Project no. 282688

ECLIPSE

Evaluating the **Cl**imate and Air Quality **I**m**p**acts of **S**hort-Liv**e**d Pollutants

Collaborative Project

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Revision [v1]

Options for addressing short-lived components in global or regional climate policies

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SUMMARY

The ECLIPSE project (Stohl et al. 2015) has demonstrated that a well-chosen set of emission control measures would provide simultaneous benefits for human development, air quality and climate change. This confirms the importance of the 17 win-win SLCP measures that have been identified in Shindell et al. 2012 and subsequently taken up for practical implementation by the CCAC Climate and Clean Air Coalition. In addition, four new opportunities for win-win measures were identified. Their promotion could be considered by the CCAC, as it has already established initiatives in related fields.

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

1 Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) requires climate policies to 'be cost-effective so as to ensure global benefits at the lowest possible cost' and that 'policies and measures should ... be comprehensive … [and] … cover all relevant sources, sinks and reservoirs'. This was made operational by the Kyoto Protocol, which sets limits on emissions of six different greenhouse gases (GHGs), or groups of GHGs – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6). Collectively these are often known as "the Kyoto gases" or the "Kyoto basket" [1]. CO_2 is the most important anthropogenic driver of global warming, with additional significant contributions from CH_4 and N_2O. However, other anthropogenic emissions capable of causing climate change are not covered by the Kyoto Protocol. Some are covered by other protocols, e.g. emissions of chlorofuorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are regulated by the Montreal Protocol, because of their role in stratospheric ozone (O_3) depletion.

But there are others, notably several short-lived components that give strong contributions to climate change that are not included in existing climate agreements. At the same time, these substances deteriorate air quality at the hemispheric, regional and local scales and cause a wide range of harmful effects to human health and vegetation. Because of their air quality impacts, these substances are already subject to local and regional air quality management strategies throughout the world.

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[1] Note that, formally, only species given values of Global Warming Potentials (GWP) in IPCC's Second Assessment Report were controlled during the first commitment period (2008-2012) of the Kyoto Protocol. The second commitment period (2013-2020), via the Doha Amendment, also includes NF_3 in the list of greenhouse gases, and uses GWP values from the IPCC's Fourth Assessment Report. The Doha Amendment is currently not in force, as it awaits ratification by a sufficient number of parties.

2 A set of promising measures

The ECLIPSE project has demonstrated that a well-chosen set of emission control measures would provide simultaneous benefits for human development, air quality and climate change. The analysis identified more than 300 specific measures that deliver positive net climate impacts, about 90% of the potential climate benefits (in terms of CO_2-equivalent emissions calculated by GWP100) emerge from a limited set of key measures (Table 2.1). These measures can be grouped into three groups of opportunities:

(i) Measures that affect emissions of methane and that can be implemented centrally by large national and international energy companies, municipalities and through modified agricultural practices. If implemented globally, these measures could CO_2eq emissions in 2030 by about one third compared to the baseline case.

(ii) Technical measures that reduce emissions of black carbon, mainly at small stationary and mobile sources. Together with the measures of group 1, these measures could reduce CO_2eq emissions in 2030 by about half compared to the baseline case.

(iii) Non-technical measures to eliminate the most polluting activities, e.g., through improved enforcement of legislation or through economic and technical assistance to the poorest population. With these measures, CO_2eq emissions could be reduced by about two thirds in 2030 compared to the baseline case.

Table 2.1: Key measures to reduce climate impacts

Methane measures	Measures targeting BC reduction
Oil and gas industry: Recovery and use (rather than venting or flaring) of associated gas	Oil and gas industry: Improving efficiency and reducing gas flaring
Oil and gas industry (unconventional): Reducing emissions from unintended leaks during production (extraction) of shale gas	Transport: Eliminating high emitting vehicles (super-emitters)
Coal mining: Reducing (oxidizing) emissions released during hard coal mining (ventilation air methane)	Residential-commercial: Clean biomass cooking stoves
Waste: Municipal waste – waste paper separation, collection, and recycling	Residential-commercial: Replacement of kerosene wick lamps with LED lamps
Waste: Municipal food waste separation, collection and treatment in anaerobic digestion (biogasification) plants	Transport: Widespread Euro VI emission standards (incl. particle filters) on diesel vehicles
Coal mining: Hard and brown coal -pre-mining emissions – Degasification	Industrial processes: Modernized (mechanized) coke ovens
Gas distribution: Replacement of grey cast iron gas distribution network	Agriculture: Effective ban of open field burning of agricultural residues
Waste: Industrial solid waste (food, wood, pulp and paper, textile) – recovery and incineration	
Waste: Wastewater treatment from paper and pulp, chemical, and food industries - anaerobic treatment in digester, reactor or deep lagoon with gas recovery, upgrading and use. For residential wastewater centralized collection with anaerobic secondary and/or tertiary treatment (incl. treatment with bacteria and/or flaring of residual methane)	
Gas production (unconventional): Good practices for unconventional gas production	
Breeding options	

