The Need for Speed

Reducing Short-Lived Climate Forcers Can Cut the Rate of Global Warming in Half

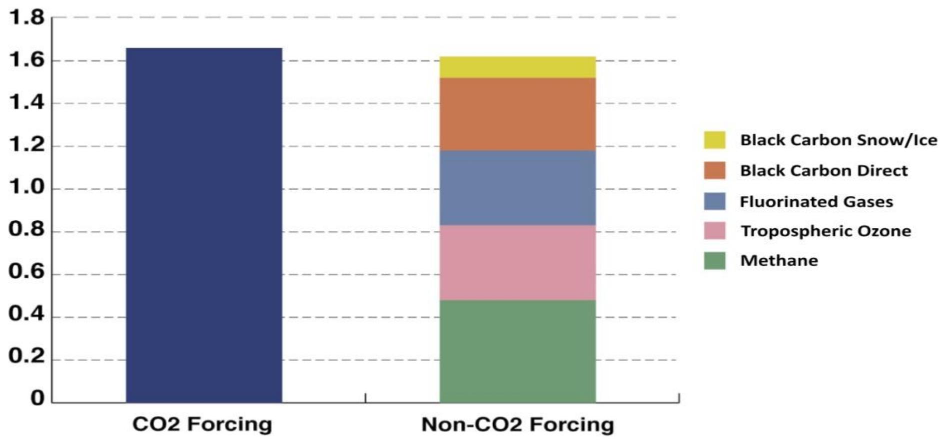
Deliberate Carbon Removal Is Another Critical Complement to CO_2 Reductions

Summary. Cutting non-CO_2 short-lived climate forcers—black carbon, ground-level ozone and its precursor, methane, and hydrofluorocarbons (HFCs)—can reduce the rate of global warming by half and the rate of warming in the Arctic by two-thirds for the next 30. These cuts can be achieved quickly using existing technologies and existing laws and institutions in most cases, and often with little or no net cost, even without considering the value of the climate mitigation. If combined with substantial CO_2 emissions reductions, these fast actions have a high probability of keeping the increase in global temperature to less than 1.5°C above the pre-industrial temperature for the next 30; they also have a high probability of keeping below the 2°C guardrail for the next 60 years, the aspirational goal many heads of State agreed upon two years ago in Copenhagen to prevent dangerous interference with the climate system.

CO_2 is responsible for 55% of radiative forcing. *See* graph below. Fast and aggressive CO_2 cuts are essential to combat the resulting climate change. But this is not enough. CO_2 cuts alone cannot provide near-term climate mitigation because CO_2 has a long atmospheric lifetime that persists for millennia and because even after emissions cease the heat CO_2 trapped in the deep-ocean is released back into the atmosphere over multiple centuries.

CO_2 cuts must be combined with fast and aggressive cuts in the pollutants causing the other 45% of warming. Because these pollutants have atmospheric lifetimes of days to decades, they are referred to as short-lived climate forcers (SLCFs). Given the profoundly persistent nature of CO_2, it also is necessary to deliberately draw down previously emitted CO_2 from the atmosphere on a timescale of decades rather than the millennia of the natural cycle in order to return to a safe and stable climate by the end of the century. This can be done using CO_2 removal strategies such as bio-sequestration, biochar, and chemical air capture and re-utilization, although these tools need to be further developed.

Changes in radiative forcing from anthropogenic emissions since the Industrial Revolution of 1750 (in W/m²)



Based on IPCC, WG 1, Fig. 2.21, AR4 (2007). (*Note graph does not include all non-CO_2 forcers.*)

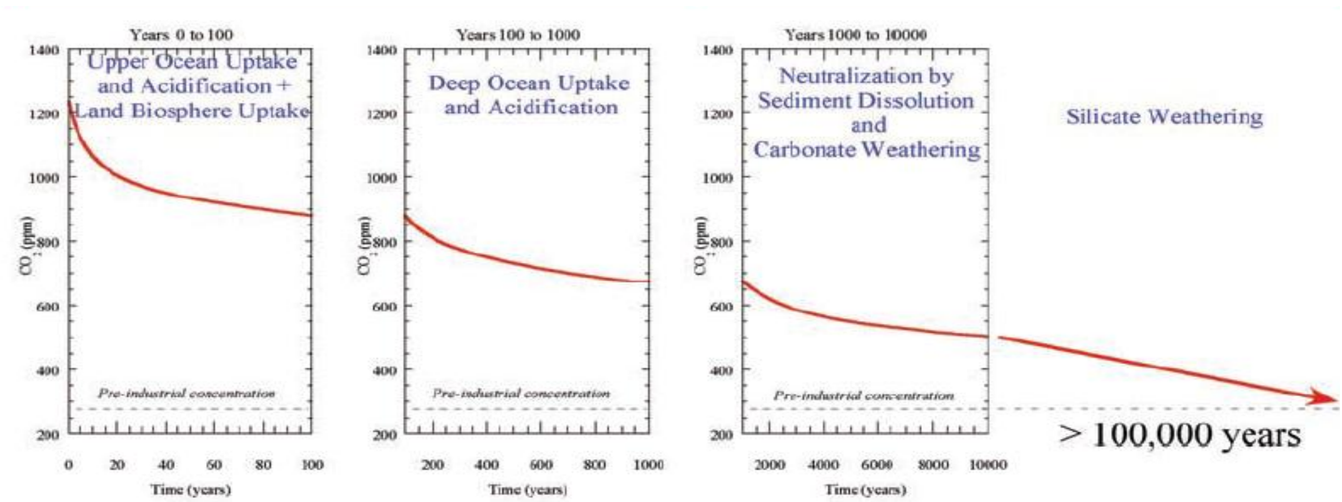
Emissions of CO_2 remain in the atmosphere for millennia. The CO_2 we are emitting and that we have already emitted will remain in the atmosphere for centuries to millennia:

> *While more than half of the CO_2 emitted is currently removed from the atmosphere within a century, … about 20% … remains … for many millennia.* (IPCC, AR4 2007.)

