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THE °CLIMATE GROUP

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This is part of THE CLEAN REVOLUTION

CLIMATE SCIENCE

PART V: SHORT-LIVED CLIMATE POLLUTANTS

Insight Briefing | Analyzing the issues that matter to the Clean Revolution

ABOUT

This briefing is the fifth and final in a series of non-technical papers on key climate science issues. Along with its companion briefings, it aims to increase awareness of climate science in advance of the publication of the Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC), from September 2013. The briefing examines the contribution of short-lived climate pollutants (SLCPs) to global warming. Other briefings in the series cover the fundamentals of climate change, observed and future climatic impacts and the IPCC report production process. This briefing is a joint collaboration between the Institute for Governance and Sustainable Development (IGSD) and The Climate Group.

KEY POINTS

- Short-lived climate pollutants (SLCPs) are warming agents with relatively short atmospheric lifetimes, from a few days to around 15 years. They include black carbon, methane, tropospheric ozone and a range of hydrofluorocarbons (HFCs)
- SLCPs are estimated to have contributed between 40-45% of observable global warming since the start of the industrial era
- Several SLCPs are traditional air pollutants that harm air quality, human health and food production as well as warm our climate
- Because they are short-lived, reducing emissions of SLCPs and their precursors can rapidly eliminate their harmful impacts
- SLCP reductions could slow the rate of climate change by up to 50% by 2050 and could prevent over 1˚C of warming by 2100, creating better opportunities for vulnerable communities and ecosystems to adapt
- SLCP reductions could also prevent premature deaths, illnesses and crop losses as well as lead to improved energy access, thereby contributing to sustainable development
- Technologies to reduce SLCPs already exist, as do regulatory regimes that can be used at national and international levels
- Addressing SLCPs to achieve rapid climate and air quality benefits is an excellent complement to reducing carbon dioxide emissions, but cannot be considered a substitute or alternative to immediately reducing emissions, since both actions are essential for a safe climate

INTRODUCTION

Global efforts to mitigate climate change have largely focused on reducing emissions of carbon dioxide (CO_2), which is responsible for more than half of man-made global warming and which, because of its long lifetime in the atmosphere, will remain the primary driver of long-term temperature rise.

Often overlooked, however, are the so-called short-lived climate pollutants (SLCPs), which include black carbon, methane, tropospheric ozone and hydrofluorocarbons (HFCs).[1] These warming agents are responsible for between 40-45% of global warming experienced to date. Because they are short-lived in the atmosphere, reducing these pollutants and their precursors offers the opportunity to rapidly eliminate much of their warming effects.

Such action could cut the rate of climate change by half in the near term and through the end of the century, affording vulnerable communities and ecosystems better opportunities to adapt[2 3]. It could also delay potentially transformative climate impacts such as sea-ice loss and permafrost melt, which have the potential to trigger powerful feedback mechanisms that could further accelerate climate change.

A number of SLCPs are also traditional air pollutants. In addition to delivering fast climate benefits, significantly reducing or eliminating these SLCPs would deliver important collateral benefits, such as better air quality, public health and agricultural security, which are critical for achieving sustainable development goals.

This paper examines the basic science of climate impacts of SLCPs and some of the policies and measures that have been proposed to address them.

PRINCIPAL SLCPS

BLACK CARBON

Black carbon is an aerosol that is emitted as the by-product of the incomplete combustion of fossil fuels, biofuels and biomass. It is estimated to be the second most powerful climate-forcing agent[2] after CO_2[4].

TABLE 1 Black carbon: key SLCP facts

MAN-MADE SOURCES	– Transport: especially diesel engine vehicles – Residential: including from coal, wood and other biomass cooking and heating stoves, as well as diesel generators – Agriculture: burning of agricultural waste – Open burning of biomass from deforestation
KEY PROPERTIES	– An aerosol (micro particle), not a gas – Not well-mixed in atmosphere, unlike CO_2 – Very short lived – only remains in the atmosphere for a period of days to weeks – As a dark material it absorbs rather than reflects incoming solar (i.e. ultra-violet, 'UV') radiation and releases it as heat (i.e. infra-red, 'IR' radiation)

[1]See generally, IGSD, Primer on Short-Lived Climate Pollutants, available at: http://www.igsd.org/documents/PrimeronShort-LivedClimatePollutants.pdf

[2]United Nations Environment Programme & World Meteorological Organization, Integrated Assessment of Black Carbon and Tropospheric Ozone, (2011).

