Air Quality Impacts from Carbon Capture and Storage

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Objective

- Quantify the *ammonia emissions* from one of the major potential carbon capturing processes, *amine scrubbing*.
- Evaluate the implications for *air quality*, focusing on the impact on $PM_{2.5}$.

1. Background

- Carbon Capture and Storage (CCS) is a potential strategy for reducing CO_2 emissions at coal power plants.
- Amine scrubbing is one of the most proven CCS technologies currently available [1].
- The major potential environmental concerns of amine scrubbing are spent solvent, amine and NH_3 emissions [2].
- An aggressive deployment of amine scrubbing may increase NH_3, a $PM_{2.5}$ precursor, in the atmosphere.

2. NH_3 emissions and CCS in 2050

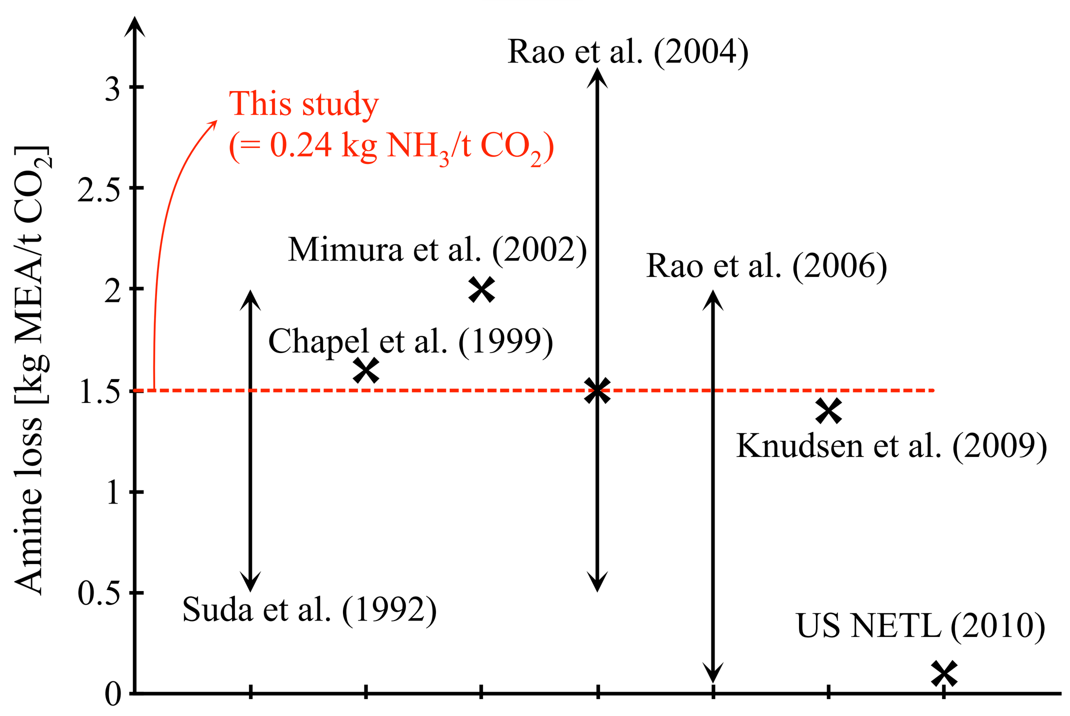

Figure 1: Amine loss

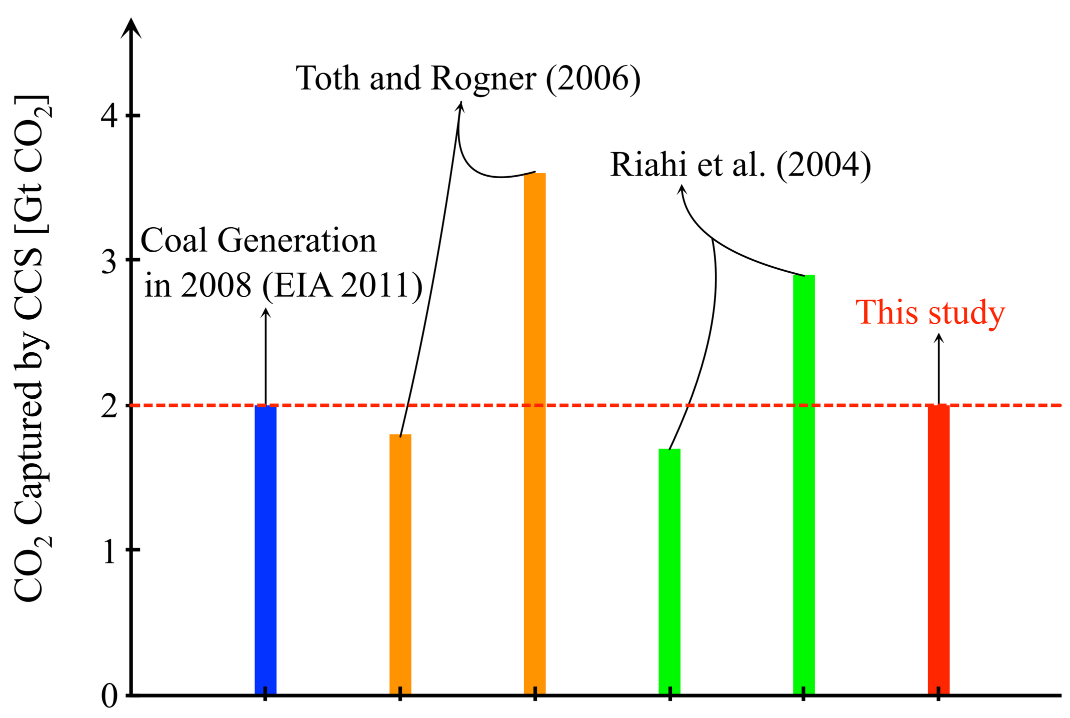

Figure 2: US CCS deployment potential in 2050

- US NH_3 emissions from CCS in 2050

  = (NH_3 Emissions Factor) × (CO_2 captured by CCS)

