table 35: Summary information for the Component Initiate international agreement on international trade of second-hand vehicles

Area of action	On- and off-road diesel engines
Action	Stricter regulation of international trade of second-hand vehicles
Component	Initiate international agreement on international trade of second-hand vehicles
Type of intervention	Primary: Regulation/legislative proposals Secondary: Non-binding/diplomatic policy statements
Time perspective	Long-term
Structural requirements	Transformative
Jurisdictional scope & **Policy forum**	International WTO Committee on Trade and Environment
Evidence	N.E.

Action 6.3: Control use of engine tuning equipment

There are today technologies available to increase engine effect by inter alia disabling the engine exhaust treatment system. For SCR[63]-equipped engines, this control is called an "AdBlue emulator". This emulator makes it unnecessary to buy urea to the SCR, and effectively increases NO_x emissions from the vehicle and risk increasing black carbon emissions. Although online ads for installing AdBlue emulators are available in the European countries the authors have visited, the use of AdBlue emulators are formally banned in most European countries (except during very low temperatures).[64] They are, however, widely used in North America.

Chip engine tuning equipment basically just increases the effect of the engine, with or without disabling the engine exhaust system. But even if it doesn't disable the engine exhaust system it might increase emissions of air pollutants, including fine particles, since exhaust systems often are dimensioned for a certain engine effect. With respect to enforcement, the earlier mentioned Spanish vehicle inspection initiative can be evaluated and re-tested, and research of roadside monitoring techniques would be needed. The Action *Encourage countries to control and stop use of AdBlue emulators and chip engine tuning equipment* is summarised in Table 36.

.

[63] Selective catalytic reduction (exhaust gas cleaning technology)

[64] http://transportoperator.co.uk/2017/03/03/industry-renews-call-ban-adblue-cheats/

Table 36: Summary information for the Action Encourage countries to control and stop use of AdBlue emulators and chip engine tuning equipment

Area of action	On- and off-road diesel engines
Action	Encourage countries to control and stop use of AdBlue emulators and chip engine tuning equipment
Type of intervention	Primary: Regulation/legislative proposals Secondary: Non-binding/diplomatic policy statements
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national UNECE, EU, national transport authorities
Evidence	N.E.

Action 6.4: Harmonisation of standards in the Arctic

Emissions standards play a substantial role to regulate existing technologies and to create incentives for new technologies for on- and off-road vehicles. Harmonisation of existing and development of new emission standards for engines is one of the key actions to reduce black carbon emissions from mobile sources. Engines following the most recent EU and US standards emit only a fraction of black carbon per unit of fuel used compared with older engines.

The current status of emission standard implementation varies between the Arctic countries. Regarding the on-road vehicles, EU have an ongoing introduction of cleaner Euro-vehicle standards and implement Euro 6-standards since 2014, while North America have CAFE[65] standards. Russia has implemented Euro 5 emission standards for on-road vehicles since 2016.[66]

Off-road diesel vehicles make a significant input to the total black carbon emissions from mobile sources, especially in the Arctic region. Emission standard for off-road vehicles varies as well. The EU has moved from Stage I towards the latest regulations on Stage V. The US regulates non-road vehicles through Tier 1-3 Standards which are partly harmonised with EU regulations of Stage I and II and to large degree with Stages III/IV. Russia has adopted some European emission standards for vehicles used in agriculture and forestry, but their implementation is substantially delayed.[67] Particulate matter emission regulation for other types of off-road machinery in Russia (trains, ships, machines used in mining and construction works, etc.) is missing (Kholod et al. 2016), so policies targeting this source could significantly contribute to black carbon emission reductions in the Russian Arctic.

[65] Corporate Average Fuel Economy (standards)
[66] https://dieselnet.com/standards/ru/
[67] https://dieselnet.com/standards/ru/

Implementation of higher emission standards could be enhanced by policies and regulations aimed at reducing the number of old, high-emitting vehicles on the roads – for instance, by promoting vehicle scrapping programmes, introducing vehicles zones, or simply prohibiting the use of high-emitting vehicles on the roads. The need to fulfil strict emissions standards could lead to further technology improvements and changes in the fuel structure, such as a switch to natural gas as engine fuel (an ongoing initiative led by corporate interests).[68]

Research on emissions during alternative test-driving cycles is important to provide information and guidance for the development of new emission standards and to verify that engines fulfil emission requirements. National and international research projects on black carbon could consider activities such as conducting black carbon emission measurement campaigns specifically focused on mobile sources in the Arctic region. The Action *Harmonisation and enforcement of engine emission standards in the Arctic region* is summarised in Table 37.

Table 37: Summary information for the Action Harmonisation and enforcement of engine emission standards in the Arctic region

Area of action	On- and off-road engines
Action	Harmonisation and fulfilment of engine emission standards in the Arctic region
Type of intervention	Funding of research and innovation Regulation/legislative proposals
Time perspective	Long term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, National EU, AC, national authorities and research organisations
Evidence	Kholod and Evans (2016a), Kholod and Evans (2016b)

[68] https://www.gazprom.com/about/production/ngv-fuel/

Area of action 7 - Open biomass burning

Globally, open biomass burning is a significant source of black carbon emissions (Klimont et al. 2017). A large part of open burning has occurred in Africa. Overall, the burning appears to have declined since the 1990s (van Marle et al. 2017), but the global earth observatory shows that quite extensive burning still occurs in areas close to the Arctic.[69]

The burning that takes place on cropland is anthropogenic, whereas wildfires in forests, shrubland or on peatland most often are caused by natural phenomena (such as lightning). Nonetheless, a significant number of wildfires may be caused by direct anthropogenic impact – careless handling of fire, overheated machinery, or uncontrolled spread of fire from agricultural burning. Climate change is projected to increase the risk of wildfires also in the tundra and taiga regions (Sun et al. 2020, Sun et al. 2019). Except for SLCFs, wildfires typically also emit large proportions of potentially cooling components (AMAP 2015). Prescribed burning is another type of biomass burning carried out to reduce fire load in forests or as a special management action to maintain specific fire dependent ecosystems in areas where effective fire control eliminated wildfires.