[3]'See, e.g., supra, notes 3, 7 and 17, and see Hu, Aixue et al., Mitigation of short-lived climate pollutants slows sea-level rise, Nature Climate Change (2013), doi:10.1038/nclimate1869.

[4]Bond, T. C et al., (2013), Bounding the role of black carbon in the climate system: A scientific assessment, J. Geophys. Res., 118, 1-173, doi: 10.1002/jgrd.50171

MAIN IMPACTS	– Warming of atmosphere through direct absorption of UV and subsequent release of IR radiation – When deposited on snow and ice it diminishes their reflectivity (i.e. reduces their albedo) and increases their heat absorption, which accelerates melting – As an aerosol it can affect the microphysical properties of clouds, influencing cloud formation and hence changing rainfall patterns – A component of the indoor and outdoor air pollution that causes major public health problems, including respiratory and cardiovascular conditions and over six million premature deaths annually worldwide[5] – Short-lived nature means impacts are often regional e.g. disruption to South Asian monsoons and warming over East Asia
MITIGATION SOLUTIONS	– Strengthen vehicle standards e.g. ensure particulate filters fitted on diesel vehicles – In developing countries, introduce clean burning fuels stoves for cooking and heating, including improved wood-burning technologies (e.g. pellet stoves and boilers) and non-biomass technologies – Replace traditional brick kilns and coke ovens with modern alternatives – Enforce bans on burning of agricultural crop residues – Reduce slash and burn forestry policies

Mitigation measures for black carbon could be very effective. One recent study[6] estimates that implementing measures such as these worldwide, could prevent up to 0.2˚C of global average temperature rise by 2050, and could prevent up to 2.5 million premature deaths as well as 25 million tons of crop losses a year by 2030.

BOX 1. THE IMPACT OF 'BROWN CARBON' FROM BURNING BIOMASS

Scientists have known for some time that sources that emit black carbon also emit other short-lived particles that may either cool or warm the atmosphere.[7] Lighter colored particles, for example, tend to reflect rather than absorb solar radiation and so have a cooling rather than warming impact. Until recently, it had been thought that the impact of lighter colored and reflecting organic carbon from the burning of biomass largely offset the warming impact of black carbon from this source. However, new studies have suggested that a component known as brown carbon may be a stronger absorber than previously understood.[8] The warming effect of brown carbon may offset the cooling impact of other organic carbon particles, with no particles offsetting the warming impact from black carbon. Therefore, in addition to the already certain benefits for air quality and public health that would result from reductions of biomass burning, there are substantial climate benefits as well in many cases.

[5] See generally, IGSD, Primer on Short-Lived Climate Pollutants, available at: http://www.igsd.org/documents/PrimeronShort-LivedClimatePollutants.pdf

[7] United Nations Environment Programme & World Meteorological Organization, Integrated Assessment of Black Carbon and Tropospheric Ozone, (2011)

[7] Ibid

[8] See, e.g., Chung, Chul E., V. Ramanathan and Damien Decremer (2012), Observationally constrained estimates of carbonaceous aerosol radiative forcing, Proc. Natl. Acad. Sci. (109) 29: 11624-11629; Feng Y., et al. (2013) Brown carbon: a significant atmospheric absorber of solar radiation?, Atmos. Chem. Phys. Discuss. 13:2795-2833; and Bahadur R., et al. (2012) Solar absorption by elemental and brown carbon determined from spectral observations, Proc Natl. Acad. Sci. 109(43):17366-17371

METHANE

Methane (CH_4) is a greenhouse gas (GHG) emitted from both natural and man-made sources. It is estimated to be the second most potent GHG, behind only CO_2 in its warming impact.

