

# Quantifying the Health Co-Benefits of Climate Action

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## LETTER

# Quantifying the health impacts of eliminating air pollution emissions in the City of Boston

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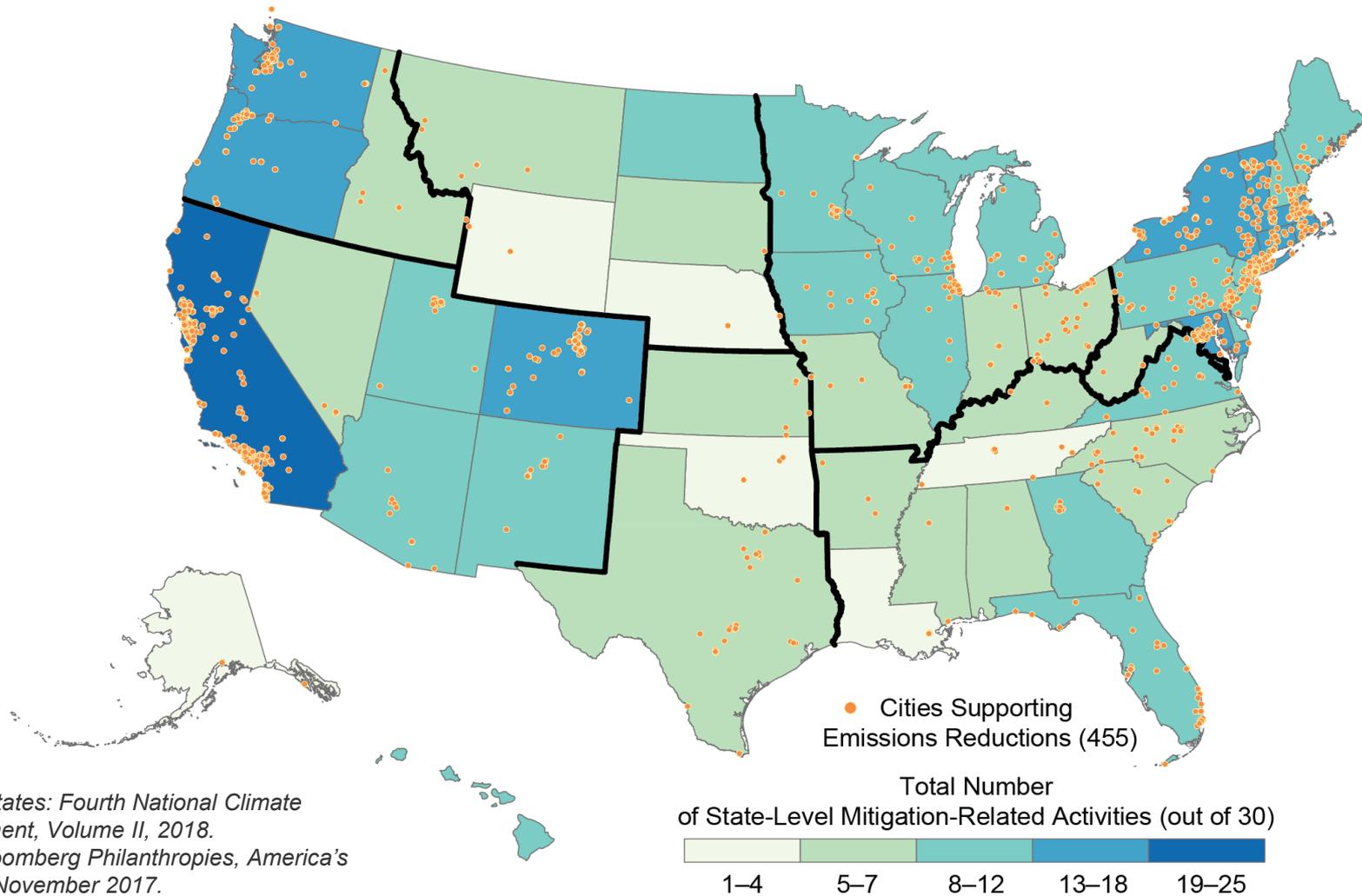
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Supplementary material for this article is available [online](#)