In its 2019 report the EGBCM recognised open biomass burning as an issue to be tackled in efforts to reduce black carbon emissions and recommended to *"develop agricultural policies and practices to reduce open burning of agricultural waste. Encourage studies and piloting of innovative solutions that reduce the need for open burning"* (Arctic Council 2019). The need to reduce wildfires was also stressed.

There are two actions identified within this area of action (Table 38); they differ depending on the underlying causes. The management of croplands is subject to regular and strong policy interventions whereas wildfires are only partly manageable through policy interventions.

Table 38: Actions within the area Open biomass burning

Action id	Short action description	Similar EGBCM (2019) recommendation
7.1	Mitigate open biomass burning on cropland	5c
7.2	Reducing/managing risks of wildfires on forest and peatland	6a – 6d

[69] https://earthobservatory.nasa.gov/global-maps/MOD14A1_M_FIRE

Action 7.1: Mitigate open biomass burning on cropland

Open biomass burning on cropland is practiced extensively in some countries whereas others have abandoned the practice almost entirely. Global estimates have been made using modelling tools (IIASA 2016, Klimont et al. 2017) suggesting that about 5% of the global black carbon emissions originate from agricultural residue burning, which has been recently declining in several countries.

Agricultural activities are producing a variety of products and the size of the facilities are ranging from small scale to industrial scale. In contrast to other industries, emissions from the agricultural sector are from non-point sources rather than chimneys or exhaust pipes. Further, the sector is subject to a variety of agricultural policy interventions affecting production and practices. Correspondingly, governance of black carbon emissions from open biomass burning on croplands is multifaceted and national circumstances are affecting the nature of actions to reduce emissions.

A motivating factor for efforts to reduce open biomass burning on croplands is the co-beneficial feature of reduced biomass burning. Not only does it reduce emissions to air of black carbon and other health-damaging particulate matter, but it also helps preserve soil carbon content: thereby aligning the interest of climate change, agricultural and air pollution polices. The main components of an action addressing black carbon emissions from open biomass burning on croplands are those guiding agricultural activities through regulation, subsidies and extension services.

Component 7.1a. Develop agricultural policies to further discourage open biomass burning

Given the varying formulation of agricultural policies in countries with emissions affecting the Arctic, the method suitable to further discourage agricultural biomass burning also varies. In some countries a ban on open burning of crop residues can be considered. In other countries, the enforcement of existing bans can be strengthened through inspections or monitoring. An example is the CCAC-funded satellite mapping of open burning in the Andes and Himalayas. For some countries it is feasible to formulate subsidy eligibility requirements in agricultural policies that guide the distribution of rural development funding for farmers and thereby influence farming open burning practices through economic incentives.

The Component *Develop agricultural policies to discourage open biomass burning* is summarised in Table 39.

Table 39: Summary information for the Action Mitigate open biomass burning on cropland, Component Developing CAP to discourage open biomass burning

Area of action	Open biomass burning
Action	Mitigate open biomass burning on cropland
Component	Develop agricultural policies to discourage open biomass burning
Type of intervention	Regulation/legislative proposals
Time perspective	Short-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	National EU
Evidence	Kühn et al. (2020)

Component 7.1b. Further development of extension services for farmers

Legal regulations and economic incentives will only slowly affect practice unless supported by extension services that provide guidance on changing the practice of open burning of crop residues on farmland. Developing extension services for farmers can contribute to the reduction and elimination of open burning trough strong message for public outreach, agricultural education and extension campaigns. As for the regulations and incentives mentioned above, there is variation between countries with respect to the degree that existing extension services and advisory systems already consider open biomass burning. Previous examples of extension services that promotes technology and cooperation to reduce the need for open burning is, for example, introduction of non-tilling practice and access to relevant agricultural machinery. Introduction of non-tilling practice, as well as mechanisation of collection and/or incorporation into soil of agricultural residues, can be exemplified by a technology promoted in India, the so-called "Happy Seeder",[70] which reduced the need for open burning agricultural residue at community-scales. Additional agricultural machinery to mulch and spread straw and stubble, creating valuable compost for subsequent crops, eliminates the need to gather or burn these excess crop residues.

No-burn alternatives for agriculture are promoted by CCAC and the International Cryosphere Climate initiatives.[71] Further, the Nordic Environment Finance Corporation has conducted capacity-building/investment projects[72] with specific focus on promotion of alternative agricultural practises in Russia, including legal and policy support as well as training programmes.

A change in agricultural practices needs to be acceptable to farmers (Pereira et al. 2016), as compliance monitoring is unlikely to be possible at the scale that would stop the practice if the

[70] https://indianexpress.com/article/explained/explained-using-happy-seeder-and-how-it-affects-wheat-yield-6017640/
[71] https://openburning.org/no-burn-alternatives/
[72] https://www.smhi.se/polopoly_fs/1.92895!/Menu/general/extGroup/attachmentColHold/mainCol1/file/NEFCO%20A%20future%20strategy%20for%20Open%20Burning%20reduction%20in%20Eastern%20Europe_20150814.pdf

practice is still considered to contribute to good yields. Promotion of new technologies should thus be reinforced by agricultural education and extension for farmers and rural communities. Public health and 'good neighbour' narratives are more powerful than statistics when enacting change in farming communities (Morgan et al. 2002). The Component *Further development of extension services for farmers* is summarised in Table 40.

