Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers

A UNEP Synthesis Report

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Contents

Foreword

Achim Steiner
UN Under-Secretary-General,
UNEP Executive Director

A range of compelling, and in many cases highly cost-effective options for fast action on black carbon, methane and tropospheric ozone are outlined in this report: *Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers.*

Research, convened by the United Nations Environment Programme (UNEP) and involving scientists from across the globe, has already outlined the sustainable development opportunities for acting on these kinds of emissions.

- Fast action has the potential to avoid an estimated 2.4 million premature deaths from outdoor air pollution annually by 2030;
- Fast action could assist in avoiding annual losses from four major crops—wheat, rice, maize and soybean-of about 32 million tonnes per year.

Meanwhile early and sustained action on short-lived climate forcers could also slow the increase in near-term global warming by around 0.4°C by 2050—thereby assisting the international community in meeting a target of keeping a temperature rise to 2°C or less during the 21st century.

In this report, requested by governments, 16 control options are discussed that cover the wide range of sources of black carbon and methane emissions from cookstoves and diesel engines through to leaky gas distribution pipes and municipal waste.

The study has grouped the options into low, moderate and high cost options as well as a further category where the cost-benefit analysis is complex and contingent on for example, strong regulatory frameworks.

It underlines the fact that action on some options might actually trigger costs savings—for example reducing leaks from gas pipelines, replacing traditional brick kilns with more efficient ones and separation of biodegradable materials from waste going to landfills in order to cut methane emissions.

Other options, for example replacing traditional coke ovens with modern ones, may carry costs but these are well within the range of today's carbon markets whereas others including feed switches in cattle may currently be more costly than current carbon prices.

There is increasing interest among governments in the developed and developing world to carry out fast action on short-lived climate forcers, some for health reasons and others for the agricultural benefits alongside the climate change opportunities.

This is a landmark report making a bridge between new scientific knowledge justifying action on SLCFs and practical measures that can be taken by countries to reduce the burden of air pollution and climate change on their sustainable development. This report identifies priority areas and sectors for action in each region with the indicative costs and benefits. It also describes the many *fora* where fast action could occur—regional and national air quality agreements being a case in point. This report also outlines the important role of action at the global scale and the enabling actions that could facilitate and speed up implementation of SLCF measures.

Climate change will, in the final analysis, never be controlled unless the principal long-lived greenhouse gas—carbon dioxide—is substantially and significantly curbed. Nevertheless, short-lived climate forcers represent a complementary measure with multiple near-term benefits increasingly ripe and ready for cooperative action.

Glossary

Albedo: a measure of the reflectivity of the earth's surface. It is the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. Ice, especially with snow on top of it, has a high albedo.

Biofuels: non-fossil fuels (e.g. biogas, biodiesel, bioethanol). They are energy carriers that store the energy derived from organic materials (biomass), including plant materials and animal waste.

Biomass: in the context of energy, the term biomass is often used to refer to organic materials, such as wood, animal dung and other agricultural wastes that can be burned to produce energy or converted into a gas and used for fuel.

Black carbon (BC): operationally defined aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability. Black carbon is formed through the incomplete combustion of fossil fuels, biofuel and biomass and is emitted as part of anthropogenic and naturally occurring soot. It consists of pure carbon (C) in several linked forms. Black carbon warms the Earth by absorbing sunlight and re-emitting heat to the atmosphere and by reducing albedo (the ability to reflect sunlight) when deposited on snow and ice.

Capacity building: in the terms of this document, the process of developing the technical skills and institutional capability in developing countries and countries with economies in transition to enable them to effectively address the causes and results of climate change and air pollution caused by short-lived climate forcers (SLCFs).

Carbon dioxide equivalent (CO_2e): a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of carbon dioxide that would have the same global warming potential (GWP) or global temperature potential (GTP), when measured over a specified timescale – generally, 20 or 100 years. The carbon dioxide equivalency for a gas is obtained by multiplying the mass and the GWP or GTP of the gas. For example, the GWP for methane (CH_4) over 100 years is 25, including also indirect effects e.g. ozone formation. This means that emissions of 1 million tonnes of methane is equivalent to emissions of 25 million tonnes of carbon dioxide.

Clean Development Mechanism (CDM): one of the three market-based mechanisms under the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC), whereby developed countries may finance greenhouse gas emissions-avoiding projects in developing countries, and receive credits for doing so, which they may apply towards meeting mandatory limits on their own emissions.

Discount rate: The rate (as a percentage) used to convert the future expected streams of costs and benefits into a present value amount. The social discount rate (SDR) is a measure used by social planners to help guide choices about the value of diverting funds to social projects. The SDR is usually a much lower rate than that used by private sector businesses who expect a higher 'market rate' return on their capital investments.

Euro-6/VI: European vehicle emission standards (Euro standards) define the acceptable limits for exhaust emissions of new vehicles sold in EU member states. The current standard is Euro-5/V. The future Euro-6/VI standards will come into force between 2013 and 2015 depending on the class of vehicle.

Ground-level ozone: ozone at the bottom of the atmosphere and the level at which humans, crops and ecosystems are exposed.

Global Temperature Potential (GTP): To take the limitations of the GWP metric regarding SLCFs into account, an alternative metric, the global temperature potential (GTP) has been developed (Shine *et al.*, 2005) which provides a comparison of a more policy-relevant impact – global mean temperature change – rather than the integrated forcing depicted by the global warming potential. GTP is defined as the temperature change due to 1 kg of emitted pollutants relative to that of 1 kg of emitted CO_2 after a given time period such as 20 or 100 years. GTP focuses on one particular chosen future point in time and gives the temperature effect at that time, relative to that of the same amount of carbon dioxide. It is expressed in terms of equivalent carbon dioxide (CO_2e) emissions. This metric provides an estimate that includes climate sensitivity so it has greater uncertainty than metrics based purely on radiative forcing and cannot be directly measured.

Global Warming Potential (GWP): The global warming potential (GWP) is a metric that has been used extensively by the IPCC to compare the impacts of various well-mixed, long-lived greenhouse gases. It is defined as the integrated radiative forcing due to 1 kg of emission of a pollutant relative to that of 1 kg of CO_2 over a particular time period such as 20 or 100 years. It is expressed in terms of equivalent carbon dioxide (CO_2e) emissions. The GWP compares the integrated radiative forcing of a particular forcing agent with the forcing from the same amount of carbon dioxide over some chosen time period resulting from pulse emissions of an equal mass. The GWP with the time horizon of 100 years (GWP_{100}) is used in the Kyoto Protocol. The use of GWP_{20} with a time horizon of 20 years has been proposed to better capture the importance of the more short-lived gases and aerosols. The choice depends on the preferred time horizon. There are many limitations to the GWP concept, especially with regards to its use for short-lived species.

High emitting vehicles: on-road measurements have shown that a relatively small fraction of the vehicle fleet is responsible for a relatively large share of emissions. Here, high emitting vehicles are defined as vehicles with emissions above a certain regional, pollutant and technology-specific threshold.

Near-term warming: in terms of this document and the *Integrated Assessment of Black Carbon and Tropospheric Ozone (UNEP/WMO, 2011),* this refers to global warming from the present up to about the next 20 to 40 years (i.e., global warming during the 2010-2050 period).

Ozone and particulate matter (PM) concentrations: Ozone concentrations are generally measured in parts per billion (ppb). For other gases their concentration in the atmosphere is usually measured as $\mu g/m^3$, or micrograms in each cubic metre of air. In studies of their effect on human health, a distinction is commonly made between PM_{10} and $PM_{2.5}$ – the mass of aerosols with a diameter of less than 10 and 2.5 µm (micrometres), respectively.

Premature deaths: the number of deaths occurring earlier due to a risk factor than would occur in the absence of that risk factor.

Radiative forcing: a measure of the net change in the energy balance of the Earth with space, that is, the change in incoming solar radiation minus outgoing terrestrial radiation. At the global scale, the annual average radiative forcing at the top of the atmosphere, or tropopause, is generally a good indicator of the global mean temperature change – though for black carbon in particular, forcing corresponds less closely to temperature change than for other agents.

Short-lived climate forcers (SLCFs): substances such as methane, black carbon, tropospheric ozone and many hydrofluorocarbons (HFCs) which have a significant impact on near-term climate change and a relatively short lifespan in the atmosphere compared to carbon dioxide and other longer-lived gases.

Surface forcing: refers to the instantaneous perturbation of the surface radiative balance by a forcing agent (Forster *et al.*, 2007). The radiative forcing at the surface may be quite different from that at the top of the atmosphere.

Tropospheric ozone: ozone in that portion of the atmosphere from the Earth's surface to the tropopause that is the lowest 10-20 km of the atmosphere.

Reference scenario: the progression of emissions based on energy and fuel projections of the International Energy Agency (IEA) *World Energy Outlook 2009* and incorporating all presently agreed policies affecting emissions. This scenario is also used in the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO 2011) for comparison with the scenarios where black carbon and methane measures have been implemented.

Win-win measures: mitigation measures which are likely to reduce global warming and at the same time provide clean air benefits by reducing air pollution.

Acronyms and Abbreviations

ABC	Atmospheric Brown Cloud
ACAP	Arctic Contaminants Action Programme
ADB	Asian Development Bank
AF	Adaptation Fund
AMAP	Arctic Monitoring and Assessment Programme
AMCEN	African Ministerial Conference on the Environment
AOSIS	Alliance of Small Island States
AR5	IPCC fifth assessment report
ASEAN	Association of South East Asian Nations
BAQ-SSA	Better Air Quality in sub-Saharan Africa
BC	black carbon
C	carbon
CAI-Asia	Clean Air Initiative for Asian Cities
CDM	Clean Development Mechanism
CEB	Chief Executive Board for Coordination
CEC	Commission for Environmental Cooperation
CER	Certified Emissions Reductions
CFCs	chlorofluorocarbons
CH_4	methane
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DPF	Diesel Particle Filter
EANET	Acid Deposition Monitoring Network in East Asia
ECA	Emission Control Area
ECE	UN Economic Commission for Europe
ECHAM	European Centre Hamburg Model
EMG	Environmental Management Group
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GACC	Global Alliance for Clean Cookstoves
GAP Forum	Global Atmospheric Pollution Forum
GAINS Model	Greenhouse Gas and Air Pollution Model Interactions and Synergies
GCM	General Circulation Model
GEF	Global Environment Facility
GGFR	Global Gas Flaring Reduction
GISS	NASA Goddard Institute for Space Studies
GMI	Global Methane Initiative
GTP	Global Temperature Potential
GURME	Global Atmospheric Watch (GAW) Urban Research Meteorology and Environment of the WMO
GWP	Global Warming Potential
HCFC	hydrochlorofluorocarbons
HFC	hydrofluorocarbons
HLPC	High Level Committee on Programmes
HTAP	Hemispheric Transport of Air Pollution
JRC	Joint research Centre of the EU
IDB	Inter-American Development Bank
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
IMO	International Maritime Organization
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental Panel on Climate Change
LDCF	Least Developed Countries Fund
LPG	liquefied petroleum gas
Malé Declaration	Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia
MARPOL	The International Convention for the Prevention of Marine Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78)
MEPC	Marine Environmental Protection Committee
MDG	Millennium Development Goals
NAAEC	North American Agreement on Environmental Cooperation

NAFTA	North American Free Trade Agreement
NAMA	Nationally Appropriate Mitigation Actions under the UNFCCC
NASA	National Aeronautics and Space Administration
NEC	EU National Emissions Ceilings Directive
NMVOCs	non-methane volatile organic compounds
NO_x	nitrogen oxides
O_3	ozone
OC	organic carbon
OECD	Organisation for Economic Cooperation and Development
ODA	Official Development Assistance
ODS	(stratospheric) ozone-depleting substances
PCFV	Partnership for Clean Fuels and Vehicles
PM	particulate matter ($PM_{2.5}$ has a diameter of 2.5µm or less. PM_{10} has a diameter of 10µm or less.)
PMFF	Prototype Methane Financing Facility
ppb	parts per billion
RIO+20	UN Conference on Sustainable Development (2012)
SACEP	South Asia Cooperation Environment Programme
SADC	Southern African Development Community
SAARC	South Asian Association for Regional Cooperation
SBSTA	Subsidiary Body for Scientific and Technological Advice under the UNFCCC
SCCF	Special Climate Change Fund
SLCF	Short-Lived Climate Forcers
SO_2	sulphur dioxide
SO_4^{2-}	sulphates
SREP	Scaling-up renewable energy programme
TEMM	Tripartite Environmental Ministers' Meeting
TM5-FASST	Fast Scenario Screening Tool of TM5
TOA	Top of the atmosphere or tropopause
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCRD	United Nations Centre for Regional Development
UNDG	United Nations Development Group
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VAM	Ventilation-Air Methane
VOCs	Volatile Organic Compounds
WHO	World Health Organization
WMO	World Meteorological Organization

Main Findings

1. **Reducing atmospheric concentrations of short-lived climate forcers (SLCFs), specifically black carbon, tropospheric ozone and methane, offers a real opportunity to improve public health, reduce crop-yield losses, and slow the rate of near-term climate change, thereby aiding sustainable development.** Because such reductions are likely to only make a modest contribution to longer-term climate goals, they must be viewed as a strategy that complements but does not replace carbon dioxide emission reductions.
2. **The health benefits from implementing black carbon mitigation measures would be realized immediately and almost entirely in the regions that reduce their emissions.** Regions taking action on black carbon would also benefit significantly from reduced regional warming, reduced disruption of regional weather patterns, as well as a substantial reduction in crop-yield losses.
3. **The mix of measures that give rise to substantial national, regional and global benefits vary by region.** This report estimates that the following actions would bring about the largest benefits:
    - **for Africa:** reducing black carbon emissions from biomass cookstoves and methane emissions from oil and gas production and municipal waste;
    - **for Asia:** reducing black carbon emissions from diesel vehicles and biomass cookstoves, and reducing methane emissions from coal mining, oil and gas production and municipal waste;
    - **for North America and Europe:** reducing methane emissions from oil and gas production, from long-distance natural gas transmission pipelines and municipal waste, and reducing black carbon emissions from residential biomass heating, shipping activities, and open agricultural biomass burning near the Arctic region;
    - **for Latin America and the Caribbean:** reducing black carbon emissions from biomass cookstoves and diesel vehicles, and reducing methane emissions from oil and gas production and municipal waste.
4. **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.
5. **The current state of knowledge is sufficiently robust to justify action on SLCFs at the national scale.** Implementing the identified measures can be seen as a 'no-regrets' policy because there is high confidence that they will significantly reduce health and crop-yield air pollution impacts. While there is high confidence concerning the climate benefits from identified methane measures, it is also likely that black carbon measures will lead to climate benefits, especially at the regional level. Therefore, these can be seen as 'win-win' policies providing both air quality and near-term climate co-benefits.
6. **National efforts to reduce SLCFs can build upon existing institutions, policy and regulatory frameworks related to air quality management, and, where applicable, climate change.** For many developing countries these policies could be connected to development goals and mainstreamed into development policies.
7. **Countries can take action now to rapidly implement control measures addressing the most obvious SLCF sources in the knowledge that multiple benefits will be realised.** Countries could develop national SLCF action plans to implement priority measures identified. These action plans should consider relevant SLCF sources and appropriate measures, the benefits and costs of action, the political feasibility of implementation, an inventory of current policies and legislation that can be used to implement relevant measures, and actions needed to raise awareness.
8. **Regional air pollution agreements, organisations and initiatives may be effective mechanisms to build awareness, promote the implementation of SLCF mitigation measures, share good practices and enhance capacity.** Emerging regional air pollution initiatives can be strengthened by including near-term and regional climate change considerations, and can be used to promote national implementation of SLCF mitigation measures.
9. **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.** One option for moving forward could be an international initiative based upon a partnership of willing countries and other partners. This could seek, and make available, appropriate financial resources and mechanisms, and work with existing global structures to support better implementation of SLCF measures, mainstreaming them into air quality, climate and development policies at all levels.

Executive Summary

Introduction

This report addresses the mitigation of short-lived climate forcers (SLCFs) and its key role in air pollution reduction, climate protection and sustainable development. SLCFs are substances in the atmosphere that contribute to global warming and have relatively short lifetimes in the atmosphere. The focus is on three SLCFs – black carbon, tropospheric ozone and methane – because reducing them will provide significant benefits through improved air quality and a slowing of near-term climate change[1].

The 'win-win' benefits for climate and public health have been overlooked in the wider climate change and air-quality debate. The challenges of improving air quality and mitigating climate change, as well as those of human development, are inextricably linked. Policy paths that integrate air quality, climate change and key development concerns bring mutual payoffs. This report builds on the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011)[2] and describes the considerable benefits that different regions of the world could experience if they were to implement specific emission-reduction measures. By including cost implications and options to promote action at the national, regional and global levels, this report charts a path for the widespread implementation of the identified measures.

Reducing SLCF concentrations now is likely to slow the rate of global warming over the next two to four decades. Near-term warming is pushing natural systems closer to thresholds that may lead to a further acceleration of climate change. For example, the melting of permafrost in the Arctic is releasing additional quantities of methane into the atmosphere, which in turn contribute to additional global warming.

Air pollution is impeding sustainable development because it threatens human health and crop production, especially in developing countries. The World Health Organization (WHO) estimates that 3.1 million people (WHO, 2009), mostly in developing countries, die prematurely each year from indoor and outdoor air pollution. Two SLCFs – black carbon and tropospheric ozone – are important pollutants causing these health impacts. In addition to the direct health impacts, ozone pollution reduces the productivity of crops and natural vegetation. A third SLCF – methane – is not an air pollutant but it contributes to tropospheric ozone pollution and its health and environmental impacts.

Climate change also presents numerous barriers to development in the near term. Current warming is already having many harmful effects, which will have the greatest impact on the world's most vulnerable populations and places. Lakes are building up at the foot of melting glaciers and are threatening to burst and cause floods downstream; warmer temperatures are leading to more frequent heat-waves; the melting of land ice in the Arctic is contributing to sea-level rise throughout the world; and shifting climatic zones of plant and animal life threaten the existence of some species. Slowing down near-term warming would reduce the intensity of these impacts and give society and nature more time to adapt to climate change.

A package of 16 measures for reducing emissions of black carbon and methane has been identified that could provide substantial combined benefits for air quality

1. A subset of hydrofluorocarbons (HFCs) also have short lifetimes and warm the atmosphere, but do not currently have air quality impacts and are not the focus of this report.

2. Available from: <http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_SDM.pdf>

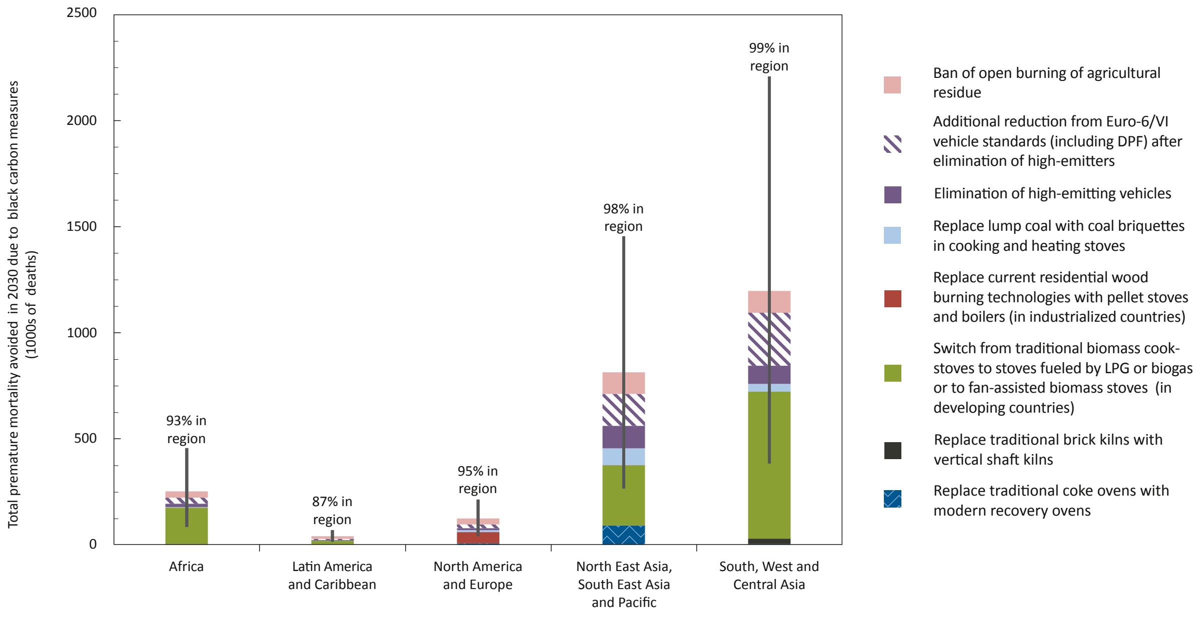
and near-term climate protection. These measures can accomplish about 38 per cent reduction of global methane emissions and around 77 per cent of black carbon emissions, if implemented between now and 2030, relative to a 2030 'reference' emission scenario. The 'reference' scenario is based on a 'business-as-usual' energy demand projection and does not include any new legislation relevant to SLCF emissions beyond that already agreed. These 16 measures form a strong starting point for the reduction of SLCF impacts in all regions, although additional measures may be more appropriate in specific circumstances. The benefits described in the following paragraphs assume that the measures will be fully implemented worldwide by 2030, starting immediately.

The air quality benefits of short-lived climate forcer mitigation

Confidence is high that black carbon measures would provide substantial health benefits. The reduction in outdoor particulate air pollution from having fully implemented the measures by 2030 would avoid an estimated 2.4 million (range 0.7–4.6 million)[3] premature deaths annually. It would also greatly reduce impacts on health from indoor exposures. The health benefits of the measures come from reduced exposure to fine particulate matter ($PM_{2.5}$) resulting from reductions in black carbon and other particle emissions. Because particulate matter is reduced rapidly after the measures have been implemented, the health benefits will also be felt immediately. 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 (Figure ES-1) with the next highest benefit likely to be achieved in Africa. Health benefits in these two regions are mainly achieved by controlling biomass cookstove 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 of about 32 million tonnes (range of 21-57 million

Figure ES-1: The annual reduction in premature deaths from the implementation of different black carbon measures in each region in 2030. The percentage given above each bar indicates the proportion of avoided deaths from inhalation of outdoor air pollution particles within the region that implements the measures. Vertical grey bars indicate the uncertainty range in the mortality figures based on the uncertainty in the concentration-response relationships



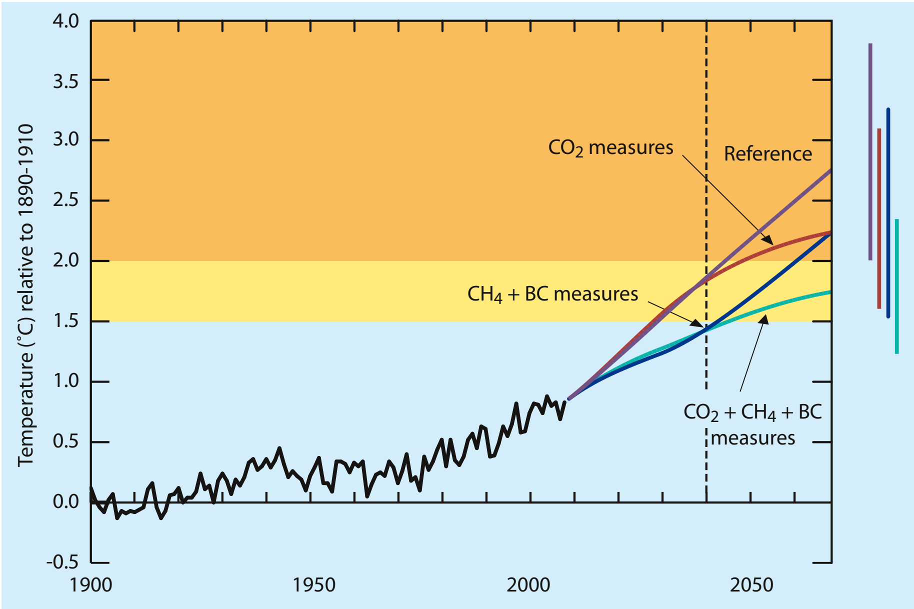
3. The ranges for health and crops reflect the uncertainty in the concentration-response relationships alone and not uncertainties in the estimation of concentrations.

tonnes) each year after 2030 when all the measures have been implemented (note that the UNEP/WMO 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 greatest crop benefit from the methane measures comes from reducing emissions from coal mines, especially in North East Asia, South East Asia and the Pacific; from oil and gas production in all regions; and from long-distance natural gas transmission pipelines in North America and Europe. The crop benefits from action on black carbon emissions largely come from the implementation of measures in the transport sector, especially the wider implementation of Euro-6/VI standards.

The near-term climate benefits of reducing short-lived climate forcer concentrations

Reducing the three short-lived climate forcers offers a realistic opportunity to significantly reduce the rate of global warming over the next two to four decades. If fully implemented by 2030, the 16 measures are estimated to reduce global warming between 2010 and 2050 by about 0.4°C (this study)[4] to 0.5°C (from the *Integrated Assessment of Black Carbon and Tropospheric Ozone,* UNEP/WMO, 2011). From here on we make reference to the 0.4°C global decrease from this study. While maximum benefits will be reached by 2050, the bulk of the benefits will already be realised by 2040, as indicated by the dotted line in Figure ES-2. This is compared to the temperature

Figure ES-2: Observed deviation of temperature to 2009 and projections under various scenarios from the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011). Implementation of the identified black carbon (BC) and methane (CH_4) measures between 2010 and 2030, together with measures to reduce carbon dioxide (CO_2) emissions, would greatly improve the chances of keeping the Earth's temperature increase to less than 2˚C relative to pre-industrial levels. The uncertainty of the temperature projections in 2070 is shown by the lines on the right hand side[5]

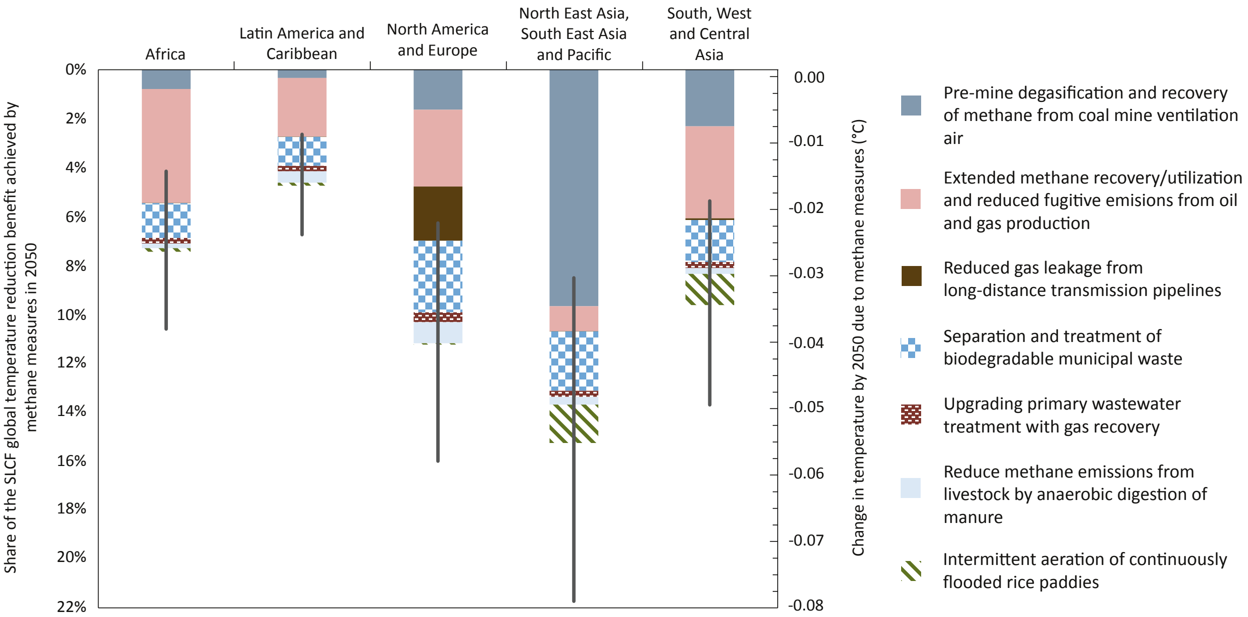


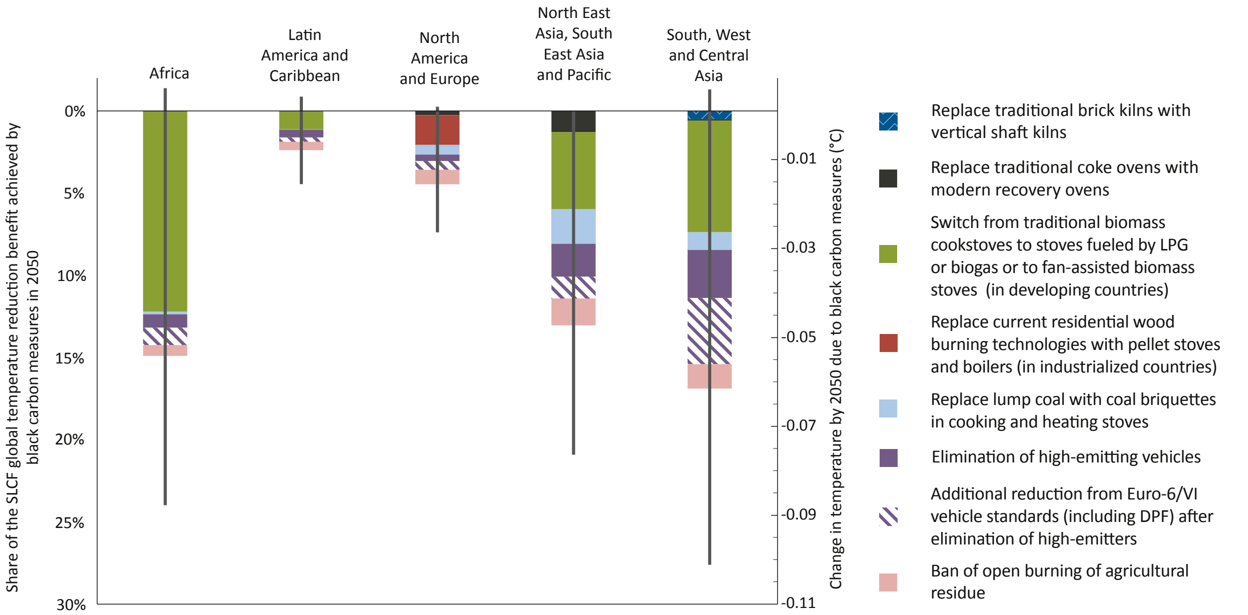
Source: UNEP/WMO (2011) using an average of two global composition-climate models (GCMs) that estimate pollutant concentrations, radiative forcing and global climate

4. The TM5-FASST model was used to disaggregate the influence of the different measures on temperature. This model estimated total temperature change to be closer to 0.4°C than 0.5°C as estimated in the Assessment by the NASA-GISS and ECHAM models (UNEP/WMO, 2011), but this will not affect the proportional contribution of the measures to the reduced warming.

