HEI

STATEMENT

Synopsis of Research Report 218

HEALTH EFFECTS INSTITUTE

Health Benefits of Location-Specific Emissions Reductions in North America

BACKGROUND

Air pollution from particulate matter, a complex mixture of microscopic particles and liquid droplets, is a leading risk factor of morbidity and mortality. Particulate matter can be emitted directly from pollutant sources such as smokestacks and vehicle exhaust, in which case it is referred to as a primary particulate matter emission. Particulate matter can also form in the atmosphere by gas-to-particle conversion of other pollutants, including ammonia, nitrogen oxides, and sulfur dioxide, and is referred to as secondary particulate matter. Carbon dioxide, a potential driver of climate change, is often co-emitted with particulate matter and its chemical precursors. Research demonstrates that the social and economic costs of air pollution include increased healthcare expenditures and reduced productivity. Research also suggests that society can benefit from air pollution reductions. Quantifying the relative costs and benefits of air pollution regulations is important for informing policy. For example, the United States Environmental Protection Agency (US EPA) estimated that the net benefit of lowering the annual fine particulate matter National Ambient Air Quality Standard from 12 to 9 μg/m^3 would be $22 billion. However, evaluating the costs and benefits of air pollution emissions reductions is complicated because standard modeling approaches have certain limitations in accuracy and difficulty estimating uncertainty.

To estimate the monetary health benefits associated with reducing emissions from transportation and other selected sources, HEI funded a study by Dr. Amir Hakami of Carleton University, titled “Quantifying marginal societal health benefits of transportation emission reductions in the United States and Canada” in response to HEI’s Request for Applications 17-2, Health Effects of Air Pollution. Dr. Hakami and colleagues proposed to apply a novel extension to the widely used US EPA’s Community Multiscale Air Quality Model (CMAQ) that they had developed to improve how health benefits are estimated. He would then estimate these benefits for specific locations and emissions sources in the United States and Canada. They also proposed to estimate the climate change cobenefit of reduced emissions of carbon dioxide.

What This Study Adds

- This study estimated potential health benefits associated with reducing emissions from transportation and other sources at specific locations across the United States and Canada.
- The investigators quantified the annual monetary benefit of averted premature mortality associated with long-term fine particulate matter exposure linked to primary emissions of fine particulate matter, ammonia, nitrogen oxides, and sulfur dioxide. They also quantified climate cobenefits linked to reductions in carbon dioxide emissions.
- The greatest estimated benefit came from reducing primary fine particulate matter emissions, and the combined health burden of all domestic emissions totaled $805 billion US dollars in the United States and $77 billion Canadian dollars in Canada in 2016.
- Climate cobenefits were higher for reducing emissions from diesel compared with gasoline vehicles, and highest for off-road vehicles or engines.
- Targeted reductions of emissions from a relatively small proportion of sources could yield substantial health benefits. Future studies should evaluate other key pollutants and other health outcomes.

APPROACH

Hakami and colleagues created a database of the health benefits associated with reduced emissions from transportation and other sectors in the United States

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Amir Hakami and his colleagues. The complete report, *Estimating Model-Based Marginal Societal Health Benefits of Air Pollution Emission Reductions in the United States and Canada*, ©2024 Health Effects Institute, can be downloaded from *www.healtheffects.org/publications*.

and Canada that could be used by decision-makers to develop air pollution control policies that would result in the greatest health benefits to society. To achieve this goal, the investigators further developed a novel extension to CMAQ that enabled them to estimate the monetary benefit-per-ton (hereafter, benefits) of reduced emissions by seamlessly linking data from recent large-scale epidemiological studies back to the original pollutant emissions. The CMAQ model accounted for complex atmospheric processes and transport of air pollutants over time and incorporated detailed information on emissions and meteorology. The novel extension to the model also allowed for detailed sensitivity analyses to assess how the results changed with different model inputs.

The investigators calculated health benefits using the estimated annual monetary cost of mortality associated with long-term fine particulate matter exposure. For the monetary cost of averted mortality, they applied values published by the US EPA and the Canadian government of $10.2 million US dollars and $7.5 million Canadian dollars, respectively. To estimate the association between fine particulate matter and mortality, the investigators chose the widely cited concentration–response function estimated by the Global Exposure Mortality Model (GEMM) because it incorporated 41 cohorts from 16 countries and a range of fine particulate matter exposures. To evaluate how this choice might affect benefit-per-ton estimates, Hakami and colleagues compared the US results from GEMM to four alternative concentration–response functions reported by more recent high-quality epidemiological studies with large cohorts.

Hakami and colleagues calculated benefits of reduced emissions of ammonia and criteria pollutants fine particulate matter, nitrogen oxides, and sulfur dioxide for the years 2001, 2016, and 2028 projections because those were the years when national emissions inventories were available. The authors also estimated the cobenefit of carbon dioxide reductions because regulations targeting combustion-related pollutant emissions typically reduce carbon dioxide emissions.