Table 40: Summary information for the Component Further development of extension services for farmers

Area of action	Open biomass burning
Action	Mitigate open biomass burning on cropland
Component	Further development of extension services for farmers
Type of intervention	Information and guidance
Time perspective	Short and long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national National authorities, non-government organisations, international organisations and initiatives
Evidence	Kühn et al. (2020)

Action 7.2: Managing risks of wildfires on forest and peatland

Wildfires represent a combination of anthropogenic and natural events that are triggered especially during high fire hazard conditions.[73] It has been estimated that approximately half of all wildfires in Canada are caused by humans (Canadian Council of Forest Ministers 2016). In the US up to 85% of wildfires have been attributed to human action (Balch et al. 2017).[74] In more sparsely populated areas the percentage is lower, but still significant, for example in British Columbia 40% of the wildfires are caused by anthropogenic activities.[75] Also in Sweden the share of wildfires caused by humans is significant (Sjöström and Granström 2020). High proportions of wildfires elsewhere in Europe are also caused by human activities (JRC 2019). Exposure to wildfire smoke is a serious health concern, particularly for small children, pregnant women, the elderly, and those with lung or heart conditions. It is estimated that 339 000 premature deaths worldwide are attributed to exposure to wildfire smoke each year (Johnston et al. 2012). The most extensive wildfires on the Northern Hemisphere occur in Russia and Canada, but many other countries have experienced serious consequences of wildfires[76] (Jolly et al. 2015). Near human settlements wildfires are a serious threat

[73] https://effis.jrc.ec.europa.eu/
[74] https://www.nps.gov/articles/wildfire-causes-and-evaluation.htm
[75] https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/wildfire-response/fire-characteristics/causes
[76] https://fires.globalforestwatch.org/home/

to health and livelihoods and efforts to prevent, control and manage wildfires is therefore a priority in disaster prevention and control.

In its 2019 report the EGBCM has recognised that wildfires should be addressed to reduce emissions of black carbon globally. The EGBCM recommended the following activities, all relevant for the three key components we have identified within this action:

- Build and maintain international mutual aid and resource exchange arrangements among Arctic nations that have specialised experience in wildfire management, suppression, and monitoring in boreal forests (Component 7.2c);
- Develop region-specific public education campaigns on wildfire prevention and safety (Component 7.2a);
- Develop and implement regionally appropriate forest management practices that reduce the risk of severe wildfires (Component 7.2a);
- Use the best available science to prediction models to predict fire activity at daily to decadal scales to support drafting of prevention and emergency response plans (Components 7.2a & 7.2c).

Wildfire-related issues have been historically addressed by national or sub-national authorities responsible for disaster risk management and emergency situations. These authorities are focused on the elimination and minimisation of the immediate risks rather than on the environmental consequences of their actions in the long run. Emphasising black carbon emissions and effects related to the wildfire management could develop a new perspective among people directly or indirectly engaged in wildfire management.

Component 7.2a. Sharing information systems and awareness raising

A key component in the prevention of wildfires is information systems and campaigns for awareness raising that use fire indices and warning systems (Costa et al. 2011, Holsten et al. 2013). This could include information brochures spread among population, social advertising, or educational events for forest managers, focused on the management aspects and techniques that could minimise the risk for wildfires. Within the awareness raising activities it would be very appropriate to emphasise synergies between the direct social and economic benefits from wildfire prevention or effective suppression (houses, goods, crops not destroyed, mortalities avoided) and the avoided adverse health and climate effects from wildfire-related black carbon emissions. Rising concerns on prevention of harmful emissions among general public and forest managers could create additional motivation to develop less wildfire-risky behaviour and to follow good forest management routines, including early season prescribed burning to reduce fuel loads and outreach to the public to communicate why off-season planned burning reduces fire risk. The Component *Sharing information systems and awareness raising to prevent wildfires* is summarised in Table 41.

Table 41: Summary information for the Action Reducing/managing risks of wildfires on forest and peatland, Component Revising information systems and awareness raising to prevent wildfires

Area of action	Open biomass burning
Action	Reducing/managing risks of wildfires on forest and peatland
Component	Sharing information systems and awareness raising to prevent wildfires
Type of intervention	Information and guidance
Time perspective	Short- and long-term
Structural change	Incremental (raise of awareness)
Jurisdictional scope & **Policy forum**	International, national National authorities responsible for disaster risk reduction, emergency management and civil protection
Evidence	Kühn et al. (2020), AMAP (2015)

Component 7.2b. Monitoring and surveillance systems of wildfires

Monitoring and surveillance systems that help to detect fires at a stage when they are still manageable are important as operational tools that can assist the actual firefighting activities. There are several organisations that work with monitoring and surveillance of wildfires. None of these systems, however, have technology that include parameters such as cloud cover, small fires, peat fires, open burning in croplands, or early and late season fires. Therefore, many of current monitoring and surveillance systems of wildfires could be considered insufficient. To establish a more reliable monitoring and surveillance system, there is a need for improved satellite and ground-based observation network for the boreal and the Arctic, co-produced with Indigenous and local populations who are living with the fire risk.

The Copernicus Atmosphere Monitoring Service[77] conducts global fire monitoring with near-real-time observation. This monitoring system includes estimation of emissions of pollutants. The Copernicus Atmosphere Monitoring Service rely on Moderate Resolution Imaging Spectroradiometer methods, which have limitations on for example detecting smouldering fires. The service to project forest fires in the EU and neighbouring countries is given by the European Forest Fire Information System. The European Forest Fire Information System also relies on the above-mentioned methods to provide short- and long-term fire weather forecasts and services on suppressing forest fires.

Another organisation that works with both scientific research and communication is the Global Fire Monitoring Center[78] which also serves as a coordinator and facilitator for the UN Office for Disaster Risk Reduction Wildland Fire Advisory Group and the Global Wildland Fire Network. The organisation publishes information on wildfires such as early warnings, global fire information,

[77]CAMS https://atmosphere.copernicus.eu/fire-monitoring
[78] https://gfmc.online/

management support, and has an emergency hotline together with the United Nations Office for the Coordination of Humanitarian Affairs.