  = 0.43 Tg N/year in the Eastern US

3. Scenarios

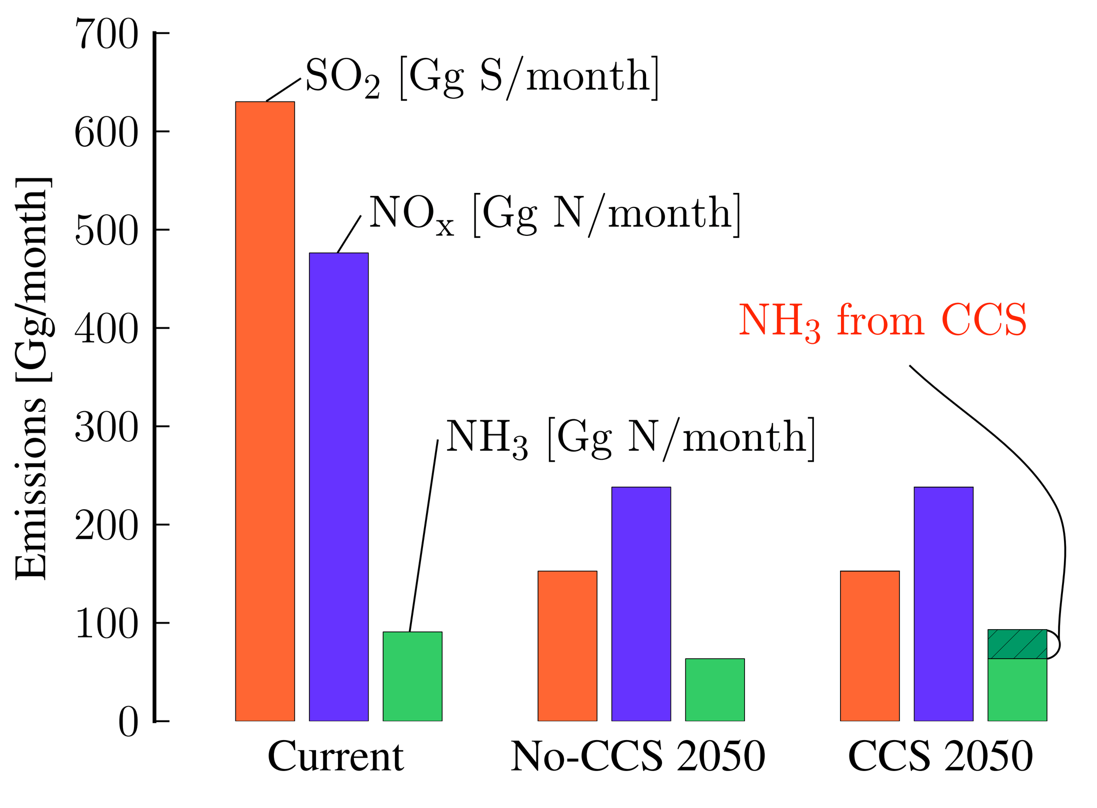

Figure 3: January emissions assumptions of three scenarios

- **Current**: represents current emissions as of 2001-2002.
- **No-CCS 2050**: Current and future air quality regulations reduce 80% of SO_2, 50% of NO_x, and 30% of NH_3.
- **CCS 2050**: In addition, coal power plants with amine scrubbing CCS capture 2.0 Gt CO_2/year.

4. $PM_{2.5}$ and Ammonia

- $PM_{2.5}$, particulate matter having a diameter of 2.5 μm or less, is known to pose the greatest human health risks.
- NH_3 reacts with SO_2 and NO_x *non-linearly* to form $PM_{2.5}$.
- PM nitrate (NH_4NO_3) formation may significantly increase $PM_{2.5}$ concentrations in winter in the US [3].

Table 1: $PM_{2.5}$ nitrate formation governing conditions.

NH_3 availability	$PM_{2.5}$ nitrate form?	Limited by
Limited	No	-
Moderate	Yes	NH_3
Excess	Yes	HNO_3