5. The uncertainty for black carbon on global temperature is greater than for methane, whose impact is relatively well known. It is possible that the impact of black carbon on warming could be around zero, but current knowledge suggests that it is more likely that removing black carbon would provide a net global climate benefit.

Figure ES-3: The estimated impact of methane (top) and black carbon (bottom) measures on global temperature expressed as their percentage share of the global temperature benefit delivered by the sum of all 16 measures in 2050 (left-hand axis) and in terms of absolute temperature change (right-hand axis). The absolute temperature benefit sums to 0.4°C (using TM5-FASST). When added together, the bars for both methane and black carbon add up to 100 per cent of the temperature reduction. Vertical grey bars indicate the uncertainty range in absolute temperature change due to the likely range of the radiative forcing of methane and black carbon (and co-emitted substances)





*Note: For biomass cookstoves, only the effect of substitution with LPG and biogas stoves is shown in the black carbon graph for clarity. With 100 per cent substitution by fan-assisted biomass stoves, the reductions would be slightly lower (i.e. the lengths of green bars would be 6 per cent shorter) increase projected in the 'reference' scenario (Figure ES-2) and represents nearly a halving of the pace of global warming between 2010 and 2040. This 0.4°C benefit (range 0.1-0.6°C) might be maintained into the future, but the contribution of these measures to long-term climate protection is difficult to assess as it is hard to predict the development of SLCF emissions from different sectors in the reference scenario into the more distant future.

About half of the 0.4°C climate benefit in 2050 comes from implementing the black carbon measures, mainly in Asia and Africa, and the other half comes from implementing the methane measures, mainly in Asia, Europe and North America. Figure ES-3 shows the contribution of the different measures in the different regions to the global warming reduction of 0.4°C in 2050. The higher uncertainty of the black carbon measures on climate compared with the methane measures is shown.

The role of short-lived climate forcers in achieving longer-term climate goals and contributing to closing the 'emissions gap'

Although reductions of SLCFs would substantially slow the rate of climate change over the next few decades, they are likely to make only a modest contribution to longer-term climate goals and help narrow but not close a greenhouse gas 'emissions gap' in 2020[6]. Therefore, reducing SLCFs must be viewed as a strategy that complements but does not replace carbon dioxide emission reductions. Because SLCFs have a relatively short atmospheric lifetime, their concentrations decline fairly quickly in the atmosphere if their precursor emissions are drawn down. Hence, reducing methane and black carbon emissions can be an effective way to slow global warming over the next two to four decades. However, because SLCFs have a short atmospheric lifetime, their removal also has a relatively small effect on long-term global warming. As an example, assuming that all the SLCF measures were implemented in 2020, the influence of the emission reductions achieved in that year on global temperature over a 100 year time horizon would be about 1.1 Gt CO_2e (range: 0.4-1.7 Gt CO_2 e)[7]. This amount would help narrow but not close the 6-11 Gt CO_2e emissions gap[8] in 2020, i.e. the gap between expected emissions if countries comply with their reduction pledges, and emissions consistent with keeping global warming below a 2°C increase for a hundred years or more. Hence, while reducing SLCFs helps slow global warming and avoid exceeding the 2°C target, immediate reductions of CO_2 and other long-lived greenhouse gases are needed to meet the target over the long run.

Regional variation in benefits from implementing the SLCF measures

In Asia, about 1.9 million premature deaths from outdoor air pollution could be prevented each year, by 2030, by implementing black carbon measures addressing the transport and residential sectors and open agricultural biomass burning. Methane measures in Asia would provide about the same global climate benefit as black carbon measures. Most of the climate benefit from methane emission reductions derives from coal mine methane recovery, especially in North East Asia, and reducing emissions from oil and gas production in South, West and Central Asia, as well as through better management of municipal waste. For black carbon, measures in Asia addressing emissions from traditional biomass cookstoves and transport would provide the largest climate benefit.

In North America and Europe, the largest climate benefit would be realized by implementing measures to reduce methane emissions from coal mining, oil and gas production and better management of municipal waste. These same measures, together with measures in the transport sector, would also bring large crop-yield benefits. Further action on black carbon emissions to replace current domestic wood-burning technologies with pellet stoves/boilers, and banning the outdoor burning of agricultural residues in countries where this practice continues, would provide climate benefits, especially for the Arctic. Shipping activity near the Arctic, which is a source of black carbon emissions, is a growing black carbon concern.

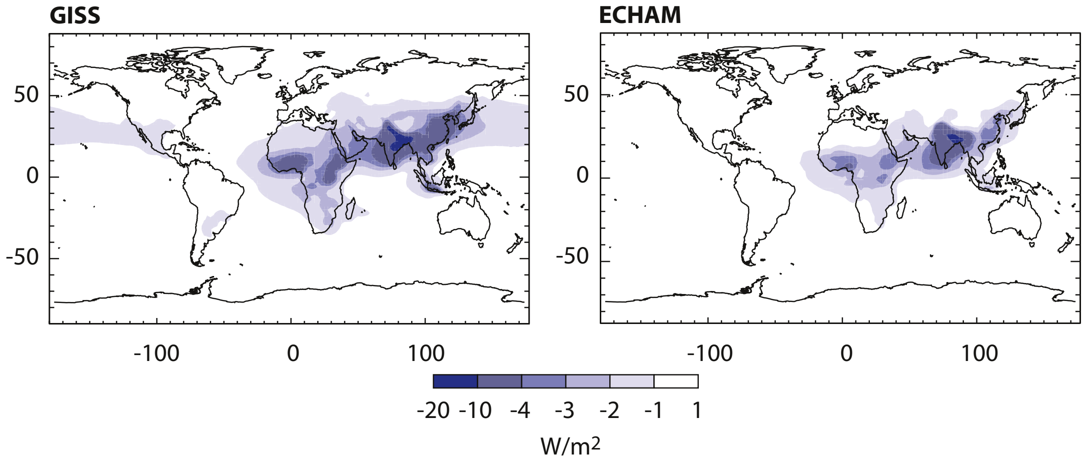
In Africa, action on black carbon, especially from biomass cookstoves, would potentially provide the largest near-term climate benefit, although the impact of black carbon mitigation on climate is subject to a higher uncertainty than

6. UNEP, 2011b.

7. Converting black carbon and methane emission reductions to CO_2 equivalents using their Global Temperature Potentials for a 100 year time horizon.

8. UNEP, 2011b.

Figure ES-4: Change in atmospheric forcing in the year 2030 relative to the reference scenario in the two general circulation models (GISS and ECHAM) of the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011). The greatest benefit for regional climate would be expected where there is the greatest change in atmospheric forcing (shown by the darker areas in the two maps). Here the benefit is expected to result from reduced disruption of rainfall patterns. The results of two models using the same input data are shown and they demonstrate similar results, despite having very different treatment of aerosols in the models



methane mitigation. The biomass cookstoves measures also provide large benefits to health protection and would prevent about 200,000 premature deaths from outdoor air pollution each year by 2030. The methane measures that bring about the largest benefit for crops and near-term climate are mainly those in the oil and gas production industries, better management of municipal waste and reducing the release of methane from coal mines.

In Latin America and the Caribbean, methane measures would provide a larger climate benefit compared to black carbon measures, mainly by recovering methane from oil and gas production and better management of municipal waste. Black carbon measures deliver more modest climate and health benefits in this region, but a relatively large benefit for crop yields, all from addressing diesel-vehicle emissions.

The package of 16 black carbon and methane reduction measures would also have a major positive impact on regional climate protection:

- A reduction in SLCFs would slow the projected warming in the Arctic by about 0.7°C in 2040, about two-thirds slower than the pace of warming under the reference scenario described above. This is very significant in light of the rapid rate at which Arctic land- and sea-ice is now melting.
- Current levels of black carbon and other particles in the atmosphere have disrupted regional weather patterns including the South Asian monsoon. Because the emission reduction measures would noticeably reduce the impact of SLCFs on the atmosphere in this region (Figure ES-4), it is possible that weather patterns could return to a less disturbed state.
- Reducing black carbon emissions would reduce the amount of these dark black carbon particles being deposited on snow and ice surfaces in the Himalayas and other mountainous areas. The deposition of black carbon is suspected of contributing to the accelerated melting of glaciers.

Taking action to reduce methane and black carbon emissions represents a 'no-regrets' policy because there is high confidence that the sum of the 16 measures would greatly reduce air pollution and its impact, thereby lowering barriers to sustainable development. Furthermore, there is high confidence that methane emission reductions would reduce global warming and that black-carbon emission reductions would result in regional climate benefits. There is still some uncertainty about the magnitude of global-warming benefits of black carbon emission measures, but the measures are expected to have a net positive global climate benefit.

The cost implications of the emission reduction measures

About half of the emission reductions of both methane and black carbon could be achieved by measures that would deliver financial cost savings (as a global average) over the lifetime of the measures. This estimate of cost savings does not account for the economic gains associated with reduced health, climate, crop yield and ecosystem impacts. These same measures account for about half of the temperature benefit that could be achieved. However, these measures may be considered less profitable by private-sector investors who expect a fast return on their investments. As a result, it is unlikely that these SLCF measures would be implemented by market forces alone under current conditions. Nevertheless, the cost saving is an important feature that could encourage the development of financing schemes for these measures. The remaining temperature reduction could be achieved through measures that would be competitive in the global carbon market, and also by measures that have already been widely implemented by developed countries.

Options for short-lived climate forcer policy development and implementation

It is essential to link SLCF benefits and measures to wider policies and processes addressing air quality management, sustainable development and climate action. Existing processes and institutions at the national, regional and global scale could be the starting points for raising awareness, implementing measures and mainstreaming the issues into these policy arenas.

National-level policy options

The current state of knowledge is sufficiently robust to justify immediate action to reduce emissions at the national level. Countries can be confident that multiple benefits will be achieved if they were to begin the implementation of SLCF reduction measures. There are good reasons for giving special priority for actions at the national level. Firstly, the greatest public health benefits of black carbon emission reductions are expected to occur close to where the reductions take place. Secondly, each country has its own unique combination of emission sources, therefore requiring an individualized national strategy for reducing emissions. Thirdly, acting at the national level allows a country to incorporate the reduction of SLCFs into its air quality, climate change and development policy and regulatory frameworks, as well as into relevant sectoral policies according to its national priorities.

An integrated approach across national agencies and policies is required to address SLCFs. Such an approach could be established in the context of national development planning based on an inter-agency structure and integrated with national priorities.

Developing national action plans for reducing SLCFs would be an effective way to consolidate mitigation activities on the national scale. Such plans could build on existing institutions and policies, including those for air quality management, development and climate change and could include:

- characterizing sources and opportunities for emission reductions;
- assessing the relative costs and benefits of action;
- determining the political feasibility of implementation;
- undertaking an inventory of current policy, legislation and institutions that could be used to implement or strengthen relevant measures;
- identifying further policies, where there are gaps, to make more rapid progress; and
- taking cost-effective action on SLCF sources.

Key actions that may be suitable for inclusion in a national action plan would depend on the specific national SLCF sources and national priorities. The actions could include:

- strengthening national regulations for coal, oil and gas industries to implement methane mitigation measures;
- strengthening support measures for recovery of methane from coal mining operations;
- strengthening support measures for recovery of methane from landfill, including separation of waste streams;
- creating and enforcing regulations to ban the open burning of agricultural wastes;
- strengthening support measures for alternative uses for agricultural wastes;
- introducing support measures to test, select and encourage widespread acceptance and use of improved cookstoves;
- establishing and strengthening inspection and maintenance of vehicles; and
- creating and implementing regulations to establish or tighten emission standards for all vehicle categories, including non-road vehicles, and stationary sources.

For many developing countries, national policies for reducing SLCFs need to take into account the lack of established systems for managing air pollution. Therefore, policies for controlling SLCFs might be more successful if they were incorporated within sustainable development frameworks and existing practices. It is also likely that financial incentives will be needed.

Regional-level policy options

Regional coordination has an important role in enhancing action taken at the national level. Existing and emerging regional air pollution management initiatives and inter-governmental agreements could be used as an effective way of building awareness, promoting the implementation of SLCF measures and enhancing capacity. National action could be supported by regional banks and other financial institutions and by pooling scientific expertise and sharing policy experience across a region.

Regional initiatives and inter-governmental networks for air pollution management are in different stages of development, but they have the potential to provide a basis for cooperative action as well as enhancing and supporting national activity. The many different institutions covering air pollution management at a regional scale could be clustered into three main categories, each requiring a different approach for including SLCF policies:

i) Legally binding regional agreements such as the Convention on Long-Range Transboundary Air Pollution (CLRTAP) covering the region of the United Nations Economic Commission for Europe (UNECE) and the ASEAN Haze Agreement. These institutions could be, and in some cases already are, platforms for policy action on controlling SLCFs.

ii) Intergovernmental initiatives such as the Malé Declaration addressing air pollution in South Asia and the Acid Deposition Monitoring Network in East Asia (EANET) covering North East and South East Asia, which have established structures and a focus on monitoring and scientific research. These institutions could be platforms for developing the scientific information, awareness raising and capacity building on SLCFs needed for policy action.

iii) Agreements or initiatives based on declarations of goals with no existing structures for pursuing knowledge or policies. These include the Southern African Development Community (SADC) Regional Policy Framework on Air Pollution (known as the Lusaka Agreement) and the Inter-governmental Network on Air Pollution in Latin America and the Caribbean. These institutions could become forums for awareness raising and capacity building with regard to SLCFs. If further developed they could also become platforms for developing scientific information and policy action regarding SLCFs.

Coordinated regional action is important to effectively address certain key impacts, for instance on the Arctic, Himalayas and South Asian Monsoon. Short-lived climate forcers cross national borders and impact neighbouring countries. Securing early progress in collaborative efforts to mitigate black carbon in the Arctic is particularly important because of increasingly obvious climate impacts in this region. This is a priority issue for the Arctic Council, which has already acted to move SLCF issues forward for that region. The Arctic Council's approach could provide a model for needed action in other regions where the effects of climate change and black carbon concentration and deposition are particularly important, such as the Himalayas and Andes, and the monsoon regions of South Asia. Existing regional institutions covering these sensitive regions could embrace the issue and work toward region-based solutions.

Global-level policy options

There are three main approaches to acting on SLCFs at the global level:

i) **Building on existing legal instruments for the purpose of abating SLCFs.** Some examples include: taking further action on methane in the context of the UN Framework Convention on Climate Change (UN FCCC); exchanging information about SLCF measures and policies within the subsidiary bodies of the UNFCCC; and working with the International Convention for the Prevention of Marine Pollution from Ships (MARPOL) to develop SLCF mitigation policies. Meanwhile, the Intergovernmental Panel on Climate Change, UNEP and other organizations can be encouraged to continue to assess the scientific knowledge about SLCFs for policymakers.

ii) **Promoting further efforts to control SLCFs by United Nations agencies and other international organizations, and by various partnerships and other cooperative mechanisms.** These "further efforts" could include:
- convening stakeholders around a shared vision and global strategy to mitigate SLCFs;
- developing common standards and guidelines for emissions and ambient levels of SLCFs;
- promoting the coherent integration of SLCFs into different policy streams such as development, public health, climate change and air pollution;
- encouraging joint action amongst and between the private sector, civil society, and governments on various activities for SLCF abatement. These could include the adoption of best practices in industry and improvement of polluting technology.

iii) **Putting enabling mechanisms in place at the global scale to facilitate national implementation of SLCF measures.** A few of the many possible global steps for enabling action at the national level would be:
- sponsoring activities such as workshops, conferences, and the production of publications

that raise awareness and generate and share knowledge about SLCFs;

- providing technical assistance and facilitating technology transfer to upgrade and retrofit technology to reduce emissions;
- helping to build capacity for controlling SLCFs, including assistance in setting up necessary monitoring and observation networks and incorporate SLCFs in air quality management plans;
- facilitating the financing of SLCF abatement. Options include the expansion of existing SLCF-specific funds (or establishing new such funds); building on existing climate-related funds and funding mechanisms (Global Environmental Facility, Clean Development Mechanism, Green Climate Fund, and others), and/or integrating SLCF abatement into funding for sustainable development.

Action on SLCFs can also be supported at the global level through a voluntary partnership of committed governments and other interested stakeholders. This initiative could be led by a small steering committee of country champions working together with a small secretariat which could be hosted by UNEP. Such an initiative could:

- identify opportunities for enhanced international coordination and outreach;
- identify knowledge gaps, human and financial resource requirements;
- raise public awareness of the problems and opportunities and discuss common approaches to taking new action, or to promoting and reinforcing action in other organizations; and
- promote the development of national or regional action plans, tracking progress of programmes and commitments and mobilizing funding for SLCF mitigation.

Chapter 1:

Introduction

This report addresses the mitigation of short-lived climate forcers (SLCFs) and the role that it can play in air pollution control and near-term climate protection and in achieving sustainable development goals. The focus is on three SLCFs: methane, tropospheric ozone (in the lower atmosphere) and black carbon, all of which have relatively short atmospheric lifetimes and lead to impacts on human health, crops and ecosystems and whose reduction would limit the rate of increase in global temperature over the next two to four decades. Scientific understanding of the role of SLCFs in near-term climate change has improved dramatically over recent years. It is now possible to examine actions that could mitigate SLCFs and that will also bring immediate benefits for health and crop production and, more broadly, benefits for development.

Air pollution continues to have significant health, ecosystem and crop yield impacts across the globe and is estimated globally to cause 1.97 million premature deaths from exposure to particulate matter indoors and 1.15 million deaths from exposure to outdoor particulate matter each year (WHO, 2009). Most of these health impacts occur in developing countries. These countries, in particular, are concerned with the need to protect public health and the environment in a way that is consistent with their development objectives. The policies and measures discussed in this report could reduce the economic burden of air pollution and its associated negative impact on human health and crop yields, as well as limit the potentially negative changes to climate affecting their regions, particularly those related to rainfall patterns (UNEP/WMO 2011).

Control of anthropogenic emissions of carbon dioxide (CO_2) and other long-lived greenhouse gases, now and further into this century, is critical and must continue. However, the rate of near-term climate change, and the wide range of associated impacts anticipated over the next two to four decades, is a growing threat that also requires immediate attention.

Why is it important to slow down warming in the near term? First of all, current climate change is already leading to many undesirable impacts: lakes are building up at the foot of melting glaciers in the Himalayas and other glaciated regions and are threatening to burst and cause floods downstream; warmer temperatures are leading to more frequent heat waves; the melting of land ice in the Arctic is contributing to sea-level rise throughout the world; and shifting climatic zones threaten the existence of some plant and animal species. Slowing the rate of warming would slow down the intensification of these impacts. Secondly, near-term warming is pushing us closer to thresholds that may lead to a further acceleration of climate change. For example, the melting of permafrost in the Arctic is releasing additional quantities of methane into the atmosphere (Christensen *et al.*, 2004), which in turn contributes to enhanced global warming. Another example is the melting of the summer Arctic sea ice which is altering the amount of solar radiation reflected over large areas and is likely to lead to climate change at regional and, perhaps, wider scales. By reducing the rate of warming over the next few decades, some of the processes that are accelerating climate change can be slowed, and perhaps it will be possible to avoid exceeding other thresholds. Finally, slowing down near-term warming will give society and nature more time to adapt to climate change. The faster the speed of change, the less time society has to develop drought-resistant crops, re-cultivate wetlands to protect shorelines, or implement flood protection schemes to cope with more frequent river flooding. The faster the rate of change, the more difficult it is for plants and animals to migrate to more climatically suitable areas, and the less time society has to develop and implement the technologies to control CO_2 emissions. Therefore, there is a need to make rapid progress to limit the speed of warming in the near term and full climate protection can only be achieved by addressing both near- and long-term climate change.

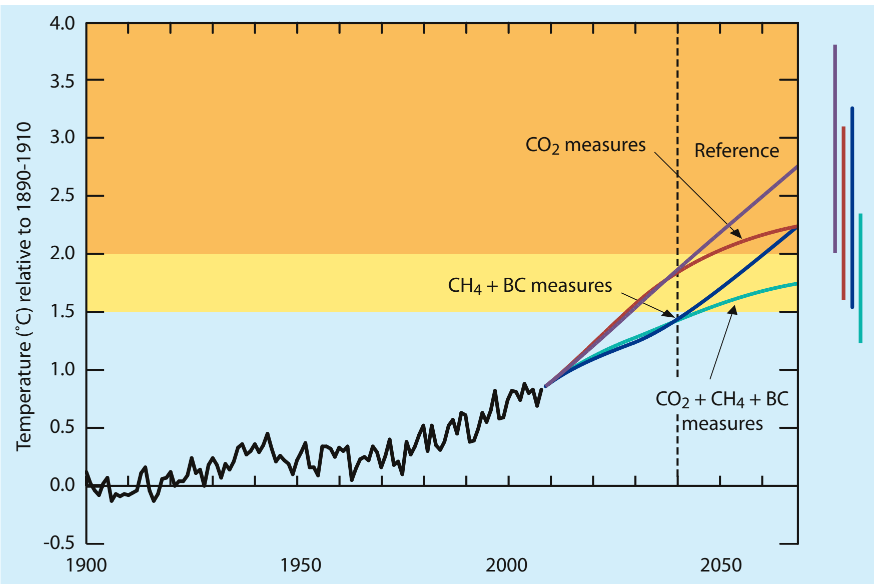
Action to reduce concentrations of SLCFs is substantiated by key scientific assessments that analyse how they influence climate and how they impact human well-being around the globe. The analysis in this report builds upon the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011), and also links to other international assessments and research programmes (HTAP, 2010; Arctic Council, 2011; ABC project: UNEP and C4, 2002, and Ramanathan *et al*., 2008). In addition, the UNEP/WMO (2011) assessment demonstrated how widespread implementation, worldwide, of a relatively small number of carefully identified measures could achieve multiple goals.

As well as achieving significant health and crop yield benefits, the implementation of identified black carbon and methane measures were shown to significantly slow the rate of near-term climate change. Figure 1.1 illustrates this impact on global temperatures. It also shows that the measures could also increase the chances of remaining below the Cancun Agreement of not exceeding a 2°C increase in global average temperature above pre-industrial levels during the 21st century (see the lower line of combined CO_2+CH_4+BC measures in Figure 1.1). This figure also illustrates that the major effects of the CO_2 reduction scenario (CO_2 measures in Figure 1.1) on temperature are realised in the longer term whereas the mitigation of SLCFs by black carbon and methane measures slow global warming in the near term.

Recognizing the need to make progress on SLCF reductions, this report examines options for national action, outlining costs and benefits of implementing certain measures and emphasizing the potential facilitating and catalysing roles of regional inter-governmental cooperation and global mechanisms. The main goals of this report are to:

- Identify the benefits of reducing SLCFs, including the global climate benefits of slowing near-term global warming, and the air quality benefits to health and agriculture.
- Identify practical policies and measures, available now, that can effectively reduce SLCFs, in particular emissions of black carbon and the precursors of tropospheric ozone, especially methane.
- Highlight the most effective measures within different regions to reduce SLCF emissions and concentrations and compare the benefits that would offset the implementation costs.
- Review and discuss policies and other actions at the national, regional and global levels that would lead to widespread reductions of SLCFs.

Figure 1.1: Observed deviation of temperature to 2009 and projections under various scenarios from the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011). Implementation of the identified black carbon (BC) and methane (CH_4) measures between 2010 and 2030, together with measures to reduce carbon dioxide (CO_2) emissions, would improve the chances of keeping the Earth's temperature increase to less than 2˚C relative to pre-industrial levels. The uncertainties of the temperature projections in 2070 are shown by the lines on the right hand side[9]



Source: UNEP/WMO, 2011

9. The uncertainty for black carbon on global temperature is greater than for methane, whose impact is relatively well known. It is possible that the impact of black carbon on warming could be around zero, but current knowledge suggests that it is more likely that removing black carbon would provide a net global climate benefit.

Chapter 2:

Short-lived Climate Forcers and their Impacts on Air Quality and Climate

Black carbon and tropospheric ozone cause health and climate impacts, while tropospheric ozone also causes damage to crop yields and ecosystem structure and function. Methane, a potent greenhouse gas, is also one of the most important precursors of tropospheric ozone and thus contributes to air pollution.

Black carbon and tropospheric ozone remain in the atmosphere for only days or weeks while the atmospheric lifetime for methane is about 12 years (Table 2.1). The critical point is that these substances have a positive radiative forcing and cause warming of the atmosphere through a number of different processes. The historical contribution of pre-industrial to present-day increases in black carbon, tropospheric ozone and methane to radiative forcing is about 1.1 W/m^2, 68 per cent of the forcing from carbon dioxide over the same time period (Forster *et al.*, 2007).

Some hydrofluorocarbons fall into the category of SLCFs but do not cause air-quality related impacts and therefore, are not considered in this report beyond the information in Box 2.1. They are, however, covered in another UNEP report (UNEP, 2011a).

2.1 Methane

The increase of methane in the atmosphere has caused the largest radiative forcing by any greenhouse gas after carbon dioxide. Methane concentrations have grown as a result of human activities related to agriculture, including rice cultivation and the keeping of ruminant livestock, coal mining, oil and gas production and distribution, biomass burning and municipal waste landfills.

Methane has a direct influence on climate, but also has a number of indirect effects including its role as an important precursor to the formation of tropospheric ozone. For some methane sources, emission control measures also reduce other co-emitted substances such as the more reactive volatile organic compounds that contribute to the local formation of ozone, as well as air toxics, such as benzene, carbon tetrachloride and chloroform. Thus, some methane mitigation measures provide local air-quality benefits.

Table 2.1: Atmospheric lifetimes of short-lived climate forcers in comparison to the long-lived greenhouse gas CO_2

Substance	Lifetime	Description / Source
Carbon dioxide	Decades to centuries and about 20 per cent will persist for many millennia	No single lifetime can be defined for carbon dioxide because of the different rates of uptake by different removal processes (IPCC: http://www.ipcc.ch/ipccreports/tar/wg1/016.htm)
Ozone	4 – 18 days	http://www.grida.no/climate/ipcc_tar/wg1/pdf/TAR-04.pdf
Methane	12 years	http://www.ipcc.ch/publications_and_data/ar4/wg1/en/errataserrata-errata.html#table214
Black carbon	3-8 days	The mean residence time in the atmosphere for black carbon varies regionally and with the season. The range given here is based on an international evaluation of 16 models (Shindell *et al.* 2008). However, black carbon may also continue to warm the atmosphere after being deposited on snow and ice.

Box 2.1: Hydrofluorocarbons –climate forcing issues emerging from chemicals designed to replace ozone-depleting substances

Hydrofluorocarbons (HFCs) are intentionally made to replace stratospheric ozone depleting substances (ODS), in such applications as air conditioning, refrigeration, solvents, foam blowing and aerosols. Although, they do not deplete the ozone layer, they are potent greenhouse gases and a substantial fraction of hydrofluorocarbons have a lifetime of 29 years or less and can be considered short lived (Velders *et al*., 2009; Forster *et al*., 2007).

