Control of Methane Emissions for Ozone Air Quality Purposes

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Air quality-Climate Linkage:

CH$_4$, O$_3$ are important greenhouse gases
CH$_4$ contributes to background O$_3$ in surface air

- Stratospheric O$_3$
- Free Troposphere (~12 km)

Direct Intercontinental Transport

boundary layer (0-3 km)

Global Background O$_3$

- NO, VOC
- CH$_4$, CO
- NO$_x$

Air quality-Climate Linkage:

CH$_4$, O$_3$ are important greenhouse gases

CH$_4$ contributes to background O$_3$ in surface air

Air pollution (smog)
How Much Ozone Can Be Reduced?

50% reduction in anthropogenic CH$_4$ emissions (Fiore et al., GRL, 2002)

- $\sim$3 ppb ozone decrease in US summer (steady-state)
- $\sim$60% realized in 10 yr, $\sim$80% in 20 yr

Comparison: Clean Air Interstate Rule (proposed) reduces 0.86 ppb over the eastern US, at $0.88$ billion yr$^{-1}$, through NO$_x$ control.
Global Human Mortality Benefits of Methane & Ozone Reductions

Avoided global premature mortalities from a 20% reduction in global anthropogenic CH$_4$ emissions.

**Atmospheric Model** - Run MOZART-2 using NCEP meteorology
  - 2000 base case (CH$_4$ = 1760 ppb)
  - 2030 SRES A2 scenario (CH$_4$ = 2163 ppb)
  - 2030 A2 methane control (CH$_4$ = 1865 ppb)

**Population Distribution** - Projected for 2000-2030 consistent with A2

**Ozone - Mortality Relationship** - Bell et al. (2004) daily time series, for 8-hr. daily max.


- Calculate avoided mortality at each model grid cell on each day, assuming a low-concentration threshold of 25 ppb.
2030 Ozone Reduction

Change in 8-hr. ozone from a 20% decrease in global anthropogenic methane emissions.

Global average ozone (ppb)

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2030</th>
<th>(\Delta O_3) 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-hr.</td>
<td>29.0</td>
<td>33.3</td>
<td>-0.78</td>
</tr>
<tr>
<td>8-hr.</td>
<td>31.4</td>
<td>36.2</td>
<td>-0.82</td>
</tr>
<tr>
<td>8-hr. in populated cells</td>
<td>40.2</td>
<td>47.6</td>
<td>-0.98</td>
</tr>
</tbody>
</table>

Anthrop. emissions 2000-2030: CH\(_4\) +48% NO\(_X\) +70%
Avoided premature mortalities per year
20% CH₄ emissions reduction

2030 avoided mortalities: 34,000 (~0.04% of total deaths),
630,000 avoided mortalities in 2000-2030.
Avoided premature mortalities per year
20% CH$_4$ emissions reduction

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2030 Avoided Premature Mortalities

25 ppb threshold, CH$_4$ reductions starting in 2000
2030 Avoided Mortalities per Million People

25 ppb threshold, CH$_4$ reductions starting in 2000
Valuation of Global Human Mortality Benefits

Assume $1 \text{ million}$ per avoided premature mortality ($5 \text{ million}$ in industrialized nations and $0.5 \text{ million}$ in developing nations).

$=>$ The 2030 monetized benefit is $34 \text{ billion yr}^{-1}$.

$=>$ Discount future benefits to a constant benefit stream (5% yr$^{-1}$): $17 \text{ billion yr}^{-1}$.

Global benefit - divide by 65 Mton CH$_4$ yr$^{-1}$: $260 \text{ per ton CH}_4$

$=$ $13 \text{ per ton CO}_2 \text{ eq.}$
# Monetized Non-mortality Benefits of Global Ozone Reductions

Assume: $\Delta O_3 \propto \Delta (\text{CH}_4 \text{ emissions}), \ \Delta (\text{monetized benefits}) \propto \Delta O_3$

Benefits per 1 ppb ozone reduction ($\text{\$billion yr}^{-1} \text{ppb}^{-1}$)

<table>
<thead>
<tr>
<th>Source</th>
<th>US</th>
<th>EU-15</th>
<th>China, S. Korea, Japan</th>
<th>Extrapolate Globally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0.40</td>
<td>0.51</td>
<td>0.42</td>
<td>2.8 (0.04 - 5.6)</td>
</tr>
<tr>
<td>Forestry</td>
<td>0.44</td>
<td></td>
<td></td>
<td>1.7 (0.5 - 2.9)</td>
</tr>
<tr>
<td>Human health (non-mortality)</td>
<td>0.59</td>
<td>0.60</td>
<td></td>
<td>3.0 (2.0 - 4.1)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>7.5 (4.4 - 10.7)</strong></td>
</tr>
</tbody>
</table>

