



EPA's Approach to Quantifying the Benefits of Air Rules

Understanding how and why the Agency estimates the quantity and economic value of health and welfare impacts

May 7th, 2012



Overview

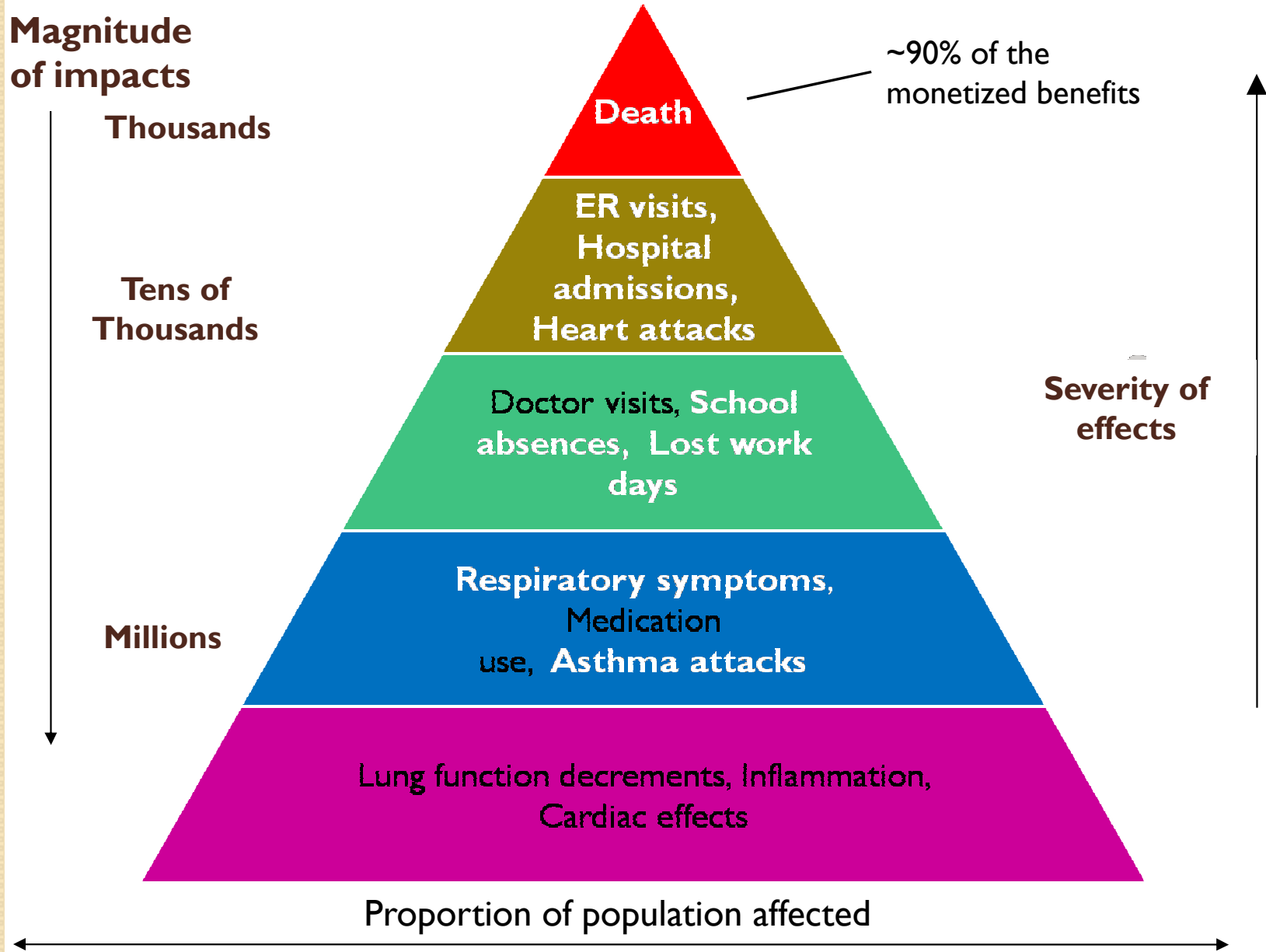
- First principles—the relationship between air pollution and health
- The role of the benefits analysis in the Regulatory Impact Assessment
- Using the BenMAP tool to quantify benefits
- Approaches to characterizing uncertainty
- Directions for future research

Presentation to NACAA 2012 meeting



AIR POLLUTION AND HEALTH

A "Pyramid of Effects" from Air Pollution



What Health Endpoints do we Include in Our **Central** Benefits Estimate?

Health Endpoint	PM_{2.5}	Ozone
Premature mortality*	✓	✓
Nonfatal heart attacks	✓	
Hospital admissions	✓	✓
Asthma ER visits	✓	✓
Acute respiratory symptoms	✓	✓
Asthma attacks	✓	✓
Work loss days	✓	
School absence rates		✓

*Long term PM_{2.5}-related mortality and short-term O₃-related mortality

What Health Endpoints do we Include in Our **Sensitivity** Analyses?