TABLE 2 Methane: key SLCP facts

MAN-MADE SOURCES[9]	– Agriculture: particularly emissions from ruminant animal digestion such as cattle, which contribute nearly 27% of man-made emissions. Rice cultivation adds 7% and other agricultural activities another 9% – Oil and gas: production and transportation is responsible for 23% of methane emissions – Landfills: the anaerobic breakdown of organic matter in rubbish dumps creates nearly 12% of the world's methane – Coal mines and waste water: 8.2% and 7.1% respectively
KEY PROPERTIES	– Atmospheric lifetime of 12 years – 25 times as powerful a GHG as CO_2 over a 100-year period – Like CO_2, methane is well-mixed within the atmosphere – Also a precursor for the creation of tropospheric ozone – another SLCP – Methane is the principal component of natural gas (which includes shale gas, an increasingly important fossil fuel – see our Unconventional Gas briefing.)
MAIN IMPACTS	– Like other GHGs, methane warms the atmosphere by blocking infra-red radiation (i.e. heat) that is re-emitted from the earth's surface from reaching space – Almost all of methane's impact occurs within the first two decades after it is emitted – In the absence of additional mitigation measures, studies suggest methane emissions could increase by more than 25% from 2005 to 2030[10]
MITIGATION SOLUTIONS	– Difficult gas to mitigate with respect to emissions from animals (e.g. can't easily modify a cow's stomach biology) but changes in human diet (e.g. less consumption of red meat and dairy products) would help reduce emissions – Capture and combustion of methane from landfills, coal mines, oil and gas wells and other sources of fugitive emissions[11] – Improve waste management systems e.g. separate out biodegradable waste before landfilling to prevent it from generating methane when it degrades – Aerate[12] flooded rice fields periodically

Fully implementing existing methane mitigation measures such as these could prevent up to 0.3°C warming by 2050, according to one study.[13] There would also be substantial co-benefits for air quality, human health and agricultural productivity, including preventing over 25 million tons of crop losses a year by 2030.

[9] Methane Finance Study Group Report, April 2013, based on data from U.S. EPA 2012. Summary Report: Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990–2030

[10] Höglund Isaksson, L., Global anthropogenic methane emissions 2005–2030: technical mitigation potentials and costs, Atmos. Chem. Phys., 12, 9079–9096, 2012

[11] Like the combustion of other hydrocarbons, the burning of methane creates CO_2 as a product. Creating one greenhouse gas from another may seem self-defeating, but given how much more potent methane is as a warming agent, its combustion is preferable to its emission

[12] This is the process of using mechanized equipment to either puncture or remove some soil to drain the rice fields and interrupt methane production

[13] United Nations Environment Programme & World Meteorological Organization, Integrated Assessment of Black Carbon and Tropospheric Ozone, (2011)

TROPOSPHERIC AND GROUND-LEVEL OZONE

Ozone in the lower atmosphere, or troposphere, and at the ground level, is a powerful man-made GHG as well as a harmful air pollutant. It is the main component of urban smog and has a broad range of negative impacts on human health, agriculture and the environment.[14]

TABLE 3 Tropospheric ozone: key SLCP facts

MAN-MADE SOURCES[15]	– Lower-level ozone is not directly emitted by human activities but is instead formed in the atmosphere by sunlight-driven chemical reactions involving other gases – These precursor gases include: carbon monoxide, methane and other volatile organic compounds (VOCs) reacting in the presence of nitrogen oxides
KEY PROPERTIES	– The atmospheric life of ozone is around one month in the upper troposphere[16] – Ozone is the third most important contributor to GHG warming after CO_2 and methane[17]
MAIN IMPACTS	– Like other GHGs, ozone warms the atmosphere by blocking infra-red radiation (i.e. heat) that is re-emitted from the earth's surface from reaching space – Ozone has serious public health impacts, causing inflammation of airways, asthma attacks and other respiratory problems – It also reduces plant growth through its effects on photosynthesis, reducing plant yields and nutritional values of major crops including rice and wheat
MITIGATION SOLUTIONS	– The most effective solutions for reducing ozone are through limiting the production of precursor gases from human activities – Since some of these gases (e.g. methane) are themselves damaging the climate system, there is an added incentive for dealing with them in addition to limiting the impacts of ozone pollution

HFCS

Hydrofluorocarbons, or HFCs, are industrial gases and very powerful GHGs. They were developed as substitutes for CFCs and HCFCs, a previous generation of chemicals, which scientists discovered were destroying the earth's protective stratospheric ozone layer.[18]

TABLE 4 HFCs: key SLCP facts

MAN-MADE SOURCES[20]	– HFCs are used in air conditioning (A/C) and refrigeration units, in the manufacture of insulation and foams, and as solvents and fire suppressants – Emissions come from the leakage of HFC gases from A/C and refrigeration units, and during manufacturing processes

[14] Tropospheric ozone should not be confused with naturally occurring ozone in the stratosphere, which provides a vital protective shield (aka the 'ozone layer') against harmful ultraviolet radiation.