Monitoring of wildfires can contribute to tools used for estimations on emissions from wildfires to build more science and knowledge on emissions and long-range transport of black carbon from the places where fires occur to the areas where air quality is affected (including the Arctic region). Early detection of wildfires enables more effective fire suppression, indirectly reducing emissions of black carbon and other pollutants. Further, exchange of good practice is a way to expediate the development of monitoring and surveillance. The Component *Further develop and exchange of good practice in Monitoring and surveillance systems of wildfires* is summarised in Table 39.

Table 39: Summary information for the Component Further develop and exchange of good practice in Monitoring and surveillance systems of wildfires

Area of action	Open biomass burning
Action	Reducing/managing risks of wildfires on forest and peatland
Component	Further develop and exchange of good practice in Monitoring and surveillance systems of wildfires
Type of intervention	Establishment and improvements of monitoring and inventories
Time perspective	Short- and long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national National authorities responsible for disaster risk reduction, emergency management and civil protection, organisations conducting research and monitoring
Evidence	Kühn et al. (2020), AMAP (2015)

Component 7.2c. International development of capacity to fight wildfires as part of disaster risk management

The third component is the capacity and skills to fight wildfires as part of disaster risk management – with respect to specific characteristics of the Arctic region. Wildland fire fighting techniques that are deemed appropriate for the boreal will differ from the techniques optimal for the Arctic and in thawing permafrost, because these are more fragile systems.

Building up capacity and skills is often a part of the education programmes for fire experts, developed by national emergency management authorities. These activities are also relevant for the international level of action. For example, the Emergency Prevention, Preparedness and Response Working Group within the Arctic Council has so far largely focused on marine safety but is now increasingly paying attention to wildfires. This development could open up new connections between policy areas in the Arctic.

The European Forest Fire Information System, the European Commission Disaster Risk Management Knowledge Centre[79] are examples of activities that aim to integrate, implement and share scientific knowledge and practical experience regarding forest fires. Another example is the Union Civil Protection Knowledge Network that has the aim to support experts, practitioners, policymakers, researchers, trainers and volunteers at every stage of disaster management – through networking, partnerships, and collaborative opportunities with the access to expertise and good practices. Globally, the Sendai Framework for Disaster Risk Reduction 2015-2030 is a network with the aim to *"guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors"*.[80]

Building an international expert network for information exchange and experience sharing, programmes and seminars on wildfire management could substantially improve professional skills and readiness to suppress emerging wildfires, in this way contributing to the progress in reducing emissions of black carbon. It is important to consider that building capacity to fight fires in the Arctic will require new research on techniques effective in tundra landscapes. Increasing capacity and skills to fight wildfires as part of disaster risk management includes outreach to Indigenous communities, who have traditional knowledge about these fire regimes.

The Component *Capacity and skills to fight wildfires as part of disaster risk management* is summarised in Table 43.

Table 43: Summary information for the Action Reducing/managing risks of wildfires on forest and peatland, Component Capacity and skills to fight wildfires as part of disaster risk management

Area of action	Open biomass burning
Action	Reducing/managing risks of wildfires on forest and peatland
Component	Capacity and skills to fight wildfires as part of disaster risk management
Type of intervention	Funding of research, independent analysis and innovation; Information and guidance
Time perspective	Short- and long-term
Structural change	Incremental
Jurisdictional scope & **Policy forum**	International, national National authorities responsible for disaster risk reduction, emergency management and civil protection, Arctic Council, international organisations and initiatives
Evidence	Kühn et al. (2020), AMAP (2015)

[79] Exchange Experts - Home (exchangeofexperts.eu)
[80] Sendai Framework at a Glance | PreventionWeb.net

Elements not assessed in this report

There were some actions under consideration during the drafting of this report for which we could not find enough information. It is however important to mention these for future reference. One omitted is investigation of the possibility to strengthen the emission standard requirements for stoves etc. in the EU Ecodesign Directive and/or expanding the scope of the Directive so that it also covers sauna stoves. To lower emissions from on- and off-road engines there are technologies available for future consideration. As an example, it is in principle easy to reduce the use of 2-stroke snow mobiles since comparable 4-stroke engines have been available on the market for many years. For stationary diesel generator engines there are engine exhaust particle filters that can be mandated to reduce particle emissions. There are also more conceivable actions in the Open biomass burning area. Burning of agricultural residue can be managed and prescribed to be done with minimal negative impact practices. Regulation of emissions from open biomass burning would also be facilitated by a standardisation of satellite remote sensing methods. It is also important to recognise that some of the actions discussed in this report are linked, with potential synergetic or trade-off effects between actions. This feature remains to be analysed in detail.

Finally, a long-term element of importance is fundamental research on black carbon. Many avenues of research are important. One such topic relates to the detailed technical definition of what type of particulate matter that should be classified as black carbon. Another topic is continued research on arctic warming effects of black carbon emissions. A final example of high policy concern is whether black carbon is more damaging for human health than other species of $PM_{2.5}$.

Awareness is necessary for action

Although too variable in its expression to be defined as a separate Action in the context of the EUA-BCA work, it is necessary to stress the importance of establishing and maintaining awareness of the black carbon Arctic problems. The environmental policy agendas are filled with urgencies and the need for prioritisation is constant. But raised awareness can enable political attention to the issue by changing public perceptions of environmental problems, alter individual's behaviour and pressure organisations to act. And targeted outreach activities are important for building the knowledge and skills required for individuals, industries, agencies, and organisations. Further still, without political attention to the issue, it is difficult for policy makers to gain support for emission reductions or costly monitoring efforts.

Awareness raising is an imprecise concept, but in the context of the EUA-BCA Element and Policy landscape reports, the most important information blocks that needs to be disseminated are information on the state-of-the-art knowledge on the health and environmental impact of black carbon, information on the importance of multilateral action, and information on large variation between states with respect to most important source sector and degree of domestic damage. One can consider national policy makers as important receivers of this information as they play a key role getting states to act. A compilation of country-specific description of the impacts together with country and sector specific emission data should thereby be an important tool for enhanced knowledge.