Health Endpoint	PM_{2.5}	Ozone
Long-Term Premature mortality*		✓
Education-modified premature mortality	✓	
Ischemic and hemorrhagic stroke	✓	
Cardiovascular emergency department visits	✓	
Worker productivity		✓
Chronic bronchitis	✓	

*Long term O₃-related mortality

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THE ROLE OF THE HEALTH BENEFITS ASSESSMENT



Key Messages on Health Benefits Analyses

- What policy questions are we trying to answer?
 - How can we organize, describe, and monetize the positive consequences of a rule?
 - How can we inform the regulatory decision and help justify a rule?
- Executive Order 12866 directs EPA to quantify the benefits and costs of regulatory actions
 - We cannot quantify or monetize all benefits
 - Only need a benefits analysis for an RIA
 - Benefits can trigger an RIA even if costs do not
 - Co-benefits and disbenefits are important considerations
- EPA's methods for characterizing the human health benefits of air quality improvements have received extensive external review from the National Academies of Science and the Independent Science Advisory Board among other bodies.



Benefits and “Co-Benefits”

- RIA goal is to provide as comprehensive an estimate of benefits of rule as possible (given time, resources, etc)
 - Such an estimate should account, as completely as possible, for the complete benefits and costs of a regulatory action
 - Co-benefits accrue as a result of meeting the policy goal of the rule—but are not central
- The value of PM_{2.5}-related co-benefits can be substantial, and frequently represent the only monetized benefit
 - Typically quantify co-benefits of reductions in PM_{2.5} precursors (e.g. metals)
 - While toxics-related benefits are important, the Agency has not yet developed a systematic approach to monetizing these benefits



Why Don't We Always Estimate Co-Benefits for Other Criteria Pollutants?

- Ozone formation is governed by complex non-linear chemistry and greatly influenced by localized conditions
 - We do not have a “reduced-form” approach to estimating ozone impacts like we do for PM
 - Ozone benefits requires air quality modeling
 - Ozone benefits tend to be smaller than $PM_{2.5}$ benefits
- We could generate benefits for other criteria pollutants (NO_2 , SO_2 , CO, and Pb)
 - Generally, we do not have the necessary air quality data
 - Generally, these benefits are much smaller than $PM_{2.5}$ benefits because only estimating non-fatal health effects



Why don't we always estimate HAP benefits?

- The health-related benefits of reducing air toxics are real, but difficult to estimate
- However, we generally lack studies characterizing population-level human health risk to air toxics
 - Large-scale epidemiological studies are most useful for benefits assessments, as they can provide a reliable central estimate of risk across the population
 - Epidemiological studies for criteria pollutants tend to be easier to develop because of the ubiquity of these pollutants and the broader population exposure
- Risk analyses (such as for Risk and Technology Reviews) are designed to estimate maximum risk, while a monetized benefits analysis is expected to estimate most likely risk
- In 2009, an EPA workshop addressed inherent complexities, limitations, and uncertainties in current methods to quantify the benefits of reducing HAPs. Recommendations from this workshop included
 - Identifying research priorities
 - Focusing on susceptible and vulnerable populations
 - Improving dose-response relationships

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QUANTIFYING BENEFITS IN BENMAP

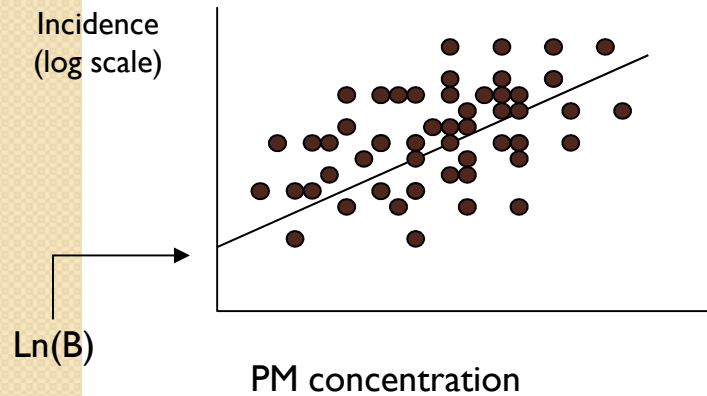
What is BenMAP?

- The “environmental Benefits Mapping and Analysis Program”
- The principal tool EPA uses to quantify the benefits criteria air quality improvements
- A PC-based and graphic user interface-driven software program
- Program estimates the incidence and economic value of adverse health outcomes