If applied at the global scale, the identified measures would reduce nearly 40% of projected baseline CH_4 emissions in 2030. A third of that potential is achieved by addressing emissions in gas and oil production in North America and Europe, Africa and Asia. Another third of the potential can be reduced from coal mining, especially from NE Asia, SE Asia and Pacific. The treatment of municipal waste could contribute one fifth of the reduction potential, of which one half could be achieved in North America and Europe. Lastly, agriculture could contribute about one tenth of the global CH_4 mitigation potential in 2030.

This would reduce surface concentrations of O_3 and $PM_{2.5}$ globally compared to the CLE scenario, with BC reductions of more than 80% in some areas. We estimate that in the EU the loss of statistical life expectancy due to air pollution will be reduced from 7.5 months in 2010 to 5.2 months in 2030 in the CLE scenario. The MIT measures would reduce statistical life shortening by another 0.9 months. Substantially larger reductions in life shortening due to the mitigation are found for China (1.8 months) and India (11-12 months).

Implementation of the SLCP measures in different world regions have different impacts on temperature changes in different latitude bands (Figure 2.1). Global SLCP measures would show largest effect in the Arctic, slowing the temperature increase by up to 0.6 degrees by 2050. For the mid northern Hemisphere, the measures would achieve up to 0.45 degrees in 2050.

These simple, metrics-based evaluations of regional temperature response (based on the RTP concept by Shindell 2012) have been repeated with four Earth Systems Models (ESM). Not surprisingly, model results show vary among each other (Figure 2.2), but in general show good agreement with the regional climate responses derived from the metrics approach.

Furthermore, there are other climate parameters than global annual mean temperature that are of relevance, related to tangible benefits that occur at the more near-term and regional level. The measures led to particularly beneficial climate responses in Southern Europe, where the surface warming was reduced by about 0.3 K from spring to autumn and precipitation rates were increased by about 15 (6-21) mm/yr (15 mm/yr corresponding to more than 4% of total precipitation), compared to the CLE scenario. Thus, the mitigation could help to alleviate expected future drought and water shortages in the Mediterranean region.

However, it has also been demonstrated that at the global scale, and addressing long-term perspectives, SLCP measures have only limited potential, and under no conditions can substitute for the mitigation of long-lived greenhouse gases.

