Air Pollution Social Cost Accounting Toward Optimal Policy Decision Making for Air Quality, Energy, and Climate Change

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Objectives

- Develop a computationally efficient method that identifies the sources of air pollution and their contributions in high spatial, temporal, and sectoral resolutions.
- Develop a framework that allows employing optimization methods for policy research associated with air quality, energy, and climate change.

1. Background

- Identifying the sources of air pollution that affects the air we breathe is essential for societal decision-making.
- However, it is a difficult task because there are innumerable emission sources and air pollutants travel long distance (hundreds of km or more) while they undergo complex chemical reactions.
- Current methods either have limited spatial, temporal, and sectoral resolutions (e.g. receptor models (Hopke and Cohen, 2011)) or require high computational costs (e.g. chemical transport models (ENVIRON, 2015; Byun and Schere, 2006)).
- We need a tool that is computationally efficient but has high spatial, temporal, and sectoral resolutions.

2. Social Cost of Emissions

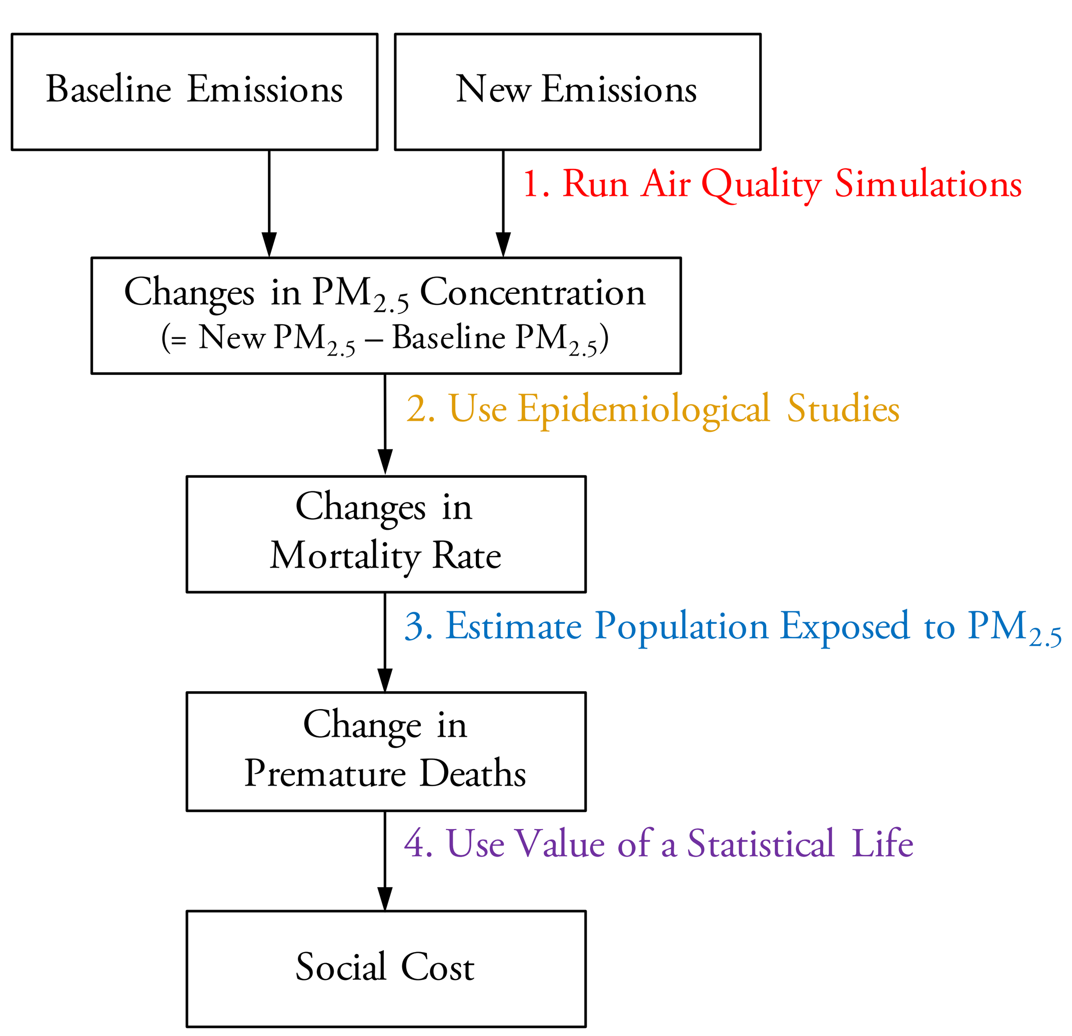


Fig. 1: A standard (or U.S. EPA's) method of estimating the social costs of emissions. We focus on $PM_{2.5}$ because it accounts for >90% when all the societal effects of emissions are monetized.