Although the abundance of hydrofluorocarbons in the atmosphere is currently small, recent scientific studies project substantial growth in their use in the coming decades as a result of increased demand for refrigeration and air-conditioning, particularly in developing countries. If left unchecked, HFC consumption is projected to double by 2020, and their emissions could contribute substantially to radiative forcing in the atmosphere by the middle of the century (UNEP, 2011a; Velders *et al*., 2009).

Currently, hydrofluorocarbons are included in the greenhouse gas emissions to be reduced under the Kyoto Protocol, thus there could be greater scope for collaboration between the Montreal Protocol, where proposals are being discussed to phase out production and consumption of HFCs, and the United Nations Framework Convention on Climate Change.

2.2 Tropospheric ozone

Ozone is a reactive gas that exists in two layers of the atmosphere: the stratosphere (the upper layer) and the troposphere (up to about 10–20 km above the ground). In the troposphere, ozone is a significant greenhouse gas. The threefold increase in ozone concentrations in the northern hemisphere during the past 100 years has made it the third most important contributor to the human enhancement of the global greenhouse effect, after carbon dioxide and methane (Royal Society, 2008). It is the main gaseous pollutant affecting the yield of many crops and also has impacts on the diversity and growth of plant communities. It also affects human health due to its action as a powerful oxidising gas causing, for example, oxidative stress in lungs once it has been inhaled (Romieu *et al.*, 2008).

Unlike many other air pollutants, ozone is not directly emitted. It is a secondary pollutant that is formed in the troposphere by sunlight-driven chemical reactions involving carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), methane and nitrogen oxides (NO_x). These precursors arise from both natural sources and a broad range of human activities. The breadth of sources of ozone precursors, the role of natural and physical processes in ozone distribution, production and destruction and its complex chemistry mean that controlling ozone requires responses that take these complexities into account. The only practical management strategy is to control the emissions of precursors from human activities and, based on the understanding of ozone formation and its impacts, determine which precursor reduction is most appropriate in order to minimise a particular ozone impact.

Reductions in both methane and carbon monoxide emissions have the potential to substantially reduce ozone concentrations and global warming. Methane contributes around 50 per cent of the increases in background ozone, with smaller contributions from non-methane volatile organic compounds and carbon monoxide (Royal Society, 2008). The ozone response to changes in methane emissions requires several decades to be fully realized, given the 12-year average atmospheric lifetime of methane. In contrast, reducing other ozone precursors, i.e. non-methane volatile organic compounds and nitrogen oxides, would only lead to limited global-scale climate benefits, but would play an important role in rapidly reducing peak ozone concentrations within a given region which will reduce air quality impacts on crops, vegetation and human health relatively close to the source of emission.

2.3 Black carbon

Black carbon, a major component of soot, exists in the atmosphere as particles. It is therefore not a greenhouse gas. Instead, black carbon particles absorb sunlight and then radiate energy to warm the atmosphere. Black carbon results from the incomplete combustion of fossil fuels, wood and other biomass. Although complete combustion would turn all the carbon contained in the fuel into carbon dioxide, in practice, combustion is never complete and always releases other gases including carbon monoxide, methane, non-methane volatile organic compounds, and particulate black carbon and organic carbon. Black carbon and other particles are emitted from many common sources, such as diesel cars and trucks, residential stoves, forest fires, agricultural open burning and some industrial facilities.

There is a close relationship between emissions of black carbon, a warming agent, and organic carbon, a cooling agent as they are always co-emitted, but in different proportions depending on the source. Similarly, mitigation measures have varying effects on the black carbon/organic carbon mix, and on concentrations of other particles and ozone precursors. Therefore, the effectiveness of mitigation measures applied to different sources must take into account the changes in all emissions that influence warming.

Black carbon causes warming of the atmosphere by a number of different processes. These particles absorb visible light due to their dark colour. This absorption leads to a disturbance of the planetary radiation balance and eventually to warming. Another impact of black carbon is that when it is deposited on ice and snow it reduces the albedo of these surfaces, increasing both atmospheric warming and the melting rate caused by increased absorption of heat by the darker snow and ice. Black carbon particles also influence cloud formation. The limited level of knowledge of how some of these processes work also leads to a level of uncertainty of the overall effect of black carbon on global warming, that is higher than that, for example, of methane.

Black carbon aerosols have a large impact on regional circulation and rainfall patterns as they cause significant asymmetry in heating patterns over a region (Ramanathan *et al*., 2005; Wang, 2004). Whilst not fully quantifiable, the impact of black carbon on regional weather patterns and regional warming is more certain than its impact on global warming. This is because, at the global scale, co-emitted species such as organic carbon may offset warming due to black carbon. At the regional scale, changes are more closely related to atmospheric heating which is dominated by black carbon, and co-emitted species have less of an impact.

Black carbon and organic carbon make up a substantial part of the fine particulate matter in air pollution that is the major environmental cause of ill health and premature deaths, globally (WHO, 2009). The health-damaging particulate matter is characterized as $PM_{2.5}$, particles with a diameter less than 2.5 micrometres – 'fine' or 'small-sized' particles which affect the respiratory and cardiovascular systems – and its impacts occur due to both outdoor and indoor exposure. The health benefits of reduced emissions from measures that focus on black carbon are mainly achieved by the overall reduction in this fine particulate matter. It should be kept in mind that all reductions of black carbon emissions reduce $PM_{2.5}$ concentrations but all reductions of $PM_{2.5}$ do not necessarily reduce black carbon.

Chapter 3:

Policies and Measures to Reduce Short-Lived Climate Forcers

3.1 Strategic approach

The preceding chapter highlighted the SLCFs of interest to this report: black carbon, methane and tropospheric ozone. The benefits of mitigating emissions have also been highlighted in the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011). In order to develop effective policies for mitigation of these SLCFs, the following guiding principles could be useful:

- *Building on current policies.* Strategies to address SLCFs can efficiently build on a number of existing policies and initiatives. One option is to incorporate SLCFs into existing air pollution policies and regulatory frameworks, including those at the international level. Another is to incorporate them into climate change agreements and regulations. In addition, it would be useful to integrate SLCF mitigation into development policies.
- *Developing an integrated approach.* Society would benefit from a more integrated approach to climate change and air pollution in policy making, because it would utilise the large overlap between the two areas and thereby make policy making more efficient and less costly.
- *Setting common goals.* Setting common goals on national, regional, or international levels, can encourage national efforts by enabling progress to be measured against targets. In the case of air quality, international guidelines such as those for particulate matter and ground-level ozone from the World Health Organisation (WHO, 2006) can be used as targets. In the case of climate change, the goal of limiting temperature increase to less than 2°C above preindustrial temperatures can be used as a comparable target. Global goals regarding total emissions of black carbon, methane and other tropospheric ozone precursors could play an equally useful role. Countries could choose to set national targets in relation to achieving these global goals. This could also apply to near-term climate goals and air quality objectives.
- *Rapid implementation of measures.* Chapter 1 makes it clear that it is important to reduce imminent climate impacts, and Chapter 4 explains that this can accomplished by reducing SLCFs and slowing down global warming over the next two to four decades. Meanwhile, Chapter 4 also explains that air pollution impacts on health and crops are large and can be addressed by reducing SLCFs. From this dual perspective, it is clear that there are many benefits to be gained by reducing SLCFs as quickly as possible, and to consider options for near-term implementation of policies and measures focussing on the reduction of black carbon and methane emissions.
- *Central role of national action.* Special emphasis should be given to action at the national level because the health and agricultural benefits of implementing the measures are normally greatest close to emission sources. This is the case for the black carbon and other particulate matter emissions from smoky stoves and poorly operating brick kilns which endanger the health of local people. Moreover, measures can be better targeted to specific emission sources and policies by integrating them into national priorities for air pollution.
- *Enabling activities at regional and global levels.* Although it makes sense to give priority to national action for abating SLCFs, there are also advantages for cooperating at the regional and global level. One reason is that some SLCFs spread beyond national borders and are distributed across regions (e.g. black carbon), across hemispheres (such as tropospheric ozone and some of its precursors), and even across the globe (for example, methane). Often international action is needed to bring down levels of SLCFs within a particular country. Another reason for cooperating at the regional level is that emission sources and abatement measures tend to be similar for several countries within a region. International cooperation also promotes technology transfer and capacity building.

A suitable starting point is to identify measures that can clearly achieve the emission-reduction targets in a sustainable manner, taking into consideration the circumstances of any particular country. Identified strategies should be readily implementable, and success should be relatively easy to measure and assess. It is especially important that the selected measures are cost effective, generating positive short-term returns on capital expenditure, and have low maintenance costs.

3.2 Identifying priority control measures

A variety of technical and regulatory SLCF measures are available to control emissions. Mitigation measures for black carbon, in most instances, will usually result in changes in emissions of other co-emitted pollutants. Therefore, to understand the full climate and public-health implications, as well as other air pollution-related impacts of each measure, it is important to look at the impact of a measure on a suite of pollutants. For example, some co-emitted substances, including sulphur dioxide (that gives rise to sulphate) and/or organic carbon (often co-emitted with black carbon), cool the atmosphere and these can potentially offset the climate benefits of reducing black carbon. Sulphate and organic carbon are particles that scatter light and hence reflect a portion of incoming sunlight back into space, thereby cooling the Earth. However, over snow-covered reflective surfaces, organic carbon actually contributes to warming. Understanding the effect of these co-emitted substances on warming, climate change and the composition and concentrations of air pollutants is important when evaluating measures to reduce concentrations of black carbon and tropospheric ozone.

To identify 'win-win' measures that simultaneously achieve air quality and climate change benefits, an analysis of available measures that focus on reducing emissions of black carbon and methane was performed. The analysis was undertaken using information on measures compiled within the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model (Amann *et al*., 2011; Klimont *et al*., 2009; Kupiainen and Klimont, 2004). The model considered all key documented pollution control options, amounting to about 2 000 measures, that reduce black carbon and methane emissions. All black carbon measures reduce fine particulate matter ($PM_{2.5}$) while ozone precursor emissions are reduced by both black carbon and methane measures, resulting in reduced air pollution impacts on health, crop yields and ecosystems.

The GAINS model determined which of these measures would give net climate benefits. To do this, the measures were ranked according to their potential climate impact using published values of the global warming potential (GWP) for all substances emitted that affect climate and that are controlled by the measures. The net effect of the emission reduction of 'warming' substances compared to the emission reduction of 'cooling' substances was calculated. As a result, measures that reduce warming overall were identified. The resulting list therefore contains 'win-win' measures that reduce both air pollution and climate change impacts. Further details on the methodology used to derive the selected measures are provided in the on-line Appendix.

Of the 2000 measures, the GAINS model identified approximately 130 that would achieve a reduction of global warming, with the top 16 measures realizing nearly 90 per cent of the maximum reduction potential in equivalent CO_2 emissions by 2030. These 16 measures (Tables 3.1 and 3.2) were therefore selected to form the basis of the analysis in the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011) and in this report. Whilst they account for a large part of the climate benefit from a global perspective, they are not the only measures available to policy makers in different regions, but this selection does provide a sound starting point from which to develop effective policies targeted at reducing SLCFs.

3.3 Baseline year and reference scenario emissions

The effectiveness of SLCF mitigation measures was analyzed relative to a baseline year - 2005, and also relative to a reference scenario - a 'business-as-usual' scenario.

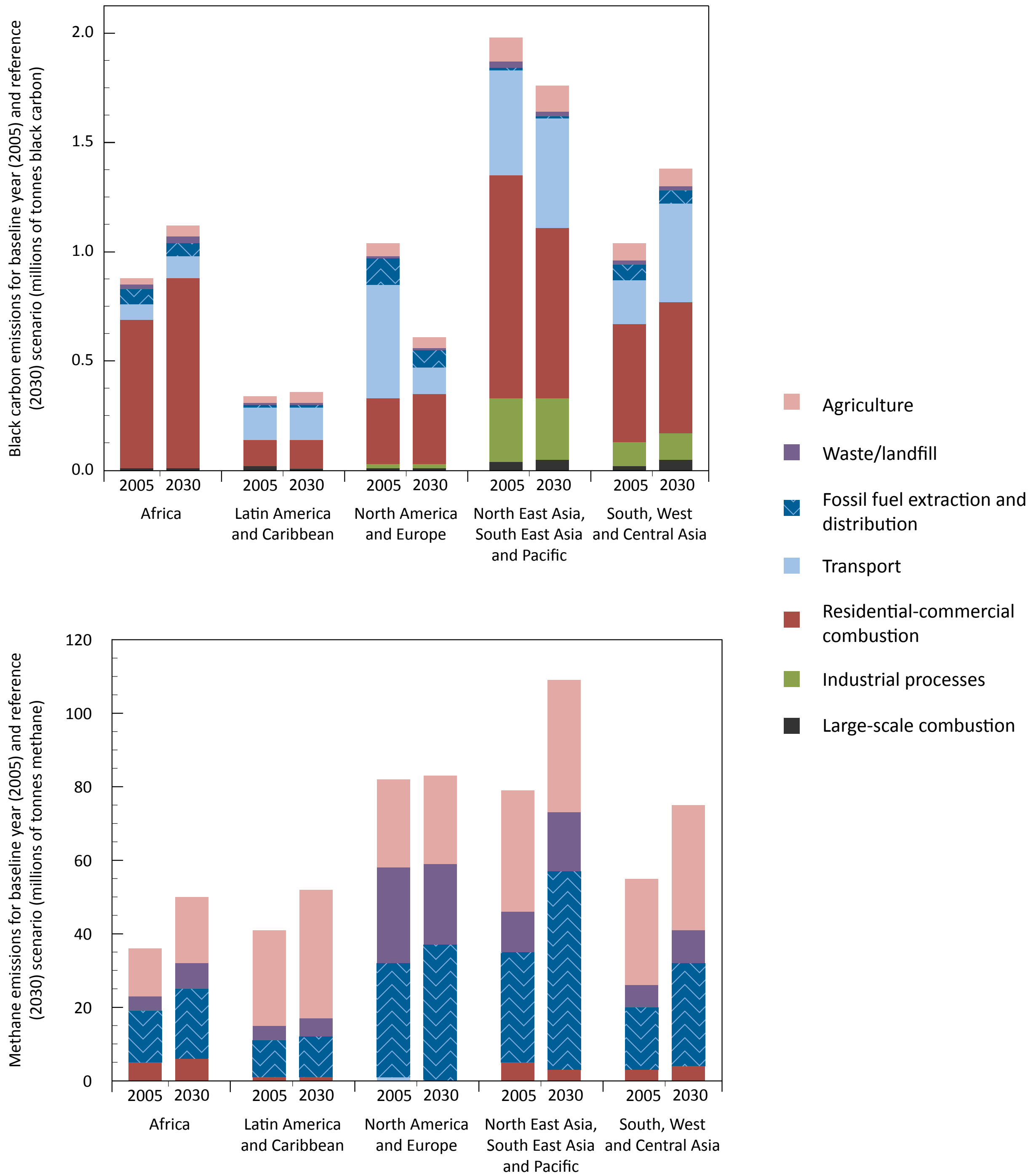
The baseline year (2005) emissions were estimated with the GAINS model, using available statistical data and data from Lamarque *et al.*, (2010) (See UNEP/WMO, 2011).

The reference scenario refers to emissions that would occur without deployment of further mitigation measures, apart from already existing ones. The values of the emissions were computed taking into consideration future energy and fuel demand as projected by the International Energy Agency (IEA) and incorporating the effects of all presently agreed policies that could affect the SLCF emissions (further details in the on-line Appendix).

The projected methane and black carbon emissions under the reference scenario in 2030 are shown in Figure 3.1. The figure shows the contributions of different sectors to emissions in each region. Details of the emission trends for other relevant substances – carbon monoxide, organic carbon, nitrogen oxides, non-methane volatile organic compounds, $PM_{2.5}$, sulphur dioxide and methane – are also provided in the on-line Appendix of this report.

At the global level three key sources of methane contribute about 94 per cent of the total anthropogenic emissions in 2005: 43 per cent from agriculture, including livestock rearing and rice production; 34 per cent from

Figure 3.1: Emissions of black carbon (top) and methane (bottom) for the baseline year 2005, and projections for 2030 based upon the UNEP/WMO assessment reference scenario for five different world regions (see Chapter 2 of UNEP/WMO, 2011). The emissions are broken down by major sector.



Note: shipping and aviation are not included in this regional analysis fossil fuel production and distribution; and 17 per cent from municipal waste and wastewater management. Asia accounts for 46 per cent of global methane emissions compared with 28 per cent in North America and Europe, 14 per cent Latin America and 12 per cent in Africa. Without further mitigation efforts, baseline methane emissions are expected to grow by about 25 per cent by 2030, with no significant changes in the regional and sectoral contributions.

At the global level, anthropogenic emissions of black carbon are dominated by residential-commercial combustion and transport sources that make up nearly 80 per cent of the total. Another 14 per cent originates from industrial production and the open burning of agricultural waste. There are significant regional differences in the importance of particular sectors – residential-commercial combustion dominates anthropogenic emissions of black carbon in Africa and Asia, while transport is currently a key contributor in North America and Europe. In Latin America and the Caribbean, both sectors are equally important black carbon sources. Industrial processes (e.g. production of bricks and coke in traditional kilns and ovens) are significant sources of emissions in some developing countries. As a global total, the reference scenario does not show a large change in total black carbon emissions by 2030 (Figure 3.1). However, significant regional and sectoral shifts are expected with, for example, declining shares from North America and Europe where emissions are estimated to fall by about half, primarily due to measures implemented in the transport sector. Meanwhile, the share of emissions from South, West and Central Asia and Africa increases significantly because of increases from the transportation and residential sectors. Combustion within the residential-commercial sector is expected to remain an important emission source over the next two decades.

3.4 Identifying key methane measures

Seven out of the 16 identified measures are focussed on reducing methane emissions (Table 3.1) from three sectors: fossil fuel production and transport, waste management, and agriculture.

The impact of these measures on emissions of methane relative to the reference scenario in 2030 is shown in Figure 3.2, assuming full implementation of measures in each region.

The identified measures are expected to reduce reference methane emissions by about 38 per cent in 2030 (Figure 3.2). A third of that figure is achieved by reducing emissions from oil and gas production in North America and Europe, Africa and South, West and Central Asia. Another third of the potential can be reduced from coal mining, especially from North East Asia, South East Asia and the Pacific region. The improved management of municipal waste could contribute one fifth of the potential reduction, half of which could be achieved in North America and Europe. Lastly, the agricultural measures considered here could account for about one tenth of global methane reductions in 2030.

A more detailed discussion of the measures and their application to different sectors is presented in Section 5.2.

3.5 Identifying key black carbon measures

Nine out of the 16 identified measures are focussed on reducing black carbon emissions (Table 3.2) from four sectors: transport, residential, industry and agriculture.

The impact of the identified measures on reference scenario emissions in 2030 is shown in Figure 3.3, again assuming full implementation of the measures in each region. The impact of the measures on emissions of other substances is given in the on-line Appendix.

These key measures achieve about 77 per cent of the potential emission reduction for black carbon in 2030 (i.e.

Table 3.1: Key methane abatement measures identified for this report (after UNEP/WMO, 2011)

Measure	Sector
Extended pre-mine degasification and recovery and oxidation of methane from ventilation air from coal mines	Fossil fuel production and transport
Extended recovery and utilization, rather than venting, of associated gas and improved control of unintended fugitive emissions from the production of oil and natural gas	
Reduced gas leakage from long-distance transmission pipelines	
Separation and treatment of biodegradable municipal waste through recycling, composting and anaerobic digestion as well as landfill gas collection with combustion/utilization	Waste management
Upgrading primary wastewater treatment to secondary/tertiary treatment with gas recovery and overflow control	
Control of methane emissions from livestock, mainly through farm-scale anaerobic digestion of manure from cattle and pigs	Agriculture
Intermittent aeration of continuously flooded rice paddies	

Figure 3.2: Methane emission reductions in 2030 achieved with the identified measures in Table 3.1 compared to the reference scenario in 2030 (in millions of tonnes of methane)

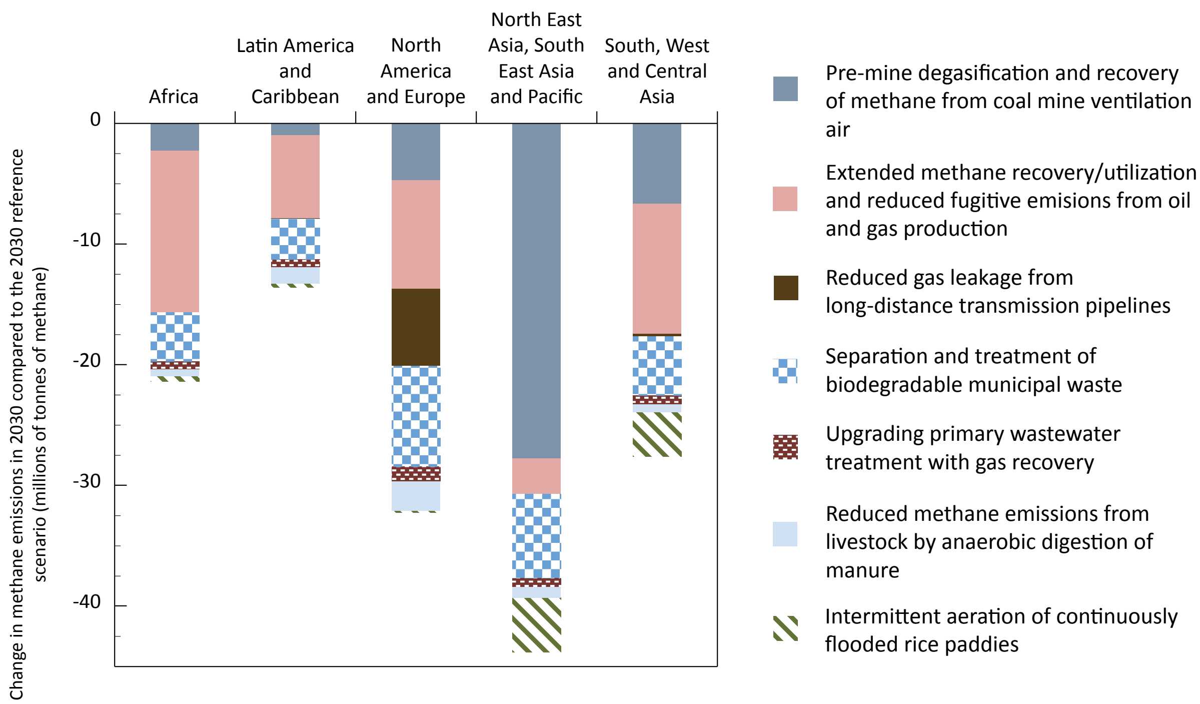
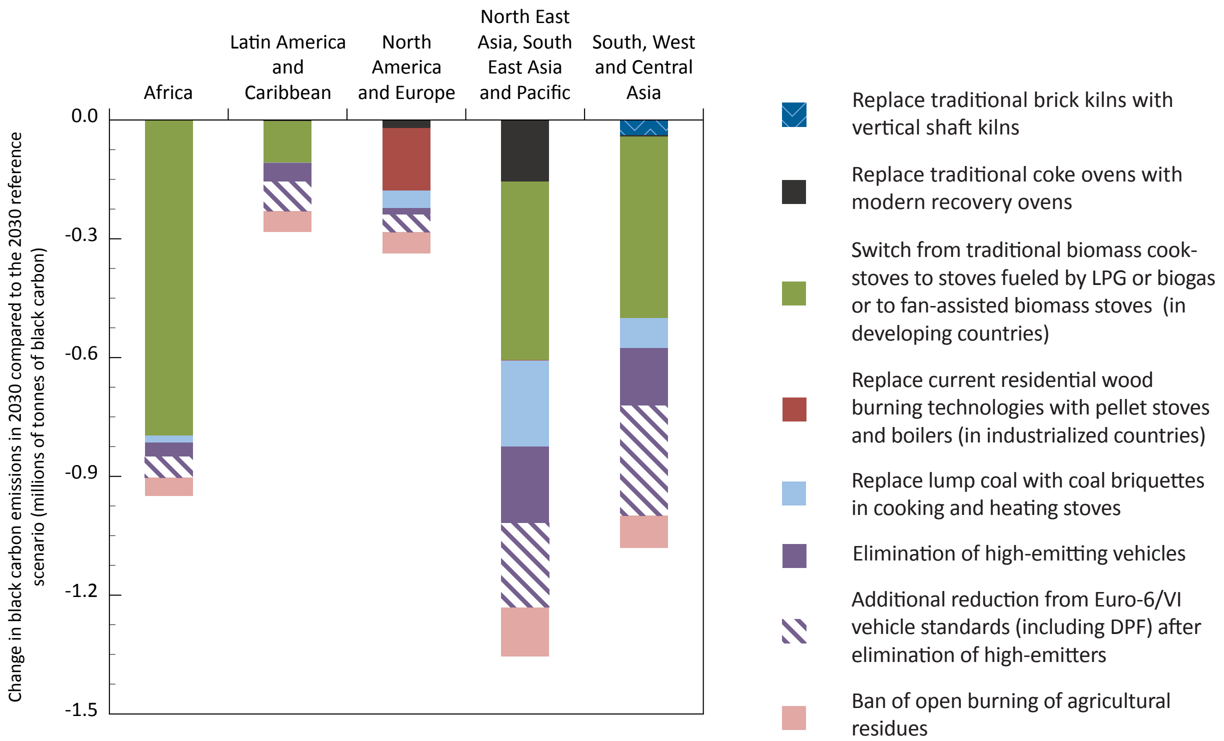


Table 3.2: Key black carbon abatement measures identified for this report (after UNEP/WMO, 2011)

Measure	Sector
Standards for the reduction of pollutants from vehicles (including diesel particle filters), equivalent to those included in Euro-6/VI standards, for road and off-road vehicles	Transport
Elimination of high-emitting vehicles in road and off-road transport	
Replacing lump coal by coal briquettes in cooking and heating stoves	Residential
Pellet stoves and boilers, using fuel made from recycled wood waste or sawdust, to replace current wood burning technologies in the residential sector in industrialized countries	
Introduction of clean-burning (fan-assisted) biomass stoves for cooking and heating in developing countries[1, 2]	
Substitution of traditional biomass cookstoves with stoves using clean-burning fuels (liquefied petroleum gas (LPG) or biogas)[1, 2]	
Replacing traditional brick kilns with vertical shaft brick kilns[3]	Industry
Replacing traditional coke ovens with modern recovery ovens	
Ban on open burning of agricultural waste[1]	Agriculture

1. Motivated in part by its effect on health and regional climate including its impact on areas of ice and snow
2. For cookstoves, given their importance for black carbon emissions, two alternative measures are included
3. Zig-zag brick kilns would achieve comparable emission reductions to vertical-shaft brick kilns

Figure 3.3: Black carbon emission reductions in 2030 achieved with the identified measures in Table 3.2 compared to the reference scenario in 2030 (in millions of tonnes of black carbon)



Note: for biomass cookstoves, only the effect of substitution with LPG and biogas stoves is shown for clarity; with 100 per cent substitution with fan-assisted biomass cookstoves, the emissions reduction would be about 6 per cent less

compared to all 2000 measures). Black carbon measures also have a significant effect on various co-emitted substances. For example, they reduce organic carbon emissions, which is an important consideration when assessing the net change in climate impact caused by the measures. They also reduce a number of ozone precursors - carbon monoxide, non-methane volatile organic compounds and nitrogen oxides – and therefore have the effect of reducing tropospheric ozone concentrations (see the on-line Appendix).

Measures addressing traditional biomass cookstoves would reduce emissions mostly in Africa and Asia, whilst those addressing emissions from the transport sector, especially by implementing Euro-6/VI vehicle-emission standards that include diesel particle filters, would bring about the largest reduction in black carbon emissions in Latin America and the Caribbean. In regions other than North America and Europe, eliminating high emitting vehicles would also have a significant beneficial impact on black carbon emissions. In North America and Europe, the largest black carbon emission reductions would come from replacing current wood-burning technologies in the residential sector with pellet stoves and boilers or another technology with equally low emissions.

Regionally, the potential to implement the measures differs depending on the source structure and the state of emission legislation. A broader discussion on the measures and their potential application to different sectors is presented in Section 5.2.

Chapter 4:

Costs and Benefits of Implementing the Measures: A Regional Analysis

This chapter focuses on the costs and benefits of black carbon and methane emission reduction measures. By articulating which measures in different sectors will bring the largest benefits in particular regions, it goes beyond the global analysis in the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011). Information is provided about benefits to human health and crop yields due to the reduction of air pollution, as well as about benefits to global and regional climate. Information is provided for the following aggregation of countries: Africa; North East Asia, South East Asia and the Pacific; Latin America and the Caribbean; North America and Europe; and South, West and Central Asia (Figure 4.1 and more detail in on-line Appendix).

