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Short Lived Climate Pollutants

Short lived Climate Pollutants (SLCPs) include black carbon, methane, hydrofluorocarbons (HFCs) and ground level ozone. Although they have a shorter residence time in the atmosphere than CO_2, from a few days to a few decades, they contribute to near term climate change. This POSTnote summarises options for mitigating SLCP concentrations and the benefits and challenges of doing so.

Overview

- Short-lived climate pollutants (SLCPs) directly affect health, agriculture, ecosystems and economic security as air pollutants (black carbon and ozone), and indirectly through near term climate change.
- The UNEP Climate and Clean Air Coalition is promoting voluntary national measures to reduce SLCP concentrations.
- While SLCP mitigation may help address climate change in the near term, long term climate protection will only be possible with rapid and large cuts in CO_2 emissions.
- There are knowledge gaps for emission sources of some SLCPs. Without evidence of effects on emission levels, measures may be less effective in achieving both long-term air pollution and climate objectives.

Background

SLCPs, also known as short-lived or near-term climate forcers, are responsible for a significant fraction of climate change experienced to date. It has been suggested that reducing emissions of SLCPs, in conjunction with mitigating CO_2 emissions, could contribute towards the internationally agreed target of limiting climate change to 2ºC above pre-industrial temperatures. A Climate and Clean Air Coalition to reduce SLCPs (CCAC), has been established, with its Secretariat hosted by the United Nations Environment Programme (UNEP). Immediate implementation of SLCP control measures targeting black carbon would deliver significant benefits for health and associated ozone reductions would increase crop yields and food security (POSTnote 458).[1]

SLCPs only influence the climate system for the short period they are in the atmosphere and emission reduction measures would have to be maintained for long-term climate benefits. SLCP mitigation would only contribute towards limiting climate change to 2ºC above pre-industrial temperatures if long-lived climate pollutant (LLCP) emissions, predominately CO_2 and also nitrous oxide, peak in the near term. There are concerns that SLCP mitigation could detract from the implementation of LLCP mitigation measures. [2]

What are SLCPs?

A diverse group of substances make up SLCPs:

- **Black carbon** is used to describe the light absorbing carbon in microscopic particles. Particles containing black carbon are emitted to the atmosphere through incomplete burning, from both natural sources (such as grassland and forest fires) and man-made sources (such as agricultural fires, domestic biomass burning, oil and gas flaring, and diesel combustion engines).[3] Exposure to these particles affects human health, reducing life expectancy and increasing healthcare costs. Particles that are mostly black carbon have a climate warming effect, such as diesel engine emissions.
- **Methane** is emitted as a by-product of the decomposition of organic matter in natural sources such as wetlands. It is also emitted through a range of human activities, including raising livestock (POSTnote 453), the oil and gas industry and waste disposal (POSTnote 387). Methane is a potent greenhouse gas (GHG) and also indirectly affects climate through chemical reactions that enhance stratospheric water vapour, increase tropospheric ozone formation and affect particle formation in the atmosphere.[4] The atmospheric concentration of methane (in the troposphere) is 1893 parts per billion (ppb) and is increasing.

- **Tropospheric ozone** is not directly emitted but is a secondary pollutant formed as a by-product of reactions in a series of complex cycles in the atmosphere in sunlight between carbon monoxide, volatile organic chemicals, methane and various oxides of nitrogen (NO_x). During summer heat waves levels of ozone can reach a peak, affecting human health, crop yields and forestry (POSTnote 458). Background ozone concentrations in the northern hemisphere have increased by up to 10 micrograms (one-millionth of a gram) per cubic meter air ($\mu g/m^{-3}$) per decade over the last 20-30 years.[5]
- **HFCs** are manufactured organic compounds used as refrigerants instead of chlorofluorocarbons (CFCs) that damage the ozone layer in the stratosphere. However, HFCs are greenhouse gases (GHGs). The current atmospheric concentration of the commonly used HFC 134a is 75 ppb. There are also other fluorine-containing GHGs used industrially, such as sulphur hexafluoride and perfluorocarbons, which may be emitted in sufficient quantities to have a climate effect.

Climate Effects and Mitigation of SLCPs

Studies have suggested that mitigating SLCP emissions at the same time as LLCP emissions may reduce predicted mid-century warming by an estimated 0.6°C, increasing the likelihood of limiting climate change to 2°C (Figure 1).[6] However, this would only be the case if emissions of LLCPs begin to fall after 2017.[7] Approaches to mitigating SLCP emissions vary between substances as some (e.g. black carbon) are co-emitted with other combustion products, ozone is not directly emitted and hydrofluorocarbons (HFCs) are manufactured. All can be mitigated with practices and technologies that already exist.

