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CARBON LIMITS AS

Assessment of possible actions for controlling Short-Lived Climate Forces

Prepared for the Norwegian

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Executive summary

Several efforts have recently been undertaken to assess the scientific understanding of the contribution to climate change of some traditional air pollutants, such as black carbon ("soot") and ozone. These short-lived climate forcers remain in the atmosphere only for days or weeks, while carbon dioxide (CO_2), the most important greenhouse gas, has a lifetime of typically hundred years. This implies that it will take relatively long before reduced emissions of CO_2 will have an impact on the temperature, while reduced concentration of the short-lived climate forcers will have a near-term effect. In addition to their potential impact on climate change, black carbon and ozone also have an impact on human health and crop yield.

International assessments provide a good basis for considering actions to reduce emissions of short-lived forcers or their precursors. All assessments underline that carbon dioxide is the dominant factor contributing to global climate change, and that it is only through CO_2 mitigation that one can combat climate change in the long-term. However, addressing short-lived climate forcers offers unique opportunities to slow warming already in the coming decades. Addressing short-lived forcers is therefore not an alternative but a complement to CO_2 mitigation. The effects on climate from reduced black carbon emissions will be particularly pronounced in the Arctic, partly because of the darkening effect of black carbon deposited on snow surfaces.

Technical measures are available that can reduce emissions of black carbon, methane (an ozone precursor) and other short-lived forcers. These are mainly addressing relatively small sources, and include the recovery of methane from coal, oil and gas extraction and transport, methane capture in waste management, use of clean-burning stoves for residential cooking, diesel particulate filters for vehicles and the banning of field burning of agricultural waste. In the Nordic countries main sources for black carbon are most likely land based transportation (on-road and off-road diesel vehicles), residential heating and open biomass burning. Carbon dioxide emission reductions, necessary to achieve the long-term goal on climate change, mainly target the energy and large industrial sectors and would therefore not necessarily result in significant reductions in short-lived forcers. Significant reduction of the short-lived climate forcers requires a specific strategy, as many are emitted from a large number of small sources.

The UNEP Assessment has quantified the effects of implementing on a global scale a limited number of measures on reducing black carbon and methane emissions, resulting in more than 70 per cent emission reductions for black carbon and about 25 per cent for methane by 2030 relative to 2005. This could reduce warming in the Arctic in the next 30 years by about two-thirds compared to the projections of reference scenario.

On the policy side there are very few efforts to achieve collective emission reductions in short-lived forcers through international agreements. The only effort in that direction so far is the revision of the Gothenburg Protocol under the Convention on Long-range Transboundary Air Pollution (CLRTAP), which includes national emission ceilings for particulate matter. In the present negotiating text it is further stated that: "In taking steps to reduce emissions of particulate matter, each Party should seek reductions from those source categories known to emit high amounts of black carbon, to the extent it considers appropriate". UNEP has decided to keep the scientific issue under review, but without indicating any policy initiatives. The Arctic Council has recommended voluntary action by the member nations.

The Nordic countries may consider strengthening their efforts on short-lived climate forcers through activities such as:

- Ensure a strong Nordic position in the various international initiatives, such as UNEP, CLRTAP, and the Arctic Council, and in particular support as strong wording as possible on black carbon emission reductions in the revised Gothenburg Protocol, and to strengthen actions under the Arctic Council.
- The Nordic countries could develop national plans for reducing its own emission of black carbon and methane, publish the plans jointly, and initiate implementation to demonstrate the feasibility.

- The Nordic countries should actively engage in efforts to improve black carbon emission data, both in their own countries as well as internationally.

- The Nordic countries should strengthen efforts to reduce black carbon/particles emissions from stoves for residential burning (cook stoves) in developing countries. This will primarily have positive health effects, but also contribute to reducing climate change.

- Intensify efforts to improve global cooperation on short-lived forcers/joint consideration of air pollution and climate change. The long-term goal could be to include this under the UNFCCC, but it is likely more effective in the near-term to focus on other solutions. One pathway could be regional agreements similar to the Convention on Long-range Transboundary Air Pollution, which covers Europe and North-America. In addition, UNEP could be requested to facilitate global focus on these issues, including issues such as financing and possible cooperation between various regional initiatives.

- Active participation in international efforts to reduce emissions of methane.

- Strengthen efforts on improving the accuracy of monitoring data, including better spatial coverage of monitoring stations; and further model developments. The latter is needed for assessing the importance of various source regions and sectors. On monitoring sites,

the feasibility of establishing more stations in the Arctic (for instance at Bjørnøya) should be explored.