For the international environmental policy agenda, it can also be important with comparable estimates on efforts made by states. For the countries belonging to the Arctic Council such reporting is taking place already but to get a better picture of the BC-actions taken by non-AC states a joint effort can be carried out by for example EGBCM and CCAC. As an example, an analysis of CCAC-countries and AC-observer state BC-actions (as reported to AC and/or UNFCCC) could identify gaps and good examples of actions taken for information sharing to other countries.

Closing remarks

This report synthesises information on a number of policy actions that can reduce black carbon emissions or improve monitoring of black carbon that impacts the Arctic Actions within several relevant areas are presented. Considered areas of actions are both sectors with significant black carbon emissions (*Gas flaring*, *Small-scale domestic heating*, *Shipping*, *On-and off-road engines*, and *Open biomass burning*) and cross-sectoral activities – *In situ observations of black carbon in the Arctic*, and *Black carbon emission inventories.* Some of the actions identified for black carbon emitting sectors relate to recommendations given by EGBCM in Arctic Council (2019).

Some of the presented actions are of legislative character and imply regulation by laws and standards – national as well as international. Banning specific activities, the most stringent type of legal action, can be necessary in some cases – e.g. the ban on open burning of agricultural residues, or on using ad-blue emulators for vehicles. Development and harmonisation of environmental performance standards, including black carbon emissions, is identified as a possible action for several areas – *Gas flaring* (standards for flare equipment), *Small-scale domestic heating* (standards for stoves, fireplaces and boilers), *On- and off-road engines* (standards for vehicles). A prerequisite for developing effective environmental performance standards is proper research on emissions from different types of equipment, as well as further development, standardisation and harmonisation of emission measurement methods. For example, within the Area *Shipping*, development of a standardised black carbon sampling, conditioning and measuring protocol is assumed to precede and underly further development of international policies. Tests and certification procedures to verify compliance with the set emission standards are also important components of these regulatory and R&D actions stimulating implementation of cleaner technologies.

A range of actions imply softer intervention in a form of information and guidance – these are, for instance, educational brochures and capacity-building events teaching how to "burn right", or how to avoid and suppress wildfires. Economic incentives are another type of action, especially relevant if the aim is accelerated renewal of vehicle fleet or heating equipment stocks. There are indications that combined with information (for instance, on the cost-efficiency and environmental benefits of new heating stoves), this type of actions would probably target wider audience and cause less resistance from the general public than bans and prohibitions.

Actions within the areas *In situ observations of black carbon in the Arctic* and *Black carbon emission inventories* are aimed at verification of effects of sector-specific policy measures rather than on emission reductions per se. Emission inventories and projections give indications on emission trends and can be used to estimate the effects of certain policies on emissions. Actions needed to improve the number and the quality of black carbon emission inventories and to ensure their inter-comparability include capacity-building activities, improved methodological guidance and harmonisation of the reporting formats between different reporting systems. Other possible actions are inclusion of black carbon in NDCs under the Paris Agreement, enhanced in-depth review mechanisms for reported black carbon emissions, and dialogue on possibility to report black carbon emission inventories with countries that are neither EU Member States nor Parties to the Air Convention. In-situ observations in the Arctic provide valuable information on actual concentrations and deposition of emitted black carbon, used to further study emission pathways and effects. In this area, key actions are establishing and sustaining more Arctic observation stations, harmonisation of measurement methods, and developing solutions and opportunities for data sharing – from long-term stations and as well as from ad-hoc measurement campaigns, e.g. within research projects.

A majority of the presented actions are of international jurisdictional scope – this especially concerns cross-sectoral areas *In situ observations of black carbon in the Arctic* and *Black carbon emission inventories.* Examples of actions with national jurisdictional scope are emission inventory capacity-building activities and evaluation of whether EU NECD has produced the desired level of black carbon reporting by EU Member States. Inclusion of black carbon in NDCs submitted under the Paris Agreement and energy efficiency improvements are other actions with national jurisdictional scope, while there are also certain actions of sub-national jurisdictional scope – for example, providing information on the benefits and techniques to "burn right".

Time perspective of the policy actions are either short-term (could be implemented within 5 years) or long-term. Some of the actions, although requiring long time for actual implementation, have a preparatory phase of more short-term perspective – this refers, for instance, to creating international stimulus to establish and sustain Arctic observation stations measuring black carbon. Typical examples of short-term actions are those already on-going in certain countries/policy fora – such as emission inventories capacity-building, or scientific synthesis of climate impacts of black carbon. Other short-term actions could be significantly enhanced within the next five years – for instance, mobilisation of voluntary compilation and reporting of black carbon emission inventories beyond EU, AC and UNECE, promoting further harmonisation of BC emission reporting formats, or legal actions such as banning use of certain types of equipment.

Evidence of the actual effect of actions on black carbon in the Arctic is so far rather limited. Available studies analyse, for instance, the effect of trade regulations and accelerated enforcement of Euro standards for mobile sources on black carbon emissions – i.e. effects of actions of mainly legislative and economic character.

Actions presented above differ in terms of time perspective, societal impact, jurisdictional scope, and relevant policy fora. Since black carbon is an issue of the international character, joint efforts and coordinated policy decisions on international, national and sub-national levels will likely often be required. Policy fora of the presented actions thus include national authorities (governments and relevant profile ministries) and international organisations, international conventions and initiatives directly and indirectly involved in the BC-related work – the Air Convention, AC, CCAC, IMO, UNFCCC, the World Bank, etc. For effective practical implementation of actions, organisations not directly involved in policymaking but also highly relevant would need to be involved – those are, for instance, research and educational institutes, consultants conducting emission measurements, non-governmental environmental organisations, large companies (e.g. oil and gas companies), branch associations, etc.