5. Results of Air Quality Simulations

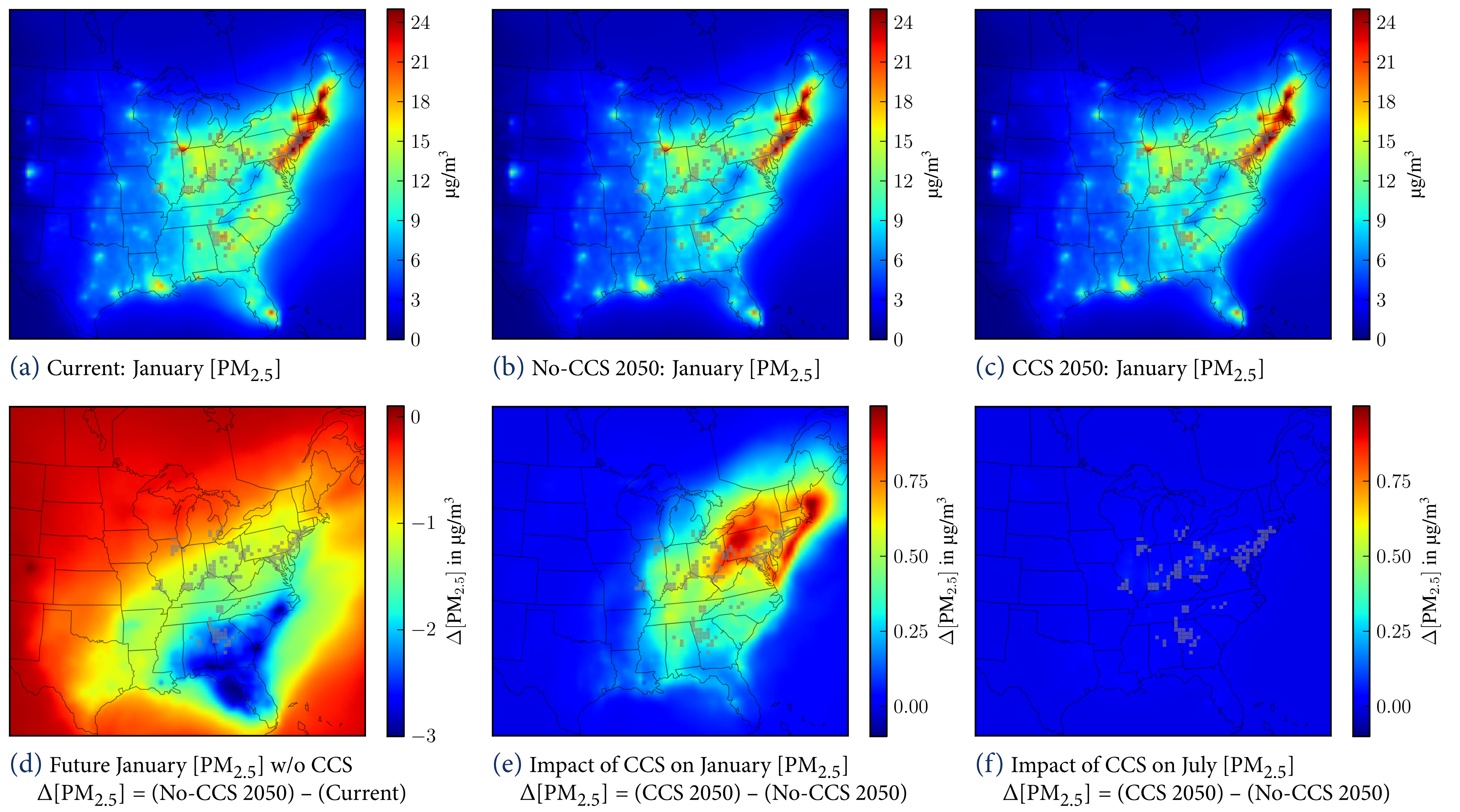

Figure 4: Air quality simulation results from PMCAMx, a 3D chemical transport model. The average $PM_{2.5}$ increase in nonattainment areas (Gray dots) is 0.53 μg/m^3 in January and 0.04 μg/m^3 in July.

6. Sensitivity Analyses

Table 2: Emissions assumption of two sensitivity scenarios, which capture the uncertainty of future emissions.

Scenarios for 2050	SO_2	NO_x	NH_3