3. The Estimating Air pollution Social Impact Using Regression (EASIUR) Model

- The EASIUR model (Heo, 2015) estimates the social cost of emissions like a state-of-the-art chemical transport model (CTM) but without high computational costs for major air pollutants emitted at three emission elevations (ground-level, 150 m, and 300 m).
- EASIUR was derived by running regression on a large (∼30 TB) dataset generated by a state-of-the-art CTM (CAMx).

Per-tonne Social Cost [\$/t] =
f (Exposed Population, Atmospheric Variables)

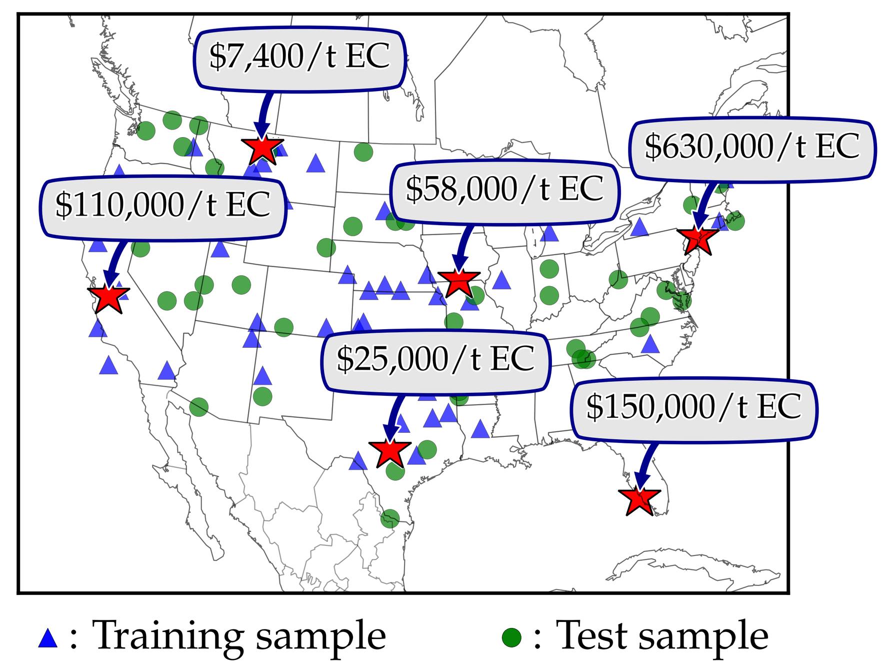


Fig. 2: Sample locations used in EASIUR.