> *[W]hile approximately half of the carbon emitted is removed by the natural carbon cycle within a century, a substantial fraction of anthropogenic CO_2 will persist in the atmosphere for several millennia.* (Matthews & Caldeira, GRL 2008, citing Archer, JGR 2005.)

> *About one-quarter of fossil fuel CO_2 emissions will stay in the air "forever", i.e. more than 500 years…. Resulting climate changes would be … irreversible.* (Hansen *et al.*, PTRS 2007.)

Time Scales for Removal of CO_2 from the Atmosphere



Model simulation of atmospheric CO_2 concentration for >100,000 years following a large CO_2 release from combustion of fossil fuels. Different fractions of the released gas recover on different timescales. (NAP 2011.)

The warming caused by CO_2 is largely irreversible for a thousand years after emissions stop. Even if we stopped all CO_2 emissions today, global temperatures would persist for nearly 1,000 years, and indeed, would continue to rise for 100 years:

> *Climate change that takes place due to increases in carbon dioxide concentrations is largely irreversible for 1,000 years after emissions stop.* (Solomon *et al.*, PNAS 2009.)

> *If anthropogenic CO_2 emissions are halted … without any direct removal of atmospheric CO_2, there is… continued warming for about 100 years.* (Cao & Caldeira, ERL 2010.)

> *[A] simplified way to view future warming persistence is that emissions of CO_2 and a handful of other extremely long-lived gases imply warming that is essentially irreversible on human timescales without geoengineering or active sequestration.* (Solomon *et al.*, PNAS 2010.)

> *The impact of carbon emissions persists longer than that of nuclear waste, the archetypical long-lived waste product. … After 10^4 years, nuclear waste is ~3000 times less radioactive*

than it was a year after discharge from the reactor, whereas the temperature impact of a large carbon perturbation driven by exponentially growing emissions is reduced from its peak by only about a factor of 2 to 4. (Keith, SCI 2009.)

While cutting CO_2 is essential for limiting long-term warming, cutting non-CO_2 SLCFs is essential for reducing current warming and near-term impacts in the next few decades. To slow current impacts, we need to complement cuts in CO_2 with fast action to reduce SLCFs. Cutting SLCFs will have fast effects, including reducing the rate of Arctic warming by two-thirds and the rate of global warming by half within decades:

*When all [16 control] measures are fully implemented, warming during the 2030s relative to the present day is only half as much as if no measures had been implemented. *** This could reduce warming in the Arctic in the next 30 years by about two-thirds compared to the projections of the Assessment's reference scenario.* (UNEP-WMO 2011.)

*We identified 14 measures targeting methane and BC emissions that reduce projected global mean warming ~0.5°C by 2050 *** and in the Arctic, where the measures reduce projected warming over the next three decades by approximately two thirds.* (Shindell *et al.*, SCI 2012.)

Limiting their presence [black carbon and ground-level ozone] in the atmosphere is an easier, cheaper, and more politically feasible proposition than the most popular proposals for slowing climate change—and it would have a more immediate effect. (Wallack & Ramanathan, FA 2009.)

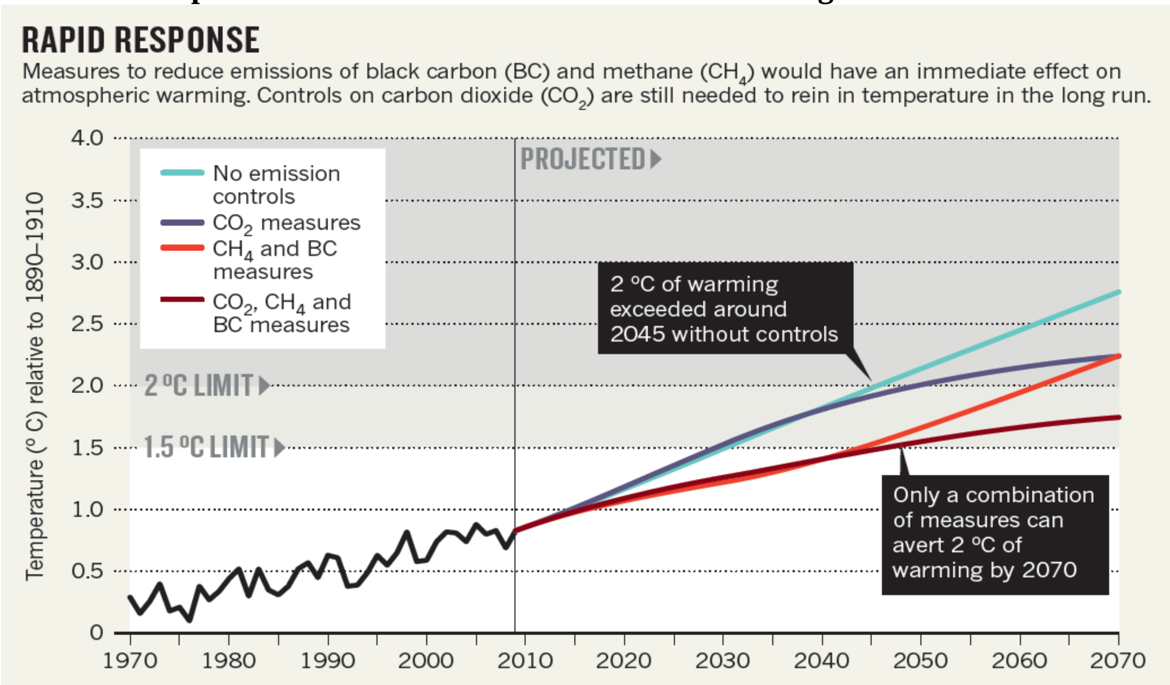
Cutting SLCFs provides the greatest chance of keeping global temperatures below 1.5°C for the next 30 years and below 2°C through 2100, if significant cuts in CO_2 are also made, according to Ramanathan & Xu (PNAS 2010), as confirmed by Shindell *et al.* (SCI 2012.) and UNEP-WMO (2011):