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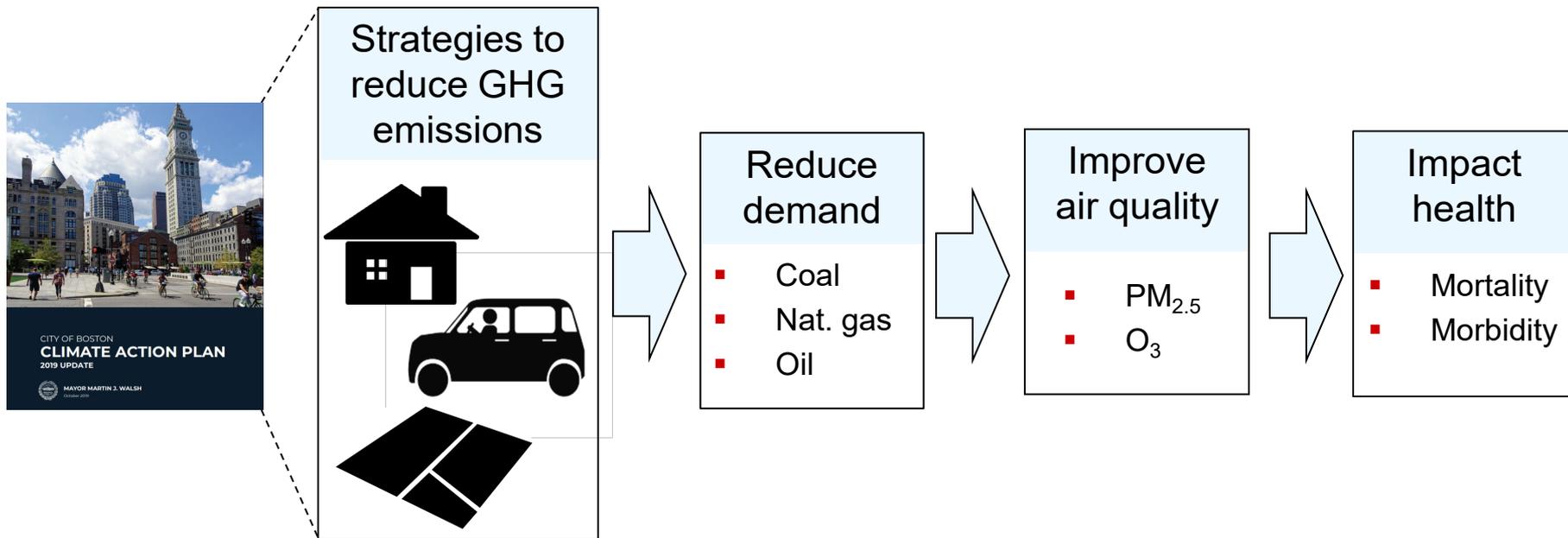
# GHG emissions targets and inventories



*United States: Fourth National Climate Assessment, Volume II, 2018.*

*Data: Bloomberg Philanthropies, America's Pledge, November 2017.*

# Pathway to Health Co-benefits from Boston's Climate Action Plan



# PM<sub>2.5</sub> and O<sub>3</sub> have strong associations with health impacts

## PM<sub>2.5</sub>

- **Mortality** (Liu et al, 2019; Laden et al, 2006; Krewski et al, 2009)
- **Myocardial infarction** (Zanobetti and Schwartz, 2006)
- **Respiratory and cardiac hospital admissions** (Zanobetti et al, 2009)
- **Asthma exacerbation** (Mar et al, 2004)
- **Lost work days** (Ostro 1987) and **restricted activity days** (Ostro and Rothchild, 1989)

## O<sub>3</sub>

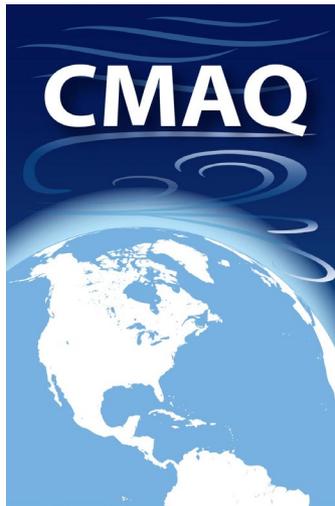
- **Mortality** (Levy et al, 2005)
- **Emergency room visits for asthma** (Mar and Koenig, 2009) and **youth asthma exacerbation** (O'Conner et al, 2008)
- **Respiratory hospital admissions** (Burnett et al, 2001; Schwatz, 1995)
- **School loss days** (Chen et al, 2000) and **restricted activity days** (Ostro and Rothchild, 1989)