References

AMAP (2015). AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers. Oslo, Norway, https://www.amap.no/documents/download/2506/inline

AMAP (Forthcoming). SLCF Assessment 2021 - Arctic Monitoring and Assessment Programme,

Arctic Council (2019). Expert Group on Black Carbon and Methane - Summary of Progress and Recommendations 2019, https://oaarchive.arctic-council.org/handle/11374/2411

Balch, J. K., et al. (2017). "Human-started wildfires expand the fire niche across the United States." Proceedings of the National Academy of Sciences 114: 2946-2951,

Bond, T. C. (2004). "A technology-based global inventory of black and organic carbon emissions from combustion." Journal of Geophysical Research 109: 1-43 10.1029/2003JD003697.

Bond, T. C., et al. (2013). "Bounding the role of black carbon in the climate system: A scientific assessment." Journal of Geophysical Research: Atmospheres 118: 5380-5552 DOI: 10.1002/jgrd.50171.

Canadian Council of Forest Ministers (2016). Canadian wildland fire strategy: A 10-year review and renewed call to action, https://www.ccfm.org/english/coreproducts-wildlandfires.asp

CCAC (2020). "Black carbon." from https://www.ccacoalition.org/en/slcps/black-carbon.

Cho, M.-H., et al. (2019). "A missing component of Arctic warming: black carbon from gas flaring." Environmental Research Letters 14(9) 10.1088/1748-9326/ab374d.

Coffin, D., et al. (2016). Examining Barriers to Trade in Used Vehicles, United States International Trade Commission, https://www.usitc.gov/publications/332/used_vehicle_wp_id-44_final_web_0.pdf

Comer, B., et al. (2017). Black carbon emissions and fuel use in global shipping 2015, https://theicct.org/sites/default/files/publications/Global-Marine-BC-Inventory-2015_ICCT-Report_15122017_vF.pdf

Conrad, B. M. and M. R. Johnson (2017). "Field Measurements of Black Carbon Yields from Gas Flaring." Environ Sci Technol 51(3): 1893-1900 10.1021/acs.est.6b03690.

Corbett, J. J., et al. (2010). "Arctic shipping emissions inventories and future scenarios." Atmospheric Chemistry and Physics 10(19): 9689-9704 10.5194/acp-10-9689-2010.

Costa, L., et al. (2011). "Sensitivity of Portuguese forest fires to climatic, human, and landscape variables: subnational differences between fire drivers in extreme fire years and decadal averages." Regional Environmental Change 11: 543-555 https://doi.org/10.1007/s10113-010-0169-6.

Davis, L. W. and M. E. Kahn (2010). "International Trade in Used Vehicles: The Environmental Consequences of NAFTA." American Economic Journal: Economic Policy 2(4): 58-82 10.1257/pol.2.4.58.

Dubey, K., Dodonov, A., Bekker, V., Piwowarska, A., Carriero, D., Dzioubinski, O., Foster, S., Roll, G. (2019). Mapping of Existing Technologies to Enhance Energy Efficiency of Buildings in the UNECE Region, UNECE Joint Task Force on Energy Efficiency Standards in Buildings

https://unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf

EUABCA (2019a). Review of Observation Capacities and Data Availability for Black Carbon in the Arctic Region: EU Action on Black Carbon in the Arctic – Technical Report 1, https://www.amap.no/documents/download/6033/inline

EUABCA (2019b). Review of Reporting Systems for National Black Carbon Emissions Inventories: EU Action on Black Carbon in the Arctic - Technical Report 2, https://www.amap.no/documents/download/3377/inline

European Commission (2017). Modernising and simplifying the CAP, Background Document - Climate and Environmental challenges facing EU agriculture and rural areas, https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/env_background_final_en.pdf

European Commission (2020). Report from the commission to the European parliament and the council on the progress made on the implementation of Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants. Brussels, https://ec.europa.eu/transparency/regdoc/rep/1/2020/EN/COM-2020-266-F1-EN-MAIN-PART-1.PDF

European environment Agency (2015). Air quality in Europe - 2015 report, http://www.eea.europa.eu/publications/air-quality-in-europe-2015

Evans, M., Kholod, N., Kuklinski, T., Denysenko, A., Smith, S.J., Staniszewski, A., Hao, W.M., Liu, L., and Bond, T.C. 2017. Black carbon emissions in Russia: A critical review. Atmospheric Environment 163 (2017) pp. 9-21.

Grahame, T. J., et al. (2014). "Public health and components of particulate matter: The changing assessment of black carbon." Journal of the Air & Waste Management Association 64(6): 620-660 10.1080/10962247.2014.912692.

Gustafsson, T. and K. Kindbom (2019). Svenskt system för reglering av utsläpp från vedpannor, https://www.regeringen.se/4ada72/contentassets/f1e7cf76c3a344be8b29d8696cf4c2e7/bilaga-4-till-redovisningen-av-ru-kartlaggning-och-analys-av-utslapp-fran-vedeldning.pdf

Hall, J. V., et al. (2016). "A MODIS-based burned area assessment for Russian croplands: Mapping requirements and challenges." Remote Sensing of Environment 184: 506-521 10.1016/j.rse.2016.07.022.

Hannah, L., et al. (2020). "The environmental consequences of climate-driven agricultural frontiers." PLOs One 15(2): e0228305 10.1371/journal.pone.0228305.

Holsten, A., et al. (2013). "Evaluation of the performance of meteorological forest fire indices for German federal states." Forest Ecology and Management 287(1 January 2013) https://doi.org/10.1016/j.foreco.2012.08.035.

Huang, K., Fu, J. S., Prikhodko, V., J. Storey, M., Romanov, A., Hodson, E.L., Cresko, J., Morozova, I., Ignatieva, Y, and Cabaniss, J. 2015. Russian anthropogenic black carbon: Emission reconstruction and Arctic black carbon simulation, J. Geophys. Res. Atmos., 120, pp. 11,306–11,333, doi: 10.1002/2015JD023358.

