UNEP/WMO Integrated Assessment of Black Carbon and Tropospheric Ozone

Main Findings

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• Black carbon, BC, and tropospheric ozone, O$_3$, are harmful air pollutants that also contribute to global and regional climate change.

• Together with methane, an important precursor to ozone, these are termed ‘Short-Lived Climate Forcers’ due to short residence time in atmosphere compared to CO$_2$.

• Control of black carbon particles and tropospheric ozone have immediate and multiple benefits for human well-being.
Black Carbon

- carbon-containing particulate matter (PM)
- absorbs light, affects health as PM
- results from inefficient and incomplete combustion
- emitted together with CO₂, CO, organic particulate matter (OC), other PM, SO₂, NOₓ

Greenhouse Forcing = 3 W/m**2
Brown Cloud Masking = -1.5 (+- 50%) W/m**2

Traps sunlight and heats the air

Reflects sunlight and cool

~60% of the total BC emissions is amenable to control

Figure Source: V. Ramanathan, and G. Carmichael, Nature Geoscience, 2008
S. Fuzzi and team, Project ABC
increase of precursor emissions by man has **more than doubled** the concentration of tropospheric ozone since pre-industrial times!
Assessment Objectives

• To review the scientific literature on black carbon (BC), tropospheric ozone and its precursors and assess the state of knowledge of their influence on climate and impacts as air pollutants

• To assess the extent by which carefully identified measures using existing technology to address BC and ozone can help protect near-term global and regional climate change

• Determine the co-benefits of the selected measures on health and crops

• Identify how the selected measures can be widely implemented with reference to case studies
Analysis Chain - Linking Emissions to SLCFs Distributions and Subsequent Radiative/Climate Impacts

E - emissions

- Emission Inventories
  - Natural - Anthropogenic
  - Meteorological Fields

CTM

4 - D Aerosol Distribution

Aerosol Optical Depth

Direct Radiative Effect

Direct Climate Forcing

CM

Climate Response

Impacts

Uncertainties

Significant

Increasing

Emission Scenarios / Policy Measures

Increasing Uncertainties

Significant
Emission Control Measures in the Analysis

IIASA ranked mitigation measures by the net GWP of their emission changes (considering CO, CH$_4$, BC, OC, SO$_2$, NO$_X$, nmVOCs, and CO$_2$), picked the top measures.

‘Methane measures’

• extraction and long-distance transport of fossil fuels (~25%)
• waste management; municipal, landfills & wastewater (~10%)
• agriculture; livestock manure & intermittent rice aeration (~5%)

(% reduction in 2030 relative to reference)
Black Carbon Measures

‘BC Measures’ that reduce emissions of black carbon and co-emissions (e.g. OC, CO)

- Diesel vehicles (particle filters+)
- Eliminate high emitting vehicles
- Coal briquettes replacing coal in residential stoves
- Pellet stoves & boilers replacing residential wood burning in industrialized countries
- Clean-burning cookstoves in developing countries OR replace biomass with other fuel
- Modern brick kilns
- Modern coke ovens
- Ban of open burning of agricultural waste
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>Based on energy and fuel projections of the (IEA) <em>World Energy Outlook 2009</em> and incorporating all presently agreed policies affecting emissions</td>
</tr>
<tr>
<td>CO$_2$ Measures</td>
<td>Emissions modelled using the assumptions of the IEA 450ppm Scenario and the IIASA GAINS database. Includes CO$_2$ measures only.</td>
</tr>
<tr>
<td>CH$_4$ Measures</td>
<td>Reference scenario plus the CH4 measures</td>
</tr>
<tr>
<td>BC Measures</td>
<td>Reference scenario plus the BC measures (also affects other pollutants, especially BC, OC, and CO)</td>
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</tbody>
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Effect of Measures on Emissions Projected in 2030 Relative to 2005

9 BC measures reduce ~80% of BC

Reference: CH₄ increases 7 CH₄ measures reduce ~25% of CH₄ (2005); or ~40% relative to 2030

BC measures reduce CO
Result for Global Temperature Change:
CO₂ and SLCF Measures are Complementary Strategies
Climate Impact of Measures: Starting Now vs Delayed

![Graph showing the impact of measures on climate, comparing starting now vs delayed actions.](image)
Regional Climate Changes: Change in atmospheric forcing at 2030 relative to the reference case in the GISS & ECHEM models.

- Dark areas: where the biggest energy change to the atmosphere occurs
- This drives regional weather pattern changes
Global and Regional Temperature Change Relative to the Reference Scenario (hybrid modelling of GISS, ECHAM)

Methane measures: Relatively uniform benefits, low uncertainty

BC measures: Larger benefits in North, greater uncertainty for temperature (large regional precipitation & glacial melting benefits)

Reduced Arctic warming by 0.7°C by 2040 compared to the reference Scenario, with measures taken 2010---2030. Mitigating ~2/3 of projected 1.2°C warming
Impact of the Measures on Health and Crop Yields

- Models give PM$_{2.5}$ and ozone concentrations for health and crop yield impact assessment.
- Concentration-response relationships from literature used to evaluate global impacts.

Exposure of wheat to ozone in Pakistan

Clean air → Air with ambient ozone → Crop growth comparison.
Impact of the Measures on Health, Crop yields and Climate

**Climate change**

- CH$_4$ measures
- CH$_4$ + BC measures

**Human health**

- CH$_4$ measures
- CH$_4$ + BC measures

**Food security**

- CH$_4$ measures
- CH$_4$ + BC measures

- Global mean avoided warming in 2050 (°C)
- Annually avoided premature deaths (millions)
- Annually avoided crop yield losses (total maize, rice, soybean and wheat, millions tonnes)
Main Findings of the Assessment

16 identified measures, implemented by 2030, would reduce global warming by 0.5°C (0.2-0.7°C) in 2050 – half the warming projected by the Reference Scenario.

- Near-term measures would improve the chance of not exceeding 2°C target, but only if CO₂ is also addressed, starting now (complementary strategies; not alternatives).

- Substantial regional climate benefits: e.g. in the Arctic reduce warming by 0.7 °C (range 0.2-1.3°C by 2040), for Himalayas and South Asian monsoon.

- Health and crop benefits are substantial – could avoid 2.4 million premature deaths (0.7-4.6 million) and loss of 52 million tonnes (30-140 million) of maize, rice, wheat and soybean, each year (plus indoor air pollution – chronic health).

- The identified measures are all currently in use in different regions around the world; much wider and more rapid implementation is required to achieve the full benefits.

- Many measures achieve cost savings over time. However, initial capital investment could be problematic, necessitating additional strategic support and investment.
‘An Integrated Assessment of Black Carbon and Tropospheric Ozone’