- Initiate activities to enhance cooperation and contact among Nordic scientists working on different aspects of short-lived climate forcers, as well as strengthening contacts between scientists and policymakers. This may be achieved by organizing workshops/seminars once or twice per year, allowing ample time for developing contacts and sharing information between various stakeholders. To ensure that this is implemented the best solution might be if one country voluntarily takes responsibility to organize such meetings. Another possibility is that the country having the chairmanship of the Nordic Council of Ministers gets the responsibility.

1: Introduction – background

Recent research during the past few years has led to a better understanding of the contribution to climate change of some traditional air pollutants, such as black carbon ("soot"), ozone and methane. These substances remain in the atmosphere only for a short time (days to about a decade) and are referred to as short-lived climate forcers (SLCFs). They are therefore fundamentally different from carbon dioxide (CO_2), the most important greenhouse gas, which has a lifetime in the atmosphere of typically hundred years. In addition to their impact on the radiative balance and then on climate change, several of the short-lived forcers also have an impact on human health and crop yield. Some of the hydrofluorocarbons (HFCs) included in the Kyoto Protocol have a short lifetime compared to CO_2 and are sometimes referred to as SLCFs. However, the HFCs do not have air quality impacts. HFCs will be only briefly discussed in Section 2.5.

During the last few years, international efforts have been undertaken to assess the scientific basis for controlling emissions of SLCFs. These efforts include the UNEP Integrated Assessment of Black Carbon and Tropospheric Ozone, and the follow-up study Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers; the Ad Hoc Expert Group on Black Carbon under the Convention on Long-range Transboundary Air Pollution (CLRTAP); the Arctic Council Task Force on Short-lived Forcers; and the Arctic Monitoring and Assessment Programme (AMAP) report on The Impact of Black Carbon on Arctic Climate. The findings of these international efforts form the main input to this report. Policy developments to achieve reduced levels of short-lived climate forcers in the atmosphere are briefly discussed, including an assessment of the role of Nordic countries in strengthening international efforts in this area.

A very brief summary of the present scientific understanding of SLCFs in the atmosphere is given in an Annex to the report.

The present report has been prepared for the Norwegian Ministry of the Environment with the intention to use it for further discussions within the Nordic Council of Ministers.

2: On the international assessments and policy developments

The various international efforts are mainly of a technical nature, but with some policy elements included. The intention with this Section is to describe briefly the results of the various efforts, as well as how the various reports have been received by parent organisations. In addition, some independent initiatives will be mentioned.

It is important to note that all the assessments underline that measures addressing short-lived forcers like black carbon, ozone and methane, complement but do not replace carbon dioxide reduction measures. Major carbon dioxide emission reductions are absolutely necessary to achieve the long-term goal on climate change, but these reduction strategies mainly target the energy and large industrial sectors and therefore would not necessarily result in significant reductions of short-lived forcers. Significant reduction of the short-lived climate forcers requires a specific strategy, as many are emitted from a large number of small sources.

2.1: UNEP Integrated Assessment of Black Carbon and Tropospheric Ozone, and Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers

The United Nations Environment Programme (UNEP) early in 2011 published an analysis of emission trends, and impacts on climate, human health and ecosystems of short-lived climate forcers. The UNEP Assessment is very comprehensive with a global perspective and includes the important short-lived climate forcers methane, ozone and black carbon, and quantifies the effects of emission reductions on climate change, human health, and crop yield[1]. Later in 2011 UNEP completed a follow-up study providing further details on the situation in the different regions of the world.[2] This will be referred to as the UNEP Synthesis Report.

An important element of the analyses is the identification of technical measures that could reduce emissions of black carbon and ozone precursors. These are co-emitted with different gases and particles, some of which cause warming and some of which, such as organic carbon and sulphur dioxide (SO_2), lead to cooling. The selection criterion was that the measure should be likely to reduce global climate change and also provide air quality benefits, so-called "win-win measures". Those

[1] UNEP and WMO, 2011: Integrated Assessment of Black Carbon and Tropospheric Ozone. Summary for decision makers. http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_SDM.pdf

[2] UNEP, 2011: Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers. http://unep.org/pdf/Near_Term_Climate_Protection_&_Air_Benefits.pdf

measures that provided a benefit for air quality but increased warming were not included in the selected measures. For example, measures that primarily reduce emissions of SO_2 were not included.