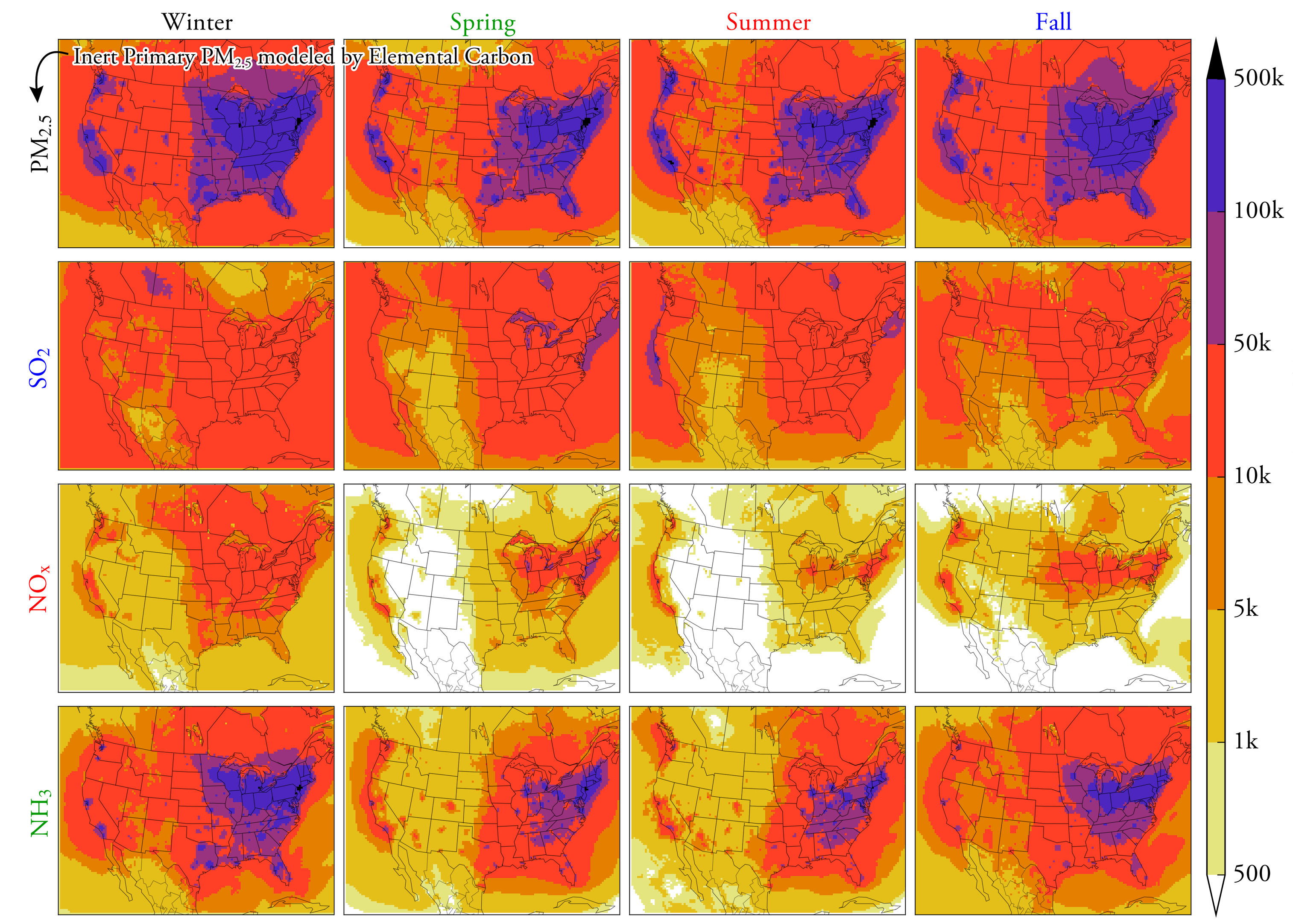


Fig. 3: EASIUR's marginal social costs (\$/t) for ground-level emissions.

4. The Average Plume Method

- A key challenge in EASIUR development was to find a simple but accurate way of describing the size of population exposed to $PM_{2.5}$.
- CTM results of 50 sample locations were averaged and normalized to create an average plume:

$$\sum_{x,y} \text{Weight}_{x,y} = 1.0$$

- used to express exposed population in regression:

$$\text{Exposed Population} = \sum_{x,y} \left(\text{Wind-Direction-Adjusted Weight}_{x,y} \times \text{Population}_{x,y} \right)$$

- This method worked great for describing exposed population in EASIUR regressions.