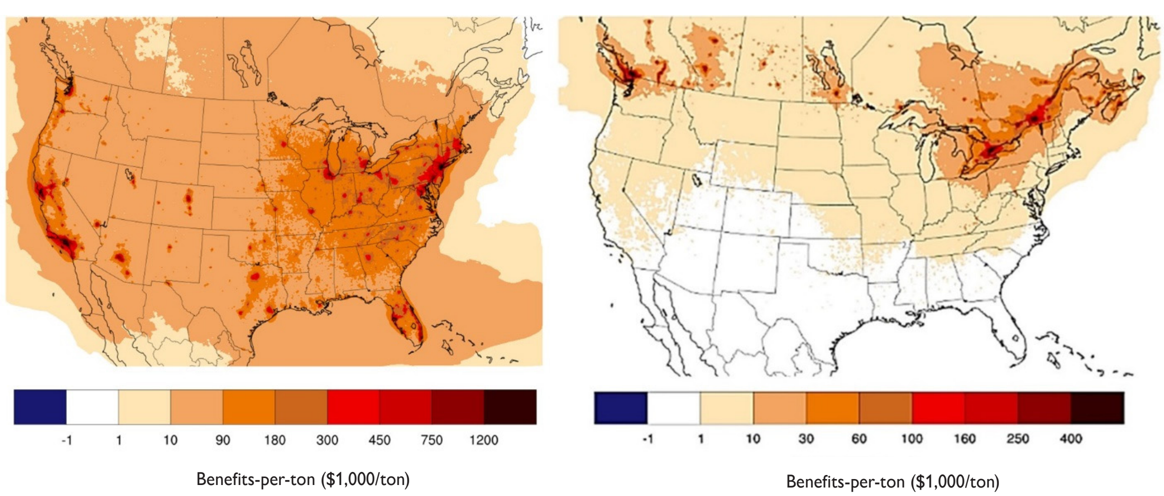
KEY RESULTS

The benefits of reduced emissions were generally higher in the eastern half of the United States, with the greatest benefits near large cities, particularly in the northeast and California (**Statement Figure**). Compared with primary fine particulate matter, benefits were lower for fine particulate matter formed as a result of emissions of ammonia and lowest for fine particulate matter formed from sulfur dioxide and nitrogen oxide emissions.

Hakami and colleagues estimated that the total burden of all primary domestic emissions combined was $805 billion US dollars in the United States and $77 billion Canadian dollars in Canada. They reported that 10% of primary fine particulate matter emissions associated with the highest benefits were responsible for 35% and 60% of the health burden in the United States and Canada, respectively.

Estimated benefits were consistent across different concentration–response functions in locations where benefits were largest, but were variable in locations with smaller benefits. Differences in emissions among the years evaluated (2001, 2016, and 2028 projections) led to variations in benefits estimates, but the investigators reported that these variations were expected to decrease in the future.

Climate cobenefits vary widely across different transportation sectors and vehicle types. Cobenefits



Statement Figure. Benefits-per-ton for reduction of primary fine particulate matter emissions in 2016 show that larger benefits could be obtained by reducing emissions in the United States (left) than in Canada (right) and in large cities.

were higher for the reduction of emissions from diesel compared with gasoline vehicles, and highest for off-road vehicles and vehicles of the oldest vintages. Regarding electricity generation, the cobenefits were higher for reducing emissions from coal-powered compared with natural gas-powered plants.

INTERPRETATION AND CONCLUSIONS

In its independent review of the study, the HEI Review Committee thought that the study was methodologically rigorous, thorough, and policy-relevant, and agreed that the authors' interpretations and conclusions were supported by the results. The use of a high spatial resolution adjoint air quality model was a key advance in evaluating the effect of location-specific sources of air pollutants and the benefits of mitigating those sources, including cross-border effects between the United States and Canada. Indicating the areas and sectors with the highest emissions reduction benefits can support targeted and efficient air quality and decarbonization policies that reduce the emissions of relevant air pollutants. The Committee appreciated that Hakami and colleagues evaluated the carbon dioxide cobenefits for a multitude of policy-relevant transportation sectors that were representative of the sectors that are expected to change over the next 10 years as newer energy technologies increase market share, older vehicle fleets are replaced, and electrification makes greater inroads.

The Committee also appreciated Hakami's efforts to conduct comprehensive sensitivity analyses to evaluate how benefits estimates might change, including the spatial resolution of the model, the shape of the concentration–response function, and changes between past, current, and projected future emissions. In general, there was less variability in benefits estimates in locations where the benefits were largest. That result illustrates the importance of concentration–response function selection in health impact studies and the need for high-quality, population-representative epidemiological studies with relevant exposure ranges.

The Committee noted that health benefits were likely underestimated in this study because it focused on emissions that contributed to long-term fine particulate matter exposure but did not evaluate the direct and indirect effects of reducing other air pollutants, such as nitrogen oxides and ozone. It would be important to consider those pollutants in future studies and to broaden the estimates beyond mortality to include other important health and economic indicators such as chronic diseases, disability, and lost workdays.

In conclusion, this health impact study evaluated the benefits of decreased 2001, 2016, and projected 2028 air pollutant emissions that contribute to mortality from long-term ambient fine particulate matter exposure across the United States and Canada. Hakami and colleagues used a novel extension of the CMAQ model at high spatial resolution to produce a database of source- and location-specific benefits useful to policymakers. Their results suggest that reductions in a relatively small proportion of emissions could yield a large societal health benefit. In addition, focused emissions reductions in certain transportation sectors, including off-road engines and diesel vehicles, could yield important climate and health cobenefits. Future studies are recommended to evaluate the effect of additional pollutants, such as nitrogen oxides and ozone, which have both health and climate importance.

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