Air Pollutants Contribute to Climate Change

These pollutants are important not just at the surface!
Progression in Scientific Understanding

Direct BC Forcing:
0.34 (0.09–0.59) W m\(^{-2}\) in IPCC AR4 (2007)
0.45 (0.20-0.90) W m\(^{-2}\) in UNEP/WMO (2011)
0.71 (0.08-1.27) W m\(^{-2}\) in Bond et al. (2013)
0.54 (0.10-1.03) W m\(^{-2}\) in IPCC AR5 (2013)

Based on observations and models!

Indirect BC Forcing:
0.0 (-0.6 to 0.5) W m\(^{-2}\) in UNEP/WMO (2011)
0.2 (-0.5 to +1.1) W m\(^{-2}\) in Bond et al. (2013)
No estimate in IPCC AR5 (2013)

Health Impacts (ambient):
800,000 premature deaths yr\(^{-1}\) due to urban PM2.5 in GBD 2004
~3.6 million due to PM2.5 & ozone in UNEP 2011
~3.4 million due to PM2.5 & ozone GBD 2012 (Lim et al, Lancet)
Uncertainties: Global

Probability of cumulative climate forcing for source categories
Year 2000 emission rates, scaled to year 2005 observations

- On-road diesel
- Off-road diesel
- Industrial coal
- Other BC sources
- Residential coal
- Biofuel cooking
- Biofuel heating
- Agricultural fields
- Forests
- Grasses and woodlands
- Total BC-rich sources
- Power generation
- Other low-BC sources
- Total

Cumulative global forcing (W m⁻²)

Bond et al, JGR, 2013
Avoided Warming from Black Carbon Measures in 2050

- Replace traditional brick kilns with vertical shaft kilns
- Replace traditional coke ovens with modern recovery ovens
- Switch from traditional biomass cookstoves to stoves fueled by LPG or biogas or to fan-assisted biomass stoves (in developing countries)
- Replace current residential wood burning technologies with pellet stoves and boilers (in industrialized countries)
- Replace lump coal with coal briquettes in cooking and heating stoves
- Elimination of high-emitting vehicles
- Additional reduction from Euro-6/VI vehicle standards (including DPF) after elimination of high-emitters
- Ban of open burning of agricultural residue

UNEP/WMO, 2011
Regional variation

**Figure 6:** Average Radiative Forcing Estimates for the Himalayas for a Range of Potential Black Carbon Emissions Reductions

**Figure 7:** Average Radiative Forcing Estimates for East Africa from Black Carbon Emissions Reductions

Note: Error bar for cookstove measure extends down to $-1.27 \, \text{W/m}^2$. From “On This Ice”, ICCI/WB, 2013.
Regional variation

Figure 18: Probability Density Functions (pdfs) for the Total Forcing due to All the Measures. PDFs are calculated using the mean of three methods (UNEP-based, Bond-based, and the mean of those two for direct plus GISS internally calculated indirect) as the central estimate and the largest of the three standard deviations as the range. Numerical values are central estimate (W m⁻²); probabilities for RF<0. Values for the Andes are -0.3 W m⁻²; 68%.

From “On This Ice”, ICCI/WB, 2013
Intermodel variation \((i.e. \ physics\ uncertainties)\)

GISS model analysis, impact of reducing E & S Asia emissions
mass-based aerosol model (solid) vs full aerosol microphysics (dashed)
Including CO2

Bond et al, JGR, 2013
## Multiple Benefits of Clean Air

<table>
<thead>
<tr>
<th>Description</th>
<th>Certainty of major SLCP-related climate benefit</th>
<th>Aggregate level of potential health benefit</th>
<th>Main health benefit(s)</th>
<th>Potential level of CO₂ reduction cobenefit</th>
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</thead>
<tbody>
<tr>
<td>Household air pollution and building design</td>
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<tr>
<td>Improved cook stoves and fuel switching to reduce solid fuel use</td>
<td>Medium to high</td>
<td>High</td>
<td>Improved air quality, lower injury risk from carrying fuel, lower violence risk during fuel collection, fewer burns</td>
<td>Medium$</td>
</tr>
<tr>
<td>Improved lighting to replace kerosene lamps</td>
<td>Medium</td>
<td>Medium</td>
<td>Improved air quality, fewer burns</td>
<td>Low to medium</td>
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<tr>
<td>Electricity</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Switch from fossil fuels to renewables†</td>
<td>Low</td>
<td>High (coal and oil) or low to medium (gas)</td>
<td>Improved air quality, fewer occupational injuries</td>
<td>High</td>
</tr>
<tr>
<td>Control of fugitive emissions from fossil fuel industry</td>
<td>High</td>
<td>Low</td>
<td>Improved air quality</td>
<td>Low to medium#</td>
</tr>
</tbody>
</table>

Scovronick et al, Lancet, 2015
Valuing Clean Air

Develop a broader Social Cost that includes impacts on human health, agriculture, etc. via climate & air quality; includes all the key pollutants causing both problems

Model response to emissions of one pollutant at a time

Climate impacts of pollutants other than carbon dioxide

Same valuation methodology for air quality and climate
Valuing Emissions

Shindell, Climatic Change, 2015
Preliminary analysis based upon method of Shindell, Climatic Change, 2015; control measures are applied to indicated IPCC emissions categories.
How to decide what to do where?

Need to know all the direct emissions (not just PM)

Need to evaluate indirect emissions (CO2)

While all PM2.5 reductions will be good for health and all emissions reductions will yield net societal benefits, ideally one would maximize benefits when comparing stove options.

One could also focus on particular regions for the sake of maximizing climate change mitigation (with ethical consequences of course).