The identified measures were chosen from a subset of about 2 000 separate measures. A small number (16) of emission reduction measures were selected for the analyses and assumed to be fully implemented. The measures target black carbon and ozone precursors that could immediately begin to protect climate, public health, water and food security, and ecosystems. Measures include the recovery of methane from coal, oil and gas extraction and transport, methane capture in waste management, use of clean-burning stoves for residential cooking, diesel particulate filters for vehicles and the banning of field burning of agricultural waste. Widespread implementation is achievable with existing technology but would require investment. The full implementation of the selected measures by 2030 would lead to significant emission reductions relative to 2005: More than 70 per cent for black carbon and about 25 per cent for methane. Relative to the reference scenario the numbers are larger.

In the reference scenario used in the Assessment, global temperatures are projected to increase by 1.3°C by the middle of this century, bringing the total increase from pre-industrial levels to about 2.2°C. Model calculations that were undertaken for the Assessment show that the measures targeted to reduce emissions of black carbon and methane could greatly reduce the global mean warming over the next few decades. Full implementation of the identified measures would reduce future global warming by 0.5°C[3] (within a range of 0.2–0.7°C) by 2030, which means halving the potential increase in global temperature projected for 2050 compared to a reference scenario based on current policies and energy and fuel projections. In contrast even a fairly aggressive strategy to reduce CO_2 emissions does little to mitigate warming in the next two to three decades

The assessment underlines that both near-term and long-term strategies are essential to protect climate: Reductions in near-term warming can be achieved by controlling the short-lived climate forcers whereas carbon dioxide emission reductions, beginning now, are required to limit long-term climate change. Implementing both reduction strategies is needed to improve the chances of keeping the Earth's global mean temperature increase to within the UNFCCC 2°C target.

Full implementation of the identified measures would have substantial benefits in the Arctic and other glaciated and snow-covered regions. According to the Assessment, this could reduce warming in the Arctic in the next 30 years by about two-thirds compared to the projections of reference scenario. This substantially decreases the risk of amplification of global warming resulting from changes in the Arctic. An important reason for the pronounced effect on climate change in the Arctic is the darkening effect of black carbon on snow surfaces which increase the absorption of solar radiation.

[3] In the Synthesis Report a different model was used compared to the Assessment, giving an estimated temperature change closer to 0.4°C.

The Assessment demonstrates that full implementation of the identified measures would substantially improve air quality and reduce premature deaths globally due to significant reductions in indoor and outdoor air pollution. The reductions in particle concentrations resulting from the black carbon measures would, by 2030, avoid an estimated 2.4 million (range 0.7–4.6 million) premature deaths annually.

The Synthesis Report states that confidence is high that black carbon measures would provide substantial health benefits. The quantitative estimates of reduced number of premature deaths are based on reduction in outdoor particulate air pollution from having fully implemented the measures. They would also greatly reduce impacts on health from indoor exposures. Due to the very high particulate-matter burden in Asia, the black carbon measures could prevent a greater number of premature deaths in this region than elsewhere, with the next highest benefit likely to be achieved in Africa. Health benefits in these two regions are mainly achieved by controlling biomass cook stove and transport emissions.

Confidence is also high that controlling methane emissions and ozone precursor emissions by implementing black carbon measures would reduce ozone concentrations and its impacts on crops. Implementing all 16 measures would avoid annual losses from four major crops (maize, rice, soybean and wheat) of about 32 million tonnes (range of 21-57 million tonnes) each year after 2030 when all the measures have been implemented (the UNEP Assessment gave a higher central value of 52 million tonnes, reflecting differences between global models). Half of these benefits result from implementing the methane mitigation measures and the other half from black carbon measures.

The analyses include only the direct effect of changes in atmospheric composition on health and agriculture without including the benefits that avoided climate change would have on human health and agriculture.

The UNEP Assessment of Black Carbon and Tropospheric Ozone was released immediately prior to the Governing Council 26 in February 2011. In the decisions, the report is recognized through the following text: "Invites the Executive Director, through engaging appropriate institutions, research networks and other partners, to continue its assessment of short-lived climate forcers and to keep under review emerging science and to update governments, international organizations and other stakeholders as appropriate" (UNEP/GC.26 2 II paragraph 6). Thus, the decision does not launch any initiatives towards policy developments.

There are several potential tasks one could foresee taken on by UNEP to implement measures and achieve emission reductions as outlined above, such as: Awareness rising; assistance in implementing measures in developing countries, including funding issues; assistance in developing regional agreements on short-lived forces; and development of a global agreement. The latter is perhaps not a particularly reasonable task for UNEP, because the climate change could be more logically treated under the Framework Convention on Climate Change while the environmental aspects (human health and crop yield) could more effectively be dealt with through regional arrangements and overseen by UNEP.