Step One: Derive Health Impact Functions from Epidemiology Literature

Epidemiology Study



$$\ln(y) = \ln(B) + \beta(\text{PM})$$

Health impact function

$$\Delta Y = Y_0 (1 - e^{-\beta \Delta \text{PM}}) * \text{Pop}$$

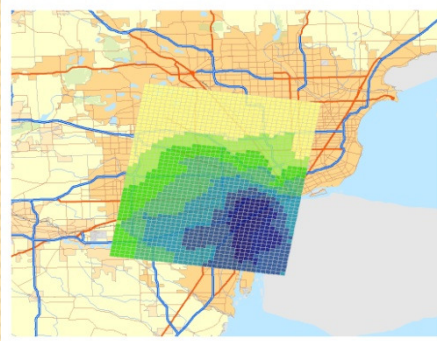
Y₀ – Baseline Incidence

β – Effect estimate

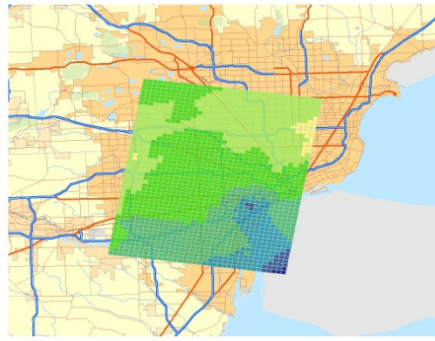
ΔPM – Air quality change

Pop – Exposed population

Baseline Air Quality



Post-Policy Scenario Air Quality



Step Two: Implement health impact function in BenMAP

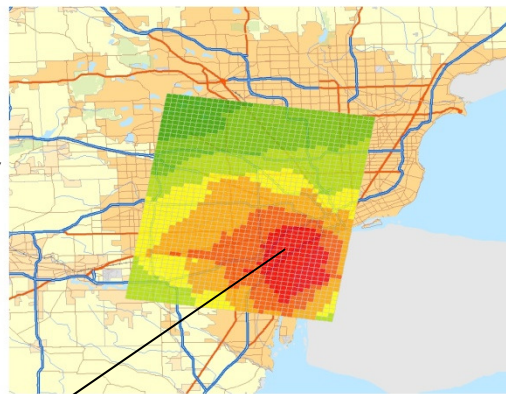
$$\Delta Y = Y_0 (1 - e^{-\beta \Delta PM}) * Pop$$

U.S. Version

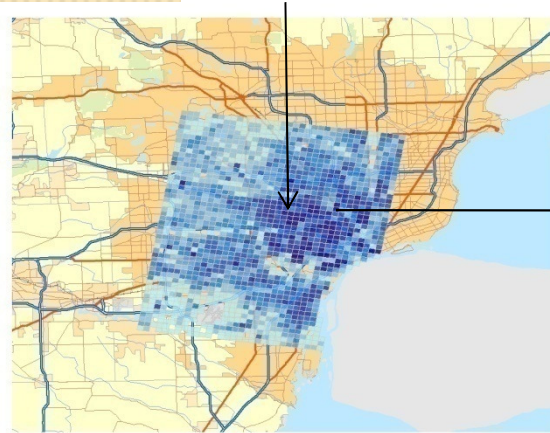


Environmental Benefits Mapping and Analysis Program

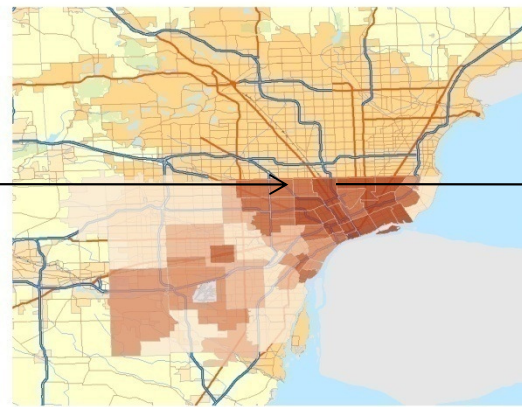
Incremental Air Quality Improvement



PM_{2.5} Reduction



Population Ages 18-65



Background Incidence Rate



Effect Estimate

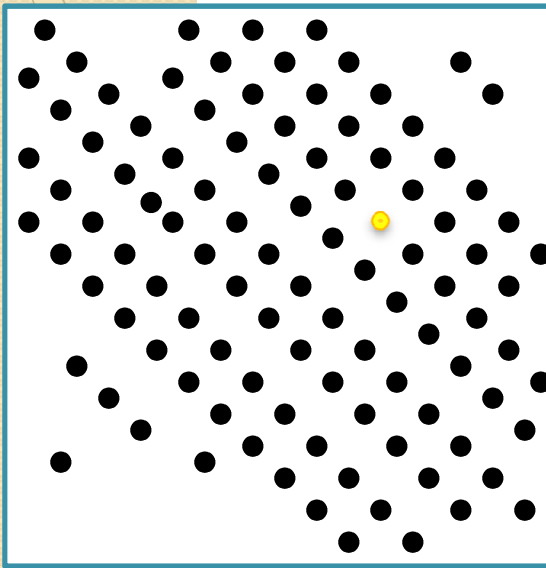
Mortality Reduction



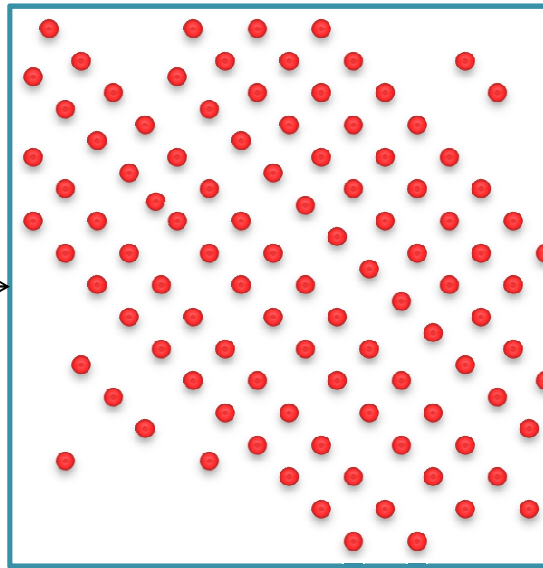
Step Three: Assign a \$ Value

- Cost of Illness (COI)
 - Medical expenses for treatment of illness
 - Captures the money savings to society of reducing a health effect
 - Ignores the value of reduced pain and suffering
- Willingness To Pay (WTP)
 - Lost wages, avoided pain and suffering, loss of satisfaction, loss of leisure time, etc.
 - Measures the complete value of avoiding a health outcomes
- OMB requires that we report monetized benefits at discount rates of 3% and 7%

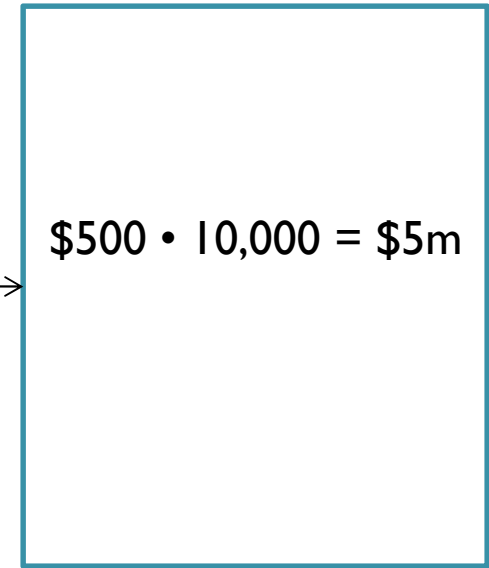
Step Three: Assign a \$ Value—How do we Calculate VSL?