# Estimating the change in PM<sub>2.5</sub> & O<sub>3</sub> from GHG emissions originating from Boston

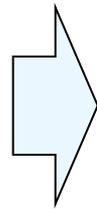
## Study domain

- Scenario 1: current air quality across the region
- Scenario 2: scenario 1 *except* emissions from Boston are eliminated
- Impact: change in air quality between the two scenarios

# Methods: modeling and analysis



- Base case
- Zero emissions



Calculate  
change in air  
quality between  
scenarios

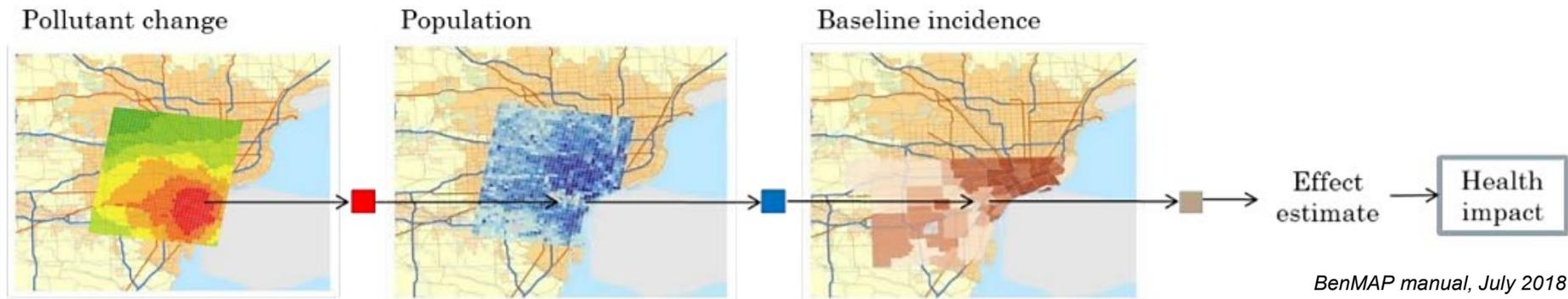
- Daily PM<sub>2.5</sub> avg
- Daily O<sub>3</sub> (8HRMAX)



- Health impacts
- Monetary valuation

# Methods: estimating health impacts

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

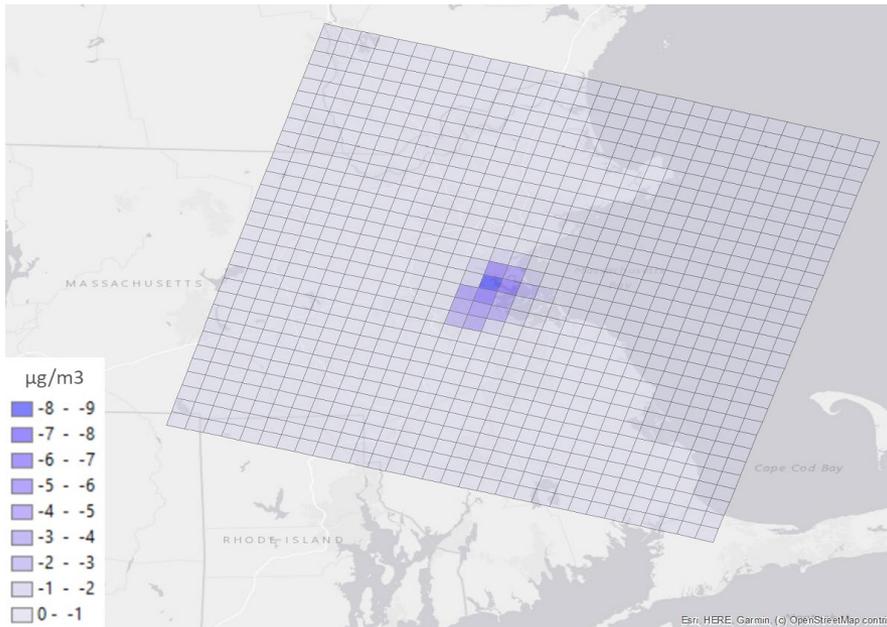


where,

- $\Delta Y$ : health impact;
- $Y_0$ : baseline incidence;
- $\beta$ : effect estimate from literature;
- $\Delta PM$ : change in air quality;
- Pop: exposed population.