2.2: Convention on Long-range Transboundary Air Pollution (CLRTAP)

The Gothenburg Protocol under the CLRTAP[4] was adopted in 1999. The Protocol specifies national emission ceilings for sulphur dioxide, nitrogen oxides, volatile organic compounds, and ammonia, with the view to abate acidification, eutrophication and ground-level ozone. The Protocol is now under revision, and the Executive Body of CLRTAP has earlier decided that new requirements for particulate matter should be included in the revised Protocol. In December 2009 an Ad Hoc Expert Group on Black Carbon was established to assess the science of black carbon with respect to both climate and public health. Based on the best science available at the moment (autumn 2010), the Expert Group agreed on several key scientific findings[5]:

- There is general scientific consensus that mitigation of black carbon will lead to positive regional impacts on climate change by reducing black carbon deposition in areas with snow and ice.

- There is virtual certainty that reducing primary particulate matter will benefit public health.

- The Arctic, as well as alpine regions, may benefit more than other regions from reducing emissions of black carbon.

- Climate processes unique to the Arctic have significant effects that extend globally, so action should be taken in the very near term to reduce the rate of warming.

Black carbon emissions in the UNECE region are expected to decline between 2000 and 2020 by about one third as a result of current emission control legislation, primarily in the transport sector. Nevertheless, measures with known technology could reduce emissions by an additional forty per cent by the year 2020. Important sectors with mitigation potential remaining after current legislation is implemented are residential combustion, non-road mobile machinery, road transport and open burning.

The Expert Group concluded that because of the public health benefits of reducing black carbon, as well as the location of the countries across the Convention regions in relation to the Arctic, the Executive Body should consider taking additional measures to reduce black carbon. On that basis, the Executive Body in December 2010, decided to include consideration of black carbon as a component of particulate matter in the process of revising the Gothenburg Protocol. This decision marks the first time an international agreement has attempted to address the issue of short-lived climate forcers in the context of air pollution policy. The decision also places a priority on developing emission inventories, ambient monitoring and source measurements in an effort to improve the

[4] The CLRTAP covers all of Europe, USA and Canada, and has about 50 Parties.

[5] ECE/EB.AIR/2010/7 and ECE/EB.AIR/2010/7/Corr.1

understanding of adverse effects, efficacy of control measures and the costs and benefits of abatement.

After the first round of negotiations it seems most likely that in the revised Protocol, the reductions in particulate emissions will be quantified by a national emission ceiling in 2020, while the "commitments" on black carbon emissions will be more qualitative with text like: "In taking steps to reduce emissions of particulate matter, each Party should seek reductions from those source categories known to emit high amounts of black carbon, to the extent it considers appropriate". The revision of the Protocol is expected to be finalized in the spring of 2012.

2.3: The Arctic Council Task Force on Short-lived Forcers

The Arctic Council Tromsø Declaration from April 2009 created a Task Force on Short-lived Forcers to identify existing and new measures to reduce emissions of short-lived climate forcers and recommend further immediate actions that can be taken. The Task Force was requested to report on progress at the Ministerial meeting in 2011.

The Senior Arctic Officials (SAOs) in November 2009 further agreed that the Task Force should initially focus on black carbon. The focus on black carbon does not represent a judgment that black carbon is necessarily more important than methane or other climate forcers in terms of Arctic impacts, but acknowledges that the Task Force needed to conduct new technical analyses to inform its recommendations on black carbon.

The Arctic Council Task Force on Short-lived Forcers presented its report to the Ministerial meeting at Nuuk (Greenland) in May 2011. It underlines that carbon dioxide emissions are the dominant factor contributing to Arctic climate change, and that addressing short-lived forcers offers unique opportunities to slow Arctic warming in the near-term. Some other important points of the report are:

- Reducing emissions of short-lived forcers will lead not only to reduced rates of warming, but also to improved human health. Many measures to reduce emissions can be considered no-regrets.
- The largest sources of black carbon in Arctic Council countries have been identified to be land-based transport (primarily on-road and off-road diesel vehicles), open biomass burning, and residential heating. It is further noted that marine shipping is an important source in the Arctic (proximity to ice and snow), and that the understanding of gas flaring requires special attention.

- Emissions from residential heating may increase in the future since many Arctic nations have turned to wood fuel in recent years.

The Arctic Council encouraged "Arctic states to implement, as appropriate in their national circumstances, relevant recommendations for reducing emissions of black carbon". The Task Force

was requested to continue its work by focusing on methane and tropospheric ozone, as well as further work on black carbon where necessary.