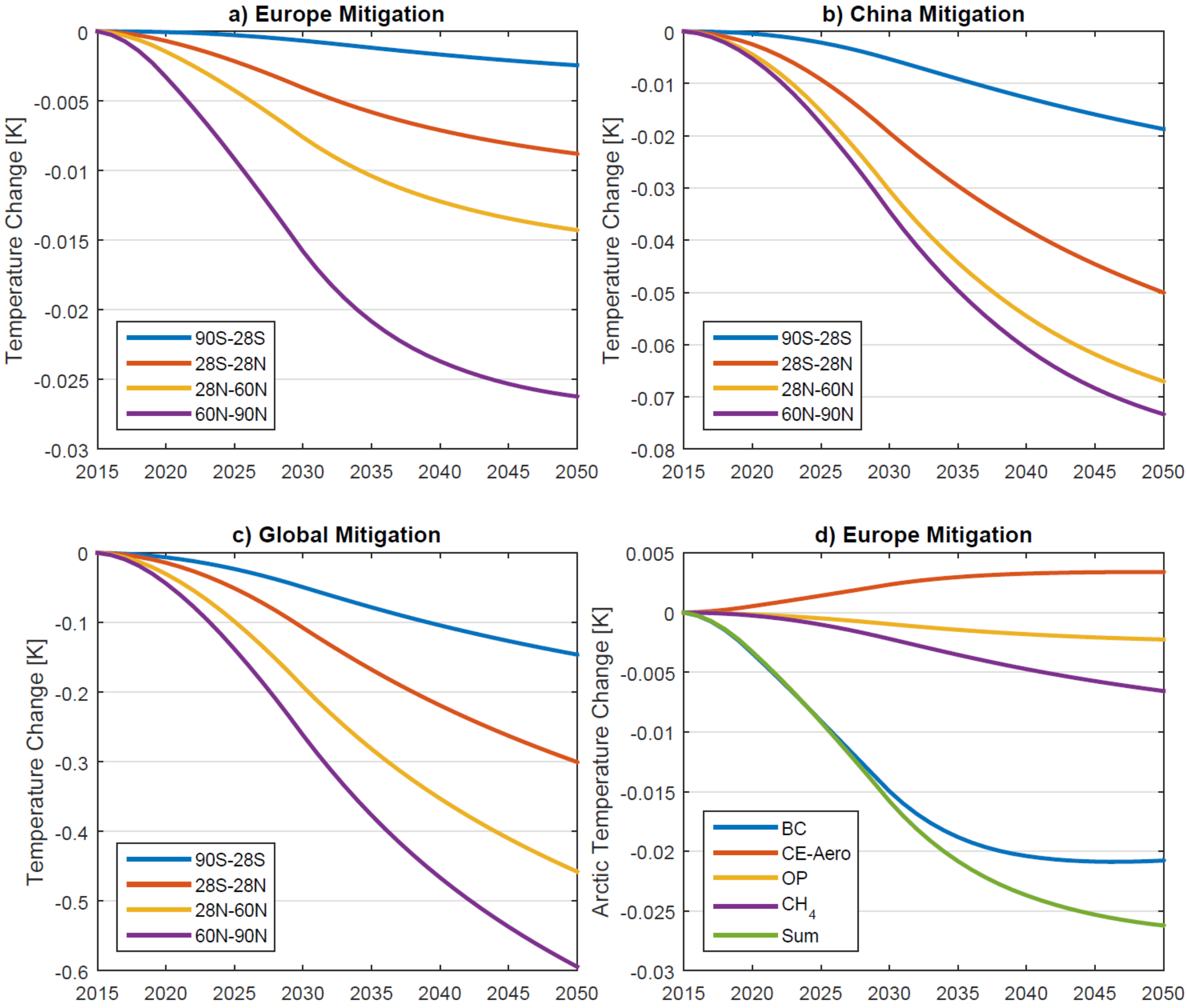

Figure 2.1: Annual mean surface temperature changes estimated by the ARTP method. Panels a-c: Changes in four latitude bands due to ECLIPSE mitigation scenario (MIT-CLE) for mitigation in Europe (a), China (b) and globally (c). Panel d: Arctic temperature changes due to mitigation of individual components from Europe. CE-Aero: Co-emitted aerosol (precursor) species (OA, SO_2 and NH_3), OP: Ozone precursors (NO_x, CO and NMVOCs). Note the different scales on the vertical axes.