The combination of CH_4 and BC measures along with substantial CO_2 emissions reductions [under a 450 parts per million (ppm) scenario] has a high probability of limiting global mean warming to <2°C during the next 60 years, something that neither set of emissions reductions achieves on its own…. (Shindell *et al.*, SCI 2012.)

[T]he combination of CO_2, CH_4, and BC measures holds the temperature increase below 2˚C until around 2070… [and] adoption of the Assessment's near-term measures (CH_4 + BC) along with the CO_2 reductions would provide a substantial chance of keeping the Earth's temperature increase below 1.5˚C for the next 30 years. (UNEP-WMO 2011.)

These actions [to reduce emissions of SLCFs including HFCs, methane, black carbon, and ground-level ozone], even if we are restricted to available technologies … can reduce the probability of exceeding the 2˚C barrier before 2050 to less than 10% and before 2100 to less than 50%. (Ramanathan & Xu, PNAS 2010.)

Temperature Rise Predictions Under Various Mitigation Scenarios



([Tollefson](), NAT 2012, based upon [Shindell *et al.*](), SCI 2012, which in turn is based on [Ramanathan & Xu](), Fig 1D, PNAS 2010.)[1]

Many vulnerable regions are warming faster than the global average warming. Global warming is expressed as an average but is experienced unevenly in different regions, with some of the world's most vulnerable regions warming much faster than the global average:

> *The increase in annual average temperature since 1980 has been twice as high over the Arctic as it has been over the rest of the world.* ([AMAP]() 2011.)

> *The proximate cause of the changes now being felt on the [Tibetan] plateau is a rise in temperature of up to 0.3 °C a decade that has been going on for fifty years — approximately three times the global warming rate.* ([Qiu](), NAT 2008.)

Warming in the Arctic and Himalayas could lead to dangerous climate feedbacks that cause warming to accelerate. The term 'tipping element' on a basic level is a chain of events that escalate to a point where it is impossible to return to former conditions. Some examples include Arctic sea-ice melt, permafrost melt, and Himalayan glacial melt:

> *The word tipping element suggests the existence of a self-amplification process at the heart of the tipping dynamics. *** A prominent example of such self-amplification is the ice-albedo feedback ... in the Arctic sea-ice region and on mountain glaciers such as the Alps and the Himalayas: An initial warming of snow- or ice-covered area induces regional melting. This*

[1] The science of SLCFs dates back to the 1970s. A major WMO-UNEP-NASA-NOAA report in 1985 concluded that non-CO_2 greenhouse gases in the atmosphere are adding to the greenhouse effect by an amount comparable to the effect of CO_2. ([Ramanathan *et al.*](), 1985.) This finding has been confirmed and strengthened in the following decades by hundreds of studies culminating in IPCC reports ([IPCC]() 1990; [IPCC]() 1995; [IPCC]() 2001; [IPCC]() 2007). In short, we have had at least 25 years to carefully develop the science of SLCFs and assess the findings.

uncovers darker ground, either brownish land or blue ocean, beneath the white snow- or ice-cover. Darker surfaces reflect less sunlight inducing increased regional warming, the effect self-amplifies. (Levermann *et al.*, CC 2012.)

A variety of tipping elements could reach their critical point within this century under anthropogenic climate change. The greatest threats are tipping the Arctic sea-ice and the Greenland ice sheet, and at least five other elements could surprise us by exhibiting a nearby tipping point. (Lenton *et al.*, PNAS 2008.)

Permafrost–permanently frozen ground–underlies most of the Arctic land area and extends under parts of the Arctic Ocean. Temperatures in the permafrost have risen by up to 2˚C over the past two to three decades.... The southern limit of the permafrost retreated northward by 30 to 80 km in Russia between 1970 and 2005, and by 130 km during the past 50 years in Quebec. (AMAP 2011.)

The thaw and release of carbon currently frozen in permafrost will increase atmospheric CO_2 concentrations and amplify surface warming to initiate a positive permafrost carbon feedback (PCF) on climate. (Schaefer *et al.*, TELLUS B 2011.)