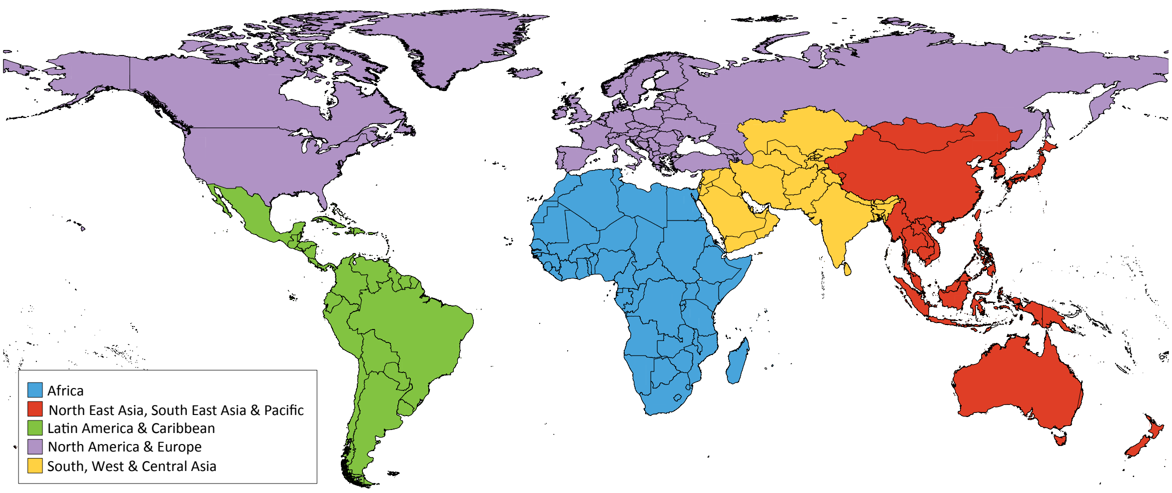
4.1 Costs of implementing the measures

There are many examples of the suggested measures already being implemented around the world, mainly in developed countries, not only for air pollution control, but also for occupational safety, climate protection and other reasons. Hence, ample experience regarding direct implementation costs already exists for many of the measures. Indirect costs, such as the cost of enforcing regulations, and the valuation of benefits associated with the measures are difficult to quantify. Investment and operating costs are fairly well known for measures to reduce methane emissions from coal mining, oil and gas production and distribution in some OECD countries. It is possible to extrapolate costs from OECD countries, but this has to be done cautiously because of differences between countries, especially between developed and developing countries.

Uncertainty is higher for cost data from the domestic sector (such as for cookstoves), agriculture and industry (such as for brick kilns) because these data are often drawn from a limited number of existing applications or specific installations. This data limitation makes it difficult to accurately reflect specific local-scale circumstances in a global assessment.

For measures that require improved governance rather than application of new technologies alone, it is difficult to quantify the costs of overcoming implementation

Figure 4.1: The aggregation of countries into the five regions used in this report



barriers and associated monitoring and enforcement. An example of this is the cost associated with regulations to stop such practices as the open burning of agricultural crop residues.

An initial global estimate of implementation costs has been developed using the GAINS model which contains cost data for the major emission reduction technologies, and uses calculation routines that consider the impacts of important local factors on emission control costs (Amann *et al*., 2011; Höglund-Isaksson *et al*., 2009 - see on-line Appendix for further details).

Cost estimations were carried out from two perspectives– that of a 'social planner' and that of a 'private investor':

i) The 'social planner' perspective considers investments in terms of the best use of resources to promote development for the long-term benefit of society; hence, the cost estimation assumes that costs and cost savings are discounted over the full technical lifetime of the equipment with a low assumed discount rate of 4 per cent.

ii) The 'private investor' perspective incorporates expectations about short-term profits. The rates of return on capital are required to compete with potential gains from alternative investments, for example, in the stock market. An assumed discount rate of 10 percent is used.

Table 4.1 provides cost estimates for the 16 identified measures, computed with the GAINS model for the year 2030. The measures were grouped into four categories according to their relative cost. Although key factors, such as labour costs, that allow estimation of differences in emission-control costs between countries were taken into account, the cost estimates calculated by the GAINS model are preliminary as reliable data are not always available for all local factors. Due to the differences in economic structures, costs vary widely between regions as can be seen in Table 4.1.

Group 1 in Table 4.1 includes measures that result in net cost savings or low costs over their full technical lifetime (taking into account the ranges given in the table). Initial investments are offset by subsequent cost savings, for example from reduced fuel use or utilization of recovered gas. It must be noted that the cost estimates do not take into account any monetary valuation of health and crop-yield benefits. While the Group 1 measures are economically profitable and would pay for themselves from a social planner's perspective, many are less attractive for private investors. As a consequence, these measures are less likely to be adopted by relying on market forces alone.

Although the exact quantification of costs depends on the chosen perspective, measures of Group 1 are the least costly from both perspectives and would realize more than half of the temperature reduction potential in 2050. About half of the emission reductions of both methane and black carbon could be achieved by these measures that would deliver financial cost savings over the lifetime of the measures (as a global average, and for the 'social planner's' perspective).

Group 2 contains measures that do not result in net savings from the social planner's perspective. Although these measures will incur costs over the lifetime of the measure, they also enhance human welfare by protecting health and crop yields and slowing down global warming. On the other hand, the Group 2 measures would be competitive on a global carbon market for less than 75 US $/$CO_2$e, if costs are calculated from a private investors perspective. These measures would collectively achieve about 18 per cent of the potential temperature reduction in 2050.

Group 3 includes other measures for which costs can be quantified. They appear less cost-effective to society when their costs are considered solely in terms of their climate benefits. Still, these measures have been widely implemented around the world, mainly in more wealthy countries, although usually for other purposes such as occupational safety, public health, groundwater protection and sanitation. Group 3 measures would achieve about 17 per cent of the potential temperature reduction in 2050.

Finally, Group 4 contains measures where the costs are difficult to quantify – a ban on open burning of agricultural waste and elimination of high-emitting vehicles. These two measures, in particular, depend on strong governance and regulatory frameworks for their successful implementation. It is difficult to quantify the costs of overcoming implementation barriers, and subsequent monitoring and enforcement. However, there are many instances around the world where such bans or removal of polluting vehicles have been successfully implemented, suggesting that the costs are not a major barrier. About 12 per cent of the potential temperature reduction is linked to this group.

The influence of costs on implementation

As mentioned, about half of the temperature reduction would emerge from Group 1 measures, which result in net cost savings to society over their full technical lifetime. However, the required up-front investments over an

Table 4.1: Overview of costs of methane (CH_4) and black carbon (BC) measures. Emission reduction potentials are shown together with the per cent share of temperature reduction in Figure 4.2 achieved by each measure. Also shown are preliminary cost estimates of methane and black carbon measures in terms of costs per tonne of methane or black carbon. Two cost perspectives are shown, that of the 'social planner', and that of the 'private investor'. See text. These are preliminary cost estimates. The uncertainty is higher for measures related to technologies that are not traded globally. All costs are in US$.

	Emission reduction potential in 2030 [1)]	**Global climate benefits expressed as share of total temperature reduction from SLCFreductions in 2050 (based on GTP**[2]**)**	**Costs per tonne reduced**[1, 5] **('social planner's' perspective; global mean value; variation across the regions shown in parentheses)**	**Equivalent carbon price**[2, 5, 6] **(private investor's perspective; global mean value; variation across the regions shown in parentheses).**	**Non-climate benefits of measure**
	A	B	C	D	E
GROUP 1: Cost Savings or Low Cost					
Cooking and heating with biomass in developing countries: - clean burning stoves instead of conventional stoves and/or - clean fuel (LPG/biogas) instead of biomass stoves.	1.8 Mt BC	24.8%	-10,100 $/t BC (-12,000 to -5,000) -200 $/t BC (-240 to -100)	-6 $/t CO_2e (-7 to -3) 7 $/t CO_2e (6 to 14)	Health protection, indoor air quality, crop protection[4]
Recovery and utilization of vented associated gas during oil production.	30.6 Mt CH_4	10.8%	-150 $/t CH_4 (-730 to 480)	70 $/t CO_2e (32 to 92)	Energy efficiency, crop protection
Separation and treatment of biodegradable municipal waste with no biodegradable waste disposed of to landfill.	27.8 Mt CH_4	9.7%	-1,650 $/t CH_4 (-1,840 to -1,450)	29 $/t CO_2e (12 to 53)	Improved waste management, energy efficiency, crop protection
Replacing coal with coal briquettes in cooking and heating stoves in developing countries.	0.4 Mt BC	3.9%	Approximately zero $/t BC	Approximately zero $/t CO_2e	Health protection, crop protection
Reduced leakage during gas pipeline transmission.	6.7 Mt CH_4	2.3%	-190 $/t CH_4 (-259 to 4,120)	27 $/t CO_2e (21 to 382)	Long-term economics, energy efficiency, crop protection
Recovery and utilization of vented associated gas during gas production.	2.4 Mt CH_4	0.85%	-690 $/t CH_4 (-721 to -632)	-7 $/t CO_2e (-8 to -6)	Long-term economics, energy efficiency, crop protection
Farm-scale anaerobic digestion on large farms with liquid manure management.	2.2 Mt CH_4	0.7%	-400 $/t CH_4 (-2,320 to +1,250)	34 $/t CO_2e (17 to 81)	Energy efficiency, crop protection
Replacing traditional brick kilns with more efficient kilns.	0.04 Mt BC	0.5%	-5,500 $/t BC (-5,600 to -4,400)	-7 $/t CO_2e (-5 to -8)	Improved quality of bricks, health protection, energy efficiency,
Total for Group 1		53.6%			
GROUP 2: Moderate Cost					
Coal mines: oxidation of ventilation air methane including improvements in ventilation air systems.	25.0 Mt CH_4	8.7%	280 $/t CH_4 (222 to 2,820)	13 $/t CO_2e (11 to 137)	Occupational safety

Coal mines: recovery of pre-mine degasification emissions.	17.5 Mt CH_4	6.1%	1,300 $/t CH_4 (500 to 10,500	74 $/t CO_2e (37 to 445)	Occupational safety, energy efficiency
Feed changes for dairy and non-dairy cattle.	3.9 Mt CH_4	1.3%	1,330 $/t CH_4 (1,090 to 1,880)	53 $/t CO_2e (44 to 75)	Improved meat quality
Replacing traditional coke ovens with modern recovery ovens.	0.2 Mt BC	1.6%	190 $/t BC (140 to 500)	0.4 $/t CO_2e (0.3 to 1.1)	More cost-effective production, energy efficiency
Total for Group 2		17.7%			
GROUP 3: High Cost					
Euro VI/6 standards (incl. DPF) for heavy duty vehicles	0.3 Mt BC [3)]	3.1%	145,000 $/t BC (120,000 to 200,000)	300 $/t CO_2e (240 to 410)	Health protection, crop protection
Euro VI/6 standards for light duty vehicles: - with diesel particle filters.	0.1 Mt BC [3)]	1.0%	80,000 $/t BC (36,000 to 150,000)	180 $/t CO_2e (80 to 350)	Health protection, crop protection
Euro VI/6 standards (incl. DPF) for off-road mobile machinery.	0.3 Mt BC [3)]	3.1%	570,000 $/t BC (225,000-815,000)	1,400 $/t CO_2e (500 to 2,000)	Health protection, crop protection
Intermittent aeration of continuously flooded rice paddies.	9.1 Mt CH_4	3.2%	3,160 $/t CH_4 (1,750 to 35,300)	130 $/t CO_2e (70 to 1,410)	Crop protection
Control of unintended leakages during oil production.	5.7 Mt CH_4	2.0%	3,410 $/t CH_4 (1,310 to 22,800)	140 $/t CO_2e (52 to 913)	Energy efficiency, occupational safety
Pellet stoves and boilers replacing current wood burning technologies in industrialized countries.	0.2 Mt BC	1.8%	320,000 $/t BC (200,000 to 400,000)	710 $/t CO_2e (440 to 880)	Energy efficiency, health protection
Control of unintended leakages during gas production.	4.3 Mt CH_4	1.5%	3,390 $/t CH_4 (1,300 to 10,300)	160 $/t CO_2e (72 to 428)	Energy efficiency, occupational safety
Upgrading of primary to secondary/ tertiary wastewater treatment.	3.9 Mt CH_4	1.4 %	4,090 $/t CH_4 (2,990 to 6,420)	430 $/t CO_2e (335 to 633)	Improved water quality
Total for Group 3		17.1%			
GROUP 4: Difficult to Quantify					
Elimination of high-emitting vehicles.	0.4 Mt BC	6.6%			Health protection, energy efficiency
Ban of field burning of agricultural waste.	0.4 Mt BC	5.2%			Health protection, crop protection, improved visibility
Total for Group 4		11.8%			

1. For the main substance affected (methane – CH_4, or black carbon - BC)
2. Taking into account impacts of co-emitted species
3. For Euro-6/VI, these are additional reductions after elimination of high-emitting vehicles
4. ‘Crop protection’ implies reduced ozone impacts on crop yields
5. The cost ranges represent regional differences in initial conditions, cost of labour, etc
6. Costs per equivalent CO_2 emission are calculated using the GWP_{100} metric

assumed 20 years implementation period do constitute a considerable barrier to implementation. Prevailing short-term profit expectations of private investors make these measures less attractive to the market. For example, implementation of the recovery and utilization of vented methane and other gases in oil production would pay for itself in about ten years and would be desirable from a social planner's perspective, even without considering health and climate benefits. In contrast, the large capital investment associated with this measure makes it quite expensive for a private investor.

The separation and treatment of biodegradable waste is the measure requiring the second highest capital investment within Group 1. It is estimated to have a pay-back period of four to six years, if the methane derived from the waste treatment process is utilized. However, this measure requires adequate coordination between the public sector responsible for setting up needed infrastructures and private households, who will be required to separate their waste at source. This requirement may pose a barrier to implementation, especially in countries where waste separation is not a common practice.

Capital investments for clean cookstoves are substantially lower than those measures already mentioned above and also provide a short pay-back period. However, because this measure applies to poor people in developing countries a major issue is how to meet up-front costs for new stoves. For all Group 1 measures, targeted interventions or appropriate financing mechanisms could help to overcome implementation barriers. In comparison, measures of Group 2, which could potentially be competitive on a carbon market, require much lower up-front investments, especially for methane recovery in coal mines.

Overall, the largest upfront investments would be required for worldwide introduction of diesel particle filters to achieve the Euro-6/VI emission standards for road vehicles and non-road mobile machinery. One way to shortcut this high cost and yet achieve similar environmental benefits would be to replace diesel powered light duty vehicles with gasoline powered ones through natural fleet turnover. This can be encouraged by changing the taxes for diesel and gasoline fuels, or by modifying emission standards for diesel and gasoline light-duty vehicles. It must be noted however that reducing emissions from light-duty vehicles only covers a small fraction of the climate benefit from introducing Euro-6/VI, as most of the benefits are projected to come from reducing the emissions from heavy-duty trucks which will continue to use diesel fuel.

Some of the more costly measures for controlling SLCFs are often/usually implemented for other development-related objectives. For example, the upgrading of wastewater treatment is contained in the list of 16 SLCF measures because it can be an effective way of reducing methane emissions. But, of course, wastewater treatment is usually upgraded in order to safeguard sanitation, protect public health, and protect aquatic ecosystems. In this particular case the benefits of reducing methane emissions articulated in this report provide additional arguments for going ahead with the upgrading of wastewater treatment.

4.2 Quantifying the climate and air quality benefits of regional implementation of measures

In the *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011) the climate, health and crop-yield benefits that would be achieved from the implementation of the 16 measures were quantified or described, mainly from a global perspective. These included a substantial reduction in global warming in the near-term, about 2.4 million fewer premature deaths (range of 0.7-4.6 million), and about 52 million tonnes of crop losses avoided (range of 30-140 million tonnes) each year. It was also noted there that, the health and crop-yield benefits of emission reductions would mostly be realised in the regions that reduce their emissions.

In this report the analysis is taken a step further by describing the regional benefit from each of the 16 measures. For each region, the effectiveness of the selected measures in reducing emissions has already been shown in Chapter 3. This chapter shows the regional and global climate benefits of these measures in 2050, as well as the health benefits, estimated in terms of the reduction in number of premature deaths per year in 2030, and the crop-yield benefits estimated as avoided crop-yield losses per year for four staple crops, also in 2030.

In the UNEP/WMO (2011) assessment the global climate benefits were calculated using output from two global climate/chemical composition models – the NASA-GISS model (Shindell *et al*., 2006) and the ECHAM model (Pozzoli *et al*., 2008). These models were used to compute the change in global temperature as shown earlier in Figure 1.1. For the purposes of this report it was not possible to run these models for each region and for each measure because of the long time required to run the models and process their output. Therefore, in order to quantify the regional benefits for each measure, the

TM5-FASST[10] rapid assessment tool has been used for this report developed at the European Union Joint Research Centre at Ispra, Italy (a more detailed description of TM5-FASST is given in the on-line Appendix).

4.2.1 Global and regional climate benefits from implementing measures in the regions

In the next sections we explain how the global and regional climate benefits from implementing the different measures were estimated, and then compare the potential effectiveness of the different measures in different regions in achieving these benefits.

Estimating global climate benefits

An important indicator of the global climate benefits of SLCF reductions is the slowing of global warming over the next two to four decades. The TM5-FASST model used in this report computes that the increase in temperature between 2010 and 2050 will be 0.4°C below the reference scenario under the full implementation of the 16 SLCF measures (range of 0.1 - 0.6°C). Put another way, the SLCF measures will slow global warming between 2010 and 2050 by 0.4°C. This benefit is not quite as large as the 0.5°C reduction by 2050 computed in the UNEP/WMO (2011) assessment with the NASA-GISS and ECHAM models, which reflects the differences between models.

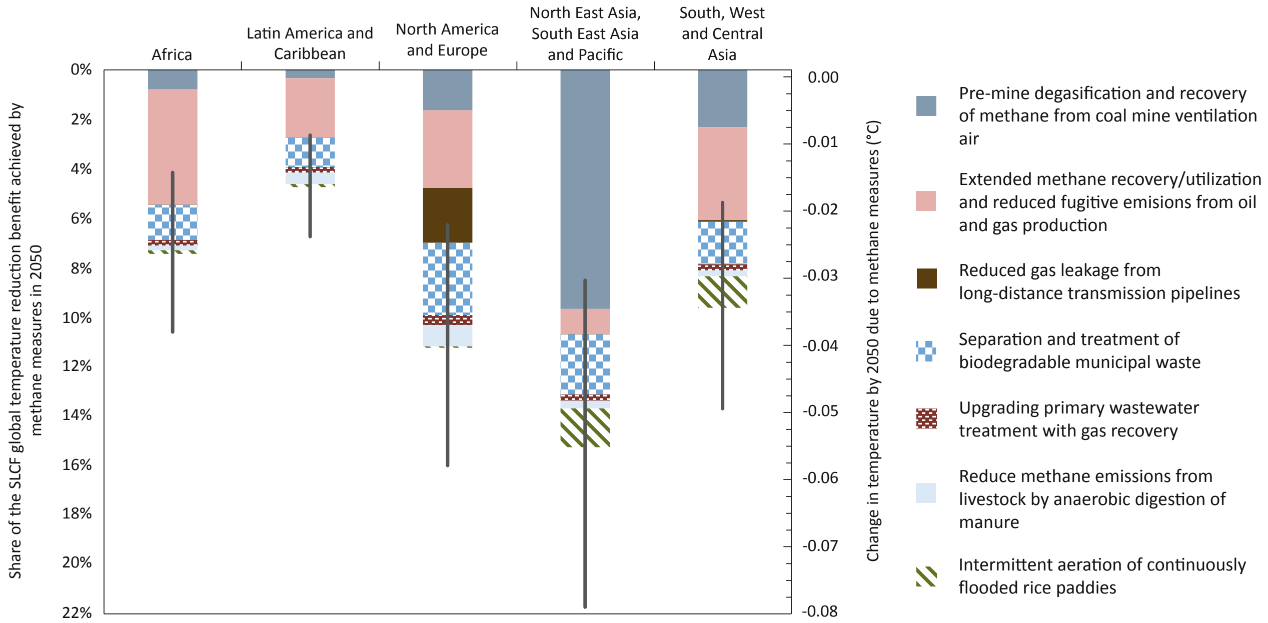
Of importance to this report, the TM5-FASST tool was used to calculate the contribution of each measure within each region to this 0.4°C reduction. It was assumed that the measures were introduced beginning in 2010, fully implemented by 2030 and then maintained up to 2050. For each measure, and for each of the five regions, the global temperature potential (GTP) metric (see glossary) was used to translate the resultant change in emissions for each year between 2010 and 2050 into a change in temperature by 2050. The percentage contribution of each measure in each region to the total 0.4°C reduction of global warming was then computed (Figure 4.2). For the black carbon measures, the individual radiative forcing of all relevant co-emitted species, both cooling and warming ones, were taken into account. The range of temperature reduction shown for black carbon in Figure 4.1 mainly reflects the uncertainty associated with the impact of black carbon on radiative forcing.

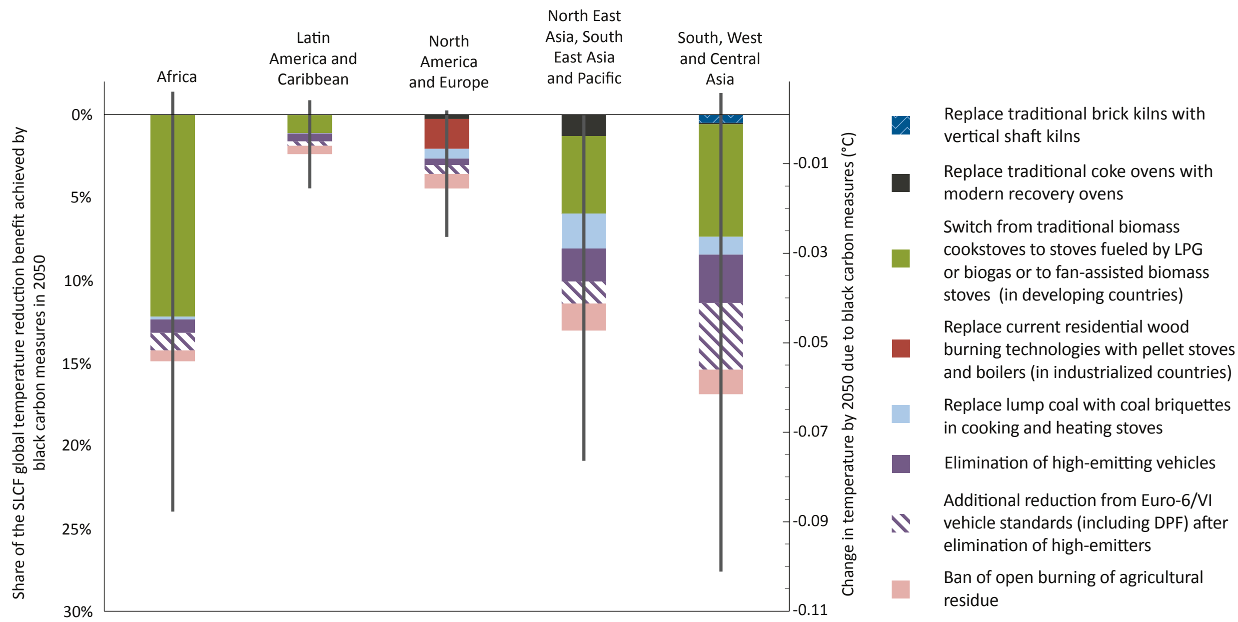
Across the regions, the most important methane measures for near-term climate protection are those focusing on coal mines, the oil and gas industry and municipal waste (Figure 4.2, upper graph). For methane measures the largest single benefit calculated for any region is from the implementation of methane capture in coal mines in North East Asia, South East Asia and the Pacific. However, within the other four regions, extended utilization and recovery of methane from oil and gas production would bring the greatest near-term climate benefit. Also, reducing methane leakage from transmission in long-distance gas pipelines in Europe and North America would provide a significant near-term global climate benefit. Across Asia, intermittent aeration of continuously flooded paddy fields also provides a significant climate benefit.

The black carbon measure likely to bring the greatest near-term global climate benefit is that addressing domestic cooking with biomass fuel, especially in Africa, but also in Asia and in Latin America and the Caribbean (Figure 4.2, lower graph). The benefit would come from substituting biomass fuels with cleaner-burning fuels such as biogas or liquefied petroleum gas (LPG), or from a complete switch to fan-assisted improved biomass cookstoves, or by some combination of these options. It should be borne in mind, that the climate impact of emissions from cookstoves are subject to a particularly high degree of uncertainty concerning the relative emissions of warming substances – black carbon, carbon monoxide, non-methane volatile organic compounds and methane – and cooling ones – especially organic carbon. It should also be noted that a wholescale switch away from using traditional biomass stoves, although technically feasible, would represent an enormous challenge in these regions. In Europe and North America, replacing current residential wood-burning stoves with pellet stoves and boilers would bring the largest climate benefit among black carbon measures in 2030.

10. The TM5-FASST (Fast Scenario Screening Tool) model (described in detail in the on-line Appendix) is a linearized source-receptor model derived from the full chemical transport model TM5-CTM. TM5-CTM is a state of the art global chemical transport model for gaseous pollutants and atmospheric aerosols (particulate matter) which has been used in numerous multi-model exercises and intercomparisons, including HTAP and AEROCOM (Krol *et al*., 2005; Dentener *et al*., 2006; Stevenson *et al*., 2006; Eyring *et al*., 2007; Anenberg *et al*., 2009; Fiore *et al*., 2009; Jonson *et al*., 2010). Radiative forcing by aerosols is pre-calculated for a reference scenario with the off-line radiative Transfer Model (OTM) described and implemented by Marmer *et al*. (2007). The normalized forcings from a reference scenario were stored and scaled with aerosol columns from actual scenarios. Radiative forcing for ozone was approximated by using the forcings obtained for the scenario results by Dentener *et al.* (2005), based on Edwards and Slingo (1996), and scaling them with ozone columns resulting from actual scenarios. The TM5-FASST model simulates well the TM5 results for concentrations of black carbon, organic carbon, sulphate, ozone and $PM_{2.5}$ and results are conformable to the results of the GISS model used in the UNEP/WMO assessment (on-line Appendix), which gives confidence in using this simplified tool to give a realistic estimate of the different benefits of implementing measures in different regions. However, it should also be pointed out that the approximations of the TM5-FASST model add additional uncertainties to modelling by TM5 alone.

Figure 4.2: The impact of methane (top) and black carbon (bottom) measures on global temperature expressed as their percentage share of the global 0.4°C (TM5-FASST estimate) temperature benefit delivered by the sum of all 16 measures in 2050 (left-hand axis) and in terms of absolute temperature change (right-hand axis). When added together, the bars for both methane and black carbon add up to 100% of the temperature benefit. Vertical grey bars indicate the uncertainty range in absolute temperature change due to the likely range of the radiative forcing of methane and of black carbon and co-emitted substances





*Note: For clarity, only the effect of substitution with LPG and biogas stoves is shown in the black carbon graph for biomass cookstoves. With 100% substitution by fan-assisted biomass stoves, the reductions would be slightly lower (i.e. the lengths green bars would be 6% shorter). (Detailed values for all measures are given in the on-line Appendix)

Globally, the next most important black carbon measures after addressing biomass cookstoves are those tackling emissions from the transport sector, that is, eliminating high-emitting vehicles and introducing Euro-6/VI vehicle standards which include the use of diesel particle filters. Indeed, compared with black carbon measures in other sectors, the transport measures account for the greatest contribution to short-term climate benefit both in South, West and Central Asia, as well as being second in importance in the other four regions.

Estimating the near- and long-term climate benefits of reducing short-lived climate forcers

Comparing the impact of SLCFs to that of carbon dioxide (CO_2) on global temperatures over the long term is difficult because of the difference in the atmospheric lifetimes of the two kinds of substances. SLCFs have short lifetimes and mainly affect the near-term temperature in the first few decades after being emitted, while CO_2 has a much longer lifetime and, once emitted, continues to have a major influence on the global temperature for centuries.

Put another way, the shorter atmospheric lifetimes of SLCFs means that their reductions in any particular year will have a much smaller effect on global warming *over the long run* as compared to reducing CO_2 or other long-lived greenhouse gases. Consistent with this, it is estimated that the package of SLCF reduction measures in this report will have only a modest effect on reducing the estimated 6 to 11 Gt CO_2e 'emissions gap' in 2020 (UNEP, 2011b). This is because the emissions gap has to do with the *long term* goal of keeping the increase in global temperature below 2°C up to the end of the century and beyond. Added together, the black carbon and methane measures, if they were all implemented in 2020, would reduce the gap in that year by an equivalent of about 1.1 Gt of CO_2 emissions (range: 0.4-1.7 Gt CO_2e) using the metric of 'global temperature potential' with a one-hundred year time horizon (see methane plus black carbon for GTP_{100} in Table 4.2). Although this will help narrow the gap, it is clear that it does not go far enough, and it confirms that the main way of staying within the 2°C limit has to be reducing CO_2 and other long-lived greenhouse gases. As shown in Table 4.2 reductions in SLCFs from implementing both black carbon and methane measures will have a much larger impact on temperatures if a 20 year time-frame is used (i.e. shown by using the GTP_{20} metric), compared to using a 100 year time-frame (using GTP_{100}).