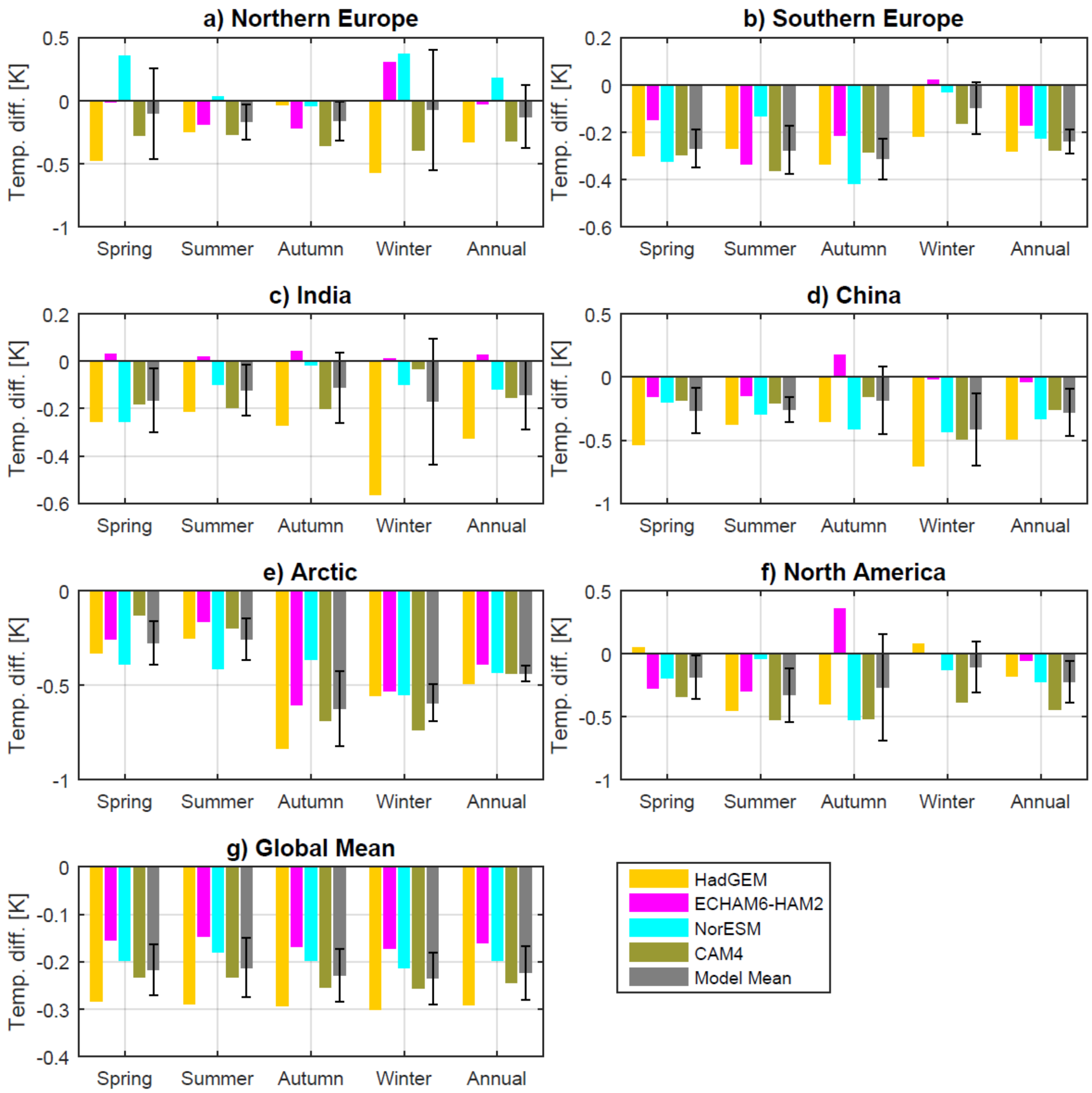

Figure 2.2: Seasonal and annual mean differences in surface temperatures (in K) in various regions (a-f) and for the whole globe (g) between transient simulations of the mitigation (MIT) and the current legislation (CLE) scenario, i.e. (MIT-CLE), averaged over the last 10 years of the simulations (2041-2050). Regions are defined as (a) 45°N-65°N,10°W-65°E, (b) 30°N-45°N, 10°W-65°E, (c) 7°N-35°N, 68°E-90°E, (d) 24°N-48°N, 80°E-132°E, (e) 60°N-90°N, (f) 30°N-60°N, 120°W-50°W. Results are shown for the four ECLIPSE models individually and for the multi-model mean. Negative values mean that temperatures are lower in the MIT than in the CLE scenario. Error bars on the model mean values show the standard deviations of the individual model results.

3 Policy approaches to address SLCPs

The potential benefits for human health, crops and climate mitigation has been demonstrated already by Shindell et al. 2012 for 17 of the 22 measures. After the message has been taken up by the UNEP/WMO Assessment on Black Carbon and Tropospheric Ozone (UNEP/WMO 2011), the international policy community recognized that international responses could facilitate rapid and widespread implementation of the measures.

At that time, several alternative institutional approaches were conceivable.

3.1 UNFCCC

As the SLCP measures offer clear climate benefits (in addition to their positive effects on human health and crops), inclusion of SLCPs into international climate negotiations has been seen as one potential approach.