The warming climate is accelerating the retreat of Tibetan Plateau glaciers, threatening the water supply of billions of people in Asia:

The Tibetan Plateau…. is melting fast. In the past half-century, 82% of the plateau's glaciers have retreated. In the past decade, 10% of its permafrost has degraded. As the changes continue, or even accelerate, their effects will resonate far beyond the isolated plateau, changing the water supply for billions of people and altering the atmospheric circulation over half the planet. (Qiu, NAT 2008.)

A substantial amount of glacial ice is considered to be melting in the Asian high mountains. Gravimetry by GRACE satellite during 2003–2009 suggests the average ice loss rate in this region of 47 ± 12 Gigaton (Gt) yr^{-1}, equivalent to ~0.13 ± 0.04 mm yr^{-1} sea level rise. This is twice as fast as the average rate over [the last] ~40 years…. (Matsuo, EPSL 2010.)

The 'greater Himalayan region', sometimes called the 'Roof of the World', is noticeably impacted by climate change.... The 'Roof of the World' is the source of ten of the largest rivers in Asia…. The basins of these rivers are inhabited by 1.3 billion people and contain seven megacities. Natural resources in these basins provide the basis for a substantial part of the region's total GDP and important environmental services, which are also of importance beyond the region. (Internal citations omitted.) (Eriksson *et al.*, ICIMOD 2009.)

Reducing emissions of black carbon and ground-level (tropospheric) ozone and its precursor methane is critical for saving the Arctic and Himalayas in the short term. Black carbon is estimated to be responsible for 50% of the increase in Arctic warming, or almost 1°C of the total 1.9°C increase from 1890 to 2007. (Jacobson, JGR 2010; Shindell & Faluvegi, NG 2009.) Roughly 50% of the warming in the elevated Himalayan region has been attributed to the direct black carbon heating of the atmosphere and the surface. (Ramanathan *et al.*, JGR 2007; Flanner *et al.*, ACPD 2009; Xu *et al.*, CB 2009; Menon *et al.*, ACP 2010) Thus reducing black carbon and other SLCFs is critical for slowing down the warming and glacier melting in the Himalayan-Tibetan region (Menon *et al.*, ACP 2010; Ramanathan & Xu, PNAS 2010.):

BC albedo and direct forcings are large in the Himalayas, where there is an especially pronounced response in the Karakoram, and in the Arctic, where the measures reduce projected warming over the next three decades by approximately two thirds. (Shindell *et al.*, SCI 2012.)

Controlling FS [fossil-fuel soot] and BSG [solid-biofuel soot and gases] may be a faster method of reducing Arctic ice loss and global warming than other options, including controlling CH_4 or CO_2, although all controls are needed. (Jacobson, JGR 2010.)

Mitigating SLCF is more effective if done sooner rather than later due to the thermal inertia of the deep oceans:

[M]ultiple centuries are required to warm or cool the deep ocean…. Maintaining a forcing for a longer period of time transfers more heat to the deep … ocean, with a correspondingly longer timescale for release of energy if emissions were to be halted…. [T]he slow timescales of the ocean imply that actions to mitigate the climate impacts of these warming agents [SLCFs] would be most effective if undertaken sooner; conversely such actions would become less effective the longer the radiative forcing is maintained. (Solomon *et al.*, PNAS 2010.)

Reducing current warming and returning to a safe climate requires fast-action mitigation for both CO_2 and SLCFs, along with deliberate CO_2 removal from the atmosphere on a timescale of decades, starting with bio-sequestration, including biochar. Most SLCF mitigation can be done with existing technologies, and through existing laws and institutions:

We define ''fast-action'' to include regulatory measures that can begin within 2–3 years, be substantially implemented in 5–10 years, and produce a climate response within decades. We discuss strategies for short-lived non-CO2 GHGs and particles, where existing agreements can be used to accomplish mitigation objectives. Policy makers can amend the Montreal Protocol to phase down the production and consumption of hydrofluorocarbons (HFCs) with high global warming potential. Other fast-action strategies can reduce emissions of black carbon particles and precursor gases that lead to ozone formation in the lower atmosphere, and increase biosequestration, including through biochar. These and other fast-action strategies may reduce the risk of abrupt climate change in the next few decades by complementing cuts in CO2 emissions. (Molina *et al.*, PNAS 2009.)

Strategy One: Strengthening climate protection under the Montreal Protocol ozone treaty. The Montreal Protocol has successfully phased out 97% of nearly 100 ozone-depleting and climate-warming chemicals. This has provided mitigation of up to 222 billion tonnes of CO_2-eq. and delayed warming by up to 12 years worth of CO_2 emissions. The 196 Parties to the treaty are now phasing out ozone-depleting and climate-damaging HCFCs. Unfortunately, "super" greenhouse gases known as HFCs are being used as substitutes by an increasing number of Parties. Vulnerable island States have proposed phasing out production and use of HFCs under the Montreal Protocol (leaving emissions of HFCs in the Kyoto Protocol). The US, Mexico, and Canada made a similar proposal. Phasing out production and use of HFCs would substantially eliminate one of the six Kyoto gases and achieve mitigation of over 100 billion tonnes of CO_2-eq. by 2050 through a treaty that has always succeeded, and at a cost that could be pennies per tonne of CO_2-eq. Without phasing out HFCs with high global warming potential, most of the climate mitigation already achieved by the Montreal Protocol will be cancelled.