Table 4.2 gives an estimation of the equivalent CO_2 emissions of implementing all black carbon and methane measures in 2020 on global warming in a 20 and 100 year time-frame, using the global warming potential and global temperature potential metrics (see glossary). The GWP values are higher than GTP values and are considered to be an overestimate of the temperature reduction. The range of values, shown in parentheses, reflects the range of radiative forcing of black carbon, its co-emitted substances, and methane. The effect of nitrogen oxides on methane over 20 or 100 years and the removal of the cooling aerosols such as organic carbon or sulphur compounds can lead to the negative values shown.

Table 4.2: Converting black carbon and methane emission reductions from implementing the 16 measures to CO_2 equivalents, over a twenty and one hundred-year time frame. Units: Gt CO_2e

	Black carbon measures		Methane measures	
GTP_{100}	0.5	(0.0 to 0.8)	0.61	(0.43 to 0.69)
GTP_{20}	3.8	(-0.6 to 6.5)	9.0	(6.3 to 10)
GWP_{100}	3.6	(-0.2 to 5.9)	4.0	(2.8 to 4.6)
GWP_{20}	13	(0.2 to 20)	11	(7.6 to 12)

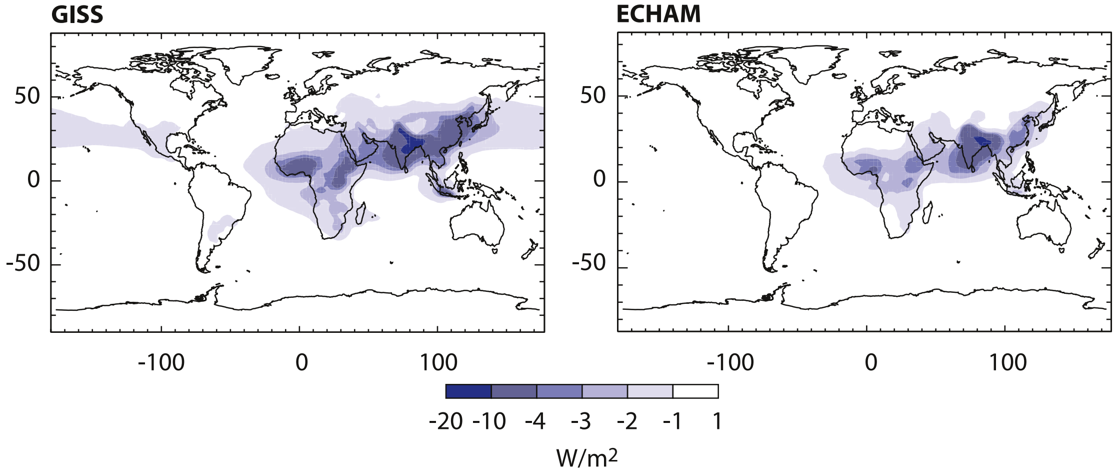
Regional Climate Benefits

There is ample scientific evidence that SLCFs have impacts on regional climate. One such impact is the effect of SLCFs on cloud formation and precipitation. Both ozone and black carbon, as well as other particles, can influence many of the processes that lead to the formation of clouds and precipitation (Jacobson, 2002; Ramanathan and Carmichael, 2008; Penner *et al*,. 2006 and Chen *et al.*, 2010). They affect evaporation, cloud formation and cloud lifetime, rainfall and weather patterns. They can also change wind patterns by affecting the regional temperature contrasts that drive the winds, influencing where rain and snow fall. These effects are both local and distant.

Several studies indicate that changes in radiative forcing caused by absorbing particles can substantially alter precipitation patterns within a given region (Ramanathan and Carmichael, 2008; Wang *et al*., 2009; Meehl *et al.,* 2006 and Menon *et al.*, 2002). The black carbon measures reduce atmospheric energy absorption by particles most strongly in South Asia and also in other parts of Asia and central Africa (Figure 4.3), as this is where the measures cause the greatest reductions in the emissions of black carbon. Hence the emission reductions may have a substantial effect on the Asian monsoon and on central African rainfall, and may lessen the disruption of traditional rainfall patterns.

The fact that the changes to both tropospheric ozone and particle concentrations mainly occur in the northern hemisphere means that they also alter the differences in temperature between hemispheres. This in turn may cause shifts in rainfall patterns throughout the tropics. Several studies have shown that such changes can have

Figure 4.3: Change in atmospheric forcing in the year 2030 due to the full implementation of the black carbon measures relative to the reference case (emissions following current policies) in the two GCM models of the UNEP/ WMO (2011) assessment. The greatest benefit for regional climate would be expected where there is greatest change in atmospheric forcing (darker areas in the graphs), where reduced disruption in the distribution of rainfall would be expected. The results from two models, using the same input data, are shown and they show similar results, despite there being different treatment of aerosols in the models



Source: UNEP/WMO, 2011

large impacts in regions such as the Sahel (Ackerley *et al.*, 2011; Biasutti and Giannini, 2006; Rotstayn and Lohmann, 2002). Therefore the benefits of mitigating black carbon may be realized in distant locations as well (Shindell and Faluvegi, 2009).

Another regional impact of SLCFs is their effect on accelerating the melting of ice and snow. Firstly, ozone and black carbon warm the atmosphere and therefore promote melting of ice and snow in the Arctic and in heavily glaciated parts of elevated regions, such as the Himalayas. The UNEP/WMO (2011) assessment concluded that by 2040 atmospheric warming could be reduced by about 0.7°C in the Arctic by implementing black carbon and methane measures, two thirds of the warming projected for that region in that year. It also concluded that this benefit was larger in the Arctic compared to the average global climate benefit.

Secondly, the deposition of black carbon has the additional effect of accelerating melting by darkening snow and ice surfaces. This increases their absorption of sunlight leading to further warming of the near-surface atmosphere as well as contributing to early melting of snow and ice. This melting in turn exposes the below darker surfaces, which then absorb more sunlight and further accelerate the local warming process. Snow- and ice-covered regions exposed to sunlight are thus especially vulnerable to accelerated warming from SLCFs.

Increased early melting of glaciers also has subsequent effects on water supplies downstream. Glaciers and seasonal snowpacks in the Himalayas, the Tibetan Plateau, the Hindu Kush and the Karakoram region provide water to a large number of people and are near to large black carbon sources in Asia. Vulnerability in this region is enhanced because of the high levels of solar radiation striking the surface as a result of the low latitude, high altitude, and low vegetation cover. A small body of peer-reviewed literature suggests that black carbon is driving significant warming and increased snow and ice melt in this region (Flanner *et al.*, 2007; Kopacz *et al.*, 2011), thus increasing the risks of flooding by outbursts from glacial lakes (Box 4.2).

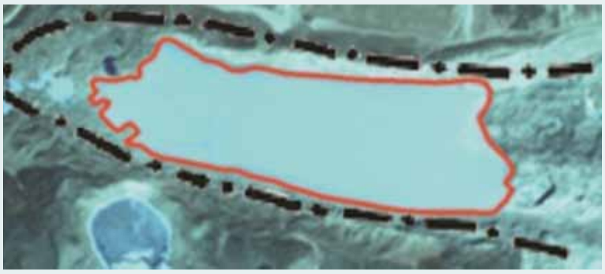
4.2.2 Estimating health benefits

Quantitative health benefits of implementing black carbon measures are estimated from the resulting reduction in exposure to outdoor $PM_{2.5}$ concentrations (particulate matter with a diameter less than 2.5 microns). Health benefits of ozone concentration changes are not included as these were found to be an order of magnitude lower than the health benefits from particulate matter reductions in the UNEP/WMO (2011) assessment. The changes in regional $PM_{2.5}$ by each individual measure were calculated from changes in black carbon, organic carbon, other $PM_{2.5}$ emissions, and sulphate, nitrate and ammonium concentrations, estimated using the TM5-FASST tool. This change in concentration was then used to scale the premature death estimates from the ECHAM model results reported in the UNEP/WMO (2011) assessment for each region (more details are given in the on-line Appendix).

Box 4.2: Glacial Lake Outburst Floods (GLOFs)

In large parts of the Hindu Kush-Himalaya region, glaciers are thinning and retreating as a result of global warming, leading to the creation of many glacial lakes (Mool *et al.*, 2001). Glacial lakes are potentially unstable because their end moraines are composed of unsorted and unconsolidated boulders, gravel, sand and clay. Furthermore, they are frequently reinforced by frozen cores (permafrost) that, like the glaciers themselves, are now beginning to melt. As the volume of a lake accumulating behind an end moraine increases, it becomes less stable and the end moraine may fail, releasing much or all of the lake water. The ensuing outbreak can be sudden and highly dangerous to people and infrastructure located downstream. In October, 1994 a part of the moraine holding back a glacial lake in Bhutan burst, and a wave of water swept downstream killing 21 people and leaving a path of destruction as it travelled 204 km before dissipating. At least 35 glacial lake outburst floods events have occurred over the last century in Nepal, Pakistan, Bhutan and China (UNEP, 2010b).

Land Sat MSS of 1975: development of a glacial lake at the tongue of Imja glacier in Dudh Koshi basin of Nepal



ALOS, AVNIR-2 March 2009: growing Imja glacial lake in Dudh Koshi basin of Nepal

Source: Ives *et al.*, (2010) and ICIMOD (2011)

It is important to note that the impact of indoor air pollution is not included. This has been estimated globally as causing a greater number of premature deaths than outdoor air pollution – 1.97 million deaths worldwide for indoor air pollution compared to 1.15 million deaths from outdoor air pollution in urban areas (WHO, 2009). Note that the method used in this report uses population estimates for 2030 and includes both urban and rural exposure which is why the number of avoided premature deaths, 2.4 million, is higher than the total number of deaths from $PM_{2.5}$ exposure reported by WHO. Health benefits in terms of reduced chronic morbidity are also not indicated and these would be substantially larger than the number of premature deaths.

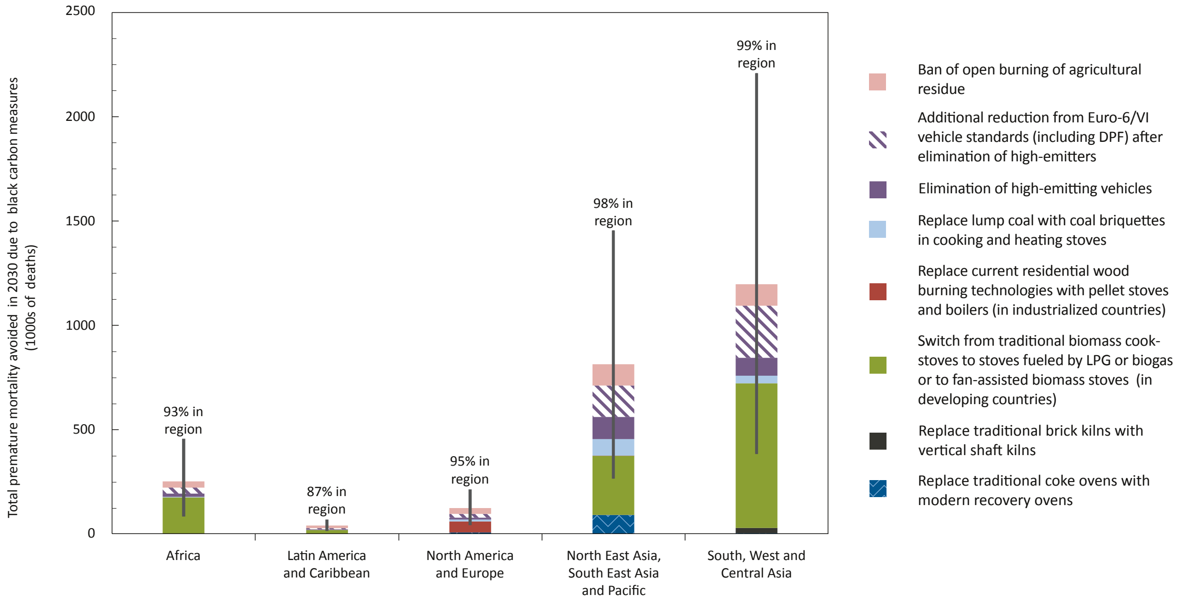
The health benefits from the reduction in outdoor $PM_{2.5}$ concentrations of different measures are shown in Figure 4.4. The uncertainty shown for each regional mortality estimate is calculated from the uncertainty in the concentration-response relationships of $PM_{2.5}$ only, and does not include uncertainties in estimating $PM_{2.5}$ concentrations themselves. The percentage values show that nearly all health benefits will be realised in the same region that implements the measures (more than 90% of the benefits in the case of Asia, Africa, Europe and North America).

A total of 2.4 million fewer premature deaths (within a range of 0.7-4.6 million) could be realized globally each year by 2030 from the widespread implementation of black carbon measures. The biggest health benefits would be felt in Asia, with 1.9 million premature deaths avoided annually (Figure 4.4). In Africa, Asia and in Latin America and the Caribbean, improved biomass cookstoves would deliver the greatest health benefit although the benefits from reduced emissions from transport would also be substantial. In Europe and North America, the largest health gains would come from switching to pellet stoves from current domestic wood-burning technologies. In most regions there would also be a significant, though smaller, health benefit from banning the burning of agricultural crop residues.

4.2.3 Estimating crop-yield benefits

Figure 4.5 shows the estimated crop-yield benefits for wheat, rice, maize and soybean from reductions in concentrations of tropospheric ozone that result from the implementation of the 16 black carbon and methane

Figure 4.4: The annual reduction in premature deaths from the implementation of black carbon measures in each region in 2030. The percentages given above each bar indicate the proportion of deaths that would be avoided within the region that implements the measures. Vertical grey bars indicate the uncertainty range in the mortality figures based on the uncertainty of concentration-response relationships



measures. These benefits arise because the measures reduce atmospheric levels of methane and other ozone precursors (carbon monoxide, nitrogen oxides and non-methane volatile organic compounds). The changes in ground-level ozone concentrations were calculated by the TM5-FASST tool which used the same concentration-response relationships that were used in the UNEP/WMO (2011) assessment. These relationships are based upon the average exposure of the crops to ozone during daylight hours in the growing season (see on-line Appendix)[11]. Estimates of avoided impacts are considered conservative because only four staple crops were assessed, and the analysis does not take into account additional benefits from avoided regional climate change (from reduced drought and heat stress).

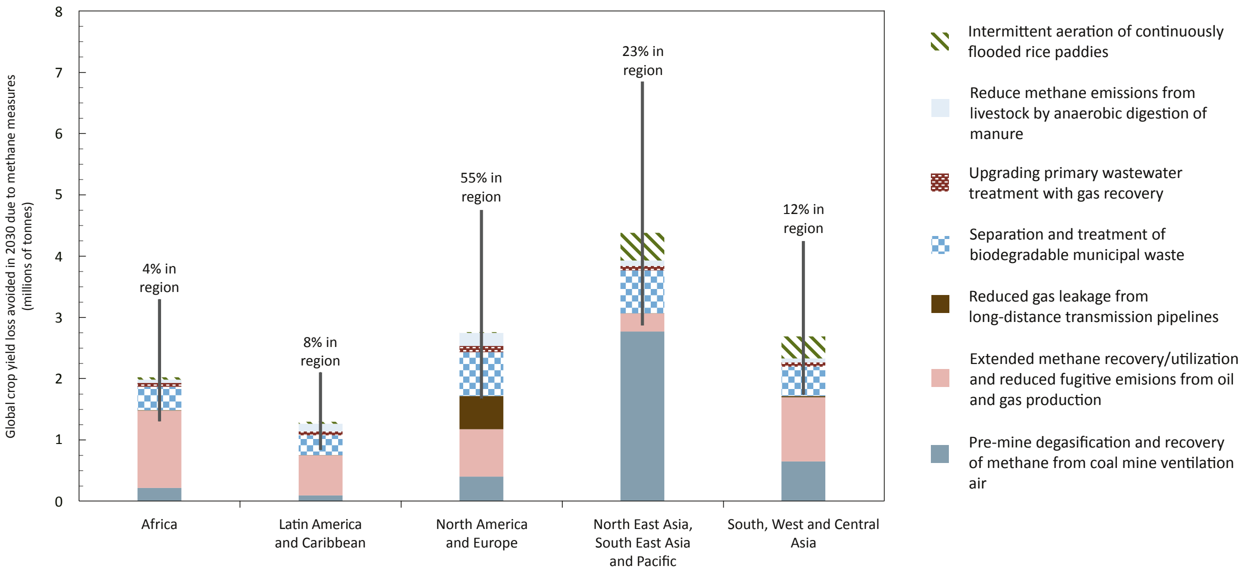
As was found in the UNEP/WMO (2011) assessment, different models have slightly differing approaches to ozone modelling and come up with different responses to changes in precursor emissions. This was observed in the result of the three models: GISS, ECHAM and TM5. Therefore, the total avoided crop yield losses calculated using TM5-FASST were 32 million tonnes per annum (range of 21-57 million tonnes) globally, compared with the average of 52 million tonnes per annum (range of 30-140 million tonnes) obtained using GISS and ECHAM.

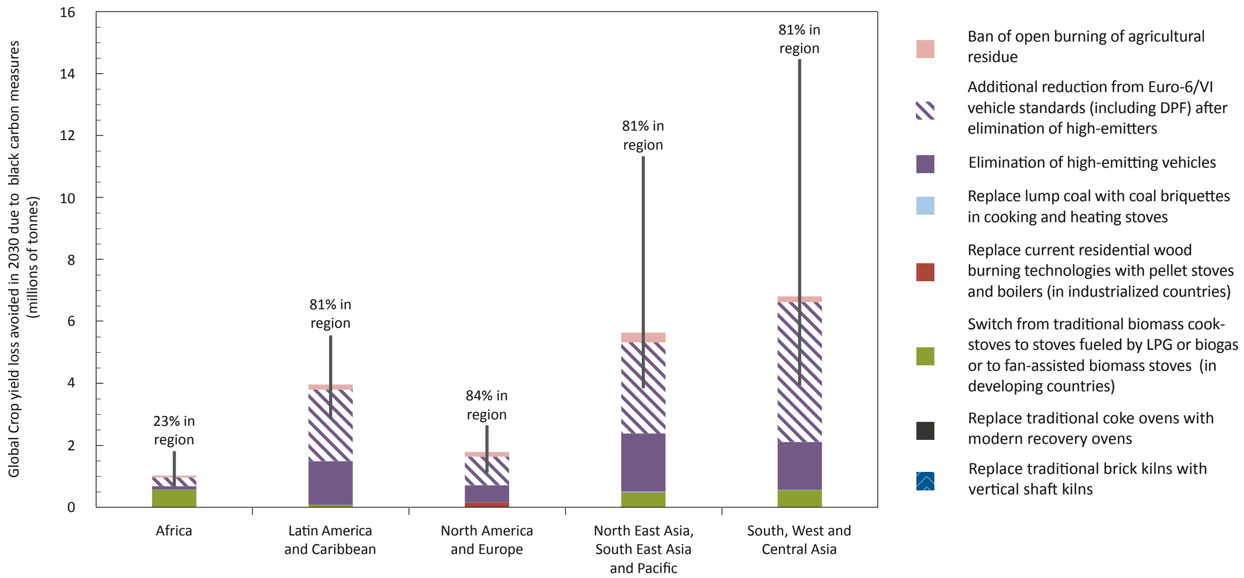
Globally, the positive impacts of SLCF measures on crop-yield is more or less evenly split between the methane and the black carbon measures, reflecting their similar impact on ozone formation (Figure 4.5). However, the methane measures tend to influence ozone formation at long distances from methane sources, because methane has a longer atmospheric lifetime than other ozone precursors and consequently becomes globally mixed. Therefore, the benefits of methane measures are less clearly confined to the regions implementing the measures. However, the black carbon measures affect the co-emitted pollutants: nitrogen oxides, carbon monoxide and non-methane volatile organic compound emissions, and these give rise to ozone formation closer to the sources of pollution. Hence, a greater proportion of the benefit of avoided crop-yield losses is felt in the regions that implement the black carbon measures (Figure 4.5).

The greatest crop benefit from methane measures comes from reducing emissions from coal mines, especially in North East Asia, South East Asia and the Pacific, from oil and gas production in all regions, and reduced gas

11. The calculation of ozone concentrations using the TM5-FASST tool assumes a linear approximation to a non-linear ozone formation process. It should be noted that the uncertainties arising from this linear approximation are probably not significantly larger than the differences observed between the results of state-of-the-art non-linear models.

Figure 4.5: Annual avoided crop-yield losses in 2030 from methane measures (in the upper graph) and from black carbon measures (in the lower graph - from reduced nitrogen oxides, volatile organic compounds, methane and carbon monoxide emissions). The percentage above each bar indicates the crop-yield loss avoided in the region that implements the measures. Vertical grey bars indicate the uncertainty range in the crop-yield loss figures based on the uncertainty in the concentration-response relationships alone





leakage from long-distance transmission in pipelines in North America and Europe. Next are the benefits from the improved treatment of municipal waste and, in Asia, the intermittent aeration of continuously flooded paddy fields.

The crop-yield benefits from black carbon measures stem largely from measures implemented in the transport sector, especially the wider implementation of Euro-6/VI standards. There is also a smaller benefit from addressing biomass cookstoves in Asia and Africa and from banning the burning of agricultural residue in all regions.

4.2.4 Uncertainty of the benefit estimation

Previous sections of the report describe emission reduction measures that provide a range of benefits to health, crops and climate. While the magnitudes of these benefits are uncertain, there is much higher certainty that some degree of benefit will accrue. For example, it is quite certain that measures for reducing black carbon will lower ambient levels of $PM_{2.5}$ and thereby protect health. Likewise, it is quite certain that black carbon and methane measures will reduce tropospheric ozone levels and thereby help to protect health and crop yields. Finally, the climate benefits of reducing methane emissions are quite clear. More uncertain are the global climate benefits of reducing black carbon emissions. On the other hand, the level of confidence is quite high that reducing black carbon emissions will have regional climate benefits.

In sum, the remaining uncertainties in the effectiveness of emission control measures should not be seen as a barrier to action. The science is sufficiently robust for action to be taken to reduce SLCFs.

4.3 Comparing costs and benefits

The costs of implementing the measures can be compared to the regional and global benefits described in this chapter. As said earlier, an investment which would implement all of the measures in all regions by 2030 would achieve about 2.4 million fewer premature deaths annually, and avoid global annual crop yield losses for four staple crops of about 32 million tonnes (according to the TM5-FASST model assessment). Full implementation of the SLCF measures would also reduce the projected near-term temperature increase by about 0.4°C (according to the TM5-FASST model) in 2050. However, the unit costs of the measures to achieve these benefits vary.

About half of the near-term temperature benefit could be achieved through measures that would result in net cost savings in the long run, even without accounting for their health and ecosystems benefits. But prevailing short-term profit expectations make these measures less profitable for private investors. Hence, it is unlikely that the measures would be implemented solely through market forces.

Another 18 per cent of the temperature benefit could be realized through measures that would be competitive on a global carbon market for less than US$75 per tonne of CO_2e. A further 17 per cent would come from measures that seem less cost-effective to society when their costs are compared solely to their climate benefits. These measures are already widely implemented in developed countries around the world, although this is usually for other purposes. The remainder, approximately 12 per cent of the temperature benefit, would require improved environmental governance (for example, by implementing bans on open-burning of agricultural crop residues) for which costs are difficult to quantify.

Nearly all of the health benefit, 87-99 per cent, would be realized within the same regions that implement the measures, which is worth considering when deciding on national actions to reduce SLCFs. It also provides an argument for including black carbon and methane measures in action plans to reduce air pollution and its impacts on health and crops. Furthermore, it should be recalled that these estimates are conservative since they do not include the likely benefits of reduced indoor air pollution or the chronic health impacts that, in number, will be much greater than avoided premature deaths. The impact of black carbon on the regional climate and weather patterns, including rainfall, is also an important benefit felt closer to the regions where measures are implemented. Also, the global climate benefits of reducing SLCFs are substantial, offering an opportunity to reduce the rate of global warming in the near term to complement necessary carbon dioxide emission reductions to mitigate long-term temperature increase.

As well as providing economic benefits, the measures will also help in the attainment of Millennium Development Goals (MDGs) related to health, including reducing premature child mortality, and the environment.

Chapter 5:

National-scale Action

There is a wide spectrum of actions that can be taken to reduce short-lived climate forcers (SLCFs) and in the following chapters reasons for pursuing them at all levels – national, regional and global - are explained. That being said, there are also good arguments for giving special priority to the national level. Firstly, the greatest public health benefits will accrue close to emission sources. Secondly, each country has its own particular mix of emission sources and acting at the national level can best take into account this unique mix. Thirdly, many countries already have institutions that deal with air pollution and climate change, and these institutions can serve as effective platforms for action on SLCFs. Fourthly, policies and measures for reducing SLCFs can, and should, be linked to national priorities for sustainable development. On the other hand, acting at the national level does not preclude regional or global action. In fact, regional and global actions can strongly support national activities as explained in following two chapters.

Many countries have already seen the added value of acting nationally. In the United States of America, the Congress has requested that the US Environmental Protection Agency prepare a 'Report to Congress on Black Carbon'[12]. Meanwhile, India has justified a new programme of cookstove replacement[13] based on the public health threat posed by black carbon and particulate matter emissions, and their link to regional climate issues. South Africa has taken the lead with legislation that allows integration of air pollution and climate policies[14] and Mexico is promoting an SLCF-mitigation plan to accompany its greenhouse gas reduction plans[15].

This chapter reviews a variety of topics important to national action on SLCFs. It first explains why action on SLCFs should be integrated into existing national policy frameworks. It then reviews the opportunities and barriers to implementing a wide range of practical measures for reducing black carbon and methane emissions, including the 16 measures introduced earlier in Chapter 3. It then lists some of the enabling activities that can help overcome the identified financial, institutional, and socio-political barriers, and presents other considerations that should be taken into account when planning national actions. Finally, it presents the basic outline of possible national action plans that would consolidate activities for mitigating SLCFs.

5.1 Integrating SLCFs into existing policy and regulatory frameworks

In most countries various decision-making processes and policy and regulatory frameworks already exist within which SLCF mitigation could be incorporated. These include:

i) air quality management institutions and programmes;
ii) national climate change programmes; and
iii) sectoral and cross-sectoral policies and plans.

Countries need to determine which of these processes and frameworks offer the best opportunity to implement SLCF measures. In some countries it may be necessary to enhance governance systems, for instance, by strengthening coordination among agencies.

For countries with effective environmental governance and regulatory systems, a natural choice might be to locate SLCF policy coordination in their air quality management institutions and to integrate SLCF mitigation in existing air quality legislation and regulations, because

12. Interior Department and Further Continuing Appropriations, Fiscal Year 2010, Public Law 111–88—Oct. 30, 2009, at p. 36. Available from: <http://www.gpo.gov/fdsys/pkg/PLAW-111publ88/pdf/PLAW-111publ88.pdf>

13. Ministry of New and Renewable Energy, India. Available from: <http://mnre.gov.in/press-releases/press-release-02122009.pdf>

14. National Environmental Management: Air Quality Act, No. 39 of 2004. Available from: <http://www.info.gov.za/view/DownloadFileAction?id=67978>

15. Also see Co-Chairs Summary, Ministerial Meeting on Short Lived Climate Forcers from <http://mce2.org/SLCF workshop>

these are likely to already address black carbon and methane emissions as part of their management of particulate matter and ground-level ozone. These institutions and regulatory instruments provide a good platform for SLCF mitigation because: (i) they typically regulate the issuance of permits to significant emission sources, as well as include regular inspection and monitoring, (ii) they sometimes provide economic instruments and education and behavioural change programmes to support emission reductions.

While one option is to embed SLCF policies within air quality management programmes, another option is to incorporate these policies into national climate action plans. They could also be included in 'Nationally Appropriate Mitigation Actions' (NAMAs)[16].

Considering the development co-benefits that are associated with SLCF mitigation, there could be opportunities to incorporate some measures into national development planning. For instance, methane capture in waste-water treatment, waste management and agriculture could lead to economic gains and result in renewable and decentralized energy production opportunities. Replacing traditional biomass cookstoves with cleaner burning cookstoves will reduce exposure to particulate matter with its consequent health risks, and thereby remove a barrier to economic development. Replacement stoves will also be more fuel efficient leading to reduced time spent collecting firewood.

Introducing certain SLCF mitigation measures as part of broader development processes would also encourage the involvement of all concerned actors and facilitate access to multiple sources of funding. For example, any action including restrictions on the burning of agricultural residues would require the involvement of the Ministry of Agriculture. Even if a national action plan is formulated outside the development planning process, many of the proposed actions will still need to be consistent with development goals. Hence, it is advisable that the development of a national SLCF action plan be coordinated with broader national development planning.

5.2 Implementing emission reductions: opportunities and barriers

A wide range of opportunities exist for reducing black carbon and methane emissions. In this section we review these opportunities in seven sectors, and identify some of the barriers that could slow implementation.

5.2.1 Residential combustion

Globally, developing countries account for the largest total emissions of black carbon and co-emitted pollutants from cooking and heating using biomass. However, in a number of developed countries, the use of biomass for heating has increased, making it the largest projected source of black carbon emissions in North America and Europe in 2030 (Chapter 3).