Black Carbon

Calculating the warming effects of black carbon is complex:

- It is short lived in the atmosphere, usually no more than two weeks, and so its warming effect concentrated near emission sites. Atmospheric conditions in that region, such as the amount of rainfall that removes black carbon will also influence the extent of warming effects.
- In addition to the warming effect in the atmosphere, black carbon is deposited on snow and ice reducing its reflectivity (albedo) and increasing absorption of sunlight (Box 1), which increases the rate of melting with further effects on the climate system (POSTnote 454). For instance, thawing permafrost leads to emissions of methane and CO_2.
- Black carbon is emitted as part of a mixture of products from incomplete combustion and is just one component of the particles that evolve and mix in the atmosphere (POSTnote 458). Although black carbon has a warming climate effect other constituents of particles can have cooling climate effects.

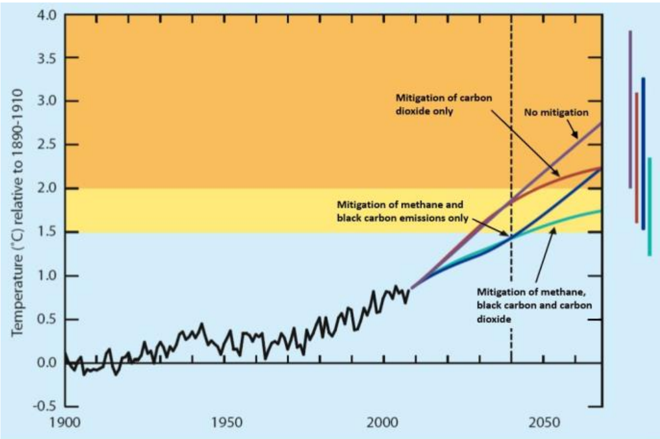

Figure 1. Observed deviation of temperature to 2009 and modelled projections for four mitigation scenarios (no mitigation, mitigation of CO_2 only, of methane and black carbon only, and of all three emission types) from the 2011 UNEP/World Meteorological Organisation Integrated Assessment of Black Carbon and Tropospheric Ozone. The uncertainty in the four modelled temperature projections to 2070 is shown by the lines on the right hand side.[1]

The 2013 International Panel on Climate Change 5th Assessment Report (IPCC AR5) suggested a global warming potential (GWP_{100}) of 900 for black carbon. This emission metric calculates that over a 100 year period in the atmosphere it will absorb 900 times more heat than the same mass of CO_2. However, black carbon only has an atmospheric residence of around two weeks. The timescale used for metrics to estimate the effect of SLCPs has been a matter of some debate (Box 2).[8] AR5 states that "the choice of metric and time horizon depends on the particular application and which aspects of climate change are considered relevant in a given context", implying that no single metric will be sufficiently comprehensive. GWP does not factor in that the warming effects of SLCPs are concentrated at the beginning of a time period and will not be inducing climate change at the end of the period.

A Mixture of Combustion Products

Depending on the make-up of particles, aerosol mixtures can have warming or cooling effects on the atmosphere. For example, particles high in sulphates, nitrates or carbon compounds (organic carbon) have cooling effects. There are no national inventories (POSTnote 428) of just black carbon emissions and estimates from different sources vary (Box 3). If inventories were implemented they could help inform specific national or local mitigation measures. In Europe and the Americas the main source is diesel engines; in Africa and Asia main sources are cooking and heating stoves and burning of forests and grasslands. Measures to mitigate

Box 1. Effects of Black Carbon on the Cryosphere

Studies indicate that comparatively small amounts of black carbon in snow and ice (10-100 parts per billion) decreases albedo by 1-5%. As noted in a recent Environmental Audit Committee Report, black carbon emissions may be having a significant effect on the Arctic.[9] Sources of black carbon affecting the Arctic include diesel vehicles, wildfires, residential heating and agricultural burning.[10] Models suggest that black carbon is also transported from Northern Europe including from St Petersburg, Moscow, London and the Ruhr Valley to the Arctic.[11] Other modelling studies, verified with monitoring, have suggested that compared to around 3% globally, flaring from gas and oil installations at high latitudes are responsible for around 40% of black carbon pollution in the Arctic. In the Arctic, black carbon emissions are higher in the winter, with emissions from residential heating (particularly wood stoves) playing a role.[12] The globally averaged radiative forcing (Box 1) of black carbon is small, but is regionally large in areas such as the Arctic and Himalayas.[13]

Box 2. Emission Metrics
In the context of climate change, emissions of different substances (e.g. CO_2 and methane) have different warming effects and persist for different lengths of time in the atmosphere. A variety of emission metrics have been developed for comparisons, the key variables being the climate impacts and time horizon. Regardless of the metric used, CO_2 is the most important climate forcer.