In a population of 10,000, reducing pollution would avoid one premature death (i.e. reduce risk by $\frac{1}{10,000}$)

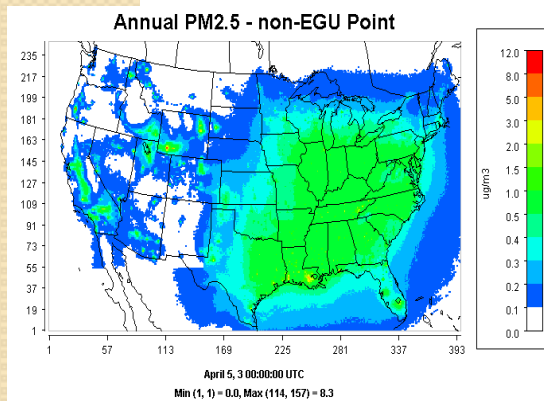


Each of 10,000 are willing to pay \$500 to reduce risk of death by $\frac{1}{10,000}$

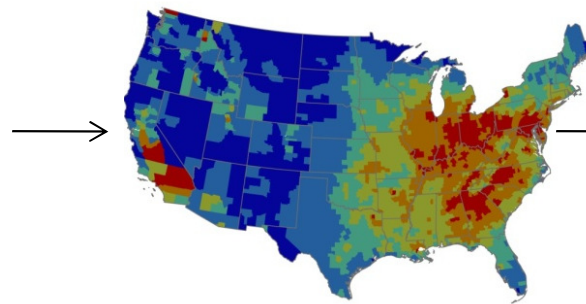


VSL is then WTP multiplied by the inverse of the risk reduction

Overview of Approach to Calculating PM_{2.5} Benefit Per-Ton Estimates



PM_{2.5} air quality change for a given sector



Human health benefits

$$\frac{\$ \text{ Benefits and avoided impacts}}{\text{Scenario emissions}} = \text{Benefit/ton}$$

Benefit-per-ton calculation



Why Do We Present Ranges of Benefits?

- Each step in the benefits analysis process has inherent uncertainty
- We report a range of benefits representing different estimates of the relationship between premature deaths and pollution exposure from the epidemiology literature
- Many unquantified sources of uncertainty, and even the range estimates have additional unquantified uncertainty
- When data are available, we also report confidence intervals for each estimate based on the standard errors in the health functions and uncertainty in the valuation functions
- Key assumptions in $PM_{2.5}$ benefits
 - National average benefit-per-ton estimates are representative of emission reductions from the rule
 - All PM species are equally toxic
 - Health effects are linear down to lowest modeled levels

Estimating Other Benefits

Likelihood of being able to quantify for rules

- Climate benefits – based on “social cost of carbon” determined by interagency group
- Visibility benefits – based on WTP studies for change in visual range due to light extinction
- Mercury health benefits – based on mercury deposition and lost earnings due to IQ loss
- Aquatic acidification benefits – based on WTP for recreational fishing for change in lake acidification
- Ozone biomass benefits – based on exposure-response relationships for different species



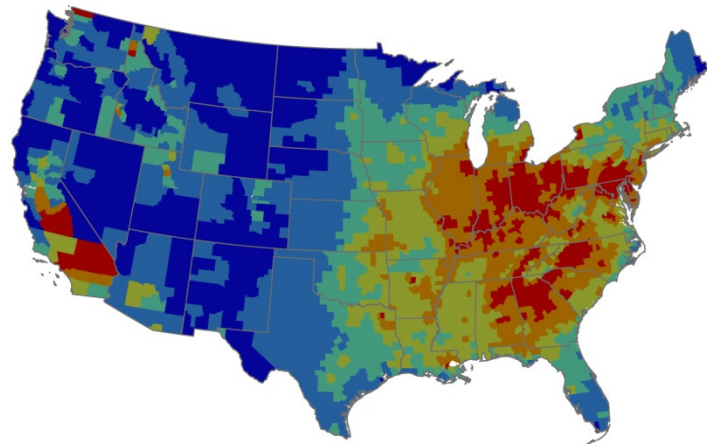
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APPENDIX

Burden Assessments: Estimating the Risk Attributable to Recent PM_{2.5} and Ozone Levels

Percentage of O₃ and PM_{2.5} related deaths due to 2005 air quality levels by county



Percentage of total deaths due to PM_{2.5} and ozone
 Krewski et al. (2009) PM mortality and Levy et al. (2005) ozone mortality estimates

- <3%
- 3.1 to 4.1%
- 4.2 to 5.3%
- 5.4 to 6.2%
- 6.3 to 7.2%
- 7.3 to 9.8%

Source: Fann N, Lamson A, Wesson K, Risley D, Anenberg SC, Hubbell BJ. Estimating the National Public Health Burden Associated with Exposure to Ambient PM_{2.5} and Ozone. Risk Analysis; 2011. In Press.