In developing countries, two tracks are being pursued for reducing black carbon emissions from household stoves. Firstly, there are programmes that promote the replacement of stoves with improved ones having better fuel efficiency and lower emissions (World Bank, 2011). Secondly, there are programmes to replace stoves using 'dirty', smoke-producing fuels (fuelwood, charcoal, crop residues and dung) with stoves that use 'cleaner' fuels (e.g. liquefied petroleum gas (LPG) or renewable options such as biogas, solar cookers or renewably produced electricity) that produce less fumes and smoke and would almost eliminate black carbon emissions. While such a strategy is a massive undertaking, given the billions of people using biomass, if achieved it would greatly reduce the major public health risk posed by smoky cookstoves, especially in Africa and Asia.

The promotion of cleaner substitute fuels for households has been a common strategy among many developing countries, most commonly implemented in the form of a fuel and/or equipment subsidy, but experience has been mixed. Attempts to increase the use of LPG and kerosene in Africa have largely failed due to costs and complexities, including fuel supply, transport and use. Even in fossil-fuel-rich countries of Africa, such as Nigeria, Gabon or Angola, biomass and fuelwood accounts for the bulk of energy consumption (IEA, 2009a). But there are also success stories. For example many households in urban areas of Botswana, Ghana, and Senegal, have successfully shifted from charcoal to LPG for cooking. By 2000 most households in Dakar and other main urban areas of Senegal owned LPG stoves. This was achieved by lowering costs, initially by exempting butane stoves from customs duties, and later with fuel subsidies. Another feature of the successful projects was that the technology supplied was adapted to the local conditions and situations.

Factors that will facilitate switching to cleaner fuels include:

- a long-term information and awareness-raising campaign;

16. Nationally Appropriate Mitigation Action (NAMA) refers to mitigation action by developing countries and was first introduced in the Bali Action Plan as part of the Bali Road Map agreed at the United Nations Climate Change Conference in Bali in December 2007, which in particular referred to "Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner".

- linking improved cookstove programmes to national goals of poverty alleviation and greater access of the poor to modern energy sources;
- political will and long-term political commitment;
- the adoption of technology appropriate to local conditions;
- the implementation of regulations and appropriate price and fiscal policies;
- attractive incentives for the various stakeholders involved;
- the guarantee of a reliable and effective supply system;
- monitoring and evaluation of the impacts of implemented policies; and
- building required capacity for successful implementation.

Ethanol cleaner cookstove

Photograph courtesy of Gaia Association

Cleaner cooking and heating stoves

Several regional programmes, introduced primarily in response to health concerns, have demonstrated the technical feasibility of introducing cleaner biomass cooking and heating stoves in Africa and Asia. Hundreds of millions of stoves have been introduced globally in countries such as China and India; but success in terms of a sustainable change has proven difficult in many regions due to cultural and financial barriers at the household level (World Bank, 2011). Some recent projects are explicitly considering black carbon emissions (Box 5.1).

Achieving wider deployment of cleaner-burning biomass cookstoves is likely to require more effective and widespread public awareness of the health impacts of emissions from traditional practices and other benefits such as reduced fuelwood usage. Financing schemes are also needed to overcome up-front capital costs. In addition, it is necessary to ensure that the designs adapted are effective in reducing black carbon emissions, such as fan-assisted models.

Fan-assisted biomass cookstove

Photograph courtesy of Surya project

Pellet stoves and boilers in the residential sector in industrialized countries

One way to hasten the replacement of old stoves and boilers with newer equipment would be to implement a stringent emission standard for black carbon together with appropriate enforcement mechanisms. This should be implemented alongside public awareness campaigns and financial incentives to assist the transition to cleaner technologies. This is likely to require a high level of political commitment, which international cooperation, through the Convention on Long-range Transboundary Air Pollution, the European Union or the Arctic Council, could help achieve (Chapter 6).

5.2.2 Agriculture and forestry

The technical mitigation options offering the greatest methane reduction potential in agriculture include measures for livestock, manure management, and intermittent aeration of continuously flooded rice paddy fields.

For black carbon, banning or limiting open-field burning of agricultural residues and the introduction of no-burn methods, such as conservation tillage or soil incorporation, have been demonstrated as effective means of reducing associated emissions. Similarly, a campaign on the prevention of wildfires and management of prescribed forest and other vegetation burning, and greater resources devoted to fire monitoring and prevention would result in reduced emissions of black carbon and co-emitted substances.

Banning the field burning of agricultural residue

In the 1970s a number of European countries implemented regulations limiting and prohibiting open burning of

Box 5.1: Project Surya

One of the most innovative cleaner cookstove projects in the world is Project Surya in India, which began in 2009 in the state of Uttar Pradesh and combines cookstove replacement with innovative data collection and monitoring techniques. Project Surya is part of the second phase of UNEP's Atmospheric Brown Cloud project. Unlike other similar initiatives, Surya documents the impact on climate forcing, regional air quality, and indoor and outdoor human exposure to particulate matter by using advanced surface, balloon and satellite monitoring platforms[17].

Photograph courtesy of Surya project

agricultural crop residues. Wider implementation of such bans in other countries can be successfully achieved, but will require awareness raising, investment by farmers, and adoption of appropriate technology. In Brazil's largest sugar cane producing state, São Paulo, the daytime burning of cane fields has been banned from 1 June to 30 November because of human health concerns[18]. In China, implementation of regulations to ban open-biomass burning is supported by a website and satellite-derived images which can identify fire spots on a day-to-day basis during harvest seasons (SEC, 2011). When it is strictly enforced, the regulation has been effective at reducing crop residue burning around large cities.

Intermittent aeration of continuously flooded rice paddies

Examples demonstrate that it is technically feasible to apply intermittent aeration – at least one aeration period of more than three days during the cropping season – to rice fields that are currently continuously flooded as a methane mitigation measure (IPCC, 1996). As with field burning of agricultural residues, however, widespread implementation may require demonstration projects, outreach programmes and attention to other crop management issues. For example, visible success of a water saving technology called alternate 'wet-dry irrigation' in pilot farms and specific training programmes for farmers in the Philippines have helped dispel the widespread misconception of possible yield losses in non-flooded rice fields (Bouman *et al*., 2007).

Methane emissions from livestock and manure

One of the available measures to control methane emissions in the agricultural sector is anaerobic digestion of manure from cattle and pigs. Anaerobic digestion, together with feed modification, is a readily available option to reduce methane emissions, mainly in intensive agriculture in North America and Europe. In Africa, for example, applying anaerobic digestion may be applicable to large farms; but there is also the potential to more broadly reduce methane emissions, with the added benefit of improving the quality and quantity of milk and meat production by improving the diet of livestock. In addition, examples from developing countries suggest that household-size anaerobic digesters with utilization of the generated biogas for cooking stoves are a promising option that also would reduce emissions from biomass burning, making this a 'win-win' solution.

Barriers to wider methane capture from manure management include lack of information, high up-front capital costs, unsatisfactory reliability of technology, and low rates paid by some utilities for the electricity generated through the recovered methane. For example, there are relatively few anaerobic digesters in the United States of America mainly due to their high capital costs. Policies to promote these measures should therefore consider development of demonstration projects, outreach, capacity building and appropriate financing.

Some other mitigation measures from the agricultural sector, such as reducing emissions from the digestion process of ruminant animals, are proving more difficult to realise and are not included as measures in this report.

17. http://www.projectsurya.org

18. http://www.enn.com/top_stories/article/37041

Box 5.2: Rice paddy mid-season drainage

Between 1980 and 2000, shifting to the practice of draining rice paddies mid-season has already reduced methane emissions from China's rice fields by about 5 million tonnes each year (Li *et al*., 2002). It is also practised in other Asian countries including the Philippines and Japan.

Photograph courtesy of UN photo/S. Rotner

Some progress could be achieved by changes in people's diets leading to a reduction in livestock numbers and changing animal feed from roughage to a cereal-grain base, although this introduces other issues such as greenhouse gas emissions related to increased cereal production.

5.2.3 Industrial processes

Brick and coke production in small-scale traditional kilns and ovens has been estimated to contribute a sizable fraction of black carbon emissions in, for example, South Asia. Furthermore, poor quality coal, fuelwood, and waste are used to fuel these inefficient kilns resulting in high pollutant emissions. Viable mitigation options are available and have been demonstrated for both activities.

Replacing traditional brick kilns with cleaner and more efficient kilns

Traditional brick kilns, such as clamp kilns, are still widespread in South Asia and Central and South America. They are based on old technology and are inefficient, in addition to being labour intensive and a health risk to workers. A number of Asian countries including China and Vietnam have managed a successful transition to much cleaner and more fuel efficient brick-kiln technologies, for example, vertical shaft, zig-zag, and Hoffman kilns. Demonstration projects have also been implemented in India and Bangladesh. In Latin America, Brazil's recent programme of modernization is seen as a successful example of what can be achieved through training and technology transfer.

Although the number of brick kilns in some regions is large, it is possible to achieve rapid progress in shifting to cleaner technology. Readily available, cost-effective technical solutions could be deployed in developing countries, through, in some cases, the transfer of technology and exchange of experience between countries. Furthermore, the number of stakeholders that need to be involved in such a shift is relatively small. In addition to promoting the shift to cleaner technology in this sector, for example by using mandatory standards, governments could also consider training and awareness-raising programmes for those involved in brick production and distribution. Governments and other institutions could also help establish mechanisms to finance cleaner kilns.

Replacing traditional coke ovens with modern recovery ones

Clean production of coke has been demonstrated in industrial countries over the past few decades. Currently, major coke producing capacity exists in China where many coke plants are still using old, polluting technology. However, fast-growing demand has already resulted in rapid technological development and new plants are now built to international standards. Speeding the phase-out of old, polluting technology by regulation or use of incentives appears to be a promising option.

5.2.4 Transport

The most promising approaches for national action on black carbon in the transport sector are the elimination of high emitting vehicles from the diesel road- and non-road-vehicle fleet and the introduction of Euro-6/VI emissions standards for new vehicles, which include the use of diesel particle filters. Other measures are to adopt policies that promote petrol or ethanol vehicles, rather than diesel vehicles, or to introduce electric cars which would also eliminate particulate emissions.

Elimination of high-emitting vehicles

Numerous studies show that in many countries a small share of the vehicle fleet – high polluting vehicles or 'super-emitters' – causes a high proportion of total emissions. In several countries, such vehicles are being phased out through a combination of import restrictions on second-hand vehicles and engines, restricting access of high-emitting vehicles to urban areas, engine replacement

Box 5.3: Improved brick kilns

Initiatives to reduce air pollution from traditional kilns, through a combination of health regulations and economic incentives, have proven effective. For example, in Ciudad Juarez, Mexico, improved kiln designs boosted fuel efficiency by 50 per cent and reduced particulate pollution by 80 per cent (TCEQ, 2002; Bruce *et al*., 2007).

Photograph courtesy of Robert Marquez

Photograph courtesy of Alba Corral Avitia

A traditional brick kiln (left) and an improved kiln (right) operating in Mexico

and conversions, and scrappage programmes. The most appropriate policy mechanism to control emissions from vehicles currently in use is the wider adoption of vehicle inspection and maintenance programmes. Many countries have such programmes, but their establishment and/or effectiveness in other countries are hampered by the lack of enforcement, infrastructure and institutional capacity.

Diesel particle filters for road and off-road vehicles

Current legislation in many industrialized countries requires installation of diesel particle filters on diesel cars, buses and trucks and, more recently, also on non-road machinery as a measure to reduce particulate matter emissions, including black carbon. Diesel particle filters can be built into new vehicles or retrofitted on to currently - used vehicles and machinery. Their relatively high costs have not inhibited their introduction in industrialized countries because of the significant health benefits resulting from emission reductions.

A prerequisite for introducing diesel particle filters is the use of fuel that meets certain standards, in particular diesel with 50 ppm sulphur or less. This fuel standard is, for instance, required under Euro-4/IV, and even lower sulphur levels are required under the more stringent Euro-5/V (15 ppm) and Euro-6/VI (10 ppm) standards.

Box 5.4: Big reductions from the transport sector

Virtually all new diesel trucks for use on-road in the United States of America, as of 2007, have been equipped with diesel particle filters. The USEPA estimates that the new standards under the Clean Air Non-road Diesel Rule will cut particulate and black carbon emissions from off-road diesel engines by over 90 percent[19].

UNEP Photo

19. http://www.epa.gov/nonroaddiesel/

Standards for the reduction of pollutants from vehicles have long been present in some countries and regions (e.g. a series of standards, up to the current Euro-6/VI in the European Union). The key issue now is the adoption of vehicle emission standards worldwide. Many developing countries are introducing Euro standards to varying degrees. The progress achieved in this area in the European Union over several decades is now being repeated in some developing countries within the span of about ten years. To guide governments in improving standards and seeking regional alignment, the *Roadmap for Cleaner Fuels and Vehicles in Asia* was prepared through a multi-stakeholder approach involving government agencies, oil companies, vehicle manufacturers and other institutions[20].

Introducing more stringent emission standards for new vehicles is attractive because compliance monitoring of these standards would be relatively easy. However, there are problems to be overcome. One is the cost of upgrading refineries to produce fuel to the required standards, and another is setting up proper inspection and maintenance programmes to ensure that emission standards are achieved in practice. Efforts should thus focus on overcoming these barriers through collaboration between different countries and stakeholder groups.

Shipping

There is only limited experience with measures that reduce black carbon emissions from ship engines. However, a recent review by Corbett *et al*., (2010) indicates a range of options available in the next decade ranging from existing slide-valve technology to diesel particle filters. The International Convention for the Prevention of Pollution from Ships (MARPOL) does not expressly cover black carbon emissions. However, developments are taking place in this area as discussed in Chapter 7.

5.2.5 Fossil-fuel production and distribution

Addressing the fossil-fuel production and distribution sector presents important opportunities for large reductions in methane emissions. Several effective measures have been identified (see Chapter 3, Table 3.1). In many industrialized countries more than 90 percent of the methane associated with oil and gas production is recovered and used. However, due to the necessary significant up-front investments, this percentage is typically less than 20 percent in developing countries, although it would be technically feasible in these countries to recover the gas at large-scale facilities and control fugitive emissions (EIA, 2010).

In addition to the introduction of relevant regulations, partnerships between governments and the private sector can offer an important opportunity to reduce emissions from fossil-fuel production and distribution. These are usually restricted to a limited number of facilities in each country, which are often owned by multi-national companies with access to the necessary financial and technical resources.

Pre-mining degasification of surface and underground coal mines, especially as a measure to ensure occupational safety, is currently applied at large scale facilities in many industrialized countries, including the United States of America, European Union countries and Australia. Given its success in many regions, there are opportunities for widespread implementation of this measure. It is considered technically feasible to control about 50 per cent of the ventilation-air methane (VAM) emitted from underground coal mines in many countries. Due to increasing demand for methane as a fuel, especially in the rapidly developing countries of Asia, methane extraction from coal mines is an increasingly valuable resource.

There may also be opportunities for reducing black carbon emissions by controlling gas flaring. Although emissions from this sector are very uncertain, the few available measurements (Johnson *et al*. 2011), remote sensing data (Elvidge *et al*. 2009) and GAINS model estimates indicate it could be a significant source. Existing practice on improving flare performance, for example, from Norway and other countries, could be used to assess

Gas flaring in Nigeria

UNEP Photo

20. Road Map for Cleaner Fuels and Vehicles in Asia; Clean Air Initiative for Asian Cities, 2008. Available from: http://cleanairinitiative.org/portal/node/3632

Box 5.5: Coal mine methane

Countries like India, Mexico and the United States of America are investigating further reductions in coal-mine methane emissions. China is a leader in coal-mine methane projects with 39 registered with the Clean Development Mechanism, including the world's largest at the Sihe Mine in Jincheng City, Shanxi Province[21], which is projected to avoid around 3 million tonnes of carbon dioxide equivalent of methane emissions per year (IEA, 2009b).

the potential and means for future reductions of these emissions.

Barriers to controlling gas flaring include legal issues, high capital costs for equipment, low electricity prices for produced energy, and restricted pipeline capacity for transporting recovered methane. However, these barriers are surmountable, as has been demonstrated in India and other countries.

There may also be considerable opportunities for further reductions of gas leakage from long-distance transmission pipelines through the implementation of improved equipment and inspection and maintenance programs.

5.2.6 Waste management

Landfill

Significant methane reductions can be achieved through waste management measures, including landfill gas collection (see Chapter 3, Table 3.1). While in most countries regulations are in place for large landfills, many smaller ones are not yet regulated. In many developed countries, however, voluntary programmes are in place such as the 'landfill methane outreach program' in the United States of America. These programmes are designed to encourage industries to capture and sell methane for energy production, and have achieved some level of success in slowing the rate of emission increases. Barriers to additional landfill-gas capture may include high capital costs, low rates paid for the gas captured and/or electricity generated, complex permit requirements, and liability concerns. Further regulation may therefore be needed to support wider implementation of this measure.

Separation and treatment of biodegradable municipal waste

Broader measures in the field of waste management, including a comprehensive cradle-to-grave approach that promotes recycling and composting, especially of biodegradable municipal waste, would achieve multiple environmental benefits in addition to reducing methane emissions. Many countries have introduced legislation to divert biodegradable waste from landfills through separation and treatment by recycling, composting or incineration and to equip existing landfills with gas recovery. Based on this wide experience, diversion of all biodegradable waste away from landfills should

Box 5.6: Landfill gas capture

The BENLESA plant, the first renewable energy project in Mexico using the biogas from landfill as fuel, has an installed capacity of 17 MW and by February 2010 had avoided the release of more than 81 000 tonnes of methane, equivalent to the reduction in emissions of 1.7 million tonnes of carbon dioxide. The project is a partnership between the government and a private company[22].

Photograph courtesy of J. Saldaña

21. http://cdm.unfccc.int/Projects/projsearch.html
22. http://seisa.com.mx/index.php?option=com_content&task=view&lang=en&id=54&Itemid=65

be technically feasible in many countries. Wider implementation requires sufficient financial resources and functioning institutions – clearly a challenge in countries lacking the necessary infrastructure.

Upgrading primary wastewater treatment

Primary treatment of centrally collected wastewater is carried out to varying extents in both developed and developing countries and can be a major source of methane emissions. It should be technically possible by 2030 to upgrade all primary wastewater treatment to secondary or tertiary treatment including methane recovery, which reduces emissions considerably, although the costs may be high. Municipalities around the world are applying biogas-treatment technologies to wastewater, such as anaerobic-aerobic activated sludge processes, to mitigate methane emissions and generate energy. For example, wastewater methane reduction projects under the Clean Development Mechanism[23] have been undertaken in India, Indonesia, Morocco (UNEP/WMO, 2011).

5.2.7 Other sources

There are a large number of control measures that reduce particulate matter emissions from large-scale combustion and production processes, including electrostatic precipitators and fabric filters, but in most cases the sources concerned emit only small amounts of black carbon (Bond *et al.*, 2004).

Stationary diesel generators are another source of black carbon which are frequently operated in harsh conditions and are rarely subject to regulation of emissions. Emissions can be reduced by retrofitting or replacing engines. However, the emission reduction potential is quite uncertain because of the lack of statistical data on fuel consumption and actual equipment in use. Lastly, some additional black carbon sources, such as open domestic waste burning, could in the future become targets for mitigation.

5.3 Enabling activities

The previous sections of this chapter have described many opportunities for introducing SLCF mitigation measures in different sectors at the national level. They also described some of the barriers that may hinder their widespread implementation and possible ways to surmount these.

Table 5.1 summarizes the 16 identified priority measures with their attendant barriers and proposed enabling activities. Note that the set of financial, institutional, and socio-cultural barriers in Table 5.1 is not exhaustive. For example, it does not include technical barriers, which in many situations could be important. It should also be noted that socio-cultural barriers in particular are often not anticipated. Nevertheless, they may become extremely important if they surface in the form of public opposition to an emission reduction measure. Successful implementation requires that community concerns be understood and addressed through outreach and awareness-raising activities. Moreover, outreach should be a two-way street: it is equally important to adapt technologies to the needs of the communities as it is to communicate the potential benefits of new technologies to communities. This exchange will yield the best results if it is based on sustained interactions between communities and outreach providers and wide public participation in decision-making.

The last column of Table 5.1 provides a long, but not exhaustive, list of enabling activities that would help surmount the barriers identified. One lesson from the implementation experience described in Section 5.2 is that benefits from SLCF policies and measures will only be realized if they are embedded in an enabling environment that can overcome financial, institutional, and socio-cultural barriers.

5.4 Other considerations for national actions

National governments have a wide choice of mitigation options for SLCFs, and a wide choice in the ways they can be implemented and the policies that would encourage their implementation. This section draws on the international experience reviewed in this chapter to suggest a number of general conclusions and implications that could provide a starting point for national strategies and action plans.

Developed countries have already accomplished substantial reductions in black carbon and methane emissions but mainly as a positive side-effect of other actions, for example, improving energy efficiency or reducing particulate matter pollution. This situation is expected to continue. However, some emission sources are not being reduced on their own, and require specific policy attention. Included here are wood burning stoves, as an example.

Overall, however, barriers to further mitigation of black carbon emissions in developed countries are not major. Furthermore, the climate for further mitigation continues to be good as industrial processes are upgraded, vehicle fleets are replaced, and new technology spreads. The

23. http://cdm.unfccc.int/Projects/Validation/index.html

Table 5.1: Major measures, barriers and enabling reforms to facilitate implementation of the package of 16 SLCF mitigation measures

Sectors	Measures	Barriers	Enabling activities
Residential combustion	Fuel switching	• High fuel and technology costs • Limited fuel supplies	• Tax incentives, subsidies • Facilitated access to alternative fuels
	Improved cookstoves	• Low awareness of health impacts of established cooking practices • Limited durability of improved stoves • High cost of technology for the poor	• Awareness raising and community outreach • Improved technology • Subsidies or loans
	Pellet stoves/boilers industrialized countries	• Lack of awareness • Lack of harmonised standards	• Public education and outreach • Introduce harmonised black carbon emission standards
Agriculture and forestry	Banning the burning of agricultural residues	• Weak enforcement of regulations	• Enhanced enforcement capacity
	Intermittent aeration of continuously flooded rice paddies	• Low stakeholder awareness	• Outreach and demonstration projects
	Emissions from manure (farm-scale anaerobic digesters)	• Adherence to traditional practices	• Outreach and demonstration projects
	Methane emissions from livestock	• High costs of modified feed	• Economic incentives
Industrial processes	Cleaner and more efficient brick kilns	• Limited access to finance and skilled personnel	• Economic incentives • Capacity building and training
	Modernisation of coke ovens	• Limited community awareness • Lack of relevant regulation and enforcement	• Outreach and demonstration projects • Issuance of relevant regulation • Enhanced enforcement capacity
Fossil fuel industry	Pre-mine gasification	• High upfront investment	• Economic incentives
	Oxidation of ventilation air methane from coal mines	• Technical constraints	• Improved technology • Technology transfer
	Recovery of vented methane from production of oil and natural gas	• Lack of infrastructure • Lack of nearby markets	• Economic incentives
	Reducing leaks from long-distance natural gas transmission pipelines	• Cost of monitoring and maintenance	• Strengthened regulations and enforcement procedures • Enhanced enforcement capacity
Transport	Diesel particle filter as part of Euro 6/VI standards	• Unavailability of ultra-low sulphur fuels	• Government regulations to require ultra-low sulphur fuels
	Removing high-emitting vehicles	• Lack of regular inspection/ enforcement	• Introduction and enforcement of inspection and maintenance programmes • Scrappage schemes
Waste management	Separation of bio-degradable solid waste, and generation and recovery of methane	• High capital costs • Low prices for methane • Complex permitting schemes and liability issues	• Economic incentives including financial mechanisms • Introduction of clear legislation
	Upgrading primary wastewater treatment	• High cost	• Further legislation requiring secondary or tertiary treatment

potential gains from controlling black carbon and methane emissions could even be seen on the national level as a new impetus for further accelerating these processes.

The reduction of methane emissions in the energy, mining, landfill and agricultural sectors represents a major opportunity to achieve benefits from voluntary programmes, partnership schemes and tighter regulations. Particularly rapid progress can be achieved when the application of best technologies and practices is required across an industry.

Addressing agricultural methane emissions, especially from livestock and, in Asia, continuously flooded rice paddies, is another important area for action, notwithstanding the possible difficulties in the near term due to the traditionally slower development pace of agricultural technology and practices. While benefits from changes in management and husbandry of livestock may be relatively limited, they may become more important with the expected increases in consumer demand for meat products. Clearly, any overall reductions in meat consumption could have an immediate effect on emissions. However, other opportunities are more readily available in the agricultural sector to reduce black carbon emissions, notably through banning or restricting open burning of agricultural crop residues, and introducing waste management measures to create viable alternatives to such practices.

In many developing countries the effectiveness of options and strategies will depend on a different set of factors: limited resources and competing priorities, lack of appropriate infrastructure, and institutional and regulatory challenges, such as how to adequately monitor and enforce regulations to control emissions. However, at all stages of development there are cost-effective measures that can be implemented successfully, so long as they take into account local culture and sustainability priorities, and are aligned with national development goals for such issues as energy, transport and agriculture.

In developing countries, SLCF strategies can also take advantage of the pivotal role that major cities play in environmental concerns. Urban centres can benefit from the fact that they provide a critical mass of people and know-how to rapidly diffuse new technologies and new management approaches. Particularly in Asia and Latin America, cities have become proving-grounds for advancements in air quality management. For example, Beijing and Shanghai have introduced tighter vehicle emission standards some years ahead of the rest of China. The same pattern has been observed in Indian cities, particularly with respect to the introduction of cleaner fuels. Some cities in Latin America, including São Paulo, Santiago de Chile and Mexico City have pioneered effective controls of air pollution sources (Molina *et al.*, 2004).

5.5 Elements of a national action plan

As shown in previous chapters, the current state of knowledge is sufficiently robust to justify immediate action at the national scale to reduce SLCF-related emissions. Countries can be confident that multiple benefits will be achieved if they begin now to implement reduction measures for obvious emission sources. Of the many steps that can be taken on the national level, one of the most useful might be to develop a National Action Plan which would consolidate and prioritize a larger number of national actions. The action plan would build on existing institutions and policies, including those concerned with air quality management and climate policy. The plan would have specific connections to other country-wide plans for sustainable development and other national priorities. A National Action Plan could include:

- *Characterizing sources and opportunities for emission reductions.* Countries with well- functioning air quality management institutions could add the assessment of SLCF-related emissions to their activities. Those countries without such institutions could set up a special expert group(s) to carry out this work.
- *Planning awareness-raising activities* to inform government, business, and civil society about the benefits and costs of controlling SLCFs and the steps to implement measures.
- *Assessing the relative benefits and costs of action,* either based on international analyses, such as the ones outlined in this report, or by conducting economic analysis to develop more local/national estimates.
- *Determining the political feasibility of implementation* to identify which options are likely to be easiest to implement, and which will require additional effort.
- *Undertaking an inventory of current policy and legislation* that is already used to implement related measures.
- *Identifying further policies, where there are gaps,* to make more rapid progress in implementing the control of SLCF-related emissions.
- *Taking cost-effective action* on obvious SLCF sources.

While there are many good arguments for giving priority to national actions, these actions can also be supported by other policies and measures at the regional and global scales. That is the subject of the next two chapters.

Chapter 6:

Regional-scale Action

Regional-level cooperation and support can enhance the successful implementation of national-level actions and is the most effective scale at which regional transboundary problems can be addressed. To date, there has been little regional action on SLCFs, in contrast to air pollution which has well-developed regional initiatives and intergovernmental agreements. Similar initiatives on SLCFs could complement and support national emission reduction efforts. This chapter discusses options for action at the regional level: it reviews the existing major regional agreements and other mechanisms and then discusses options for regional activity to further the understanding of regional impacts and build consensus around regional objectives.

One major initiative, carried out in Asia over the last ten years, is the Atmospheric Brown Cloud (ABC) project (Ramanathan et al., 2008). Although not originally aimed specifically at SLCFs, the ABC project made important findings relevant to these issues. More recent examples of efforts specifically focusing on SLCFs include scientific assessments carried out by international organizations, including with a regional focus, such as the United Nations Environment Programme (UNEP) and the Word Meteorological Organization (WMO), the Ad Hoc Expert Group on Black Carbon of the Convention on Long-Range Transboundary Air Pollution (CLRTAP), and the Arctic Council, as further detailed in the following sections.

There are four reasons why action at the regional level could add value to, or stimulate, national actions:

- The impacts of SLCFs often go beyond the national level and occur at the regional level, and therefore SLCF mitigation is best addressed at this level. Examples include: the health impacts from particulate matter transported across national boundaries; regional impacts of tropospheric ozone on crops; long-range transport and impact of black carbon on the Arctic and the Himalayas, and disruption of weather patterns on all continents.
- Economies of scale or other benefits that arise from pooling and sharing of scientific expertise and knowledge, joint research and capacity building and technical assistance programmes. This is particularly important in regions where the pollution problems extend across national boundaries and where resources may be scarce. Raising awareness of the impacts of SLCFs and sharing knowledge within regional groupings could also facilitate joint or complementary policy solutions and help overcome barriers to delivery. It is also arguable that it is easier to reach consensus on policies at a regional, rather than a global, scale.
- Common clean technology standards can be developed at the regional level, and can serve as models to other nearby countries, ensuring the more cost-effective use of scarce human and technical resources.
- Accountability may be enhanced by the presence of a regional forum to which progress on emission reductions is reported. Such shared accountability has the potential to provide further incentives for action at a national level.

