



Ozone Air Quality Management by Reducing Methane Emissions: Global Health Benefits

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1. Motivation

- Methane**, the most abundant volatile organic compound (VOC), **contributes to the tropospheric ozone background concentration** through oxidation in the presence of nitrogen oxides (NO_x). Background ozone has roughly doubled since the preindustrial, to 20-30 ppbv, due to anthropogenic emissions of methane and NO_x. This background underlies urban and regional ozone.
- Ozone affects human health, crop productivity, and ecosystems, and recent studies have shown substantial evidence that **ozone influences premature mortality**.
- Methane and ozone are also important greenhouse gases**, ranking only behind CO₂ in anthropogenic climate forcing.
- Ozone management has emphasized urban and regional reductions of non-methane VOCs (NMVOCs) and NO_x. Methane control has not been considered because its long lifetime (8-9 yr) suggests that it has little local benefit.
- However, climate abatement research suggests that **cost-saving and low-cost methane reductions are available**.

GOAL: Consider the viability of methane control for managing tropospheric ozone, by considering the costs of control and benefits for avoided human mortality.

2. Potential for Ozone Control via Methane

In Figure 1, estimates of the costs of methane abatement are combined with the ozone sensitivity to methane from Fiore *et al.* (2002), assuming that ozone responds proportionally to methane emissions.

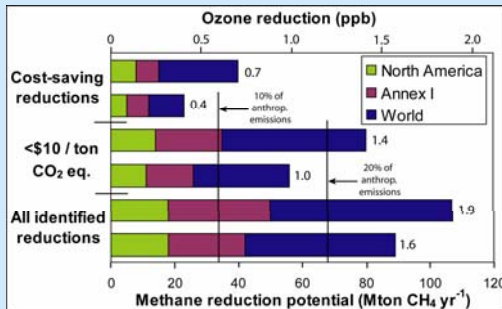


Figure 1. Methane reduction potential in 2010 from IEA (top bar of each pair) and EPA (bottom), and corresponding reductions in global surface ozone. Both IEA and EPA focus on industrial methane sources, omitting possible methane mitigation from agriculture. West & Fiore (2005)

NET COST SAVINGS: ~10% of global anthropogenic methane emissions can be reduced at a net cost savings, due to the recovery of natural gas.

OZONE RESPONSE: ~0.5 ppb from identified global cost-saving controls; ~1 ppb at modest cost.

TIME SCALE: ~60% of the ozone reductions in Figure 2 will be realized in 10 yr, ~80% in 20 yr (using a methane perturbation lifetime of 12 yr).

3. Response of Surface Ozone to Methane Mitigation

We consider a methane emission reduction of 65 Mton CH₄ yr⁻¹ (~20% of current global anthropogenic emissions), implemented in 2010 and sustained relative to the SRES A2 scenario until 2030. The MOZART-2 tropospheric chemistry-transport model is used to simulate surface ozone in 2000, 2030, and the 2030 methane perturbation case.

Surface ozone is projected to decrease globally by ~1 ppbv due to the 20% methane emission reduction (Table 1). This change in surface ozone is fairly uniform globally, with the largest reductions in the temperate Northern Hemisphere (Figure 2).

	2000	2030 A2	ΔO ₃ 2030
24-hr. avg.	29.1	33.6	-0.82
8-hr. daily max. population-weighted	49.4	61.7	-1.16

Table 1. Global average surface ozone (ppbv) in 2000 and 2030, and the steady-state change in ozone due to a 65 Mton CH₄ yr⁻¹ reduction.

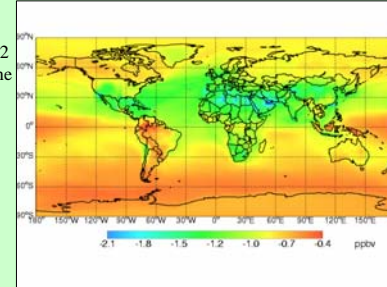


Figure 2. Change in annual average daily maximum 8-hr. surface ozone at steady state, due to a 65 Mton CH₄ yr⁻¹ reduction, relative to the 2030 A2 base case.