No-CCS 2050	80%	50%	30%
High-sensitivity	90%	20%	50%
Low-sensitivity	30%	70%	0%

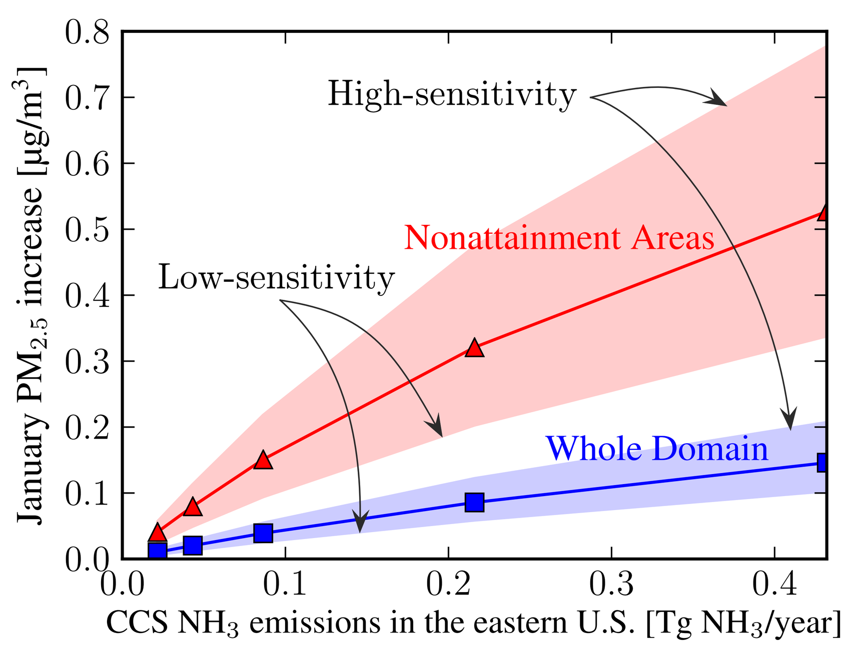

Figure 5: Sensitivity of January $PM_{2.5}$ increase to two major uncertainties, NH_3 emissions and future air quality.

7. Social Health Risks and Economic Valuations

- Software: BenMAP 4.0 developed by US EPA.
- Health Endpoint: Premature death from $PM_{2.5}$.
- Value of a Statistical Life (VSL): $8 millions (in 2010$).