This chapter examines the existing regional initiatives in terms of the following three categories:

i) ***Regional entities with established infrastructure and a policy focus:*** in some regions detailed regional legal instruments and infrastructure have been established. The most established example is the CLRTAP, which mandates legally-binding national emission ceilings for different pollutants, and the European Union (EU) which issues legislation on emissions, ambient air quality and climate change.

ii) ***Regional entities with permanent structure and a science focus:*** though not based on legally-binding agreements, other regional entities do have permanent structures (e.g. a secretariat) but focus largely on developing a regional scientific base, for example by promoting or undertaking regional monitoring and modelling. Examples include the Acid Deposition Monitoring Network in East Asia (EANET) and the Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia (Malé Declaration).

iii) ***Other initiatives:*** which have no permanent structures, but provide viable policy making fora for regional cooperation. Examples include:

- in Sub-Saharan Africa, ministerial declarations (also known as 'agreements') were recently adopted, such as the Lusaka Agreement for southern Africa, the Nairobi Agreement for eastern Africa, and the Abidjan Agreement for west and central Africa. These declarations lay out common policy, set regional priorities and offer a framework for future cooperation;
- in Latin America and the Caribbean: the Intergovernmental Network on Air Pollution in Latin America and the Caribbean was created and given a mandate from the Regional Forum of Environment Ministers of Latin America and the Caribbean to develop a regional work plan;
- in Asia and the Pacific, regional cooperation has been enhanced through a new Joint Forum on Atmospheric Environment Issues in Asia and the Pacific, drawing together several institutions and intergovernmental initiatives.

In addition to these three categories this chapter also considers the role that economic integration organizations and other relevant regional and subregional organizations could play in developing action on SLCFs.

6.1 Potential for action through regional entities with established infrastructure and a policy focus

The three inter-governmental bodies that currently address short-lived climate forcers are the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP), the European Union (EU) and the Arctic Council.

6.1.1 Convention on Long-Range Transboundary Air Pollution

The Convention on Long-Range Transboundary Air Pollution (CLRTAP)[24] and its protocols have resulted in specific measures to be taken at national level to cut emissions of air pollutants. In particular, it mandates national emission ceilings of pollutants that cause acid rain, eutrophication (excess nutrient deposition), and tropospheric ozone in its 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone. The Task Force on Hemispheric Transport of Air Pollution (TFHTAP) is undertaking modelling of tropospheric ozone including the role of methane and other ozone precursors, such as carbon monoxide. CLRTAP is currently incorporating SLCFs into its activities, taking an initial step to include consideration of black carbon as a component of particulate matter (PM) in the process of the revision of the Gothenburg Protocol, probably in the form of ceilings for $PM_{2.5}$. Some areas of discussion on black carbon within the context of CLRTAP include:

i) improving measurement coverage of black carbon across the region, and clarifying the definition of black carbon;

ii) developing guidelines for black carbon emission inventories; and

iii) prioritizing reductions of primary particulate matter emissions in sectors with high black carbon to organic carbon ratios, recognizing that black carbon is only emitted in conjunction with other pollutants such as organic carbon which is a cooling agent[25].

CLRTAP has considerable potential to address the linkages between air pollution and climate change, including continuation of its work to integrate black carbon in the next phase of the Gothenburg Protocol. Methane could also be included in the Protocol, informed by the findings of the TFHTAP. There is also the possibility that expertise within the CLRTAP region could be shared with other world regions to make policy makers aware of options to mitigate SLCFs. The sharing of information and knowledge could build on the linkages that have already been established with regional air pollution networks in Asia and Africa, in the area of scientific research.

6.1.2 European Union

The European Union (EU) Directive 2001/81/EC of the European Parliament and of the Council on National Emissions Ceilings for Certain Atmospheric Pollutants Directive, known as the National Emission Ceilings (NEC) Directive, sets emission ceilings for member states for sulphur dioxide, nitrogen oxides, volatile organic

24. The Convention on Long-Range Transboundary Air Pollution (CLRTAP) was signed in 1979 and entered into force in 1983. It has 51 parties, with a geographical coverage extending from North America to Europe. www.unece.org/env/lrtap/welcome.html

25. Decision 2010/2 by the Executive Body on Implications of the reports of the Task Force on Hemispheric Transport of Air Pollution and the Ad hoc Experts Group on Black Carbon (document ECE/EB.AIR/106/Add.1), decided to "include consideration of black carbon, as a component of particulate matter (PM), in the process of the revision of the 1999 Gothenburg Protocol". In addition, also see the Report by the Co-Chairs of the Ad Hoc Expert Group on Black Carbon, available from: http://www.unece.org/env/lrtap/ExecutiveBody/welcome.28.html

compounds and ammonia, some of which are precursors of tropospheric ozone. The European Union also supports action by appropriate international fora to reduce the effects of emissions of greenhouse gases, black carbon and other SLCFs in the Arctic. In January 2011 the European Parliament stated that it '…recognises the disproportionately large Arctic warming impact caused by black carbon emissions in the EU and other regions in the northern hemisphere, and stresses the need for inclusion of black carbon emissions in the relevant UNECE and EU regulatory frameworks, such as the Convention on Long-Range Transboundary Air Pollution and the National Emissions Ceilings Directive'[26]. In September 2011 the Parliament further came forward with two resolutions calling for more action on SLCFs, in particular on hydrofluorocarbons, black carbon and tropospheric ozone[27].

The European Union formulates its own air quality and climate change legislation and has just begun a review of its air quality legislation, aiming to conclude by 2013. At present it is not clear to what extent this will result in further action on SLCFs although the European Union is likely to incorporate particulate matter emissions in the NEC Directive, following the indication by the Parliament referred to above.

European Union legislation also has the potential to affect other regions as the motor-vehicle emission standards set by the EU (the Euro standards) have been taken up by both India and China amongst others (Chapter 5).

6.1.3 Arctic Council

The Arctic nations[28] may play a special role in demonstrating a strong resolution to reduce emissions of SLCFs, and most of these countries are highly motivated by the fact that the Arctic, is warming at a higher rate than the global average. The Arctic Council was an early actor on SLCFs, publishing two reports in 2008 on science and mitigation[29] and an SLCF task force is further exploring policy and mitigation options[30], while the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) is continuing to develop the science of SLCFs and assessing their Arctic impacts. In addition, the council's Arctic Contaminants Action Program (ACAP) working group has begun coordinating demonstration projects funded by member governments aimed at sources of black carbon in Arctic nations, initially focusing on stationary and mobile diesel sources but potentially including other important sources such as residential stoves and open-field and forest burning[31].

The Arctic Council is a high level intergovernmental forum to provide a means for promoting cooperation, coordination and interaction among the Arctic States; the recent signing in 2011 of the first legally binding agreement, the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic[32] may open the door to additional future agreements. The Arctic Council's own analysis indicates that the eight member nations are responsible for more than half of the black carbon affecting the Arctic, demonstrating the potential benefits of a regional Arctic agreement that could serve as a model for others. The Arctic nations could also spearhead more global efforts such as those aimed at methane abatement or oil and gas SLCF emissions. Such actions, even if taken outside the Arctic region, could benefit Council members by mitigating some of the more extreme impacts of rapid warming there.

6.1.4 Commission for Environmental Cooperation

Since 1994, Canada, Mexico and the United States of America have been collaborating in protecting North America's environment through the North American Agreement on Environmental Cooperation (NAAEC), which is the environmental side agreement to the North American Free Trade Agreement (NAFTA). NAAEC created a framework to better conserve, protect and enhance the North American environment through cooperation and effective enforcement of environmental laws. The Commission for Environmental Cooperation (CEC) was also established in the context of the NAAEC in order to address regional environmental concerns. Ongoing CEC

26. European Parliament resolution of 20 January 2011 on a sustainable EU policy for the High North (2009/2214(INI)). The full text of the Resolution is available from: <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&reference=A7-2010-0377&language=EN>

27. European Parliament resolution of 14 September 2011 on a comprehensive approach to non-CO_2 climate-relevant anthropogenic emissions. The text of the Resolution is available from: <http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2011-0384>

28. The Arctic nations include: the Russian Federation, Canada, the United States of America, Sweden, Norway, Denmark, Finland and Iceland.

29. Arctic Monitoring and Assessment Programme (AMAP): http://www.amap.no/

30. The task force provided recommendations to ministers at the 2011 ministerial meeting in Nuuk, Greenland, which focused primarily on black carbon, and will continue its work in the coming years on black carbon as well as methane and tropospheric ozone, with Sweden joining as a co-chair. Nuuk Declaration (2011) Seventh Ministerial Meeting of the Arctic Council, Nuuk, Greenland. http://arctic-council.org/filearchive/Nuuk%20Declaration%20FINAL.pdf

31. Funding for these various projects is approaching US$10 million.

32. The Agreement will strengthen cooperation between the Arctic states and improve the way Arctic countries respond to emergency calls in the region.

programmes, as well as new strategic priorities, present a good opportunity to integrate SLCF mitigation in its work.

6.2 Potential for action through regional entities with permanent structure and a science focus

6.2.1 Malé Declaration in South Asia

The Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia was adopted at the Seventh meeting of the Governing Council of SACEP in 1998. The main objective of the Malé Declaration programme is to promote the establishment of a scientific base for prevention and control of transboundary air pollution in South Asia to encourage and facilitate coordinated interventions of all the stakeholders on transboundary and shared air pollution problems at national and regional levels[33]. It already includes consideration of the air quality impacts of tropospheric ozone, especially on crops, and the impact of particulate matter pollution on health. Activities include developing emission inventories, integrated assessment modelling and consideration of policies and measures to reduce air pollution. Sharing practices and experiences from countries within this region on emission reduction policies and measures is already an important part of this forum and could be further expanded to key sources of black carbon and tropospheric ozone precursors, including methane. Priority sources for this region include transport, cookstoves, brick kilns and agricultural residue burning, all of which are included in the Declaration. Assessment and action on these issues could be promoted through awareness raising and appropriate financing of the Malé Declaration activities.

6.2.2 EANET – Acid Deposition Monitoring Network in East Asia

The Acid Deposition Monitoring Network in East Asia (EANET) was established in 1998 as an inter-governmental initiative to create a common understanding of the state of acid deposition problems and to provide inputs into the decision-making process[34]. The focus at this stage is chiefly scientific and concerned with the pollutants involved in acid deposition but includes a group of countries with some of the largest emissions of SLCFs. Many of the key countries involved are promoting national co-benefit strategies that enhance the synergy between air pollution and climate policy and it would be important to investigate the potential of this forum to focus on SLCF issues.

6.2.3 ASEAN Agreement on Transboundary Haze Pollution in South East Asia

The governments of the ten member countries of the Association of South East Asian Nations (ASEAN) signed an Agreement on Transboundary Haze Pollution in 2002[35].

It is the first regional agreement in the world that binds a group of contiguous states to tackle transboundary haze pollution resulting from land and forest fires[36]. It arose as a result of the transboundary transport of particles from forest-fire outbreaks that has significant health impacts in countries thousands of kilometres from the source of emissions. As outdoor burning of biomass is a major source of SLCFs, the agreement could provide an excellent opportunity in the region to discuss wider measures that reduce particulate matter pollution and SLCF emissions.

6.2.4 The Central Asian Environment Convention

Countries of Central Asia have made a political commitment on air pollution issues under the 2006 Framework Convention on Environmental Protection for Sustainable Development in Central Asia[37]. This offers an opportunity for these countries to address SLCFs.

6.2.5 Other Initiatives in Asia

There are other regional initiatives, such as the Tripartite Environmental Ministers' Meeting (TEMM) among China, Japan and Republic of Korea[38] and ASEAN+3 Meeting[39], which might be effective in addressing the issues of transboundary air pollution and its link with climate change, including aspects related to various SLCFs.

33. The Malé Declaration covers Bangladesh, Bhutan, India, Iran, the Maldives, Nepal, Sri Lanka and Pakistan.

34. Thirteen countries participate in EANET: Cambodia, China, Indonesia, Japan, Lao PDR, Malaysia, Mongolia, Myanmar, Philippines, Republic of Korea, Russia, Thailand and Vietnam. UNEP is the Secretariat and the Asia Centre for Air Pollution research, located in Japan is the Network Centre for EANET.

35. ASEAN is the Association of South East Asian Nations, a geopolitical and economic organization of ten countries originally formed in 1967 involving Indonesia, Malaysia, the Philippines, Singapore and Thailand. Membership then expanded to include Brunei, Myanmar, Cambodia, Laos and Vietnam.

36. The Agreement entered into force in 2003 and was ratified by nine of the ten ASEAN countries. See: http://haze.asean.org/hazeagreement/

37. See http://www.ecolex.org/ecolex/ledge/view/RecordDetails;document_Framework%20Convention%20on%20Environmental%20Protection%20for%20Sustainable%20Development%20in%20Central%20Asia.html?DIDPFDSIjsessionid=20D91EE559E0718840CF60B3AFCE560A?id=TRE-143806&index=treaties . The agreement has been signed only by Kyrgyzstan, Tajikistan and Turkmenistan.

38. http://www.env.go.jp/earth/coop/coop/english/dialogue/temm.html

39. ASEAN+3 includes the ASEAN countries plus China, Japan and Republic of Korea. http://www.aseansec.org/4918.htm

The Clean Air Initiative for Asian Cities (CAI-Asia) is a partnership[40] that actively promotes policies to address air pollution and climate change in an integrated fashion, and, given the opportunity of policy development at city scale in rapidly industrializing countries in Asia, it focuses on how urban centres could help be a catalyst for enhanced implementation of the black carbon and methane measures.

The Asian Co-benefits Partnership[41] was officially launched in November 2010 and serves as an informal and interactive platform to improve knowledge management and stakeholder cooperation on co-benefits in Asia. The SLCF issue is central to this partnership.

The Asian Development Bank (ADB) has a number of programmes and initiatives for Asia and the Pacific that are relevant to SLCFs and the measures required to control them. These include the Climate Change Programme, Clean Energy Programme, Energy Efficiency Initiative, Energy for All Initiative, and Sustainable Transport Initiative. The Cities Development Initiative for Asia (CDIA) may also be relevant to SLCF mitigation, as it provides assistance to medium-sized Asian cities to bridge the gap between their development plans and the implementation of their infrastructure investments[42].

6.3 Potential for action on SLCFs through other initiatives

6.3.1 Africa

Regional cooperation on air pollution was initiated by the Air Pollution Information Network for Africa (APINA) in 1997 culminating in the adoption by the Southern African Development Community (SADC) Ministers of the Regional Policy Framework on Air Pollution, known as the Lusaka Agreement in 2008. APINA has also worked in partnership with UNEP's Partnership for Clean Fuels and Vehicles (PCFV)[43], the USEPA, the World Bank and others since 2006 on better air quality for African cities[44]. This process has resulted in further regional instruments on air pollution adopted at the ministerial level, the Eastern Africa Regional Framework Agreement on Air Pollution, known as the Nairobi Agreement (2008), the West and Central Africa Regional Framework Agreement on Air Pollution, known as the Abidjan Agreement (2009)[45], and a draft regional framework in northern Africa. All these regional instruments specifically mention air pollution and climate change co-benefits. Elements of the Lusaka Agreement have been considered for inclusion in the SADC environment protocol that is currently being developed. UNEP has been encouraging national governments to implement measures outlined in the regional agreements across Africa, through the Partnership for Clean Fuels and Vehicles (PCFV) initiative, on unleaded petrol and low sulphur fuel. There is considerable potential for these processes to promote action on SLCFs. Investments in these regions to develop stable institutional structures would promote progress and provide a platform for coordinating SLCF activities. Including the issues addressed in these declarations into the discussions at the African Ministerial Conference on Environment (AMCEN) could provide an opportunity to elaborate a regional framework and strategy on SLCF mitigation.

6.3.2 Asia

Regional cooperation in Asia has been enhanced through a new Joint Forum on Atmospheric Environmental Issues in Asia and the Pacific convened by UNEP. The Forum draws together ASEAN, the Malé Declaration, EANET, CAI-Asia, the Central Asian Environment Convention, the Pacific Regional Environment Programme (SPREP), the South Asia Cooperative Environment Programme (SACEP) and the governmental meetings on Urban Air Quality in Asia. Although in its early stages, the Joint Forum has the potential to promote action on SLCF through the exchange of information across the region. It could also provide a focus for inter-regional scientific collaboration on SLCF issues, awareness raising and capacity enhancement.

6.3.3 Latin America and the Caribbean

In 2008, the XVI Forum of Ministers of the Environment of Latin America and the Caribbean secured support in principle for the establishment of an Inter-Governmental

40. CAI-Asia leads efforts to enable Asia's 2500 cities to reduce both air pollution and CO_2 emissions. http://cleanairinitiative.org/portal/node/2288

41. http://www.iges.or.jp/en/cp/co-benefits.html

42. http://www.cdia.asia/about-cdia/

43. www.UNEP.org/PCFV/

44. The Better Air Quality in Sub-Saharan Africa (BAQ-SSA) policy dialogue was held in July 2006 with participation by forty nine sub-Saharan countries and Ministers of Environment of thirty of them. See: www.gapforum.org for details.

45. Lusaka Agreement: (2008) - Southern African Development Community (SADC) Regional Policy Framework on Air Pollution'. See: www.gapforum.org for details. Nairobi Agreement: (2008) http://www.unep.org/urban_environment/PDFs/EABAQ2008-AirPollutionAgreement.pdf, Abidjan Agreement: http://www.unep.org/urban_environment/PDFs/BAQ09_AgreementEn.Pdf

Network on Air Pollution in Latin America and the Caribbean. The initiative is being promoted by the Global Atmospheric Pollution (GAP) Forum[46] and includes recognition of air pollution climate change issues. Although the inter-governmental network is still in its infancy, and will require further financial commitment, it does have enormous potential to promote action on SLCFs. Draft Elements of a Framework Agreement on Atmospheric Pollution in Latin America and the Caribbean has been discussed at the Seventeenth Meeting of the Forum of Ministers of Environment of Latin America and the Caribbean in 2010[47]. Bilateral donors have also supported SLCF mitigation in the region. For example, the Swiss Development Agency for Development and Cooperation established a project to increase the energy efficiency of artisanal brick kilns in seven Latin American countries. The project promotes the reduction of greenhouse gas emissions through the use of more energy-efficient technologies and processes, and the use of less polluting fuels.

The Inter-American Development Bank (IDB) has a sustainable energy and climate change initiative and also finances several climate change and sustainable energy efforts such as a climate change programme in Latin America including the Biodigester Network and Knowledge Sharing Platform (BioLAC).

The WMO Global Atmospheric Watch (GAW) Urban Research Meteorology and Environment (GURME) project addresses both air quality and climate change[48] and is an initiative that could be approached to promote the science around SLCFs across Latin America and the Caribbean.

6.3.4 Other Relevant Initiatives

Environmentally sustainable transport (EST) forums were established for Asia and Latin America by the United Nations Centre for Regional Development (UNCRD), bringing together senior transport and environment sector government officials each year to share experience and discuss strategies for making transport more sustainable. In Asia, the Fifth Regional Environmentally Sustainable Transport Forum held in Bangkok in August 2010, adopted the Bangkok Declaration for 2020, in order to demonstrate their 'renewed interest in, and commitment to, realizing a promising decade (2010-2020) of sustainable actions and measures for achieving safe, secure, quick, reliable, affordable, efficient and people-centric and environment friendly transport in rapidly urbanizing Asia'[49]. The Latin America Forum (Foro de Transporte Sostenible para América Latina) held a meeting in Bogota, Colombia in June 2011 and adopted the Bogota Declaration, which outlines common goals on environmentally sustainable transport in Latin America until 2020. These forums could provide an avenue to promote SLCFs measures in the transport sector.

6.4 Economic groupings

In addition to the atmosphere-based groupings discussed above, there are also economic integration organizations and other regional and sub-regional organizations that potentially could play a role in SLCF mitigation. The role of some of them, such as SADC and ASEAN, has already been discussed in this chapter. Organizations covering other sub-regions could also become active on SLCF mitigation. These could include for instance Mercosur in Latin America[50], the South Asian Association for Regional Cooperation (SAARC)[51] and the Economic Community of West African States (ECOWAS)[52]. ASEAN, in addition to being the forum under which the Haze Agreement was adopted, hosts formal meetings of senior officials from national ministries, such as the ASEAN Senior Transport Officials Meeting, that are relevant to the SLCF issue. It also has several working groups that could be relevant to the SLCF policies and measures, amongst others on transboundary air pollution, environmentally sustainable cities, agriculture and training extension and multilateral environment agreements.

6.5 Possible options for progress at a regional Level

This chapter shows that throughout the world there are now regional inter-governmental networks and initiatives that can provide a basis for cooperative action on SLCFs, as well as enhancing and supporting national activity. At present their scale and effectiveness vary significantly, and

46. A global forum of regional atmospheric initiatives. www.gapforum.org.

47. http://www.pnuma.org/forumofministers/17-panama/FORO%20DE%20MINISTROS%202010%20VERSIONES%20FINALES/EXPERTOS/DE%20TRABAJO%20INGLES/UNEP-LAC-IGWG-XVII-%206%20Draft%20Elements%20Framework%20Agreement%20Atmospheric%20Pollution.pdf

48. http://mce2.org/wmogurme/

49. http://www.uncrd.or.jp/env/5th-regional-est-forum/index02

50. Involving Argentina, Brazil, Paraguay and Uruguay. See www.mercosur.int

51. http://www.saarc-sec.org/

52. http://www.ecowas.int/

although some are still at an early stage of development, they are developing rapidly. These initiatives can provide a useful platform for awareness raising, capacity building, technical cooperation and financing at the regional level.

6.5.1 Awareness of the benefits

A key requirement for going forward with SLCF mitigation is to adequately inform decision makers. It should be made clear that many benefits, especially for human health, will accrue to the populations of regions and individual countries that take action. While the responsibility to select and implement measures to mitigate SLCFs could lie primarily with national governments, it should be made clear that co-ordinated regional action is indispensible if certain key impacts – for instance on the Arctic, the Himalayas and the South Asian Monsoon – are to be effectively addressed.

6.5.2 Technical knowledge

Existing agreements and their institutions and partnerships could be used to raise awareness, improve scientific understanding, facilitate the transfer of technology, and develop capacity as prerequisites for policy makers to take action on SLCFs.

Regional instruments and initiatives such as CLRTAP, the Malé Declaration, EANET and others could be involved in a series of regional meetings or workshops, which could be tailored to the needs of the different regions. The meetings could be linked to the development of region-specific SLCF assessment reports. In an initial phase, these meetings could involve scientists and decision makers to define the scope of the issues at stake, refine priorities, promote capacity building and scientific research and lay the foundations for policy action at regional or national levels. Inviting participants from other regions to these meetings could promote cross-fertilization and the sharing of experiences.

The more developed institutions, as well as countries, individually or jointly, could play an important role in capacity building and awareness raising. The CLRTAP and the EU, for example, can offer their experience in formulating mitigation policies and in particular offer examples of how science informs and drives policy development in these areas, as well as help disseminate scientific findings related to SLCFs.

South-south cooperation also can increase the flow of information, resources, expertise, technology and knowledge among developing countries. One example is UNEP's efforts to actively promote the streamlining of approaches to south-south cooperation in the implementation of the capacity-building components of its biennial programmes of work[53].

6.5.3 Financing and enabling mechanisms

Regional and sub-regional development banks, such as the Asian and African Development Bank, the European Bank for Reconstruction and Development and the Inter-American Development Bank, as well as other similar institutions, could play a strong role in supporting regional activities. Regional initiatives have already received support from the regional development banks, such as through the Clean Air Initiative for Asian Cities, but these institutions could play a bigger role through funding and promoting additional initiatives such as high-level dialogue among governments in their respective regions. Increased knowledge and awareness among countries about funding opportunities and other enabling mechanisms available through these institutions in the field of SLCFs would also be useful to advance mitigation efforts.

6.5.4 Further regional development to enable SLCF Action

In order to move forward, it is important to capitalize on the important role played by regional networks, which are able to address the circumstances of individual regions and catalyze policy discussion and promote action.

Some of the declarations and other instruments emerging in Africa and Latin America and the Caribbean and other developments mentioned in this chapter offer the prospect of moving to effective collaborative action in a relatively quick fashion. A positive aspect of some initiatives is their close alignment with regional development communities such as the SADC (in the case of the Lusaka Agreement) and ASEAN (in the case of the ASEAN Haze Agreement) which could offer an opportunity for mainstreaming near-term climate and air-quality protection into development.

Building on the successes of the network of well-established institutions and agreements at the regional level, as well as promoting collaboration among them, can offer an effective way to strengthen on-going efforts to mitigate SLCF emissions. It can also offer the opportunity to incorporate SLCF mitigation into existing air quality policies where this has not yet happened.

53. See: http://www.unep.org/south-south-cooperation/; this also closely links with some aspects of the North-South cooperation and the so-called triangular cooperation.

Chapter 7:

Global-scale Action

Efforts at the global level can catalyze action at the national and regional scales and help promote widespread implementation of black carbon and methane mitigation measures. Global cooperation can also provide needed support to help achieve development goals, including the Millennium Development Goals. A global strategy to attain widespread mitigation of SLCFs could be based on common objectives, include priorities set at the regional level, and build upon existing instruments, initiatives and organisations. A systematic international approach would help ensure the efficient use of scarce resources and support integrated policy development at the global level. While the implementation of SLCF mitigation measures needs to occur primarily at the national level, the international community could have an important role in putting in place the enabling conditions for this to take place.

This chapter considers the following major global approaches for promoting the mitigation of SLCFs:

i) building upon existing legal instruments;

ii) promoting further efforts by international organisations and cooperative mechanisms, including partnerships and networks; and

iii) putting enabling mechanisms in place at the global scale to facilitate the national implementation of black carbon and methane mitigation measures. These include: awareness raising; technical assistance, technology transfer and capacity building; and financing.

This chapter focuses on early opportunities rather than longer-term efforts, and therefore does not include negotiation of new multilateral environmental agreements or the amendment of existing ones, but also does not preclude such action.

7.1 Building upon existing legal instruments

Global strategies to mitigate SLCF emissions need to be based on action that can be implemented in the next couple of decades if their potential to improve public health, crop yields and slow the rate of climate change is to be realised in the near term. While there is currently no dedicated global regime to regulate SLCFs *per se,* rapid progress might be possible by building on existing instruments, initiatives and organisations as outlined in this and the previous chapter.

Considering the interconnected nature of environmental problems across the globe, it is important that a holistic and synergistic approach is taken to tackle these emissions. Benefits could therefore be realised by associating SLCF mitigation with other related issues, including climate and air pollution, and also through global agreements that address specific sectors and sources of emissions such as the MARPOL Convention (Box 7.1).

It may be beneficial to have some level of connection between SLCF mitigation and the global climate regime. Methane, one of the substances that is the subject of this report is in fact already covered by this regime and is one of the six greenhouse gases addressed by the Kyoto Protocol. It is also likely to be included in any successor agreement, although currently there is no specific emission reduction target for methane and the other gases covered in the Kyoto Protocol. Instead, the protocol requires that Annex I parties limit their aggregate greenhouse gas emissions in accordance with their respective commitments[54]. Additional efforts to specifically address methane emissions could be helpful to achieve the full health, environmental and development benefits of its mitigation. These could include using existing vehicles or avenues within the climate regime.

54. Kyoto Protocol, Article 3(1). The relevant commitments are set out in Kyoto Protocol, Annex B. Gases controlled by the Kyoto Protocol are set out in Kyoto Protocol, Annex A. http://unfccc.int/kyoro_protocol/items/2830.php

Information exchange could be promoted under the framework of the climate regime, for example by building upon the work of subsidiary bodies of the UNFCCC, especially the Subsidiary Body for Science and Technological Advice (SBSTA) which has already discussed the results of the UNEP/WMO (2011) assessment, as well as the impact of SLCFs on sensitive areas such as the Arctic.

The Intergovernmental Panel on Climate Change (IPCC) will have an important role through its development of its Fifth Assessment Report (AR5) to further expand the scientific understanding of SLCF issues. The IPCC Task Force on National Greenhouse Gas Inventories could further consider developing guidelines on emissions reporting, initially voluntary, to encompass black carbon, possibly in conjunction with air quality experts in the Arctic Council and United Nations Economic Commission for Europe Convention on LRTAP.

However, notwithstanding the linkages between climate protection and the reduction of SLCF-related emissions, it is important that any strategy to mitigate the emissions of these SLCFs is treated as complementary to the primary efforts being undertaken to stabilize long-lived greenhouse gases under the global climate regime.

Benefits could also be realised by integrating SLCF mitigation into air pollution efforts taking place in the context of global agreements that address specific sectors and sources of emissions such as the MARPOL Convention (Box 7.1).