The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty with the ultimate objective laid down in its Article 2: *"… to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.*

However, there is a range of value-based views over what level of climate change is dangerous. Scientific analysis can provide information on the risks of climate change, but deciding which risks are dangerous requires value judgements. This also includes the time scale of concern, as both the long-term temperature increase as well as the rate of change of temperature increase causes potentially dangerous impacts. To this end, the second part of Article 2 adds, in addition to the stabilization target, the *rate of change* as an additional objective: "*Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*."

In its Kyoto protocol, UNFCCC included a large group of gases spanning a broad range of timescales. HFCs have lifetimes down to months, CH_4 order of a decade while CO_2 operates on a scale of several centuries. At the time of designing the protocol, this broad span was not given much attention, and GWP with a 100 year time horizon was chosen as the metric to transform these gases on to a common scale of CO_2 equivalent emissions. After the adoption of the Kyoto Protocol, however, the challenges related to different lifetimes received more attention (e.g., Fuglestvedt et al., 2003; Shine, 2009).

Common metrics (CO_2eq based on the GWP100 metric) were defined to establish equivalency between these substances for the commitments of the protocol. Since then, negotiations proceed on these 'basket of greenhouse gases' with the main focus to achieve GHG stabilization within this century. Due to the absolute dominance of the importance of long-lived greenhouse gases for the long-term stabilization target (and presumably due to the prevailing scientific complexities and uncertainties associated with shorter-lived substances), UNFCCC negotiations did not open up for an inclusion of SLCPs. The considerations related to policy options and inclusion of SLCPs span several dimensions:

- Time. The SLCP have shorter lifetimes in the atmosphere and their net RF can be reduced more quickly by reductions in emissions than the LLGHGs.
- Space. The effects of emissions depend on location of emissions and may also have different regional response patterns than LLGHG.
- Their effects on the hydrological cycle may be different from that of the WMGHG.

The current UNFCCC led approach after Lima up to the COP in Paris adopted a bottom up approach where the countries are free to choose the level of ambitions of reductions, timing and mix of reductions themselves. This represents a new approach, and it may be argued that the full flexible bottom up approach may lead to higher participation and stronger deviations from baseline. In this context, the inclusion of SLCP is in line with the philosophy of the approach.

A somewhat more sophisticated design could also be envisioned: The ultimate goal of the UNFCCC addresses both level and rate of change. Thus, climate policies could be designed to meet both goals by formulating a long term stabilization target and a short term rate-focused target. This could be supported by a multi-gas approach that uses two baskets of components (Fuglestvedt et al., 2000; Rypdal et al., 2009, Daniel et al 2011). The same set of components can be included for both baskets, but with different weights in the two baskets.

The recent research on SLCPs has also raised the issue whether global mean temperature change or RF are the appropriate indicators for measuring the anthropogenic perturbations of the climate system. Several studies have shown different behaviour of the SLCP when other aspects of climate change are considered. Many impacts scale with globally average surface temperature but some do not; e.g., extreme precipitation, drought, and – further down the cause effect – food security.

In the design of multi-gas policies there will be a weighting of scientific accuracy on the one hand and political feasibility and level of participation on the other. Thus, some scientific simplifications may eventually lead to higher effectiveness in terms of climate impact due to broader coverage of components, possibilities and participation.

It was generally felt that, while there are clear benefits of SLCP measures on near-term climate change, an inclusion of SLCPs in the international climate negotiations under the UNFCCC could potentially divert attention from the urgency to mitigate long-lived greenhouse gases if long-term climate stabilization targets were to be achieved. This was supported by the clear finding in Shindell et al. 2012 about the rather small impact of SLCP measures on long-term temperature target, a finding that has been reconfirmed by the ECLIPSE project (Stohl et al. 2015).

3.2 Regional air quality policy frameworks

The dependence on location of emissions and to some extent the more regional character of effect of emissions may motivate for sub-global initiatives; i.e., regional agreements or other "club approaches". So far all efforts in international climate polices have applied a global mean perspective in terms of effects (i.e., global mean RF or dT). However, agreements may also focus on certain "receptor regions" or impacts regions. This could for instance be the Arctic, which already has received attention due to high observed warming rate recent decades and vulnerable environment (e.g., the AMAP report). Efforts to reduce the disturbance of the Asian monsoon could also be subject to this approach.