One of the products available from the work of the Task Force is a technical report assessing the emission data from the Arctic countries.[6]

2.4: Arctic Monitoring and Assessment Programme (AMAP)

AMAP in late 2011 published a study of the impact of black carbon on Arctic climate[7]. This study provides a comprehensive overview of the scientific knowledge on black carbon: Sources, measurement and modelling of ambient concentrations, and calculations of climate forcing. The study illustrates, using available monitoring data, the challenges associated with model calculations. They conclude that black carbon represent a positive radiative forcing for the Arctic.

The AMAP study identifies science needs, and strongly recommends strengthened efforts on improving the quality of emission data for black carbon and other short-lived climate forcers; improving the accuracy of monitoring data, including better spatial coverage of monitoring stations; and further model developments. The latter is particularly important for assessing the importance of various source regions and sectors.

AMAP is strengthening its work on SLCFs on the basis of Arctic Council's Nuuk Declaration. The work includes follow-up of the report presented in 2011 covering black carbon, organic carbon and ozone. In addition, a group on methane has been established. This will focus on natural sources of methane in the Arctic and is strongly linked to activities on permafrost.

2.5: Other international activities

Intergovernmental Panel on Climate Change (IPCC)

There is rather little information on black carbon and other short-lived forcers included in the Fourth Assessment Report of the IPCC (AR4). This is expected to be improved in the Fifth Assessment Report (AR5) which is presently under preparation. However, due to the principles under which the IPCC works, it is not expected that AR5 will contain significant new information compared to what is presently known from the assessments mentioned above, but inclusion of this material in AR5 will clearly give higher "status" to the work on SLCFs.

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[6] An Assessment of Emissions and Mitigation Options for Black Carbon for the Arctic Council, Technical Report of the Task Force on Short-Lived Climate Forcers, April 2011

[7] AMAP, 2011. The Impact of Black Carbon on Arctic Climate (2011). By: P.K. Quinn, A. Stohl, A. Arneth, T. Berntsen, J. F. Burkhart, J. Christensen, M. Flanner, K. Kupiainen, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov, and V. Vestreng. Arctic Monitoring and Assessment Programme (AMAP), Oslo.

An important function of the IPCC is to develop methodologies for estimating greenhouse gas emissions and guidelines for reporting such data. Efforts have been made to initiate work on black carbon emissions in the Task Force on National Greenhouse Gas Inventories. However, it has not yet been possible to reach consensus on this, but it is expected that work on black carbon may be started at the latest when the AR5 has been finalized.

United Nations Framework Convention on Climate Change (UNFCCC)

In the negotiations under the Bali Mandate, a proposal was made on launching a technical study of the knowledge base for short-lived forcers (including HFCs). The substance of the proposal was not discussed, and the proposal seems to have disappeared in the negotiating process, and there is no clear sign of it in the present negotiating texts. SLCFs are not mentioned in the Durban Platform adopted at the Conference of the Parties (COP 17) in December 2011, and there are no indications that this will be taken up in the coming negotiations.

In view of the rather difficult negotiations on an international climate agreement, it does not seem constructive to introduce work on short-lived forcers in the UNFCCC now. However, this does not rule out the possibility that the UNFCCC could take up the issue later.

Initiatives to reduce methane emissions

A couple of voluntary initiatives have been launched to reduce emissions of methane with the USA playing a key role in the developments. The Global Methane Initiative (previously called Methane to Markets Partnership) is an international initiative that advances cost-effective, near-term methane recovery and use as a clean energy source. It is working to reduce methane emissions in four key sectors: agriculture (animal waste management), coal mines, landfills, and oil and gas systems. In each sector, existing cost-effective technologies and practices can be employed to reduce emissions and generate clean energy. Around forty governments are participating in this initiative.

The Prototype Methane Finance Facility (PMFF) is a recent effort to gain interest in CDM projects with methane reductions by providing a price guarantee. The main idea of the PMFF is to provide a guaranteed minimum price ("floor price") for carbon credits that come from projects that reduce methane. This guarantees private sector investors in such projects that they will receive, at the least, that minimum price when carbon credits are generated by the projects when they begin operating. The PMFF would create certainty to investors by agreeing to cover any shortfall by paying the difference between the guaranteed price and the actual market price when credits are issued. If the price is higher than the guaranteed price, the PMFF would be paid some portion of that profit, to use for future guarantees or other methane reduction activities. The Facility is presently under development and it is premature to assess its chances for success.

International Maritime Organization (IMO)

Marine shipping in the Arctic region is a relatively small source of black carbon, yet potentially high in impact due to its proximity to snow and ice. The importance of this source may increase in the future due to projected increases in global ship traffic.