7.2 Promoting further efforts by international organisations and cooperative mechanisms

International organizations, such as FAO, ICAO, IMO, UNDP, UNEP, WHO, WMO and the World Bank among others, have institutional air-quality or climate mandates relevant to SLCFs. Several global networks, partnerships and associations also exist that are already active in the field of air quality, or that address sectors that can generate SLCFs.

Many of these organizations and cooperative mechanisms have already undertaken action to address SLCFs, and these could be enhanced and coordinated to promote much wider implementation of the identified black carbon and methane mitigation measures. This should be done in cooperation with relevant stakeholders, including national governments, regional bodies and civil society organisations.

International organizations and their partners could promote the generation and sharing of knowledge and awareness raising, design and implement technical assistance and capacity building programmes, and facilitate technology transfer. In addition, relevant international organizations could play a key role in facilitating financing. These enabling measures are discussed in section 7.3.

International organizations and cooperative mechanisms are also well placed, especially if they work in a coordinated manner, to undertake or strengthen existing initiatives to:

Box 7.1: Opportunities to build on the International Convention for the Prevention of Marine Pollution from Ships (MARPOL)

The International Maritime Organization's (IMO) MARPOL Convention regulates air pollution from ships in its Annex VI, which entered into force in 2005 and limits the main air pollutants contained in ships' exhaust gas and prohibits deliberate emissions of ozone-depleting substances. It also regulates shipboard incineration and the emissions of volatile organic compounds from tankers. A revised Annex VI, containing a progressive reduction globally in emissions of sulphur dioxide, nitrogen oxides and particulate matter and introducing Emission Control Areas (ECAs), was recently adopted and entered into force in 2010. International maritime shipping is not one of the sectors addressed by the 16 measures identified in Chapter 3, but probably emits significant quantities of black carbon close to sensitive regions. Shipping traffic in the Arctic is anticipated to grow substantially as the area of summer sea ice diminishes and new major sea lanes open up in the region, thereby increasing the impact of black carbon from shipping on the Arctic environment (IMO, 2010). In 2011, the IMO's Marine Environment Protection Committee (MEPC) agreed to address the impact of black carbon emissions in the Arctic, investigate appropriate control measures to reduce the impacts of such emissions in the Arctic and establish mandatory energy efficiency standards for international shipping (IMO, 2011). These are expected to help reduce emissions from the projected increase under a "business as usual" scenario. These developments underscore the way in which national and regional efforts on SLCFs can also lead to action on a global scale.

- convene stakeholders around a shared vision and global strategy to mitigate SLCFs;
- develop common standards and guidelines;
- promote policy integration through existing inter-agency coordination mechanisms; and
- encourage joint actions amongst and between the private sector, civil society and governments, including the promotion of best practices and improvement of technology.

7.2.1 Facilitating a shared SLCF vision and global strategy

Convening different international organizations around common near-term climate protection objectives could be a powerful way of integrating various initiatives, reducing duplication, and inefficient use of resources, and leading to more effective implementation of SLCFs mitigation measures in different sectors worldwide. A variety of organizations have already begun initiatives that directly or indirectly affect SLCFs, such as the World Bank on gas flaring, ICAO on air pollution, UNEP on the Atmospheric Brown Cloud and other initiatives discussed in the following sections.

7.2.2 Developing common standards and guidelines for SLCFs

Sector-specific emission standards could be modified to more clearly and comprehensively include SLCFs. Examples, which range from mandatory to voluntary standards and guidelines, applied to emissions, products and concentrations, are given here from the oil and gas, aviation, road transport and cookstoves sectors.

Current research points to gas flaring possibly being a large source of black carbon emissions; gas venting and inefficient seals on pipelines are also known to be a large source of methane emissions. The World Bank Global Gas Flaring Reduction Partnership (GGFR)[55] is a public-private partnership launched at the World Summit on Sustainable Development in Johannesburg in 2002. It supports the efforts of oil producing countries and companies to reduce flaring and venting and increase the use of associated natural gas. Global Gas Flaring Reduction partners have established a collaborative global standard for gas flaring reduction, which provides a framework for governments, companies, and other key stakeholders to consult with each other, take collaborative actions, expand project boundaries, and reduce barriers associated with gas utilization.

The International Civil Aviation Organization (ICAO) has issued standards and recommended practices on aircraft engine emissions[56]. The standards regulate, *inter alia*, particulate matter and the tropospheric ozone precursor carbon monoxide (UNEP/WMO, 2011). Although the initial focus was on improving air quality in the vicinity of airports by regulating emissions during landing and take-off, ICAO is considering developing the standards further to regulate emissions during the cruise phase of flights (ICAO, 2010).

The Global Alliance for Clean Cookstoves (GACC)[57], a public-private partnership initiated by the UN Foundation in 2010, is currently working with several governments and organizations to develop international cookstove standards and guidelines that will incorporate standards for black carbon.

The development of other SLCF-focused guidelines in other sectors could be spearheaded by relevant international organizations to address all major sources of SLCF emissions that require international regulation (World Bank, 2011), and could constitute a reference in the development of national standards.

WHO's air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide, are intended to provide guidance to policy makers in developing measures to reduce impacts of air pollutants on human health and ecosystems (WHO, 2006). Furthermore, WHO is preparing new indoor air quality guidelines for household fuel combustion, which are also relevant to SLCF reduction[58].

International organizations, individually or jointly, could also initiate the development of guidelines to assist policy makers in developing national action plans to address SLCFs (see Chapter 5).

7.2.3 Promoting policy integration through existing inter-agency coordination mechanisms

Cooperation mechanisms have been established to promote integrated policy making within the United Nations system to ensure enhanced coherence in global policy-making, linking together the environment, development and other areas of international

55. Global Gas Flaring Reduction Partnership. http://go.worldbank.org/NEBP6PEHS0
56. International Civil Aviation Organization. Environment Branch: Air Emissions. http://www.icao.int/icao/en/Env2010/Aee.htm
57. http://cleancookstoves.org/overview/
58. http://www.who.int/indoorair/interventions/CHEA_brochure_rev.pdf

cooperation. These mechanisms can be used to promote the progressive integration of decision making on issues related to climate change mitigation, air pollution prevention and control, ecosystems management, agriculture, food security and, more broadly, development including through the angle of SLCF mitigation. Examples of coordination measures include:

- The High-Level Committee on Programmes (HLCP) to the Chief Executives Board for Coordination (CEB), which fosters coherence, cooperation and coordination on programme dimensions of strategic issues for the United Nations system.
- The United Nations Development Group (UNDG) to the Chief Executive Board that unites the 33 United Nations funds, programmes, agencies, departments, and offices that play a role in development, with a common objective to deliver more coherent, effective and efficient support to countries seeking to attain internationally agreed development goals, including the Millennium Development Goals.
- The Environment Management Group (EMG), established by the United Nations General Assembly as a UN system-wide coordination body. Its membership consists of its specialized agencies, programmes and organs including the secretariats of the Multilateral Environmental Agreements, and is chaired by the Executive Director of UNEP[59].

These and other mechanisms could be used to enable continued dialogue and ensure that SLCF policy development and implementation in areas ranging from climate change, environment, public health, agriculture and development are undertaken in a coherent way encompassing multiple benefits. In addition, ministerial and other meetings of high-level representatives of interested governments, and global meetings such as the Rio+20 meetings in June 2012, could provide a vehicle for drawing high-level global attention to SLCFs and the imperative of addressing near-term climate change, with its air quality, sound economic development and poverty alleviation benefits.

7.2.4 Encourage joint actions amongst and between the private sector, civil society and governments

Further action and enhanced collaboration on SLCF mitigation could be sought through existing global networks, partnerships and associations, such as the Global Atmospheric Pollution Forum (GAP Forum), the Atmospheric Brown Cloud (ABC) project and others outlined in Chapter 6. Several of these groups focus specifically on air quality, whereas others focus on specific sectors, such as transport or cookstoves. Such *fora* can catalyze regional and global coordination and synchronize action.

Public-private partnerships, which promote joint action by public institutions and the private sector for the achievement of common objectives, engage the affected industries in a way that can accelerate the rate and the scale of abatement of SLCFs and assist the public sector in overcoming market barriers. They can also establish best practices, guidelines and voluntary industry standards. The UNEP Partnership for Clean Fuels and Vehicles (PCFV), for example, is a public-private partnership made up of over 120 partners worldwide, with the shared goal of reducing air pollution in developing countries through technological improvements within the transport sector and the adoption of clean fuel and vehicle strategies[60].

Multi-sector initiatives such as the Global Methane Initiative (GMI) provide a basic framework for multi-stakeholder cooperation on one particular SLCF. The GMI brings together resources and technical expertise to enable methane emission abatement projects in a voluntary action network. The USEPA has also established the SmartWay Partnership with the private sector, initially as a national programme to advance green freight practices that improve fuel efficiency and reduce emissions. It includes a supply chain partnership of over 2,000 shippers (manufacturers) and carriers, and programmes concerned with technologies, financing and marketing[61].

7.3 Enabling mechanisms at the global scale to facilitate implementation of national SLCF mitigation

Adequate institutional and legal frameworks are essential in achieving SLCFs mitigation, but to be effective they need to be accompanied by adequate human, technical and financial resources. While efforts to secure adequate resources need to occur primarily at the national level, they can be supported through a variety of ways at the global level. Overcoming financial challenges, for instance, requires readily accessible financing systems

59. UN Systems High-Level Committee on Programmes (HLCP): http://hlcp.unsystemceb.org/, United Nations Development Group: http://www.undg.org/, Environment Management Group: http://www.unemg.org/
60. http:// www.unep.org/transport/pcfv
61. http://www.epa.gov/smartway

at the national level such as incentive schemes, existing credit institutions, the Clean Development Mechanism, among others, which can entirely originate and be funded through national sources, or be supported by external sources, including bilateral and multilateral donors. Similarly, strengthening national capacities and institutions, and access to technology, can be supported by global programmes. Awareness raising is also essential to mobilize political support and wide acceptance of, and participation in, mitigation efforts at national level. This need is discussed at length in Chapter 5, in relation to the specific sectors addressed, and Chapter 8.

7.3.1 Technical assistance, technology transfer and capacity building

International organizations and donors can play an important role in facilitating access to appropriate technology, information, knowledge and data and can support national efforts to strengthen institutions and capacities to implement measures to reduce SLCF emissions. An example is the Global Fuel Economy Initiative by UNEP and other partners to promote fuel-efficient vehicles, with the co-benefit of reducing emissions of black carbon[62]. Other examples are the institutional strengthening projects funded under the multilateral fund for the implementation of the Montreal Protocol, which support ozone units in relevant ministries worldwide in their efforts to implement national measures to phase out ozone depleting substances[63].

While technical assistance and capacity building programmes to support SLCF mitigation are already being implemented by various organizations, a more coherent, coordinated SLCF-specific approach based on synergies among existing programmes and plans for future activities would be beneficial.

7.3.2 Financing SLCF mitigation

Given the multitude of conflicting and often pressing development and economic priorities facing decision makers, investment in SLCF mitigation may not be the immediately preferred choice, and only those measures that provide an increase in earnings in the relatively near-term will directly appeal to the private sector (Chapter 4). So, when cost savings can only be realised over the long-term, the resources required for the up-front investment need to be found in other ways.

Action to mitigate SLCFs can be funded through a wide range of sources from the national to the global level and from micro-finance to large-scale funding. Creative ways to generate and access funding have already been devised and continue to evolve, in addition to traditional official development assistance (ODA) and multilateral funding mechanisms.

Considering the development co-benefits of mitigating SLCFs, a more comprehensive approach to policy on SLCFs that takes such co-benefits fully into account could positively affect funding to address SLCF concentrations. The links between the impacts of near-term climate change and poverty eradication, for example, need to be drawn more clearly both at national and international levels.

Mechanisms specifically funding SLCFs

One initiative aimed at specifically reducing an SLCF is the Prototype Methane Financing Facility (PMFF)[64], introduced by the Methane Blue Ribbon Panel and supported by UNEP and several donor and recipient countries. The PMFF provides a guaranteed floor price for certified emission reductions (CERs) arising from qualified methane projects, especially in least developed countries, and for cookstoves projects that abate methane. Financing is expected to arise from guarantees issued by governments, and therefore would not require extensive additional funding; if successful, this model could be used to target other SLCFs as well. Proposals also exist for a more extensive price floor mechanism that would actually purchase and retire the CERs, rather than using them as offsets in meeting climate obligations. Several private methane funds also exist, targeted specifically at methane abatement activities.

The PMFF is an example of a 'forcer fund' approach, with the focus on an individual SLCF. Another option would be for groups of donors, both government and private actors, to take a sectoral approach instead of focusing on individual forcers. The Global Alliance for Clean Cookstoves (GACC) has for example encouraged donors to set aside development loan guarantees for cookstove manufacturers. This approach could be used for other sectors impacting SLCF emissions as well, such as oil and gas, brick-making kilns, diesel combustion or agricultural waste burning.

62. http://www.globalfueleconomy.org/Pages/Homepage.aspx

63. http://www.multilateralfund.org/default.aspx

64. Methane Blue Ribbon Panel, A Fast-Action Plan for Immediate Methane Abatement. http://www.globalmethanefund.org/

Multilateral environmental agreement-related funds

Many financial mechanisms have been established to help implement multilateral environmental agreements. While some are trust funds that support the operation of the agreement's secretariats, others aim to support parties in their implementation of the agreement's obligations. In particular, several funds have been established under the United Nations Framework Convention on Climate Change to finance projects both for adaptation and mitigation including technology transfer and capacity building in various sectors.

In addition to the two funds specifically established to assist with the implementation of the Convention and the Protocol, three special funds have been established under the climate regime: the Special Climate Change Fund (SCCF); the Least Developed Countries Fund (LDCF), both under the Convention; and the Adaptation Fund (AF), under the Kyoto Protocol. The SCCF, in particular, was established to finance projects in the fields of adaptation and mitigation, including technology transfer and capacity building in various sectors (energy, transport, industry, agriculture, forestry and waste management, and economic diversification)[65]. These funds could be explored as possible avenues for financing activities that also result in SLCF mitigation. In addition to managing specific funds established under relevant multilateral environmental agreements, the Global Environment Facility (GEF), which is replenished every four years, and is currently operating under GEF V (1 July 2010 - 30 June 2014), provides grants and concessional funding to meet the incremental costs of measures needed to achieve global environmental benefits in agreed focal areas, including climate change. The following objectives apply to the climate change focal area for the current funding window:

- demonstration, deployment and transfer of innovative, low-carbon technologies;
- market transformation for energy efficiency in the industrial and buildings sectors;
- investment in renewable energy technologies;
- energy-efficient, low-carbon transport and urban systems;
- conservation and enhancement of carbon stock through sustainable management of land use, land-use change and forestry;
- support for enabling activities and capacity building[66].

Subject to countries own choice and to applicable funding policies, GEF allocations could be used to support SLCF work, if proposed projects respond to the above objectives or fall under one of its cross-cutting areas, especially for pollutants such as black carbon and tropospheric ozone that are not traditionally considered primary climate forcers. In addition, future replenishment periods - GEF VI and beyond - could provide an additional opportunity for the GEF to specifically target SLCFs emissions.

The Clean Development Mechanism and new Green Climate Fund

Other mechanisms associated with the global climate regime, including the 'Fast Track Fund' and the Clean Development Mechanism (CDM), could be explored for their potential to facilitate SLCF mitigation.

Under the 'Fast Track Fund', developed countries have pledged to provide US$ 30 billion by 2012 for adaptation and mitigation. This funding is supposed to increase to US$ 100 billion annually by 2020. Some or all of these resources will be allocated through a 'Green Climate Fund' that could provide an opportunity in the future for further SLCF mitigation[67].

Although not technically financial mechanisms, the CDM and other flexible mechanisms can play an important role in channelling funds to mitigate SLCFs - especially methane - but also to some degree black carbon and other ozone precursors. This is because many of the measures for SLCFs also abate Kyoto Protocol gases and therefore are eligible for credits under such financing schemes[68]. Unfortunately, however, the system does not fully cater to the needs of SLCFs mitigation, and some methane projects, such as those associated with landfills and wastewater, present challenges that make them less likely to attract investment. This is also due to the way by which carbon credits such as Certified Emissions Reductions (CERs) are calculated.

The CDM could do more to reduce methane emissions but further incentives need to be put in place to this end, and especially to promote small-scale projects such as municipal waste management. One such incentive mechanism is the Prototype Methane Financing Facility, described above.

65. http://unfccc.int/cooperation_and_support/financial_mechanism/items/2807.php

66. GEF Secretariat (2010). GEF-5: Programming Document, available from: http://www.thegef.org/gef/sites/thegef.org/files/documents/GEF.R.5.31.pdf

67. Fast-start finance: http://unfccc.int/cooperation_support/financial_mechanism/fast_start_finance/items/5646.php, Green climate fund: http://unfccc.int/cooperation_and_support/financial_mechanism/green_climate_fund/items/5869.php

68. About CDM: http://cdm.unfccc.int/about/index.html

Emissions of methane and black carbon often arise from multiple small sources such as cookstoves, diesel engines, brick kilns and agriculture, and may need to be addressed through 'Programmatic CDM' methodologies designed to cover these multiple small sources. Programmatic CDM projects, while proving at times difficult to implement, tend to be associated with significant development benefits, especially in least developed countries. The United Nations Framework Convention on Climate Change, UNEP and individual governments could work with the CDM Executive Board to facilitate the approval of such projects and work to shape new CDM methodologies or its eventual successor in the context of the new climate regime that include mitigation of SLCFs and air quality as an important co-benefit.

Integrating SLCFs into development assistance and other funding

Incorporating SLCF mitigation as an integral part of national development and poverty reduction strategies, particularly in relation to public health and food security, would be beneficial to eventually attract additional resources. To encourage this, the connection between poverty reduction, air pollution and near-term climate change needs to be made more explicit. The fact that reducing the risk of environmental impacts that would result from near-term climate change will create large cost savings and overall promote economic development, needs to be more widely appreciated.

Bilateral and multilateral donors, including multilateral development banks, could choose to finance SLCF abatement activities directly for the specific purpose of near-term climate benefit to sensitive areas such as the Himalayas and the Arctic, or they could add and integrate black carbon and tropospheric ozone precursor reduction projects into their existing development assistance portfolios. Funding programmes would need to be tailored to support the specific SLCF mitigation measures applicable in a given country or region, and build on the relevant key sectors. For many countries, for example, SLCF mitigation could be integrated into improved cookstoves and waste management projects, while in other countries a good avenue could be provided by wastewater, transport and landfill infrastructure or brick kiln projects.

Chapter 8:

A Way Forward

The previous chapters have outlined the benefits for health, crop yields and near-term climate protection of taking action, starting now, on short-lived climate forcers (SLCFs). Other chapters discussed the options to promote implementation of identified black carbon and methane emission control measures at national, regional and global scales. The challenge for the international community is to put these measures in place quickly, as effective action must be taken over the next two decades to achieve the full potential for the near-term benefits outlined in this document. This will be influenced by the very diverse starting points of different governments and regional and international organizations. In order for SLCF mitigation to be successful, implementation of the key measures needs to be integrated into national programmes according to national priorities. Fortunately, there is a substantial basis on which to build national strategies. Chapter 5 indicates the need to take full advantage of the wide range of policy measures and instruments which have already been developed to address air pollution, as well as the potential to integrate SLCF mitigation- when appropriate - into sustainable development planning, and sectoral and climate-related policies. The principal instruments available are regulation of emission levels, bans of substances or particular processes, and deployment of cleaner technology (e.g. cookstoves). These approaches can usefully be complemented by a wide range of tools, including economic incentives, technology transfer, awareness raising, capacity enhancement and education.

A suitable starting point is the identification of relevant sources and measures that can achieve the emission reduction goals, are sustainable in the circumstances of the country, can be readily introduced and effectively implemented, and where success can be measured and assessed. It is especially important that the selected measures are cost-effective, generating positive short-term returns on capital expenditure and have low maintenance costs. This work can be consolidated into national action plans or other planning or strategy documents.

Although the principal route for abating SLCFs is through national programmes, cooperative action at regional and global scales will also be required. This is because, like all air pollutants, some SLCFs are also transported at regional, hemispheric or even global scales. For the same reasons, different SLCFs may require different approaches. Measures to reduce black carbon emissions may be motivated by important local health benefits alone, even though they also have regional benefits in ice- and snow-covered areas and limit global temperature increases. Measures to address tropospheric ozone, a regional and hemispheric pollutant, may require cooperation at those scales to effectively reduce concentrations. Methane is globally mixed in the atmosphere, so methane abatement lends itself to global cooperation. Global- and regional-scale efforts will also help widespread implementation of national-level actions and allow the development of a more coordinated and comprehensive approach.

Existing international and regional instruments and policies can provide a useful foundation on which to anchor an SLCF strategy, without having to create costly and time-consuming new ones. SLCF policy development can build on existing processes to promote cross-cutting activities such as awareness raising, agenda setting, policy formulation and monitoring. It is also important to focus on what could be implemented within current sustainable development pathways and existing air quality and climate change programmes, expanding and accelerating those efforts that will have significant development co-benefits.

The above considerations are based on the fundamental premise that addressing near-term climate change by interventions that reduce concentrations of SLCFs is time sensitive. The opportunity to achieve near-term global and regional climate benefits and significantly reduce the rate of climate change needs to be realised within the next two decades if changes already seen in sensitive and at-risk regions, such as the Himalayas and the Arctic, are to be slowed. This near-term climate strategy complements the long-term climate strategy of reducing long-lived greenhouse gases, especially carbon dioxide. If taken in conjunction with the necessary carbon dioxide reductions, reducing SLCFs increases the chance of remaining below the 2°C temperature increase target during this century.

8.1 The need for awareness raising

Mobilizing political support to address environmental concerns has always depended on raising general awareness of the problem both within government and among the public. It also means seeing the benefits of taking action and the negative impacts of inaction. The attention given to the need for SLCF mitigation, and consequent decision-making, can only derive from a firm grounding in science and knowledge of the impact that these substances have on climate, public health, agricultural crop yields, ecosystems and development. Despite some progress in the understanding of these issues among both governments and the public, there is a need for greater recognition of the urgency of the near-term climate situation and the potential threats of continued rapid temperature increase in the coming two to four decades. In addition, the ready availability of SLCF-reduction measures and their health, environment, climate and development co-benefits need to be emphasised and brought to the attention of the public. This needs to be coupled with efforts to advance scientific and technical knowledge on SLCFs and their potential for achieving near-term climate and air-quality gains.

Awareness-raising efforts should target a broad spectrum of actors across multiple sectors. At the global level, raising political awareness at such suitable international forums as UNEP's Governing Council, the Commission for Sustainable Development and United Nations Framework Convention on Climate Change meetings is an essential aspect of developing a framework for international cooperation on SLCFs. To achieve the scale of intervention needed to rapidly reduce SLCFs, the discussion of the issues must occur beyond air-pollution circles and also be considered together with climate-change policies at global, regional and national levels. This discussion should also move into broader development circles, such as through the United Nations Development Programme, the World Bank, regional development banks, and the Global Environment Facility. The policy challenges resulting from the convergence of climate change and air-quality objectives are complex and the ability of outreach campaigns to influence action at all levels will depend on their ability to highlight the cost-effective, 'win-win' nature of SLCF reduction measures.

Governments could also initiate or support joint activities to promote awareness raising, information exchange and other enabling actions to facilitate implementation of policy measures. Technical meetings and policy dialogues with national and sub-national authorities and stakeholders are essential to raise awareness and facilitate subsequent implementation of mitigation measures in any country. Such meetings would foster an understanding of the available implementation options and mechanisms, highlight available internationally transferrable experience, and facilitate the building of political support and funding. Organizing such meetings would also promote information sharing and greater coordination.

Coordinated awareness-raising efforts at global, regional and national scales involving governments and other key stakeholders, including the public, would increase political support for the implementation of SLCF measures.

8.2 Setting the agenda

While raising awareness is the first step required to put SLCFs on to governments' agendas, the widespread adoption and implementation of policies at global, regional and national levels will depend to a large extent on a willingness to set an agenda that clearly identifies priorities for the course of action. Policy development at all levels needs to be based on the science and understanding of SLCFs. Government officials also require cost-benefit analyses to define the most cost-effective measures for their country's circumstances, as well as the means to measure and evaluate the success of implementation. The natural way to achieve this is through national action plans as discussed in Chapter 5.

The knowledge represented by *Integrated Assessment of Black Carbon and Tropospheric Ozone* (UNEP/WMO, 2011), together with this and other recent reports, provide a concrete basis for policy-making and action to mitigate SLCFs. The involvement of key governments in developing these reports, and high-level policy dialogues in different regions, will further the development of an effective agenda at national, regional and global levels.

At the global level, SLCF mitigation needs to be placed on the international agenda so that governments can address this issue in a coordinated manner. This requires wider acceptance of the problem and an appreciation of how the mitigation of SLCFs can assist countries to meet their immediate air-quality and development goals, as well as helping to solve their short- and medium-term climate change challenges. A key point at this stage is to enhance understanding of the need to act quickly and build on existing policies and processes.

Agenda setting at the regional level could build on the existing regional initiatives, agreements and networks already responsible for addressing air quality. Incorporating SLCFs into regional agendas will require that the issues are elevated to the level where the authority exists to address them, for example at ministerial meetings. Due to its convening power, the United Nations Environment Programme (UNEP) and its regional offices can play an important role here because many of the existing instruments were originally promoted through UNEP cooperation and awareness-raising projects.

Setting priorities at the regional level will face underlying challenges, related to the fact that the development of transboundary air pollution agreements is still a work-in-progress in many regions. There may be resistance to move away from traditional air pollution approaches, as closer association with climate issues might be perceived as adding further complexity; similar challenges may also be faced at the national level. Near-term and regional benefits, and opportunities to realise co-benefits, may however remove part of that reluctance. To achieve this, it will be important to have a clear understanding of the costs and benefits of SLCF mitigation, and financial and other forms of support that could assist implementation of SLCF mitigation activities. Therefore, successful agenda setting will require early engagement with stakeholders active in air pollution, climate and development policy, to enhance understanding of the added value of linking air pollution with near-term climate mitigation in the context of development. At the national level, policy makers need to be aware that national efforts are not only possible, but implementable at marginally increased costs to existing efforts.

8.3 Establishing an effective governance framework

An adequate governance framework is important for ensuring coordinated efforts among governments and international agencies. It is also important to ensure the delivery of the required enabling activities and financing, and for monitoring progress.

The challenge for SLCF mitigation is that while specific policies can be initiated by building on existing policies and processes, it still is a cross-cutting issue that falls outside the scope of any single existing regime or governance framework that would specifically address this problem in a dedicated and cohesive manner. An international governance framework is required that can coordinate and collaborate with existing initiatives, and be recognized by them as the primary framework. However, the framework must be flexible and framed in a way that will allow it to take quick and effective action working through the entire United Nations system, as well as at regional and national levels. Because of these requirements, an *ad hoc* arrangement might be best suited for moving forward on SLCFs.

One important role for a global initiative would be to provide a menu of policies and measures that countries could use to develop national actions on SLCFs. Such a menu, along with some understanding of best practices, could be an important tool for assisting countries in developing their own national strategy and could become part of an action plan on near-term climate protection and clean-air benefits.

International organizations with relevant mandates could individually or jointly facilitate a global initiative on SLCFs, or provide secretariat functions, in addition to other roles they can play as outlined in chapter 7. An organization like UNEP could provide a platform for cooperation under such an initiative as a global organization that deals with environmental issues across different levels and sectors, including those most relevant to an effective SLCF strategy – climate change, ecosystems management, and transboundary air pollution, and due to its regional presence.

A model for a global initiative could be a voluntary partnership of committed governments and other major stakeholders, led by a small steering committee of country champions working together with a small secretariat. The initiative could:

- identify opportunities for enhanced international coordination and outreach;
- report on domestic activities;
- identify knowledge gaps and human and financial resource requirements;
- raise public awareness of the problem and opportunities, and discuss common approaches to taking new action or promoting and reinforcing action in other organizations;
- serve as a forum for increasing awareness of, and participation in, existing efforts;
- promote the development of national or regional action plans, tracking progress of programmes and commitments, and mobilizing funding commitments for SLCF mitigation;
- aim to provide up-front finance to help create the necessary enabling environments for action, as well as to provide funds to leverage private sector investments in SLCF mitigation.

The initiative could further task relevant international organizations to work through regional ministerial forums to develop awareness, set agendas and facilitate regional and national actions or promote the establishment of regional structures where they are missing. The initiative could include an inter-agency mechanism for collaborative activities, a system-wide strategy and governance arrangements that would allow the types of partnerships that are needed to instigate and enable policies.

When establishing such a governance framework it would be important to achieve:

- a critical mass of countries across regions that will take leadership;
- recognition of the legitimacy of the global initiative by key actors and organizations in the climate and air-pollution arenas;
- access to funding to kick-start early actions, e.g. pilot projects; and
- implementable and realistic action to achieve the agreed global agenda.

With these elements, the opportunities that SLCF mitigation presents for near-term climate change mitigation and for air-quality benefits can be utilized to their fullest extent and not be lost.

The imperative for early action seems clear. The co-benefits to human development and environmental health, and avoidance of risks associated with existing rapid climate change demand an effective response by the global community.

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