ICCT (2017). Prevalence of heavy fuel oil and black carbon in Arctic shipping, 2015 to 2025, https://theicct.org/sites/default/files/publications/HFO-Arctic_ICCT_Report_01052017_vF.pdf

ICCT (2019). "IMO agrees that we can control black carbon emissions from ships. But will we?". from https://theicct.org/blog/staff/imo-agrees-we-can-control-black-carbon-emissions-ships-will-we.

IIASA (2016). "ECLIPSE V5 global emission fields." from https://iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv5.html.

IIASA (2021). "ECLIPSE V6 global emission fields.", from https://iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv6.html

IMO (2015). Investigation of appropriate control measures (abatement technologies) to reduce black carbon emissions from international shipping, http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Air%20pollution/Black%20Carbon.pdf

IMO (2020). "Sub-Committee on Pollution Prevention and Response (PPR 7), 17-21 February 2020 ". from http://www.imo.org/en/MediaCentre/MeetingSummaries/PPR/Pages/PPR-7th-Session.aspx.

Janssen, N. A. H., et al. (2011). "Black Carbon as an Additional Indicator of the Adverse Health Effects of Airborne Particles Compared with PM10 and PM2.5." Environ Health Perspect 119(12): 1691-1699 10.1289/ehp.1003369.

Johnston, F. H., et al. (2012). "Estimated global mortality attributable to smoke from landscape fires." Environ Health Perspect 120(5): 695-701 10.1289/ehp.1104422.

Jolly, W. M., et al. (2015). "Climate-induced variations in global wildfire danger from 1979 to 2013." Nat Commun 6: 7537 10.1038/ncomms8537.

JRC (2019). Forest Fires in Europe, Middle East and North Africa 2018 doi:10.2760/1128.

Khan, S. A. and K. Kulovesi (2018). "Black carbon and the Arctic: Global problem-solving through the nexus of science, law and space." Review of European, Comparative & International Environmental Law 27(1): 5-14 https://doi.org/10.1111/reel.12245.

Kholod, N. and M. Evans (2016a). Black carbon emissions from diesel sources in Russia - Final inventory report, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25754.pdf

Kholod, N. and M. Evans (2016b). "Reducing black carbon emissions from diesel vehicles in Russia: An assessment and policy recommendations." Environmental Science & Policy 56: 1-8 10.1016/j.envsci.2015.10.017.

Kholod, N., Evans, M. and Kuklinski, T. (2016). Russia's black carbon emisions: focus on diesel sources. Atmos. Chem. Phys., 16, 11267–11281, 2016, doi:10.5194/acp-16-11267-2016

Kindbom, K., et al. (2018). Measures to reduce emissions of Short-Lived Climate Pollutants (SLCP) in the Nordic countries, https://www.ivl.se/download/18.14bae12b164a305ba11741d/1536914622413/C335.pdf

Kindbom, K., et al. (2018). Potentials for reducing the health and climate impacts of residential biomass combustion in the Nordic countries. TemaNord. N. C. o. Ministers http://dx.doi.org/10.6027/TN2018-530.

Klimont, Z., et al. (2017). "Global anthropogenic emissions of particulate matter including black carbon." Atmospheric Chemistry and Physics 17(14): 8681-8723 10.5194/acp-17-8681-2017.

Kuittinen, N., et al. (2021). "Shipping Remains a Globally Significant Source of Anthropogenic PN Emissions Even after 2020 Sulfur Regulation." Environ Sci Technol 55(1): 129-138 10.1021/acs.est.0c03627.

Kühn, T., et al. (2020). "Effects of black carbon mitigation on Arctic climate." Atmospheric Chemistry and Physics 20(9): 5527-5546 10.5194/acp-20-5527-2020.

Lelieveld, J., et al. (2015). "The contribution of outdoor air pollution sources to premature mortality on a global scale." Nature 525(7569): 367-371 DOI: 10.1038/nature15371.

Levander, T. and S. Bodin (2014). Controlling Emissions from Wood Burning, Legislation and Regulations in Nordic Countries to Control Emissions from Residential Wood Burning An examination of Past Experience

Lund, M. T., et al. (2014). "Global and regional climate impacts of black carbon and co-emitted species from the on-road diesel sector." Atmospheric Environment 98: 50-58 10.1016/j.atmosenv.2014.08.033.

Macias, J., et al. (2013). Policy Handbook for the Regulation of Imported Second-Hand Vehicles, https://www.globalfueleconomy.org/media/45362/wp7_regulation_for_2nd-hand_vehicles-lr.pdf

Morgan, S. E., et al. (2002). "Stories or statistics? Farmers' attitudes toward messages in an agricultural safety campaign." Journal of agricultural safety and health 8(2) https://doi.org/10.13031/2013.8427.

Nordic Ecolabelling (2018). About Nordic Ecolabelled Stoves, Version 4.3, Background to ecolabelling 11. June 2014 - 30 June 2022

Parfenova, E., et al. (2019). "Assessing landscape potential for human sustainability and 'attractiveness' across Asian Russia in a warmer 21st century." Environmental Research Letters 14(6) 10.1088/1748-9326/ab10a8.

Pereira, P., et al. (2016). "Stakeholders' Perceptions about Fire Impacts on Lithuanian Protected Areas." Land Degradation & Development 27(4): 871-883 doi.org/10.1002/ldr.2290.

Peters, G. P., et al. (2011). "Future emissions from shipping and petroleum activities in the Arctic." Atmospheric Chemistry and Physics 11(11): 5305-5320 10.5194/acp-11-5305-2011.

Quinn, P. K., et al. (2008). "Short-lived pollutants in the Arctic: their climate impact and possible mitigation strategies." Atmospheric Chemistry and Physics 8: 1723-1735

Salonen, H. (2020). "Modernization of Russian district heating systems with the help of biomass energy – A Gordian knot?" Environmental Innovation and Societal Transitions 36: 291-302 https://doi.org/10.1016/j.eist.2019.10.006.