In a submission to the International Maritime Organization, Norway, Sweden and USA have raised the importance of black carbon emissions from shipping on the Arctic climate, and identified a range of technical and operational measures. IMO's Marine Environment Protection Committee (MEPC) considered the issue at its meeting in July 2011. It agreed a work plan and instructed the Sub-Committee on Bulk Liquids and Gases (BLG) to inter alia develop a definition for black carbon emissions from international shipping; and investigate appropriate control measures to reduce the impacts of black carbon emissions from international shipping in the Arctic. A report is to be submitted to MEPC in 2013.

European Union

A revision of EU's directive on air quality is planned to be undertaken in 2013. Based on the observed air quality in the Member States, particulate matter (PM) and ozone are likely to be key pollutants in the revision. There are, however, no sign that black carbon will be treated separately, but because black carbon is part of the PM, reduction in emissions of PM may reduce also the emissions of black carbon. Experiences from the negotiations on a revised Gothenburg Protocol under the CLRTAP indicate that not all Member States are very ambitious in defining specific black carbon commitments. Since the SLCFs are important both for climate change and traditional air pollution effects, one may speculate that it may perhaps be more complicated to handle emission reduction initiatives when climate change and air quality are handled at the same time but under different ministries or directorates.

Montreal Protocol

Hydrofluorocarbons (HFCs) are included in the Kyoto Protocol, and some of these have a relatively short lifetime (some years) while other have longer lifetimes (up to some hundred years). There have been proposals to include HFCs in initiatives to reduce short-lived climate forcers. However, these are not traditional air pollutants with effects on human health and the environment and many are therefore arguing that these substances should not be handled in the same way as for instance black carbon.

Independent from these considerations there has been discussions to use the Montreal Protocol on Substances that Deplete the Ozone Layer to limit HFCs, widely used as substitute for ozone-depleting substances. The HFCs pose no threat to the ozone layer, but are extremely potent greenhouse gases and have therefore been regulated under the Kyoto Protocol rather than the Montreal Protocol. The problem is that the two agreements work at cross-purposes: the Kyoto Protocol is trying to reduce

the use of HFCs, while the Montreal Protocol has served to encourage HFCs as ozone-friendly substitutes for various ozone-depleting substances.[8]

Although HFCs today account for less than 1% of global greenhouse gas emissions, their use is projected to grow rapidly due to increased demand for air conditioning and refrigeration, particularly in developing countries as they phase out HCFCs. Some estimates show that by mid-century, HFCs could contribute 9-19% of global GHG emissions.

It has been proposed to regulate HFCs under the Montreal Protocol (and not the Kyoto Protocol), but this have prompted several objections. One objection is that HFCs cannot be regulated under the Montreal Protocol because they are not ozone-depleting substances; another is the principle of common but differentiated responsibilities and respective capabilities, enshrined in the UNFCCC but not in the Montreal Protocol. Presently it is difficult to assess if there will be a resolution of the question in the near future.

Climate Change and Clean Air Initiative

On 16 February 2012 in Washington, USA, Canada, Mexico, Sweden, Bangladesh and Ghana launched a new Initiative on Climate Change and Clean Air. The Initiative will address reduction of emissions of short-lived forcers, including HFCs. It is premature to assess how this initiative will develop.

3: Activities in the Nordic countries

During recent years, several Nordic research groups have addressed various elements related to the SLCFs, particularly black carbon. The knowledge about SLCFs available in Nordic scientific institutions is therefore relatively good. The SLCF issue has received increasing attention also from various ministries, including through active participation in various activities within international organisations.

Although the collective Nordic knowledge base is rather good, there are differences between the countries and in some cases it is important to work towards improving the situation in some of the countries. One such area is emission inventories. These are a basic requirement for explaining effects on the environment and are essential in assessing emission reductions. Based on the technical report prepared by the Arctic Council Task Force on Short-Lived Climate Forcers (footnote 6) it seems that

[8] An issue linked to these considerations is the controversies under the Clean Development Mechanism (CDM) of the Kyoto Protocol. When producing HCFC-22 (an ozone-depleting substance used for instance as refrigerant and in foam blowing), HFC-23 is formed as an unwanted by-product. Several CDM projects, mainly in China, destroy the HFC-23 at costs substantially below the market carbon price (CER), and has provided large profits to project hosts. Under the Montreal Protocol it has been agreed to phase-out the HCHC-22, and the fear has been that such profitable CDM projects may lead to overproduction of HCHC and possibly delay the phase-out of the ozone-depleting substance.