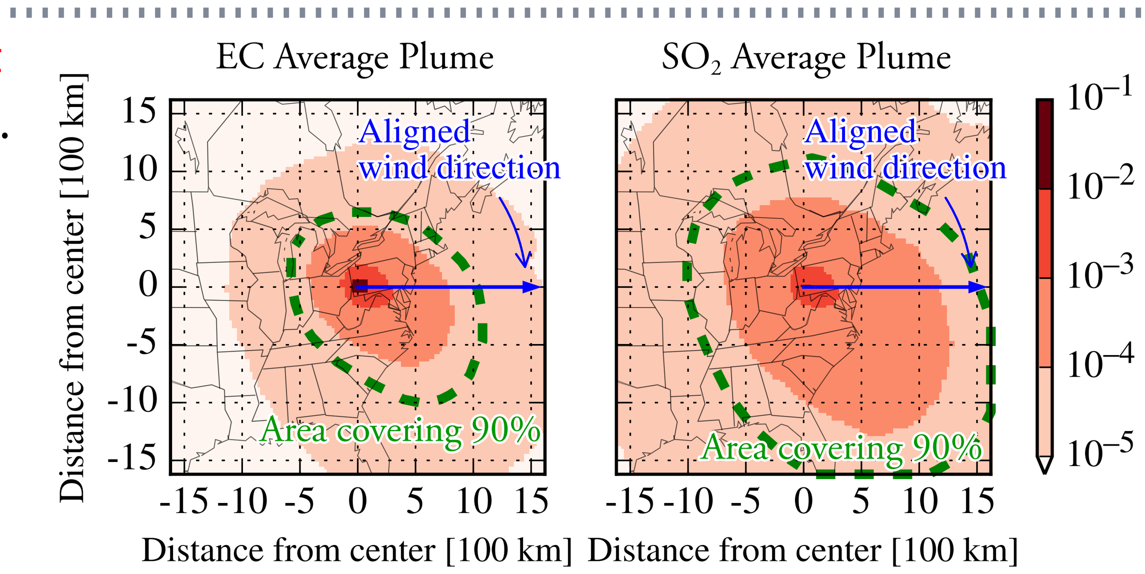
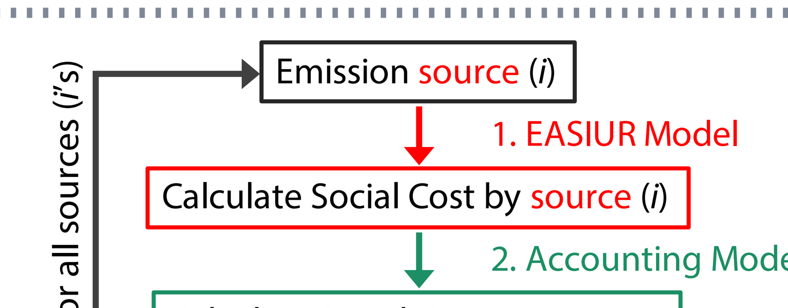


Fig. 4: Average plumes for winter emissions (placed on Pittsburgh to illustrate a sense of scale).

5. The Air Pollution Social Cost Accounting (APSCA) Model

- The key idea of the APSCA model is to distribute EASIUR's social cost estimates spatially using population-weighted average-plumes.
- The APSCA model identifies all the sources for a given downwind (or receptor) location quickly mostly within 0% mean fractional biases$_{eq}$ and 50% mean fractional errors$_{eq}$ against CTM-based estimates for four species (Primary $PM_{2.5}$, SO_2, NO_x, and NH_3).



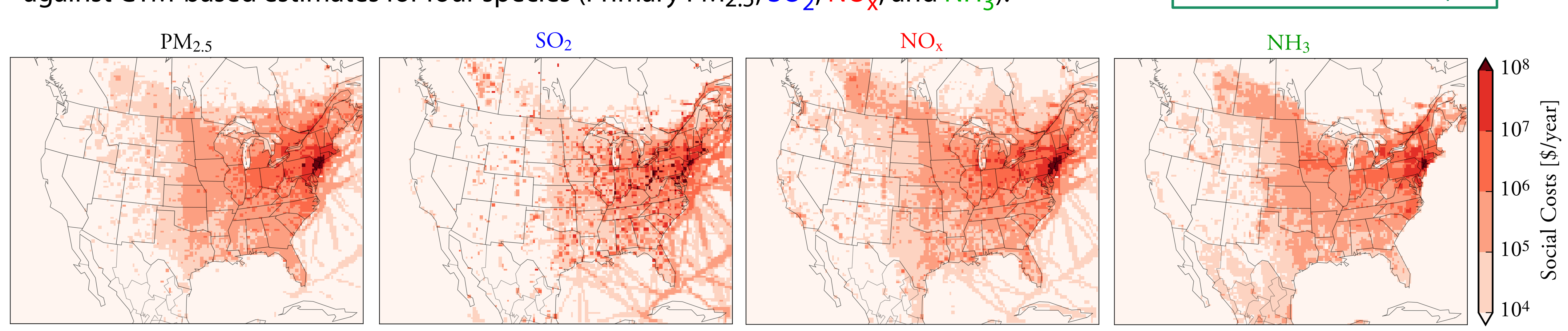


Fig. 5: Emission sources affecting the air pollution social costs imposed on the New York metropolitan area.