- **Radiative forcing** is the net change in the energy balance of the Earth system due to the emitted substance. It is usually expressed in watts per square metre averaged over a particular period of time and quantifies the energy imbalance that occurs. For example, the radiative forcing attributed to methane by the IPCC is 0.48 W m^{-2}, compared to 1.82 W m^{-2} for CO_2).[14]
- **Global Warming Potential (GWP)** compares the radiative forcing of an emitted substance with the radiative forcing of CO_2 over a given time horizon (in other words the GWP of CO_2 over that time period will be one). GWP with a 100-year time horizon is used for reporting by the UNFCCC (GWP_{100}), but 20 years is also used in studies focussing on near term temperature impacts. For example, for methane the GWP_{100} is 28 and 84 for GWP_{20}.[14]
- **Global Temperature Potential** compares the temperature change at a point in time (20, 50 or 100 years in the future) caused by the emission of a substance relative to the temperature change caused the emission of CO_2. For example, for methane the GTP_{20} is 67, GTP_{50} is 14 and GTP_{100} is 4.[14]

emissions include particulate filters on diesel vehicles, reducing agricultural burning and providing clean cooking stoves.

Methane
Methane is the most abundant GHG after CO_2 in the atmosphere, with a lifetime of approximately 12 years, depending on atmospheric conditions. It has a large warming impact over a short period, with a GWP_{100} of 28.[14] Of all the SLCPs, mitigating methane would have the most significant climate benefit. The oil and gas industry accounts for more than 20% of all man-made methane emissions globally. Mitigation measures include the recovery of methane emissions from oil and gas production, reducing leakage from gas transmission pipelines, intermittent aeration of rice paddies, reducing livestock emissions, and methane recovery from biodegradable waste and sewage. Methane is also one of the precursor gases involved in background ozone formation.

Ozone
Ozone is resident in the atmosphere for a short time. Although natural sources contribute ozone precursor gases, the major factor in increasing background ozone levels is likely to be manmade methane emissions and nitrogen oxides from fossil fuel combustion. However, background ozone concentrations are rising faster than known emissions of precursor gases and rates of decomposition in the atmosphere would suggest, implying that there are unaccounted emission sources for the precursors. Given its secondary nature and brief residence in the atmosphere, there is no direct GWP calculated for ozone: instead it is incorporated into the GWP of the precursor gases. Measures to mitigate methane and nitrogen oxides emissions should reduce ozone levels.

Box 3. Difficulties in Determining Black Carbon Emissions
Estimating emissions from some black carbon sources is difficult. For example, it is straightforward to measure emissions of a cooking stove in a lab, but determining how stoves are used in practice, including the fuels used, make estimates of emissions uncertain. Being able to estimate the climate effects of combustion requires accurate estimates of the amount of black carbon produced, as the ratio of co-emitted cooling substances to warming black carbon needs to be calculated. In the case of stoves, there will be daily variation according to the type of fuel used, whether it is wet or dry and whether the fire is smouldering or flaming, leading to uncertainties. Estimates of emissions from technologies such as diesel cars are more reliable as they emit mostly black carbon rather than organic carbon.

HFCs
HFCs persist in the atmosphere for 15 years on average and have a greater potential for a cumulative effect on climate than other SLCPs. The global warming potential of HFCs varies, and they are often used in differing mixtures depending on purpose. The commonly used HFC 134a has a GWP_{100} of 1,550.[14] In terms of total greenhouse gas emissions, HFCs only account for 2% of emissions in Europe. However, some scenarios suggest that without mitigation measures global HFC emissions will amount to the equivalent of 4 gigatonnes (GT) of CO_2 by 2050[15] (31 GT of CO_2 were emitted in 2013). Substitutes are available for HFCs[16] and some European and UK supermarkets have begun to adopt HFC-free refrigeration systems.[17] The new EU regulation will prohibit (by 2022) the use of HFCs in new equipment in a number of sectors, including commercial refrigerant and air conditioning.[18] It aims to reduce the availability of HFCs to 21% of current levels by 2030. Department of Energy and Climate Change projections suggest that UK HFC availability will be reduced by 50% by 2030, and by 75% in the longer term.