[15] Methane Finance Study Group Report, April 2013, based on data from U.S. EPA 2012. Summary Report: Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990–2030

[16] IPCC, Working Group I. Fourth Assessment Report, 2007. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch7s7-4-4.html

[17] Ibid

[18] CFCs and HCFCs are also extremely powerful GHGs. Their phase out under the Montreal Protocol is estimated to have avoided nore than 20 times the GHGs emissions prevented by the Kyoto Protocol. (See, for example http://www.pnas.org/content/104/12/4814.long)

[19] Greenpeace, HFCs: A growing threat to the climate - The worst greenhouse gases you've never heard of…., 2009. http://www.greenpeace.org/usa/PageFiles/58801/hfcs-a-growing-threat.pdf

[20] Methane Finance Study Group Report, April 2013, based on data from U.S. EPA 2012. Summary Report: Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990–2030

KEY PROPERTIES	– Average atmospheric lifetime for HFCs is about 15 years – There are around 20 different types of HFCs – They are extremely potent GHGs, up to 14,000 times as powerful as CO_2 in trapping heat (but present volumes are very small)[21] – Presently, HFCs are the fastest growing GHGs worldwide[22]
MAIN IMPACTS	– Like other well-mixed GHGs, HFCs warm the atmosphere by blocking infra-red radiation (i.e. heat) re-emitted from the earth's surface from reaching space – HFCs do not harm the protective stratospheric ozone layer like their predecessors – Left uncontrolled, HFCs could account for 20% of total global GHG emissions by 2050. They currently account for around 1%[23]
MITIGATION SOLUTIONS	– Powerful HFCs can be replaced with natural refrigerants such as CO_2 and other far less potent HFCs – HFC emissions can also be cut indirectly by reducing the need for A/C and refrigeration systems through better building design (e.g. to maximize natural cooling). This can also cut electricity-related CO_2 emissions since building cooling systems are often major power consumers

Scientific studies estimate that mitigation solutions for HFCs could avoid between 45-115 gigatons of CO_2eq[24] emissions by 2050 and prevent up to 0.1˚C of global average temperature rise by 2050, and up to 0.5˚C by 2100.[25]

[23]Velders G. J. M, et al. (2012) Preserving Montreal Protocol Climate Benefits by Limiting HFCs, SCIENCE 335 ("Measured in terms of radiative forcing, HFCs are on course to increase as much as thirty-fold by 2050, going from a forcing of 0.012 W/m^{-2} - currently less than 1% of the global total - to as much as 0.40 W/m^{-2}.") See also UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT, at 9, 20

[24]Carbon dioxide equivalency (CO_2eq) is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming impact

[25]Velders G. J. M, et al. (2012) Preserving Montreal Protocol Climate Benefits by Limiting HFCs, SCIENCE 335 ("Measured in terms of radiative forcing, HFCs are on course to increase as much as thirty-fold by 2050, going from a forcing of 0.012 W/m^{-2} - currently less than 1% of the global total - to as much as 0.40 W/m^{-2}.") See also UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT, at 9, 20

INTERNATIONAL EFFORTS TO ADDRESS SLCPS

Given the importance and contribution of SLCPs to global warming, it is perhaps surprising that coordinated international efforts to control these pollutants have only emerged relatively recently. Although methane and HFCs were included in the Kyoto Protocol in 1997, reduction commitments have always been restricted to a limited group of countries, representing an ever-declining proportion of world emissions. Today, however, a number of initiatives at the international and regional level are beginning to address the challenges to, and opportunities from, addressing SLCPs.

THE CLIMATE AND CLEAN AIR COALITION (CCAC)

www.unep.org/ccac

The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) was established in February 2012 with the aim of achieving near-term climate and air quality benefits from reducing black carbon, methane and HFCs.[26] In particular, it aims to "protect human health and the environment and slow the rate of climate change within the first half of this century". It is the first global effort to treat SCLPs as an urgent and collective challenge.

The six founding members of the group were Bangladesh, Canada, Ghana, Mexico, Sweden and the United States, together with the UN Environment Program (UNEP). Membership has subsequently expanded to 30 country partners as well as the World Bank, the World Health Organization, UNIDO[27], UNDP[28] and a growing number of NGOs. UNEP acts as the secretariat for the group (www.unep.org/ccac).