6. Analysis on 14 Metropolitan Areas

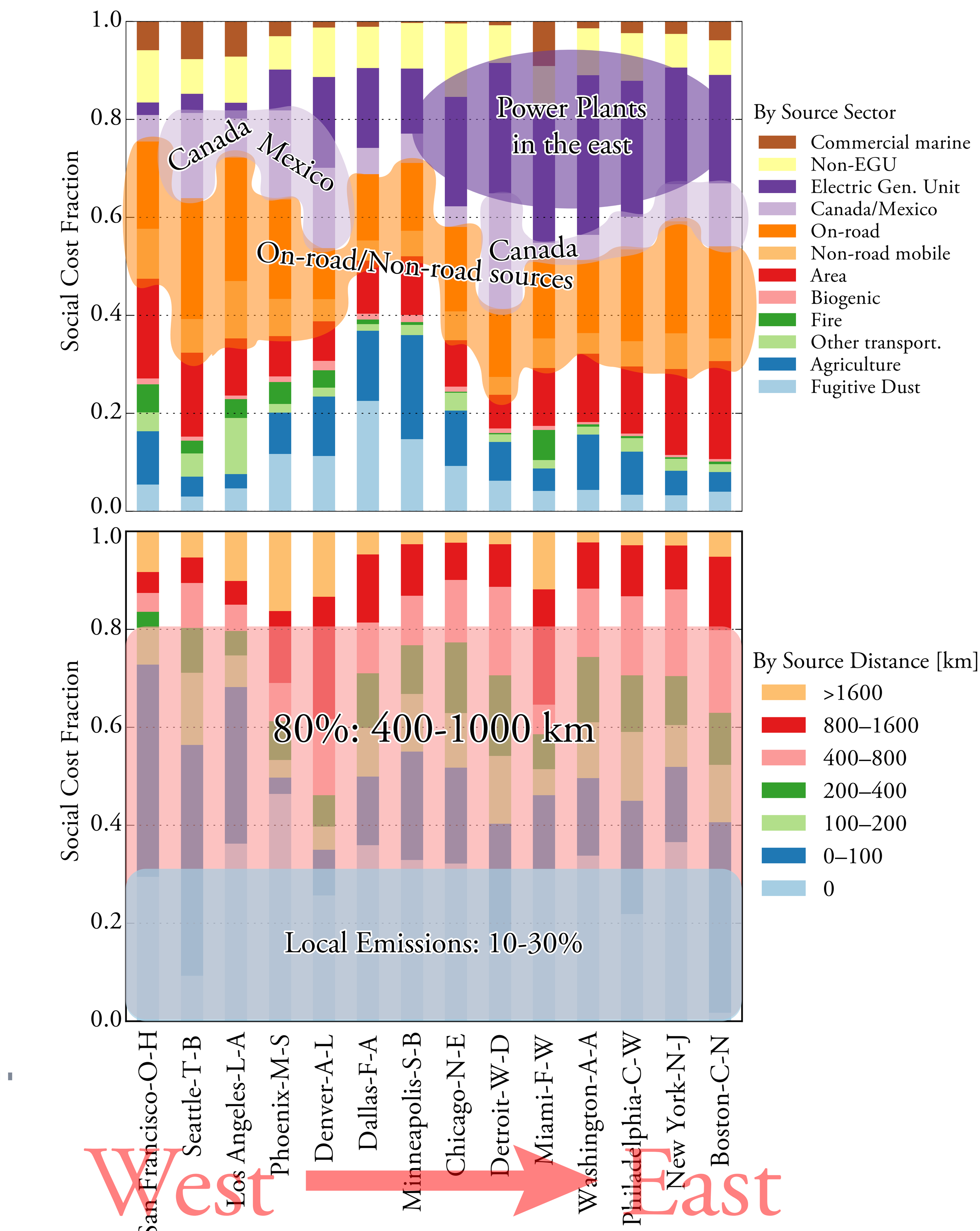


Fig. 6: Air pollution social cost accounting estimated by APSCA for 14 metropolitan areas across the nation.

7. Conclusions

- The Air Pollution Social Cost Accounting Model identifies the sources of air quality burden at a receptor location with high spatial, sectoral, and temporal resolutions.
- The most comprehensive accounting of air pollution social costs can be provided.
- The new model provides useful information for policy strategies from a receptor's point of view.

8. Future Work

- combine EASIUR and APSCA with optimization methods for policy research associated with air quality, energy, and climate change.
- evaluate U.S. EPA's air regulations (e.g. State Implementation Plans and the Cross-State Air Pollution Rule).

Acknowledgments

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