Finland has devoted more attention to this issue than the other Nordic countries and therefore seems to have higher quality data. However, recently other Nordic countries have given increased attention to this issue and hopefully all Nordic countries will have reasonably good emission inventories shortly. Emission data are a basis for assessing various mitigation options and develop action plans. As soon as satisfactory data are available, all the Nordic countries should develop action plans for reducing emissions of black carbon and other SLCFs. If such action plans could be presented jointly by all the Nordic countries, preferably also with a concrete plan for implementation, it might provide an important signal to the rest of the world.

On atmospheric modelling Norway has been particularly active and contributed to several of the international processes. Monitoring of air quality is essential, including providing a data base for comparison with model calculations, and is undertaken by all Nordic countries. However, scientists underline the need for improving the accuracy of monitoring data, including better spatial coverage of monitoring stations. The latter is particularly important for assessing the importance of various source regions and sectors for the Arctic. On monitoring sites, it has been suggested that the feasibility of establishing more stations in the Arctic (for instance at Bjørnøya) should be explored.

The scientific work of various groups is not necessarily well coordinated among the Nordic countries, and that should not be a goal. However, scientists have suggested that it may be beneficial to increase informal contacts among Nordic scientists working on different aspects of short-lived climate forcers. This could also include strengthening contacts between scientists and policymakers. Better contacts may be achieved by organizing workshops/seminars once or twice per year, allowing ample time for developing contacts and sharing information between various stakeholders. To ensure implementation the best solution might be if one country voluntarily takes responsibility to organize such meetings. Another possibility is that the country having the chairmanship of the Nordic Council of Ministers gets the responsibility.

4: Conclusions and recommendations

Recent studies show that control of black carbon particles and tropospheric ozone through rapid implementation of proven emission reduction measures would have immediate and multiple benefits for human well-being by reducing the rate of climate change, reducing negative health effects, and reducing crop damage. The studies clearly demonstrate the benefits of considering climate change mitigation and air pollution reductions together. However, controlling short-lived forcers is not an alternative to reducing emissions of carbon dioxide and other greenhouse gases; it is a complement to achieve near-term results and also help to avoid global temperature increases above 2C.

For climate change it is the near-term effects of reducing short-lived forcers that are most striking. If we want to reduce the rate of temperature increase during the coming two to three decades, this can only be achieved by addressing the short-lived forcers. This is particularly important for the Arctic where the warming during the coming two-three decades can be reduced by two-thirds (compared

to the reference scenario) by implementing existing technical measures addressing relatively small sources: Recovery of methane from coal, oil and gas extraction and transport, methane capture in waste management, use of clean-burning stoves for residential cooking and heating, diesel particulate filters for vehicles and the banning of field burning of agricultural waste.

Methane measures have a large impact on global and regional warming by reducing the greenhouse gases methane and ozone. The climate mitigation impacts of the methane measures are also the most certain because there is a high degree of confidence in the warming effects of these greenhouse gases.

The global warming effect of black carbon is less certain because of the compensating cooling effect of co-emitted organic carbon, and because particles can influence clouds that have multiple effects on climate that are not fully understood. However, for the Arctic, mitigation of black carbon will lead to positive regional impacts (reduced warming) by reducing black carbon deposition in areas with snow and ice.

On the policy side there are few efforts to achieve collective emission reductions in short-lived forcers through international agreements. The effort under the Convention on Long-range Transboundary Air Pollution to include black carbon in the revised Gothenburg Protocol is the only one in that direction so far. UNEP has decided to keep the scientific issue under review, but without indicating any policy initiatives. The Arctic Council has agreed on voluntary action, and this has the potential to be further elaborated towards concerted action.

On that background the Nordic countries may consider to strengthen their efforts on short-lived climate forcers through activities such as:

- Ensure a strong Nordic position in the various international initiatives, such as UNEP, CLRTAP, and the Arctic Council, and in particular support as strong wording as possible on black carbon emission reductions in the revised Gothenburg Protocol, and to strengthen actions under the Arctic Council.
- The Nordic countries could develop national plans for reducing their own emission of black carbon and methane, publish the plans jointly, and initiate implementation to demonstrate the feasibility.

- The Nordic countries should actively engage in efforts to improve black carbon emission data, both in their own countries as well as internationally-

- The Nordic countries should strengthen their efforts to reduce black carbon/particles emissions from stoves for residential burning (cook stoves) in developing countries. This will primarily have positive health effects, but also contribute to reducing climate change.

- Intensify efforts to improve global cooperation on short-lived forcers/joint consideration of air pollution and climate change. The long-term goal could be to include this under the

UNFCCC, but it is likely more effective in the near-term to focus on other solutions. One pathway could be regional agreements similar to the Convention on Long-range Transboundary Air Pollution, which covers Europe and North-America. In addition, UNEP could be requested to facilitate global focus on these issues, including issues such as financing and possible cooperation between various regional initiatives.