Strategy Two: Cutting black carbon, ground-level ozone and its precursor, methane—local air pollutants that harm public health, crops, ecosystems, and carbon sinks, and that also cause

climate change. Unlike CO_2, black carbon, tropospheric ozone and its precursor, methane, disappear quickly from the atmosphere once emissions are cut. Reducing these local air pollutants can cut the rate of warming in half and up to two thirds in the Arctic and Himalayas over the next thirty years. In addition to producing fast climate results, cutting these local air pollutants also protects public health, food security, and ecosystems, providing independent justification for fast action. For example, eliminating emissions of black carbon from traditional solid biomass stoves with improved cook stoves would have a major impact (about 60%) in reducing black carbon direct climate effects over South Asia (Ramanathan & Carmichael, NG 2008.):

> *Reducing black carbon, methane and tropospheric ozone now will slow the rate of climate change within the first half of this century…. A small number of emission reduction measures targeting black carbon and ozone precursors could immediately begin to protect climate, public health, water and food security, and ecosystems.* (UNEP-WMO 2011.)

Methane Control Measures

- Control fugitive emissions from oil and gas production
- Control emissions from coal mining
- Control fugitive emissions from long distance gas transmission
- Capture gas from municipal waste and landfills
- Capture gas from wastewater treatment facilities
- Capture gas from livestock manure
- Intermittent aeration of constantly flooded rice paddies

Black Carbon Control Measures

- Install particulate filters on diesel vehicles
- Replace traditions cooking stoves with clean burning biomass stoves
- Modernize brick kilns
- Modernize coke ovens
- Ban open burning of biomass
- Eliminate high emitting on and off-road diesel vehicles
- Provide global access to modern cooking and heating

(Shindell *et al.*, SCI 2012.)[2]

> *Full implementation of the identified measures by 2030 would reduce future global warming by 0.5˚C (within a range of 0.2–0.7˚C) by 2050… Full implementation of the identified measures could reduce warming in the Arctic in the next 30 years by about two-thirds compared to the projections of the Assessment's reference scenario, in addition to substantial benefits in the Himalayas and other glaciated and snow-covered regions.* (UNEP-WMO 2011.)

> *This strategy avoids 0.7 to 4.7 million annual premature deaths from outdoor air pollution and increases annual crop yields by 30 to 135 million metric tons due to ozone reductions in 2030 and beyond.* (Shindell *et al.*, SCI 2012.)

> *Full implementation of the identified measures could avoid … the loss of 52 million tonnes (within a range of 30–140 million tonnes), 1–4 per cent, of the global production of maize, rice, soybean and wheat each year*. (UNEP-WMO 2011.)

Most of the strategies that reduce HFCs, black carbon, and ground-level ozone and its precursor methane can be done today with existing technologies and legal authorities that are cost-effective in comparison to CO_2 mitigation. All control measures for reducing black

[2] The UNEP-WMO assessment identified 16 SLCF control measures. By consolidating three of the measures into one, Shindell *et al.* reduced the number to14.

carbon and ground-level ozone and its precursor methane identified in the UNEP-WMO and Shindell assessments "are already mature technologies with demonstrated results at scale in the real world." (UNEP-WMO 2011.) Implementation of these control measures can be done by existing authorities and institutions at national, regional, and global levels to ensure rapid and coordinated emission reductions:

> *About 50 per cent of both methane and black carbon emission reductions can be achieved through measures that result in net cost savings (as a global average) over their technical lifetime. The savings occur when initial investments are offset by subsequent cost savings from, for example, reduced fuel use or utilization of recovered methane. A further third of the total methane emission reduction could be addressed at relatively moderate costs.* (UNEP 2011.)

> *Benefits of methane emissions reductions are valued at $700 to $5000 per metric ton, which is well above typical marginal abatement costs (less than $250). *** ... [T]he bulk of the BC measures could probably be implemented with costs substantially less than the benefits given the large valuation of the health impacts.* (Shindell *et al.*, SCI 2012.)

> *BC can be reduced by approximately 50% with full application of existing technologies by 2030…. Strategies to reduce BC could borrow existing management and institutions at the international and regional levels, including existing treaty systems regulating shipping and regional air quality.* (Molina *et al.*, PNAS 2009.)

> *National efforts to reduce SLCFs can build upon existing institutions, policy and regulatory frameworks related to air quality management, and, where applicable, climate change. *** Regional air pollution agreements, organizations and initiatives may be effective mechanisms to build awareness, promote the implementation of SLCF mitigation measures, share good practices and enhance capacity. *** Global actions can help enable and encourage national and regional initiatives and support the widespread implementation of SLCF measures. A coordinated approach to combating SLCFs can build on existing institutional arrangements, ensure adequate financial support, enhance capacity and provide technical assistance at the national level.* (UNEP 2011.)

> *Many other policy alternatives exist to implement the CH4 [methane] and BC measures, including enhancement of current air quality regulations.* (Shindell *et al.*, SCI 2012.)

> *Regulatory policies and forums exist to reduce non-CO2 warming agents. The Montreal Protocol with modifications for HFC regulations can be an effective tool for reducing watts attributable to HFCs. National policies exist to limit CO and other ozone-producing gases.* (Ramanathan & Xu, PNAS 2010.)