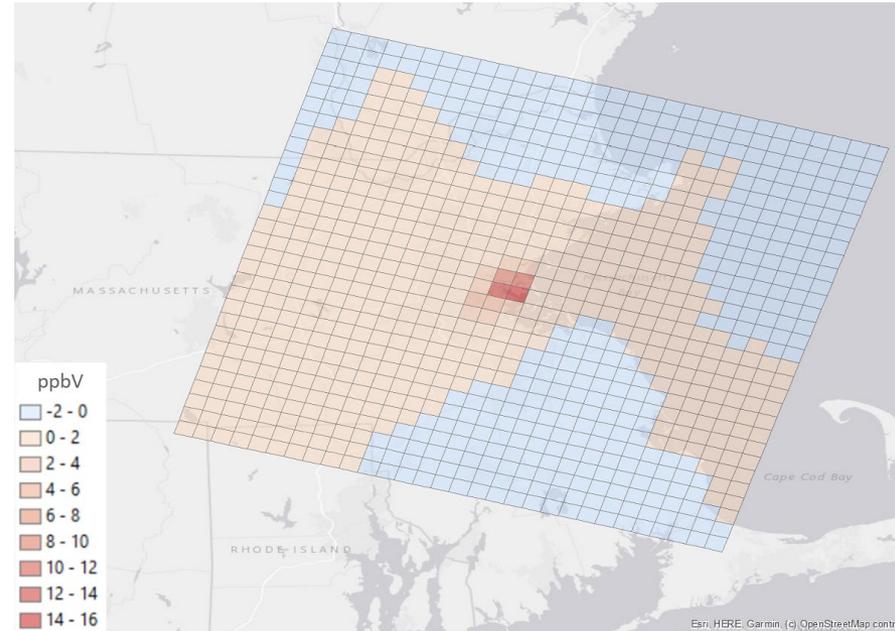
# Results: change in air quality

## Change in PM<sub>2.5</sub> concentration



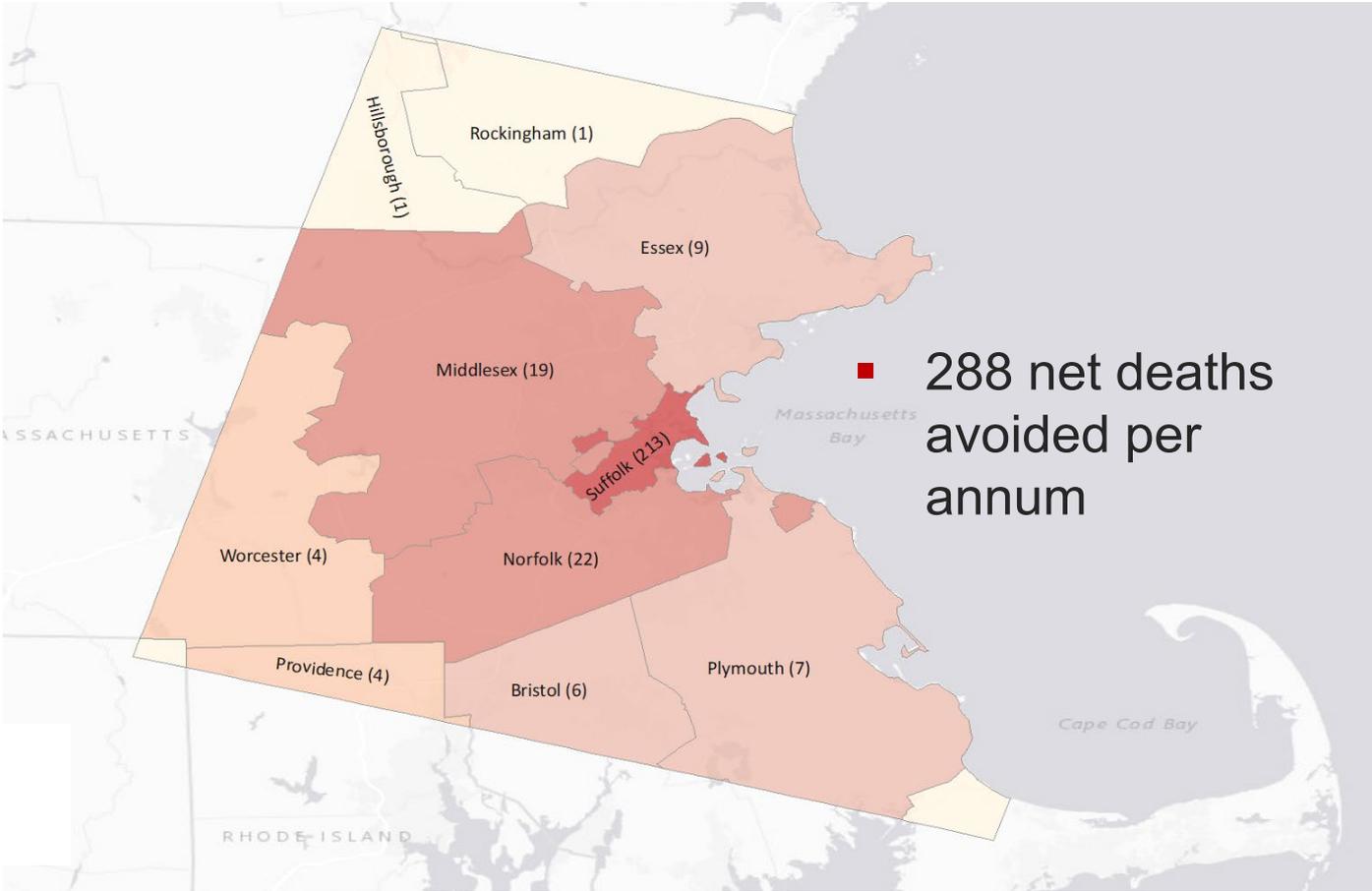
Max  $\Delta$ : downtown Boston from  $15.8 \mu\text{g}/\text{m}^3$  to  $7.3 \mu\text{g}/\text{m}^3$

## Change in O<sub>3</sub> concentration



Max  $\Delta$ : +14.2 ppb would occur near Logan Airport

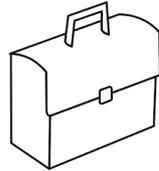
# Results: spatial distribution of net mortality impact