Summary of National PM_{2.5} & O₃ impacts due to 2005 air quality

Excess mortalities (adults) ^A	130,000 to 340,000
Percentage of all deaths due to PM _{2.5} and O ₃ ^B	6.1%

Impacts among Children

ER visits for asthma (age <18)	110,000
Acute bronchitis (age 8-12)	200,000
Exacerbation of asthma (age 6-18)	2,500,000

^A Range reflects use of alternate PM and ozone mortality estimates

^B Population-weighted value using Krewski et al. (2009) PM mortality and Levy et al. Ozone mortality estimates

EPA Regulatory Analyses: Health Benefits of 2014 Cross-State Air Pollution Rule

Summary of health impacts avoided

Health endpoint	Value
PM _{2.5} -related mortality (Pope et al. 2002)	13,000 (5,200—21,000)
PM _{2.5} -related mortality (Laden et al. 2006)	34,000 (18,000—49,000)
O ₃ -related mortality (Bell et al. 2004)	27 (11—42)
O ₃ -related mortality (Levy et al. 2005)	120 (90—160)
PM _{2.5} -related chronic bronchitis	8,700 (1,600—16,000)
PM _{2.5} -related non-fatal heart attacks	15,000 (5,600—24,000)
PM _{2.5} and O ₃ -related respiratory hospitalizations	2,900 (1,300—4,300)
PM _{2.5} and O ₃ -related emergency department visits	9,900 (5,800—14,000)

Monetized health and welfare benefits^A

Endpoint	Value (billions of 2006\$)
<i>Human health^B</i>	
Pope et al. 2002 PM _{2.5} and Bell et al. 2004 O ₃ mortality estimates	\$120 (\$14—\$350)
Laden et al. 2006 PM _{2.5} and Levy et al. 2005 O ₃ mortality estimates	\$280 (\$29—\$810)
<i>Visibility</i>	\$3.6
Total	
Pope et al. 2002 PM _{2.5} and Bell et al. 2004 O ₃ mortality estimates	\$120 (\$10—\$360)
Laden et al. 2006 PM _{2.5} and Levy et al. 2005 O ₃ mortality estimates	\$290 (\$26—\$850)

^A All values rounded to two significant figures

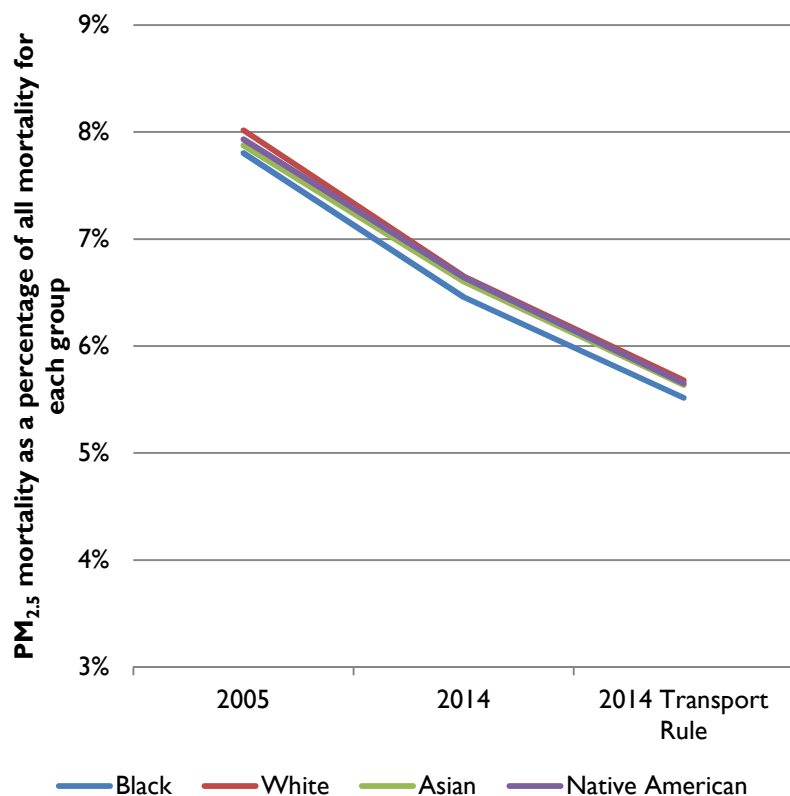
^B Discounted at 3%

Source:

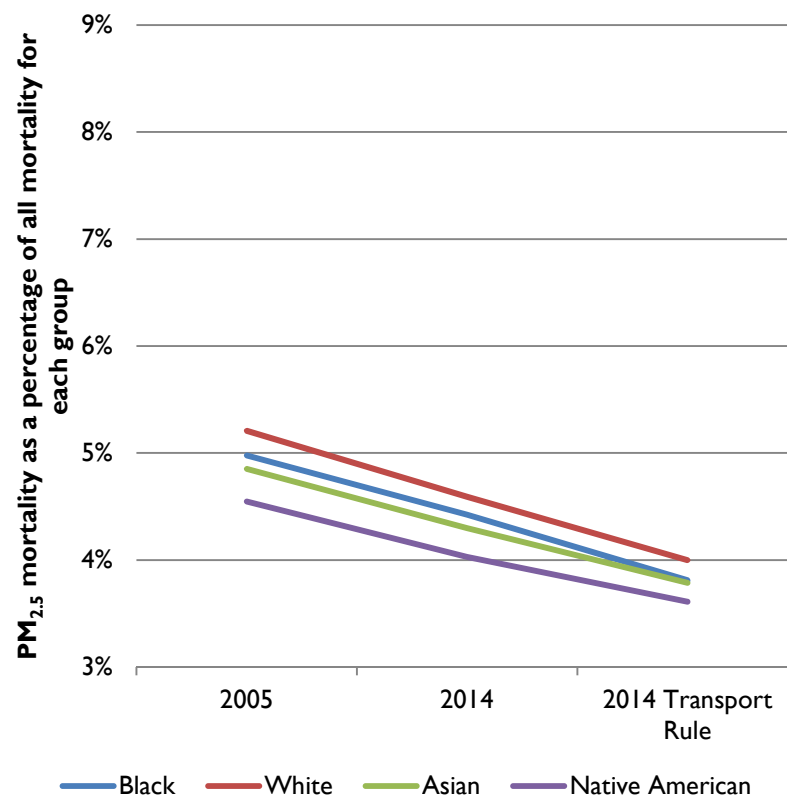
<http://www.epa.gov/airtransport/pdfs/FinalRIA.pdf>

National Environmental Justice Analyses: 2014 Proposed Transport Rule

Among populations living in counties at **greatest risk** of air pollution*



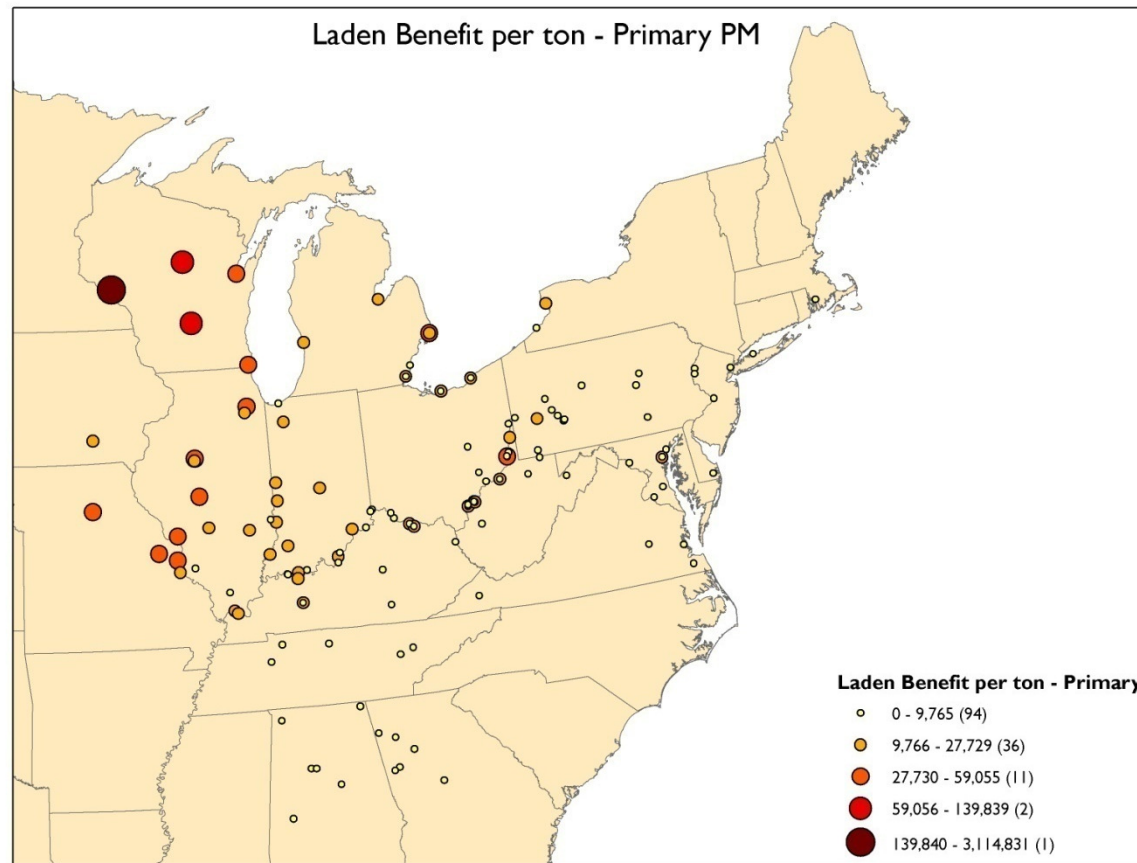
Among populations living in **all other** counties



Draft deliberative materials

*Data are not sensitive enough to delineate relative PM mortality among races with confidence. However, we are more confident that populations, irrespective of race, receive a substantial health benefit.