From a perspective on the air quality benefits of SLCP measures, implementation of the win-win measures could also be dealt with by existing regional air quality policy frameworks. However, in a global context this approach is still in its very early stage in most regions of the world. For example, the Convention on Long-Range Transboundary Air Pollution (CLRTAP) agreed to address BC in the revision of the Gothenburg Protocol in 2011 and to consider the impacts of CH_4 as an O_3 precursor in the longer term. Similarly, the European Commission in its 2013 Clean Air Policy package proposed the inclusion of CH_4 in the EU National Emission Ceilings Directive, to recognize the importance of CH_4 as a critical precursor for ground-level ozone with significant impacts on human health and vegetation damage.

Other regional agreements are fairly new, and predominantly concentrate on scientific cooperation and capacity building. These arrangements might serve as a platform from which to address the emerging challenges related to air pollution from BC and tropospheric O_3 and provide potential vehicles for finance, technology transfer and capacity development. Sharing good practices on an international scale, as is occurring within the Arctic Council, is a coordinated way could provide a helpful way forward.

3.3 Policy institutions addressing other development issues

A third alternative relates to the fact that largest benefits of SLCP measures would be delivered in regions where it is unlikely that significant national funds would be allocated to these issues due to other pressing development needs. International financing and technology support would catalyse and accelerate the adoption of the identified measures at sub-national, national and regional levels, especially in developing countries.

Financing would be most effective if specifically targeted towards pollution abatement actions that maximize air quality and climate benefits. Funds and activities to address CH_4 (such as the Global Methane Initiative; and the Global Methane Fund or Prototype Methane Financing Facility) and cookstoves (the Global Alliance for Clean Cookstoves) exist or are under consideration and may serve as models for other sectors. Expanded action will depend on donor recognition of the opportunity represented by SLCP reductions as a highly effective means to address near-term climate change both globally and especially in sensitive regions of the world. Black carbon and tropospheric O_3 may also be considered as part of other environment, development and energy initiatives such as bilateral assistance, the UN Development Assistance Framework, the World Bank Energy Strategy, the Poverty and Environment Initiative of UNEP and the United Nations Development Programme (UNDP), interagency cooperation initiatives in the UN system such as the Environment Management

Group and UN Energy, the UN Foundation, and the consideration by the UN Conference on Sustainable Development (Rio+20) of the institutional framework for sustainable development. These, and others, could take advantage of the opportunities identified in the Assessment to achieve their objectives.

3.4 CCAC

Eventually, in 2012 the governments of Bangladesh, Canada, Ghana, Mexico, Sweden and the United States, along with the United Nations Environment Programme (UNEP), came together to initiate the first effort to treat these pollutants as a collective challenge. Together, they formed the Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants (CCAC), and agreed on specific action-oriented initiatives to promote the implementation of the 17 win-win SLCP measures that have been identified before (www.ccaccoalition.org).

The Coalition's objectives are to address short-lived climate pollutants by:

- Raising awareness of short-lived climate pollutant impacts and mitigation strategies
- Enhancing and developing new national and regional actions, including by identifying and overcoming barriers, enhancing capacity, and mobilizing support
- Promoting best practices and showcasing successful efforts
- Improving scientific understanding of short-lived climate pollutant impacts and mitigation strategies

After only three years, by 2015 the Coalition has brought together more than 100 partner institutions including 46 national governments. As a voluntary initiative, CCAC recognizes that action on short-lived climate pollutants must complement and supplement, not replace, global action to reduce carbon dioxide, in particular efforts under the UNFCCC.

Currently, CCAC has formed common initiatives to accelerate action to reduce SLCP emissions from diesel engines, brick production, waste management, oil and natural gas production, agriculture and household cooking and domestic heating.

3.5 Policy options for addressing further SLCP reductions

The ECLIPSE project reviewed the original set of measures in view of updated information on emission sources, progressing implementation of emission control measures, and findings from the ECLIPSE project on regional and near-term climate impacts of SLCPs (Stohl et al. 2015). The findings confirm the importance of the 17 win-win SLCP measures that have been identified in Shindell et al. 2012 and subsequently taken up for practical implementation by the CCAC Climate and Clean Air Coalition. Thereby, the reconfirmation of the effectiveness of these measures lend support to the current activities of the CCAC initiatives in these fields.