- Active participation in international efforts to reduce emissions of methane.

- Strengthen efforts on improving the accuracy of monitoring data, including better spatial coverage of monitoring stations; and further model developments. The latter is needed for assessing the importance of various source regions and sectors. On monitoring sites, the feasibility of establishing more stations in the Arctic (for instance at Bjørnøya) should be explored.

- Initiate activities to enhance cooperation and contact among Nordic scientists working on different aspects of short-lived climate forcers, as well as strengthening contacts between scientists and policymakers. This may be achieved by organizing workshops/seminars once or twice per year, allowing ample time for developing contacts and sharing information between various stakeholders. To ensure that this is implemented the best solution might be if one country voluntarily takes responsibility to organize such meetings. Another possibility is that the country having the chairmanship of the Nordic Council of Ministers gets the responsibility.

Annex:

Short summary of present scientific understanding

Black carbon (BC) exists as particles in the atmosphere and is a major component of soot. Black carbon warms the atmosphere by absorbing sunlight, darkens snow when it is deposited, and influence cloud formation. Other particles (for instance sulphates and organic carbon) may have a cooling effect in the atmosphere, but all particles influence clouds.

Black carbon results from incomplete combustion[9] of fossil fuels, wood and other biomass. Black carbon is thus emitted from many common sources, such as cars and trucks, residential stoves, forest fires and some industrial facilities.

There has been large scientific debate on the global impact of black carbon on climate change. In fact until recently there was no consensus on whether black carbon would be causing warming or cooling on a global scale. Today there is broad agreement that black carbon will be warming, but some estimates give very low global warming values. The uncertainties of the effect of black carbon on climate can be illustrated by available estimates of a Global Warming Potential (GWP) for black carbon. (GWP is used in the Kyoto Protocol to calculate the CO_2 equivalent value for the other greenhouse gases.) The contribution to warming of 1 gram of black carbon seen over a period of 100 years has been estimated to be anything from 100 to 2 000 times higher than that of 1 gram of CO_2.

For the Arctic the situation is less unclear. The deposition and darkening effect of black carbon on snow surfaces leads to increased absorption of sunlight. Black carbon therefore leads to warming in the Arctic.

Ozone (O_3) exists in the stratosphere and the troposphere (from ground level to 10–15 km). In the stratosphere, ozone protects life on Earth from the sun's harmful ultraviolet (UV) radiation, and the stratospheric ozone is therefore beneficial. At ground level, ozone is an air pollutant harmful to human health and ecosystems, and is a major component of urban smog. In the troposphere, ozone is also a significant greenhouse gas and thus being an important contributor to the human enhancement of the global greenhouse effect.

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[9] Complete combustion would turn all carbon in the fuel into carbon dioxide (CO_2). In practice, combustion is never complete and CO_2, carbon monoxide (CO), volatile organic compounds (VOCs), organic carbon (OC) particles and BC particles are all formed.

In the troposphere, ozone is formed by precursors nitrogen oxides (NOx), volatile organic compounds (VOCs, including methane (CH_4)) and carbon monoxide (CO) under the influence of sunlight. In controlling ground level ozone, focus has mainly been on NOx and non-methane VOC because reactions involving methane and carbon monoxide are much slower. However, reductions in both methane and CO emissions have the potential to substantially reduce ozone concentrations in the troposphere and reduce global warming. It should be noted that methane is a greenhouse gas included in the Kyoto basket of gases. Reduced methane emissions will itself reduce warming.

Black carbon as part of fine particulate matter (often referred to as $PM_{2.5}$) and ground-level ozone damage human health. $PM_{2.5}$ causes premature deaths primarily from heart disease and lung cancer, and ozone exposure causes deaths primarily from respiratory illness. The health benefit estimates in the UNEP Assessment are limited to changes in these specific causes.

Ozone is toxic to plants and impact include effects on visible leaf health, growth and productivity for a large number of crops, trees and other plants, and also affects vegetation composition and diversity.

In relation to climate change, a very important point is the short lifetime of black carbon and ozone in the atmosphere (days – weeks), and also methane with a lifetime of about a decade is relatively short-lived compared to CO_2, which is the main greenhouse gas. This implies that it will take relatively long before reduced emissions of CO_2 will have an impact on the temperature, while reduced concentration of the short-lived forcers will have a near-term effect. To achieve reductions in the on-going global temperature increase during the coming two to three decades, reductions in concentrations of short-lived forces will be very important.