4. Global Mortality Benefits of Reduced Ozone

The daily ozone change is overlaid onto the future population, which is projected consistent with the A2 scenario. We use the daily ozone-mortality relationship from Bell *et al.* (2004) for the 8-hr. daily maximum, and non-accident baseline mortality rates from WHO (2004). We assume a low-concentration threshold of 25 ppbv, below which ozone is assumed to have no effect on mortality.

Figure 3 shows that **~30,000 premature mortalities are prevented in the year 2030, with ~370,000 avoided premature mortalities between 2010 and 2030**. These avoided mortalities are distributed globally, with the greatest benefits per person in Africa. Avoided mortalities are sensitive to uncertainties in the ozone response to methane and the ozone-mortality relationship.

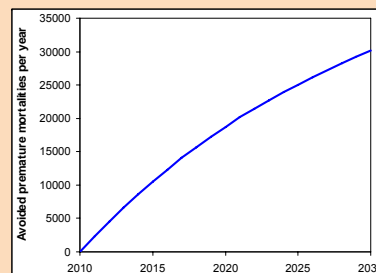


Figure 3. Avoided global premature mortalities from a 65 Mton CH₄ yr⁻¹ emission reduction.

Using the marginal cost of reducing 65 Mton CH₄ yr⁻¹ of ~\$100 per ton CH₄ (IEA, 2003), and a discount rate of 5% yr⁻¹, the marginal cost-effectiveness of methane reductions are estimated to be **\$420,000 per avoided mortality**. The 65 Mton CH₄ yr⁻¹ reduction would be fully justified in cost-benefit terms for any value of a statistical life >\$420,000.

If \$1 million is used as the global average value of a statistical life, the **benefit of the methane reduction is \$240 per ton CH₄ (\$12 per ton CO₂ eq.)**. Since CO₂ reductions are currently trading at \$10-25 per ton CO₂, our results suggest that much of the methane reductions currently pursued for climate purposes could be justified for air quality and human health.

5. Multiple Benefits of Reducing Methane

Reducing 65 Mton CH₄ yr⁻¹ (~20% of anthropogenic methane) can be justified solely on the benefits of avoided human mortality from reduced ozone. This reduction would:

- Reduce ozone globally by **~1 ppb**.
- Reduce global radiative forcing of climate by **~0.14 Wm⁻²** (75% from methane, 25% from ozone).
- Provide **~2% of current global natural gas production**.
- Save **~\$1.9 billion yr⁻¹** through implementation (IEA, 2003).
- Prevent **~30,000 premature deaths globally in 2030, ~370,000 from 2010-2030**.
- Avoid other damages to health, agriculture, and forestry, valued at **~\$5 billion yr⁻¹**.

6. Methane in Ozone Management

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

Table 2. Comparative advantages of managing ozone through local / regional NO_x, NMVOC and CO emission reductions, and through global methane reductions. West & Fiore (2005)

7. Conclusions

- Methane emission reductions decrease ozone and improve air quality everywhere, while also reducing greenhouse warming.**
- A 20% reduction of current global anthropogenic methane emissions will:**
 - Come at a **net cost-savings** using identified technologies.
 - Avoid roughly **30,000 premature mortalities in 2030 (17,000-56,000), ~370,000 from 2010-2030**.
- Monetized health benefits are estimated to be \$240 per ton CH₄ (\$12 per ton CO₂ eq.), which can justify the 20% methane reduction.**
- Global identified cost-saving measures alone can reduce ozone by ~0.5 ppbv globally.**
- Methane abatement can be a cost-effective component of international long-term (decadal) ozone management, complementing local and regional ozone management.**

References

- West, J. J., and A. M. Fiore (2005) Management of tropospheric ozone by reducing methane emissions, *Environmental Science & Technology*, 39(13): 4685-4691.
- West, J. J., A. M. Fiore, L. W. Horowitz, and D. L. Mauzerall (submitted) Mitigating ozone pollution with methane emission controls: global health benefits, *Proceedings of the National Academy of Sciences*.
- Fiore, A. M., D. J. Jacob, B. D. Field, D. G. Streets, S. D. Fernandes, and C. Jang (2002) Linking ozone pollution and climate change: the case for controlling methane, *Geophysical Research Letters*, 29(19): 1919.