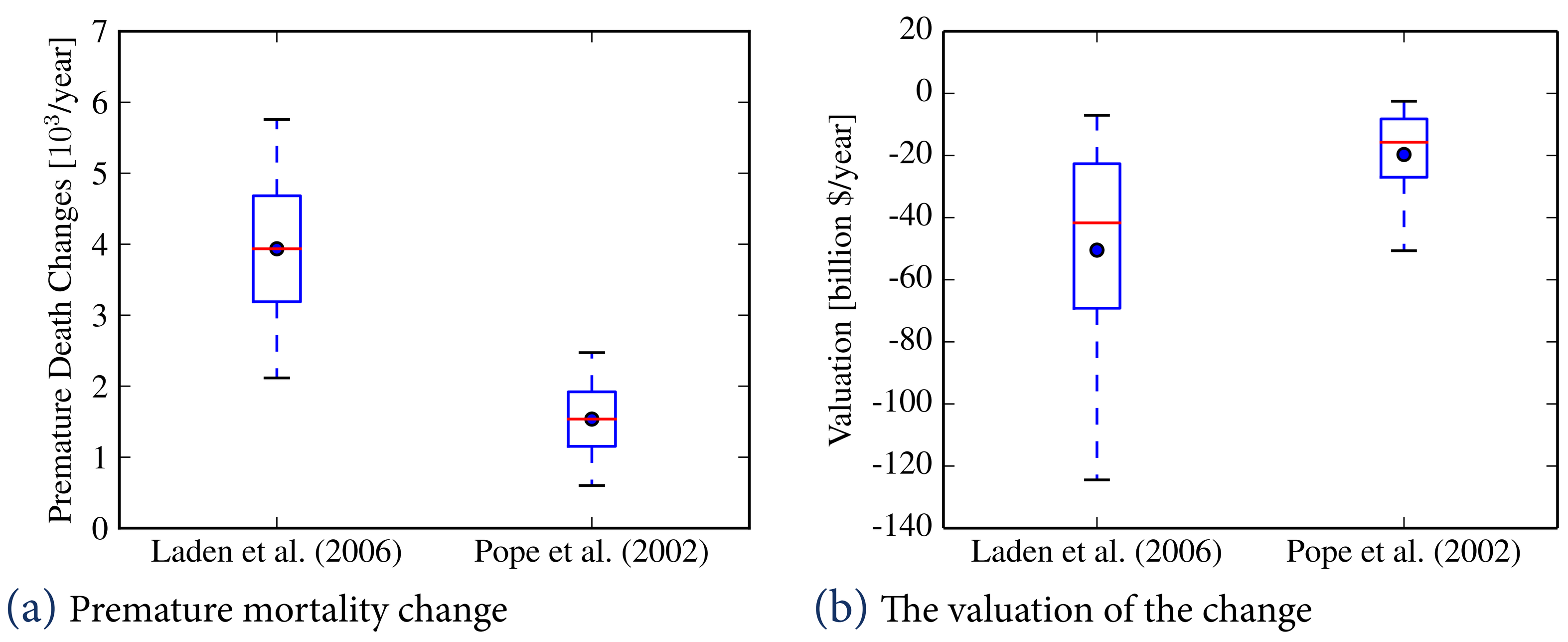

Figure 6: Social health risks of $PM_{2.5}$ increase from CCS NH_3 in 2050. Only uncertainties surrounding the CR functions and VSL are represented.

Table 3: Social health costs of CCS NH_3 and CO_2.

CR function	2010$/t NH_3	2010$/t CO_2
Laden et al. (2006)	120,000	28
Pope et al. (2002)	46,000	11

8. Conclusions

- *January* $PM_{2.5}$ may increase by 0.5 μg/m^3 on average and up to 0.9 μg/m^3 in $PM_{2.5}$ nonattainment areas, *a considerable amount if not a tremendous increase.*
- NH_3 from CCS may be *burdensome for $PM_{2.5}$ nonattainment regions* targeting 1-2 μg/m^3 reductions.
- If not properly controlled, amine scrubbing CCS may *seriously compromise the CCS social benefits* from CO_2 reductions.
- Since 60% of the social health costs occur during the winter, seasonal regulation could be considered.

References

[1] Rochelle, G. T. *Science* **2009**, *325*, 1652-1654.

[2] Rao, A. B.; Rubin, E. S.; Berkenpas, M. B. Department of Engineering and Public Policy, Carnegie Mellon University: Pittsburgh, PA 15213, **2004**.

[3] Ansari, A. S.; Pandis, S. N. *Environmental Science & Technology* **1998**, *32*, 2706-2714.

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