> *These measurements ... provide a direct link between regulatory control policies and the long-term impact of anthropogenic emissions. Our model calculation indicates that the decrease in BC in California has lead to a cooling of 1.4 W m^{-2} (±60%). The regulation of diesel fuel emissions in California therefore has proven to be a viable control strategy for climate change in addition to mitigating adverse human health effects.* (Bahadur *et al.*, AE 2011.)

Strategy Three: Given the profoundly persistent nature of CO_2, it is necessary to deliberately remove excess CO_2 from the atmosphere on a timescale of decades rather than millennia in order

to return to a safe and stable climate. Reducing CO_2 concentrations to a level consistent with a stable and safe climate requires that sinks ultimately exceed sources. Strategies for enhancing sinks include protecting and expanding forests, wetlands, grasslands, and other sources of biomass that are removing CO_2 from the atmosphere, as well as pyrolysis of waste biomass (cooking with limited oxygen) to produce a permanent form of carbon called biochar that can safely return carbon to permanent storage for hundreds to thousands of years. Bio-sequestration of CO_2, including biochar, can match and ultimately exceed CO_2 emissions to achieve a net drawdown of CO_2 on a timescale of decades rather than the millennia timescale of the natural cycle, assuming aggressive CO_2 mitigation as well:

> *A combined approach of deliberate CO_2 removal (CDR) from the atmosphere alongside reducing CO_2 emissions is the best way to minimize the future rise in atmospheric CO_2 concentration, and the only timely way to bring the atmospheric CO_2 concentration back down if it overshoots safe levels.... By mid-century, the CDR flux together with natural sinks could match current total CO_2 emissions, thus stabilizing atmospheric CO_2 concentrations. By the end of the century, CDR could exceed CO_2 emissions, thus lowering atmospheric CO_2 concentration and global temperature.* (Lenton, CM 2010.)

> *In the most optimistic scenarios, air capture and storage by BECS [bioenergy and carbon sequestration], combined with afforestation and bio-char production appears to have the potential to remove ≈100 ppm of CO_2 from the atmosphere…on the 2050 timescale.* (Lenton & Vaughan, ACP 2009.)

> *Strong mitigation, i.e. large reductions in CO_2 emissions, combined with global-scale air capture and storage, afforestation, and bio-char production, i.e. enhanced CO_2 sinks, might be able to bring CO_2 back to its pre-industrial level by 2100, thus removing the need for other geoengineering.* (Lenton & Vaughan, ACP 2009.)

Other CO_2 removal strategies include direct air capture and capture at smokestacks. The captured CO_2 then requires permanent storage, or re-utilization, for example as calcium carbonate, which could be used as a substitute for a portion of ordinary Portland cement or of aggregate:

> *[D]irect air capture (DAC) of carbon dioxide (CO_2) from the atmosphere with chemicals… involves a system in which ambient air flows over a chemical sorbent that selectively removes the CO_2.... DAC is not currently an economically viable approach to mitigating climate change…. The physical scale of the air contactor in any DAC system is a formidable challenge…. Nonetheless, DAC is one of a small number of strategies that might allow the world someday to lower the atmospheric concentration of CO_2.* (APS 2011.)

> *Calera … can capture up to 90% of CO_2 from power plants…and can convert the CO_2 into stable calcareous material and bicarbonate solution with an energy penalty ranging from about 10% to 40%.... The … calcareous material … [can] replace a portion of either the product called "Ordinary Portland Cement" (OPC) or to replace or reduce OPC ingredients in blended cement, and thus potentially avoiding CO_2 emissions from cement manufacture… In some cases, the combined reductions in greenhouse gas emissions from power plant CCS and avoided cement production are potentially greater than the total emissions of either process alone….* (Zaelke *et al.*, 2011.)

Conclusion. All of these strategies are necessary to reduce current climate impacts and to avoid tipping points and irreversible climate impacts. Reducing CO_2 remains a top priority, but we also need to simultaneously reduce SLCFs for near-term benefits that will keep us from losing the climate battle before serious CO_2 cuts are made. We also need to perfect and implement strategies to deliberately reduce excess CO_2 on a time scale of decades. The take-away message from the science and the growing impacts is *the need for speed* and the importance of fast-action mitigation to address all causes of climate change.

Statements of support for reducing SLCFs from key international, regional, and bilateral policy meetings

2011 Fact Sheet: The United States and Norway - NATO Allies and Global Partners (Washington DC, USA):

> *President Obama hosted Norwegian Prime Minister Jens Stoltenberg for a meeting in the Oval Office on October 20…. The leaders renewed their commitments in the following areas: ****
>
> ***The Arctic:*** *In the Arctic Council, the United States and Norway co-chair a task force examining the role of certain greenhouse gases (such as methane and hydrofluorocarbons) and aerosols (such as black carbon), known collectively as "short-lived climate forcers," in causing global climate change….*

2011 Co-Chairs' Summary, Ministerial Meeting on Short-Lived Climate Forcers Near Term Climate and Air Quality Benefits (Mexico City, Mexico):