# Results: selected annual morbidity endpoints



~116 fewer heart attacks



~26,500 fewer work days lost

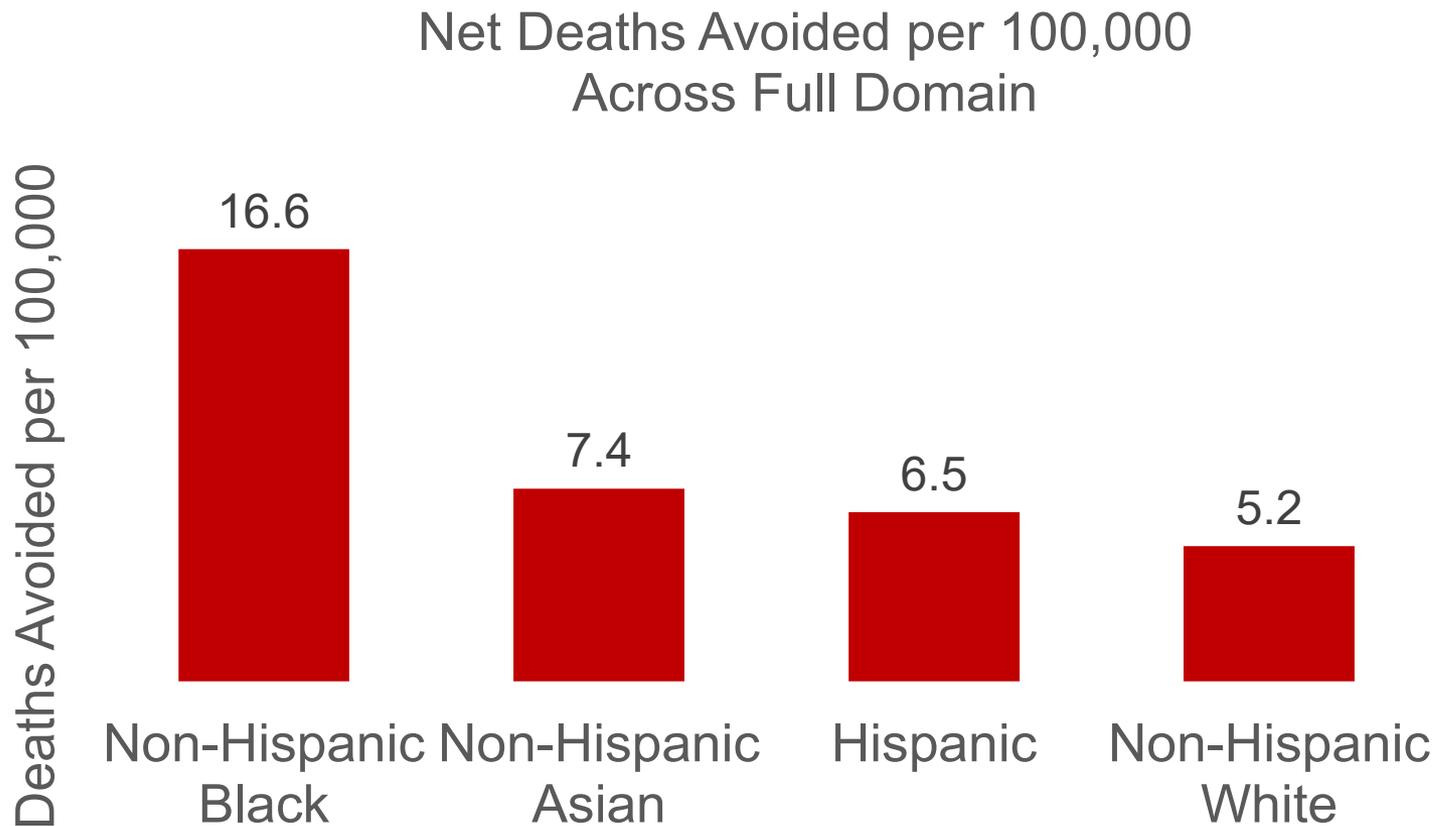


~17,000 fewer asthma exacerbation



~92,000 fewer minor restricted activity days

# Results: change in mortality incidence by race and ethnicity



# Thank you

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# Appendix

# Methods: zeroing out emissions

Table 1. Anthropogenic emissions and sources zeroed out for the City of Boston. Check mark indicates that emissions of the pollutant from the specified source category was included in the base case simulations and zeroed out for the zero emissions case.

Source Category	CO	NH <sub>3</sub>	NO <sub>x</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	VOC
Fugitive Dust	---	---	---	✓	✓	---	---
Agriculture <sup>1</sup>	---	---	---	---	---	---	---
Commercial Marine Sources	✓	✓	✓	✓	✓	✓	✓
Miscellaneous Area Sources	✓	✓	✓	✓	✓	✓	✓
Offroad Mobile	✓	✓	✓	✓	✓	✓	✓
Onroad Mobile	✓	✓	✓	✓	✓	✓	✓
Oil & Gas	✓	✓	✓	✓	✓	✓	✓
Electric Generating Units	✓	✓	✓	✓	✓	✓	✓
Fires <sup>1</sup>	---	---	---	---	---	---	---
Other Industrial Point Sources	✓	✓	✓	✓	✓	✓	✓
Rail	✓	✓	✓	✓	✓	✓	✓
Residential Wood Combustion	✓	✓	✓	✓	✓	✓	✓

<sup>1</sup> No sources of agriculture or fire emissions were located in the City of Boston