The CCAC seeks to address SCLPs in a number of ways, including: raising awareness of their impacts and available mitigation strategies; enhancing and developing new national and regional actions; promoting best practices; and improving scientific understanding to inform action. To this end, the CCAC is developing and managing a range of initiatives focused on the mitigation solutions outlined in the previous section. Examples include programs on: heavy duty diesel vehicles; brick production; treatment of municipal solid waste; promoting climate-friendly alternatives to HFCs; and reducing emissions from household cooking. Cross-cutting initiatives, for example on finance, are also underway.

GLOBAL METHANE INITIATIVE

www.globalmethane.org

The Global Methane Initiative (GMI) predates the CCAC having been established in 2004. Its membership is made up of both governments and private sector businesses, covering around 70% of global methane emissions, including the ten largest emitters.[29]

The GMI aims to reduce methane emissions in five key sectors: agriculture, coal mines, municipal solid waste, oil and gas systems, and wastewater. Reductions are achieved through public-private initiatives which lower the informational, institutional and other market barriers to project development. Initiatives include the development of tools and resources, training and capacity building, technology demonstration and direct project support.

MONTREAL PROTOCOL PROPOSALS

Recently, increasing attention has been paid to the idea of phasing down production and consumption of HFCs under the Montreal Protocol. Since its entry into force in 1989, the Protocol has phased out nearly 100 similar chemicals to protect the atmosphere's ozone layer from destruction.

In 2013, countries established a formal discussion group to address the management of HFCs under the Protocol. Two separate proposals—one by Micronesia, Morocco and the Maldives, and one by Canada, Mexico and the United States—have been submitted calling for a phase down to take place under the treaty. These estimate that 85-100 gigatons of CO_2e emissions could be prevented by 2050. In September 2013 the G20 leaders pledged to use the expertise and institutions of the Montreal Protocol to phase down HFCs.

[26]See website for CCAC: http://www.unep.org/ccac/About/tabid/101649/Default.aspx

[27]United Nations Industrial Development Organisation

[28]United Nations Development Program

[29]Global Methane Initiative. https://www.globalmethane.org/partners/index.aspx

Action under the Montreal Protocol is seen by many as the more effective way to control HFCs rather than through the UN's climate regime (the UNFCCC). This is because mitigation efforts through the Montreal Protocol would target the production and use of HFCs directly, with specific targets and phase-down periods. By contrast, UNFCCC action (for example under the post-2020 climate treaty currently under negotiation) is likely to include emissions of HFCs in a basket of GHGs (i.e. the same approach used by the Kyoto Protocol). This would give countries the flexibility to reduce emissions from that overall basket as they wished, but provide little incentive to target HFCs specifically, such as by directly cutting HFC production, which is likely the most effective abatement approach.

EU HFC MEASURES

HFCs are also being addressed at national and regional levels. For example, the EU has regulated the use of HFCs in the mobile air conditioning (MAC) sector, by requiring that MAC refrigerants be no more than 150 times as powerful a warming agent as CO_2. This regulation rules out the most abundant HFC presently in the atmosphere, which is over 1,400 times more potent, in favor of newer, more climate-friendly alternatives.

CONCLUSION

Short-lived climate pollutants, such as black carbon, methane, tropospheric ozone and HFCs are responsible for 40-45% of global warming to date. The short atmospheric lifetime of these pollutants offers the promise of achieving near-term benefits from reducing them, since once emissions have ceased, the presence of these substances in the atmosphere, and their harmful impacts on human beings, the climate system and other aspects of the environment, diminish rapidly.

Reducing these pollutants would deliver fast regional and global climate benefits. This could reduce the rate of global warming by half over the next three to four decades and could prevent more than 1˚C of warming by 2100.[30] It could also reduce the rate of warming in the vulnerable Arctic by two-thirds. Reducing these pollutants would also provide significant sustainable development co-benefits, such as improved human health and increased food and energy security.

Action to reduce SLCPs cannot serve as a substitute for the urgent action needed to drastically reduce carbon dioxide emissions, since these emissions will control the planet's long term temperature. But addressing SLCPs can serve as an important complement to carbon dioxide emissions reductions, helping to slow the rate of climate change and limit average peak atmospheric warming.

[30] See, e.g., supra, notes 3, 7 and 17, and see Hu, Aixue et al., Mitigation of short-lived climate pollutants slows sea-level rise, Nature Climate Change (2013), doi:10.1038/nclimate1869

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