Apply methane-ozone sensitivity: $7.5 \text{ billion yr}^{-1} \text{ppb}^{-1}$ ($4.4 - 10.7$)

$\rightarrow 132 \text{ per ton CH}_4$ ($78 - 189$)

Discount future benefits (5% yr$^{-1}$): $81 \text{ per ton CH}_4$ ($48 - 116$)

= $3.9 \text{ per ton CO}_2 \text{ eq.}$ ($2.3 - 5.5$)

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Combine Benefits and Compare with Costs

Add the monetized benefits for mortality and non-mortality:

$260 + $80 = $340 per ton CH$_4$ = $16 per ton CO$_2$ eq.

“Air quality ancillary benefits of CO$_2$ mitigation”

= $0.5 - $140 per ton CO$_2$ (IPCC, 2001)

Accounting for all global measures less than $340 per ton CH$_4$ …

… a global reduction of 84 Mton CH$_4$ yr$^{-1}$ can be justified - ~25% of current global anthropogenic emissions.
# Methane in Ozone Management

<table>
<thead>
<tr>
<th></th>
<th>NO$_x$ and NMVOCs</th>
<th>Methane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-cost emission</td>
<td>Few; least-cost options already exhausted in some regions</td>
<td>Many cost-saving and low-cost measures exist</td>
</tr>
<tr>
<td>Potential for ozone reductions</td>
<td>Large</td>
<td>Limited to ~2 ppb in the coming decades</td>
</tr>
<tr>
<td>Time scale</td>
<td>Hours to weeks</td>
<td>Realized gradually (~12 yr)</td>
</tr>
<tr>
<td>Spatial scale</td>
<td>Local to regional, focusing on polluted areas (NO$_x$ also global)</td>
<td>Global, widespread benefits</td>
</tr>
<tr>
<td>Impact on high-ozone episodes</td>
<td>Strong</td>
<td>Ozone reduced roughly equally in all cases</td>
</tr>
<tr>
<td>Radiative forcing of climate</td>
<td>Small</td>
<td>Beneficial, from both methane and ozone</td>
</tr>
<tr>
<td>Ancillary benefits</td>
<td>Reduced fine PM, nitrogen and acidic deposition (NO$_x$), and airborne toxics (NMVOC)</td>
<td>Many measures make methane available for energy; controls may reduce NMVOC emissions</td>
</tr>
</tbody>
</table>

If California eliminated its methane emissions, ozone would reduce by ~ 0.02 ppb \( \rightarrow \) suggests national / international management.

A Global Methane Reduction Scenario

Reducing 65 Mton CH$_4$ yr$^{-1}$ (~20% of anthropogenic emissions) will:

- Reduce 8-hr. ozone globally by ~1 ppb.
- Reduce global radiative forcing by ~0.13 W m$^{-2}$.
- Save ~$1.9$ billion yr$^{-1}$ through implementation.
- Avoid ~34,000 premature deaths globally in 2030.
- Avoid other damages to health, agriculture, and forestry, valued at ~$8$ billion yr$^{-1}$.
- Provide ~2% of global natural gas production.
Ozone Abatement Strategies Evolve as our Understanding of the Ozone Problem Improves

- **1950s**
  - O₃ smog recognized as an URBAN problem: Los Angeles, Haagen-Smit identifies chemical mechanism

- **1980s**
  - Smog considered REGIONAL problem; role of biogenic VOCs discovered

- **Present**
  - A GLOBAL perspective: role of intercontinental transport, background

**Abatement Strategy:**
- NMVOCs
- + NOₓ
- + CH₄??
Conclusions

• Methane emission reductions are viable in long-term ozone management.

• Cost-saving methane abatement measures identified globally can reduce background ozone by 0.4-0.7 ppb.

• Roughly 34,000 premature mortalities can be avoided in 2030 through a 20% reduction of current global anthropogenic methane emissions.

• Total monetized benefits are estimated to be $340 per ton CH$_4$ ($16$ per ton CO$_2$ eq.) - which can justify reducing ~25% of anthropogenic emissions.

• Methane abatement also has benefits for climate, natural ecosystems, and energy supply, although the ozone benefits are realized gradually (~12 yr).

• Air quality planning should consider national & international methane controls alongside NO$_X$ and NMVOC controls.

Double dividend of methane controls:
Decreased greenhouse warming and improved air quality