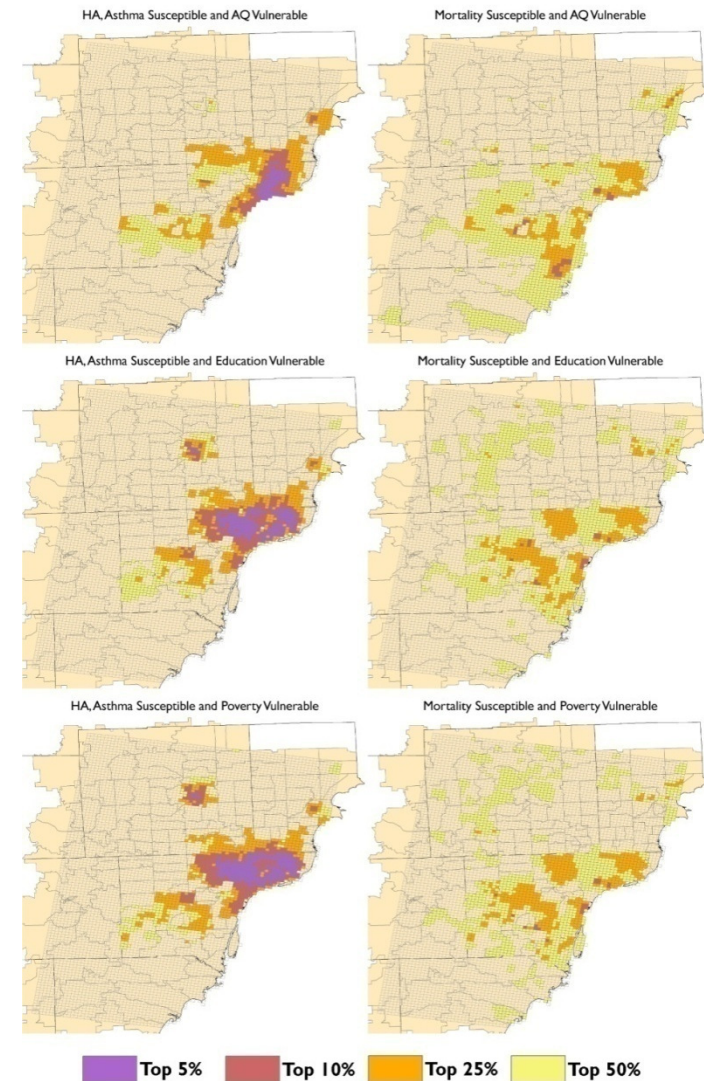
Benefit per ton estimates



UPDATED: 2/8/2011

Detroit Multi-pollutant Pilot Project: EJ Assessment

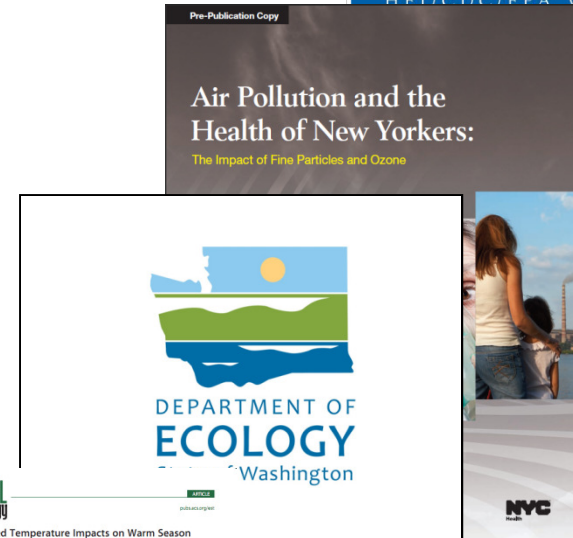
- Analysts can consider alternate variables to identify susceptible and vulnerability populations
 - Susceptibility:
 - Hospital Admissions
 - Mortality
 - Vulnerability
 - Annual mean $PM_{2.5}$ levels
 - Educational attainment
 - Poverty
- Irrespective of variables used, the multi-pollutant risk-based approach provides greatest reductions in $PM_{2.5}$ exposure



Source: Fann N, Roman HR, Fulcher C, Gentile M, Wesson K, Hubbell BJ, Levy JI. Maximizing Health Benefits and Minimizing Inequality: Incorporating Local Scale Data in the Design and Evaluation of Air Quality Policies, *Risk Analysis*, 2011; in press.

Supporting Methods Development and State Analyses

- CDC Environmental Public Health Tracking Program
- NYC Health Burden Assessment
- WA State Health Burden Assessment
- Assessment of Climate-Induced Heat Mortality



Climate Change-Related Temperature Impacts on Warm Season Heat Mortality: A Proof-of-Concept Methodology Using BenMAP
 A. Scott Voohees,* Neal Funn, Charles Fulcher, Patrick Dubick, Bryan Hubbell, Bretta Berwagen, and Philip Morefield
 United States Environmental Protection Agency (USEPA), 109 TW Alexander Drive, Research Triangle Park, North Carolina 27711, United States

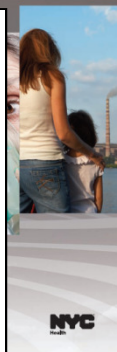
ABSTRACT: Climate change is anticipated to cause annual temperature and a likely to increase heat-related human health morbidity and mortality risk. The objective of this work was to develop a proof-of-concept approach for estimating future heat-related premature deaths in the continental United States resulting from potential changes in future temperature using the BenMAP model. In this approach we adapt the methodology and tools that the US Environmental Protection Agency uses to assess air pollution health impacts to incorporating temperature modeling and heat mortality health impact factors. This new method demonstrates the ability to apply the existing temperature-health literature to quantify temperature changes in climate-scenarios heat-related mortality. We compared estimates of future temperature with and without climate change and applied heat-mortality health burden assessment metrics change to heat-related premature mortality. Using the 100 scenarios scenarios we applied the CDC's global climate model (GCMs) to the 30-day daily and monthly using the meteorological - climate model. For annual temperature derived from the 30-year 2040-2050 relative to 1980-2002 we selected for the warm season (May-September) a scenario of annual increase of heat-related mortality to 1700-2000 times of cases, 1000 from cardiovascular disease, and 2100-27000 from noncardiovascular death, applying various health impact factors. Our estimate of mortality produced by the application of a new methodology suggest the importance of quantifying heat impacts in economic assessments of climate change.