> *Because SLCFs are a large fraction of current warming they present an enormous near term mitigation opportunity. Strong support was expressed during the meeting for a strengthened concerted approach that would support national and regional measures in the form of an action oriented initiative at global level. It was further stressed that any future initiative would need to consider existing work in the field, and it was particularly stressed that action on SLCF should be complimentary to efforts under the UNFCCC, particularly long term CO_2 mitigation. Participants noted the importance of including the private sector and civil society. Given the need to address SLCF, participants agreed to develop an inclusive and voluntary global initiative to increase the political awareness and support future cooperation for action on SLCF.*

2011 Chair's Summary, Eleventh Leaders' Representative Meeting of the Major Economies Forum (Washington DC, USA):

> *[T]he Major Economies Forum should recall its dual-mandate of helping to advance the negotiations, and to facilitate concrete action to cut emissions among this group – such as the cooperation on clean technology that led to the Clean Energy Ministerial – and noted recent interest in short-lived climate forcers.*

2011 European Parliament Resolution on Financing of Reinforcement of Dam Infrastructure in Developing Countries (Strasbourg, France):

> *30. Urges the EU to widely implement and promote emission reduction measures targeting black carbon, such as the recovery of methane from coal, oil and gas extraction and transport, methane capture in waste management and the use of clean-burning stoves for residential cooking, which will contribute to combating climate change and to reducing glacial retreat;*

2011 European Parliament Resolution on a Comprehensive Approach to Non-CO_2 Climate-Relevant Anthropogenic Emissions (Strasbourg, France):

2. Calls for a comprehensive European climate policy, which can benefit from considering all sources of warming and all mitigation options; stresses that in addition to considering CO2 emission reductions, it should place emphasis on strategies that can produce the fastest climate response;

3. Notes that fast-action regulatory strategies are available to phase down production and consumption of HFCs and to reduce emissions of black carbon and the gases leading to the formation of tropospheric ozone, and that these can begin within 2–3 years and be substantially implemented within 5–10 years, producing the desired climate response within decades or sooner, in particular for some HFCs at a public price as low as 5 to 10 cents per tonne, whereas the carbon price is currently over EUR 13 per tonne;…

2011 Pontifical Academy of Sciences Working Group Report, Fate of Mountain Glaciers in the Anthropocene (Rome, Italy):

Possible mitigation by reducing the emission of non-CO_2 short-lived drivers: *The second part of an integrated mitigation strategy is to cut the climate forcers that have short atmospheric lifetimes. These include black carbon soot, tropospheric ozone and its precursor methane, and hydrofluorocarbons (HFCs). Black carbon (BC) and tropospheric ozone strongly impact regional as well as global warming. Cutting the short-lived climate forcers using existing technologies can reduce the rate of global warming significantly by the latter half of this century, and the rate of Arctic warming by two-thirds, provided CO_2 is also cut.*

2011 Nuuk Declaration, Seventh Ministerial Meeting of the Arctic Council (Nuuk, Greenland):

Welcome the Arctic Council reports on Short-Lived Climate Forcers (SLCF), that have significantly enhanced understanding of black carbon, encourage Arctic states to implement, as appropriate in their national circumstances, relevant recommendations for reducing emissions of black carbon, and request the Task Force and the AMAP expert group to continue their work by focusing on methane and tropospheric ozone, as well as further black carbon work where necessary and provide a report to the next Ministerial meeting in 2013, …

Decide to establish a Short-Lived Climate Forcer Contaminants project steering group that will undertake circumpolar demonstration projects to reduce black carbon and other SLCF emissions….

2011 Joint Statement, Conclusion of the Sixth basic Ministerial meeting on Climate Change (New Delhi, India):

HFC gases are not ozone depleting substances but some of these have high global warming potential. The Ministers felt that the issue of phase down of HFCs with high global warming potential required in-depth examination.

2009 G8 Declaration, Responsible Leadership for a Sustainable Future (L'Aquila, Italy):

66. We recognize that the accelerated phase-out of HCFCs mandated under the Montreal Protocol is leading to a rapid increase in the use of HFCs, many of which are very potent GHGs. Therefore we will work with our partners to ensure that HFC emissions reductions are achieved under the appropriate framework. We are also committed to taking rapid action to address other significant climate forcing agents, such as black carbon. These efforts, however, must not draw away attention from ambitious and urgent cuts in emissions from other, more long-lasting, greenhouse gases, which should remain the priority.

2009 Tromsø Declaration, Sixth Ministerial Meeting of The Arctic Council (Tromsø, Norway):

Urge implementation of early actions where possible on methane and other short-lived climate forcers, and encourage collaboration with the Methane to Markets Partnership and other relevant international bodies taking action to reduce methane and other short-lived forcers,

Decide to establish a task force on short-lived climate forcers to identify existing and new measures to reduce emissions of these forcers and recommend further immediate actions that can be taken and to report on progress at the next Ministerial meeting,

2009 Remarks by United States Secretary of State Hillary Clinton, Joint Session of the Antarctic Treaty Consultative Meeting and the Arctic Council, 50th Anniversary of the Antarctic Treaty (Baltimore, US):

There are also steps we must take to protect the environment. For example, we know that short-lived carbon forcers like methane, black carbon, and tropospheric ozone contributes significantly to the warming of the Arctic. And because they are short lived, they also give us an opportunity to make rapid progress if we work to limit them.