Sand, M., et al. (2016). "Response of Arctic temperature to changes in emissions of short-lived climate forcers." Nature Climate Change 6(3): 286-289 10.1038/nclimate2880.

Sand, M., et al. (2020). "Surface temperature response to regional black carbon emissions: do location and magnitude matter?" Atmospheric Chemistry and Physics 20(5): 3079-3089 10.5194/acp-20-3079-2020.

Saunier, S., et al. (2019). Best Available Techniques Economically Achievable to Address Black Carbon from Gas Flaring. EU Action on Black Carbon in the Arctic Technical Report, https://www.amap.no/documents/download/3827/inline

Savolahti, M., et al. (2014). Ecodesign directive for residential wood combustion appliances: impacts and emission reduction potential in Finland. The Sustainable City IX: 1493-1504 10.2495/sc141262.

Seay, B., et al. (2020). "Estimating Arctic Temperature Impacts from Select European Residential Heating Appliances and Mitigation Strategies." Earth's Future 10.1029/2020ef001493.

Shindell, D., et al. (2012). "Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security." Science 335: pp 183-189 DOI: 10.1126/science.1210026.

Sjöström, J. and A. Granström (2020). Skogsbränder och gräsbränder i Sverige - Trender och mönster under senare decennier. MSB, https://rib.msb.se/filer/pdf/29089.pdf

Stohl, A., et al. (2013). "Black carbon in the Arctic: the underestimated role of gas flaring and residential combustion emissions." Atmospheric Chemistry and Physics 13(17): 8833-8855 10.5194/acp-13-8833-2013.

Sun, Q., et al. (2019). "Global heat stress on health, wildfires, and agricultural crops under different levels of climate warming." Environ Int 128: 125-136 10.1016/j.envint.2019.04.025.

UNEP and UNECE (2017). Used Vehicles: A Global Overview, https://www.unece.org/fileadmin/DAM/trans/doc/2017/itc/UNEP-ITC_Background_Paper-Used_Vehicle_Global_Overview.pdf

UNEP and WMO (2011). Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers, https://wedocs.unep.org/rest/bitstreams/12809/retrieve

van Marle, M. J. E., et al. (2017). "Historic global biomass burning emissions for CMIP6 (BB4CMIP) based on merging satellite observations with proxies and fire models (1750–2015)." Geoscientific Model Development 10(9): 3329-3357 10.5194/gmd-10-3329-2017.

WHO (2012). Health effects of Black Carbon, http://www.euro.who.int/__data/assets/pdf_file/0004/162535/e96541.pdf

World Health Organization (2014). Burden of disease from Ambient Air Pollution for 2012. Environ Health Perspect. 122: 397-403 10.1289/ehp.1307049.

Wunderlich, S. and K. A. Gatto (2015). "Consumer perception of genetically modified organisms and sources of information." Adv Nutr 6(6): 842-851 10.3945/an.115.008870.

Appendix: Summary of EGBCM 2019 Recommendations

Full report available at: https://oaarchive.arctic-council.org/handle/11374/2411

1. Mobile and stationary diesel-powered sources

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

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

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

Recommendation 1d: Develop, as appropriate, and report on measures and best practices to reduce particulate matter and black carbon emissions from shipping.

Recommendation 1e: Reduce emissions from stationary diesel engines by adopting targeted policies and programs, including shift to new technologies and improved efficiency.

2. Oil and gas

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

Recommendation 2b: Encourage the adoption of best practices in reducing routine flaring and in improving gas capture.

Recommendation 2c: Urge firms to engage in international and domestic voluntary methane and black carbon emission reduction activities, including the implementation of methane management strategies.

Recommendation 2d: Promote targeted and cost-effective measures at large methane emission sources, where relevant.

3. Residential combustion

Recommendation 3a: Reduce emissions from new solid fuel combustion appliances by accelerating deployment of cleaner and more efficient heating sources and by promoting proper operation and maintenance of appliances, including storage and treatment of fuels.

Recommendation 3b: Reduce emissions from legacy solid fuel combustion appliances by accelerating replacement with cleaner and more efficient new heating sources and promoting proper operation and maintenance of appliances, including storage and treatment of fuels.

Recommendation 3c: Reduce emissions by promoting enhanced energy efficiency in residential dwellings reducing the need for heating, especially in buildings heated with oil or solid fuels.

4. Solid waste

Recommendation 4a: Avoid methane emissions by preventing food waste and the landfilling of organic waste. Improve resource efficiencies as appropriate for Arctic conditions, including new ways of reusing organic material based on more efficient sorting of waste, composting and biogas production.

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

Recommendation 4c: Promote best practices for waste management in northern and remote communities.

5. Agriculture and animal husbandry

Recommendation 5a: Promote food consumption patterns that utilise Arctic food chains sustainably and efficiently, support the preservation of carbon sinks, and minimise life-cycle emissions of methane.

Recommendation 5b: Promote work on possibilities to reduce emissions of enteric methane under Arctic conditions, in co-operation with relevant organizations.

Recommendation 5c: Develop agricultural policies and practices to reduce open burning of agricultural waste. Encourage studies and piloting of innovative solutions that reduce the need for open burning.

6. Management of wildfires

Recommendation 6a: Build and maintain international mutual aid and resource exchange arrangements amongst Arctic nations that have specialised experience in wildfire management, suppression, and monitoring.

Recommendation 6b: Develop region-specific public education campaigns on wildfire prevention and safety.

Recommendation 6c: Develop and implement regionally appropriate forest management practices that reduce the risk of severe wildfires.

Recommendation 6d: Use the best available science to develop prediction models that can be used to examine fire risks at daily to decadal scales, to support drafting of prevention and emergency response plans.

IVL Swedish Environmental Research Institute Ltd.
P.O. Box 210 60 // S-100 31 Stockholm // Sweden
Phone +46-(0)10-7886500 // www.ivl.se