INTRODUCTION
 The United States Environmental Protection Agency (USEPA) estimated that greenhouse gases (GHGs) in the atmosphere will increase the public health and welfare of current and future generations. Climate variability and change on the upcoming decade is likely, and rising temperatures are one manifestation of a warming world. Heat waves and hot weather are expected to become more frequent. The frequency of extreme heat events is forecast to increase, and air quality may worsen. Global average temperature is projected to increase between 1.4 and 6.4°C by the end of the century.¹ On a continental scale, change in land cover have already contributed to a surface warming of +0.2°C per century in the United States and +0.5°C per decade since 1970 in China.^{2,3} Heat is the primary contributor of 40% of total mortality in 1995, 1998, 2004, 2005, and 2007 and is projected to increase from 3000 deaths between 1999 and 2020 among the elderly, the young, the young, the young, and the young.⁴ Mortality risk increases with elevated temperatures, they are further dependent, and create socio-economic factors such as age and poverty impact health risk during a heat event.^{5,6} Increases in mortality risk occur as a result of heat waves and also as a result of high temperatures over longer time periods.⁷ The long-term impact of heat on climate works, have become more frequent in recent years.⁸ Climate change is anticipated to be an increase in the frequency and intensity of heat waves.⁹ Demographic shifts in the United States are expected to produce a larger population with a higher mean age and heightened vulnerability to heat stress.¹⁰

and Economic Impacts of Pollution in Washington

Department of Ecology
 Health and Safety Program
 October 15, 2009

number: 09-02-021



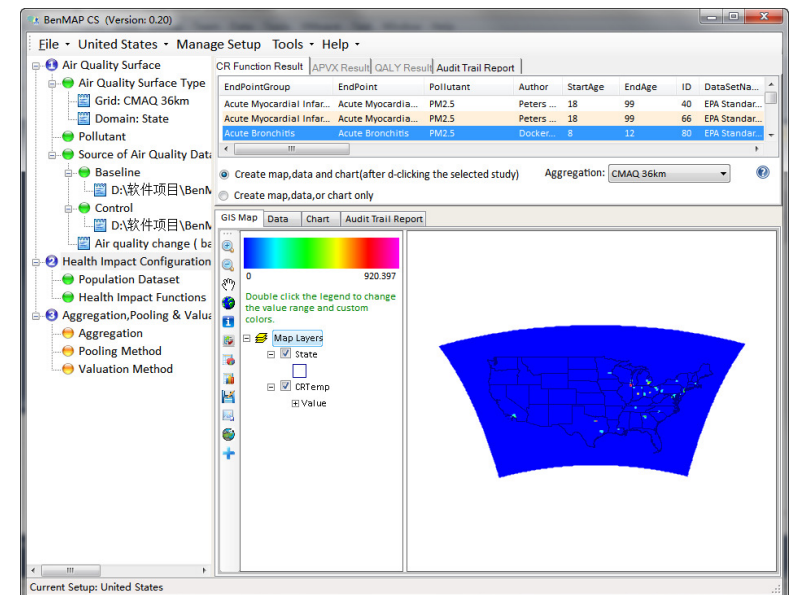


Redeveloping the Model to Address Future Policy Questions

- Rebuilding the model from the ground up
 - Improve computational efficiency
 - Address bugs and user interface issues
- Transition from proprietary to open-source framework
 - Code maintained by the contractor
 - Open-source framework may facilitate broader ownership of the model
- Implement a modern codebase
 - Current BenMAP written in Delphi, which is familiar to a more limited audience

BenMAP Community Software (BenMAP CS)

- Written in C#
 - More broadly used code
 - Distribute uncompiled code freely. EPA will retain regulatory version.
 - Multi-threading processes promises to decrease computation time
- GIS more tightly integrated into program
 - GIS will continue to interact with a database of population and health impact functions to calculate impacts
 - Users can add/modify all data
- Ability to perform multi-pollutant health impact assessments





Future BenMAP CS Enhancements and Modules

- Explore the feasibility of incorporating ecological endpoints
 - Recreational and residential visibility
- Multi-pollutant
 - Assess the impacts from multiple pollutants jointly
 - Incorporate variance/co-variance matrices to quantify uncertainty
- Environmental Justice
 - Calculate inequality metrics (Gini coefficient and Atkinson Index)
 - Use race-specific health data when calculating impacts
- Climate
 - Characterize temperature-modified air pollution effect estimates
 - Include ICLUS-based population projections that account for climate change scenarios
- International
 - Include new health impact functions for indoor cookstove pollution
 - Include health impact functions from non-U.S. studies
- Local-scale assessments
 - More easily assess city-specific impacts
- More easily quantify the benefits of EPA enforcement cases

Key terms

- Discounting – method for calculating how much future benefits and costs are worth today
- Cost of Illness (COI) - total costs of treatment and time lost due to illness, which often excludes pain and suffering
- Willingness to pay (WTP) - maximum amount of money an individual would pay to obtain an improvement in the environmental effects of concern
- Value of a Statistical Life (VSL) - aggregate dollar amount that a large group of people would be willing to pay for a small reduction in their individual risks of dying in a year
- Disbenefits – increase in pollution emissions, frequently as a secondary impact
- Net benefits – calculated by subtracting total costs from total monetized benefits.