2009 Co-chairs' Concluding Statement at the High-Level India-EU Dialogue (Delhi, India):

3.We urge the governments of Europe and India to: . . . b) Recognise Black Carbon as a significant climate driver and develop a joint programme to:

- *build international support for mitigation of the threat of Black Carbon to the glaciers of the Hindu Kush-Himalaya-Tibet area;*
- *support a major clean cook stove initiative, including Project Surya and the application of pyrolysis and biochar.*

2008 Declaration of Leaders, Meeting of the Major Economies on Energy Security and Climate Change (Toyako, Japan):

10. To enable the full, effective, and sustained implementation of the Convention between now and 2012, we will: . . .· Continue to promote actions under the Montreal Protocol on Substances That Deplete the Ozone Layer for the benefit of the global climate system; …

2007 G8 Declaration on Growth and Responsibility in the World Economy (Heiligendamm, Germany):

59. We will also endeavor under the Montreal Protocol to ensure the recovery of the ozone layer by accelerating the phase-out of HCFCs in a way that supports energy efficiency and climate change objectives. In working together toward our shared goal of speeding ozone recovery, we recognize that the Clean Development Mechanism impacts emissions of ozone-depleting substances.

Select press coverage of SLCFs

1. *Nature*, "Pollutants key to climate fix" (17 January 2012)
2. *New York Times*, "Climate Proposal Puts Practicality Ahead of Sacrifice" (16 January 2012)
3. *National Public Radio*, "To Slow Climate Change, Cut Down on Soot, Ozone" (12 January 2012)
4. *Scientific American*, "How to Buy Time in the Fight against Climate Change: Mobilize to Stop Soot and Methane" (12 January 2012)
5. *Washington Post:* "Study: Simple measures could reduce global warming, save lives" (12 January 2012)
6. *Climate Central*, "Groundbreaking New Study Shows How to Reduce Near-Term Global Warming" (12 January 2012)
7. *Le Monde France*: "A few simple steps to limiting global warming" (12 January 2012)
8. *Agence France-Presse*: "Cut back on soot, methane to slow warming: study" (12 January 2012)
9. *Press Trust of India*: "Simple measures could reduce global warming, save lives: NASA" (12 January 2012)

10. *Nature*, “More in Montreal: Momentum builds for ozone treaty to take on greenhouse gases” (3 Nov 2011)
11. *EnviroLib*, “European Parliament urges fast cuts in black carbon and ground-level ozone to reduce threats from dangerous glacial dams in Himalayas” (11 Oct 11)
12. *The Economist*, “Beating a retreat: Arctic sea ice is melting far faster than climate models predict. Why?” (24 Sept 11)
13. *Humanitarian News*, “European Parliament calls for fast action to cut non-CO2 climate forcers” (16 Sept 11)
14. *Washington Post*, “Arctic Council to address role of soot in global warming” (11 May 11)
15. *Politico*, “Hot-button issues at Arctic summit” (11 May 11)
16. *Climatewire*, “Green Smoke Is Sighted as Vatican Releases Glacier Report” (6 May 11)
17. *Washington Post*, “Global warming rate could be halved by controlling 2 pollutants, U.N. study says” (23 Feb 11)
18. *New York Times*, “A Stopgap for Climate Change” (22 Feb 11)
19. *The Economist*, “Climate change in black and white” (17 Feb 11)
20. *The Economist*, “Piecemeal possibilities” (17 Feb 11)
21. *The Telegraph*, “Action speaks louder than hot air” (10 Dec 10)
22. *Nature*, “Dispute over carbon offsets continues in Cancun” (8 Dec 10)
23. *Washington Post*, “New front opens in war against global warming” (29 Nov 10)
24. *New York Times*, “To Fight Climate Change, Clear the Air” (28 Nov 10)
25. *New York Times*, “Support Grows for Expansion of Ozone Treaty” (12 Nov 10)
26. *Nature*, “Ozone Talks Delay Action on Climate” (12 Nov 10)
27. *New York Times*, “A Novel Tactic in Climate Fight Gains Some Traction” (9 Nov 10)
28. *Nature*, “Ozone Treaty Could Be Used for Greenhouse Gases” (9 Nov 10)
29. IISD’s *MEA Bulletin*, “A Proposal to Change the Political Strategy of Developing Countries in Climate Negotiations” (15 July 10)
30. *ClickGreen*, “US Climate Bill “breaks the mould” of CO2 climate policy” (12 May 10)
31. *Science for Environment Policy*, “Four fast-action strategies to tackle abrupt climate change” (11 Feb 10)
32. *LA Times*, “Climate negotiators eye the ‘forgotten 50%’ of greenhouse gas pollutants” (14 Dec 09)
33. *The Economist*, “Unpacking the problem” (3 Dec 09)
34. *The Guardian*, “CO2 is not the only cause of climate change,” (11 Sept 09)
35. *The Washington Post*, “CO2 replacements intensify climate concerns” (20 July 09)
36. *Nature*, “Time for early action” (1 July 09)
37. *Financial Times*, “Black-and-white answers to motley puzzle” (18 May 09)
38. *Nature*, “Time to act” (29 April 09)
39. *Science*, “New Push Focuses on Quick Ways To Curb Global Warming” (17 April 09)

Additional background on SLCFs

Molina, M., Zaelke, D., Sarma, K. M., Andersen, S. O., Ramanathan, V., and Kaniaru, D., *Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO_2 emissions*, PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES (2009).

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IGSD: 29 January 2011