In addition, four new opportunities for measures were found that could make significant additional contributions for a simultaneous improvement of human health, food security and near-term climate change. These four opportunities relate to

- Good practices for shale gas production
- Controlling emissions from flaring during oil and gas production
- Livestock breeding aimed at enhanced productivity and sustained animal health and fertility
- Substitution of kerosene lamps.

In principle, it seems conceivable that promotion of these additional emission reduction options could be taken up by the CCAC, as it has already established initiatives in related fields.

For instance, the introduction of global standards for good practices in shale gas operations could be added to the current priority of the CCAC "Oil and Gas Initiative". This initiative aims at accelerating methane and black carbon reductions by working with key stakeholders to encourage cooperation and support the implementation of new and existing measures to substantially reduce methane emissions from natural gas venting, leakage, and flaring (http://www.unep.org/ccac/Initiatives/tabid/130287/Default.aspx#sthash.N5vM8pCH.dpf).

The same holds for reducing black carbon emissions from gas flaring in the Arctic, which is already addressed by the CCAC Initiative, although not specifically for the Arctic region.

The CCAC has also established an initiative on SLCPs from agriculture, which aims at reducing emissions of methane and black carbon from the agricultural sector (http://www.unep.org/ccac/Initiatives/tabid/130287/Default.aspx#sthash.N5vM8pCH.dpf). Work is currently progressing along four components: (1) livestock & manure management; (2) open agricultural burning; (3) paddy rice cultivation; and (4) enteric fermentation (under development), and the modified cattle breeding practices would potentially fit as an alternative work stream.

A similar situation exists for the new option of eliminating kerosene lamps, which could complement current activities of the CCAC Initiative on Reducing SLCPs from Household Cooking and Domestic Heating**.** This initiative aims to work through advocacy and education to raise awareness of the harmful effect of emissions from this sector to human health climate, agriculture and climate.

It should be mentioned that the above analyses explored the suitability of the additional measures as extensions of already existing initiatives that deal with sources in the same sectors. However, there might well be political concerns from CCAC partner governments or business interests from CCAC stakeholder organizations that would make extensions of the current foci of CCAC initiatives difficult.

4 Conclusions

The ECLIPSE project has demonstrated that a well-chosen set of emission control measures would provide simultaneous benefits for human development, air quality and climate change. These measures can be grouped into three groups of opportunities:

(i) Measures that affect emissions of methane and that can be implemented centrally by large national and international energy companies, municipalities and through modified agricultural practices.

(ii) Technical measures that reduce emissions of black carbon, mainly at small stationary and mobile sources.

(iii) Non-technical measures to eliminate the most polluting activities, e.g., through improved enforcement of legislation or through economic and technical assistance to the poorest population.

Full implementation of these measures at the global scale, would reduce global anthropogenic emissions of CH_4 and BC by 50% and 80%, respectively. This would substantially reduce premature mortality from the exposure to fine particulate matter, and extend statistical life expectancy by one month in Europe, by 1.8 months in China, and by up to one year in India.

At the same time, these measures would achieve significant climate benefits in the near-term, with the largest impact felt in the Arctic, where these measures would slow the temperature increase by up to 0.6 degrees by 2050. In Southern Europe, these measures would reduce surface warming by about 0.3 K from spring to autumn, and increase precipitation rates during this season.

The findings confirm the importance of the 17 win-win SLCP measures that have been identified in Shindell et al. 2012 and subsequently taken up for practical implementation by the CCAC Climate and Clean Air Coalition. Thereby, the reconfirmation of the effectiveness of these measures lend support to the current activities of the CCAC initiatives in these fields.

In addition, four new opportunities for measures were found that could make significant additional contributions for a simultaneous improvement of human health, food security and near-term climate change. These four opportunities relate to

- Good practices for shale gas production
- Controlling emissions from flaring during oil and gas production
- Livestock breeding aimed at enhanced productivity and sustained animal health and fertility
- Substitution of kerosene lamps.

In principle, it seems conceivable that promotion of these additional emission reduction options could be considered by the CCAC, as it has already established initiatives in related fields. It should be mentioned that the above analyses explored the suitability of the additional measures as extensions of already existing initiatives that deal with sources in the same sectors. However, there might well be political concerns from CCAC partner governments or business interests from CCAC stakeholder organizations that would make extensions of the current foci of CCAC initiatives difficult.

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