Air Pollution and Climate Change
As discussed above, air pollutants affect climate differently according to their physical and chemical characteristics. For example, NO_x has a warming effect as a precursor of ozone but also a cooling effect by reducing the lifetime of methane in the atmosphere, calculating the net effect is complex and varies with the metric used (Box 2), but for Global Temperature Potential is always negative (a cooling net effect). Targeted air quality controls may have complex effects on climate, including on precipitation patterns, which are not yet well understood.[14]

Air pollution and climate change are addressed through different regulatory frameworks. Methane and HFCs are two of the six gases covered by the Kyoto Protocol and subject to United Nations Framework Convention on Climate Change (UNFCCC) negotiations. HFCs may also be regulated under the Montreal protocol. The black carbon as a constituent of particulate matter is subject to regional and national regulation as an air pollutant, as are the precursor gases for ozone formation. The CCAC promotes measures to address SLCPs on a voluntary basis that are intended protect the environment and public health, promote food and energy security while reducing climate effects.

HFCs and the Montreal Protocol
The future global growth in emissions of HFCs could be substantial. Discussions are ongoing as to whether to include HFCs in the Montreal protocol to phase down production. As HFCs do not affect stratospheric ozone,

inclusion remains controversial. The two countries that are the largest consumers of HFCs, China and the US, have agreed to the proposal in principle, as have the G20 countries. The Montreal protocol has an established system of national inventories of gases and enforcement and it is not clear whether any new mechanisms set up under the UNFCCC would be as effective.

PM, Black Carbon and the Gothenburg Protocol

The revision of the UN Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollutants sets out national emission limits for fine particles ($PM_{2.5}$), as well as NO_x and volatile organic compounds, throughout the UNECE region (56 European, North American and Central and Western Asian Countries) for 2020. A reduction in $PM_{2.5}$ emissions would achieve significant health benefits and in some cases reduce the climate effects of the black carbon component. The EU has proposed to implement the revised Gothenburg protocol through a revision of the National Emissions Ceiling Directive and more stringent targets for 2030, including for methane. The UK has already implemented measures that will reduce black carbon emissions, such as European vehicle emission standards requiring diesel particulate filters (POSTnote 458), but further controls may be needed to achieve 2030 targets for $PM_{2.5}$, addressing issues such as domestic biomass stoves and boilers.

Further Regional Air Quality Agreements

Other regional agreements could provide a mechanism for addressing black carbon and tropospheric ozone. A number of South Asian countries signed the Malé declaration on transboundary air pollution in 1998. However, the declaration is only a knowledge sharing programme, with regional protocols and limits some way from being agreed. A draft Regional Action Plan on Air Pollution is under consideration by the Regional Inter-Governmental Network on Air Pollution of Latin America and the Caribbean. No transboundary agreements exist for East Asia or Africa.

National Approaches to SLCP Mitigation

Most CCAC partner countries are implementing measures that reduce black carbon and ozone as part of air pollution policies, primarily to deliver health benefits. A UNEP report has set out 16 methane and black carbon control measures.[1] In Norway, a National Action Plan for reducing emissions of SLCPs has been developed by the Norwegian Environment Agency. It includes recommendations for measures to cut SLCP emissions up to 2030, such as reducing food waste (to reduce methane emissions) and emissions from residential wood burning stoves. The Agency is also developing a black carbon emission inventory for Norway.[19]

Challenges to Mitigating SLCPs

There are a number of constraints to controlling SLCP emissions to mitigate near term climate change. For example, while there are both natural and manmade sources of both methane, only the manmade portion of emissions can be mitigated. Implementation of SLCP control measures also need to be consistent with long term protection of the climate system. For instance, aerating rice paddies (with dry periods) to reduce methane emissions can increase nitrous oxide emissions,[20] a long lived climate pollutant, although this may also be affected by tillage systems.[21] These interactions highlight the evidence required to understand the complex outcomes of control measures and their effectiveness. They are not necessarily inconsistent with long term climate protection; measures that decrease background ozone levels, reduce the effects of ozone on plant growth rates, increasing the rate at which CO_2 is fixed by vegetation.

Adoption of HFC Alternatives

Although alternative refrigerants are widely used in some sectors,[22] there is a range of views about how efficient they are. If the alternative refrigerants are less efficient, they could result in higher electricity use and CO_2 emissions if the electricity system is not decarbonised. There is limited evidence on the efficiency of different technologies being developed by companies and uncertainty about what will be made available on the market. Disputes have also arisen from the patenting of substitute refrigerants and the higher cost of using them. [23] There will be a lag of decades before existing installed HFC using equipment is replaced in many sectors.

Uncertainties in SLCP Emissions and Levels

There are significant uncertainties in relation to methane emissions. For instance, it is not clear why emissions levelled off around 2000, and then began to rise again around 2007. The cause could be industrial activity yet to be accounted for in inventories or increased emissions from wetlands as they become warmer. In addition, current European emissions inventories cannot explain the rise in background ozone levels.

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