# Methods: Health impact functions

Pollutant	Endpoint	Age Range	Concentration-Response	Valuation Option
Ozone	Mortality	0-99	Levy et al, 2005	VSL, Weibull distribution, 26 studies
Ozone	Youth Asthma Exacerbation	6-18	O'Conner et al, 2008	WTP, 1 symptom-day
Ozone	School Loss Days	5-17	Chen et al, 2000	Loss based on daily wages
Ozone	Emergency Room Visits, Asthma	0-99	Mar and Koenig 2009	COI, normal distribution
Ozone	Respiratory Hospital Admissions	0-1, 65-99	Burnett et al 2001, Schwartz 1995	COI, medical costs, wage loss
Ozone	Minor Restricted Activity Days	18-64	Ostro and Rothschild, 1989	WTP, 1 day CV studies
PM2.5	Mortality (low estimate)	30-99	Krewski et al., 2009	VSL, Weibull distribution, 26 studies
PM2.5	Mortality (high estimate)	25-99	Laden et al, 2006	VSL, Weibull distribution, 26 studies
PM2.5	Non-fatal Acute Myocardial Infraction	25-99	Peters et al., 2001	10 years medical costs, 3% discount rate
PM2.5	Asthma, Emergency Room Visits	0-99	Mar et al., 2010	COI, normal distribution
PM2.5	Cardiovascular Hospital Admissions	18-99	Moolgavkar, 2000	Medical and wage costs
PM2.5	Respiratory Hospital Admissions	65-99	Zanobetti et al, 2009	COI, normal distribution
PM2.5	Chronic Bronchitis	27-99	Abbey et al, 1995	COI, medical costs and wage loss, 3% discount rate
PM2.5	Minor Restricted Activity Days	16-64	Ostro and Rothschild, 1989	WTP, 1 day CV studies
PM2.5	Work Days Lost	18-64	Ostro, 1987	Median daily wage
PM2.5	Asthma Exacerbation, Shortness of Breath	6-18	Mat et al. 2004	WTP to avoid a 1 symptom-day

# Results: why do PM<sub>2.5</sub> and O<sub>3</sub> move in different directions?

- In high NO<sub>x</sub> environments, the reaction of NO with O<sub>3</sub> to produce NO<sub>2</sub> and O<sub>2</sub> can be an O<sub>3</sub> sink as NO<sub>2</sub> acts to scavenge the radical



- When Boston area emissions were eliminated, the sink effect is diminished, leading to higher O<sub>3</sub> concentrations in those high NO<sub>x</sub> areas, with reductions in ozone downwind.

# Results: health impacts (PM<sub>2.5</sub>)

Health and monetary impacts from change in PM<sub>2.5</sub> when anthropogenic emissions from the City of Boston are eliminated.

Endpoint	Full Domain		Suffolk County Only	
	Incidence Avoided	Monetary Savings (\$2015 millions)	Incidence Avoided	Monetary Savings (\$2015 millions)
<b>Mortality (low estimate)</b>	125 (85, 164)	998 (92.7, 2710)	93 (63, 123)	746 (69.4, 2030)
<b>Mortality (high estimate)</b>	316 (144, 482)	2,530 (218, 7270)	236 (108, 358)	1,890 (163, 5410)
<b>Non-fatal Acute Myocardial Infraction</b>	116 (30, 192)	9.63 (2.48, 16.0)	77 (20, 127)	6.43 (1.69, 10.5)
<b>Asthma, Emergency Room Visits</b>	173 (46, 296)	0.07 (0.02, 0.11)	146 (39, 248)	0.06 (0.02, 0.96)
<b>Cardiovascular Hospital Admissions</b>	46 (25, 66)	1.77 (0.98, 2.55)	33 (19, 48)	1.29 (0.72, 1.86)
<b>Respiratory Hospital Admissions</b>	35 (20, 50)	1.03 (0.59, 1.46)	25 (15, 35)	0.73 (0.42, 1.04)
<b>Chronic Bronchitis</b>	117 (3, 224)	24.4 (0.64, 46.8)	87 (2, 165)	18.1 (0.48, 34.5)
<b>Minor Restricted Activity Days</b>	154,000 (126000, 181000)	9.83 (5.17, 14.9)	120,000 (98000, 141000)	7.66 (4.03, 11.6)
<b>Work Days Lost</b>	26,500 (22400, 30400)	5.05 (4.28, 5.80)	20,800 (17600, 23900)	3.82 (3.24, 4.39)
<b>Asthma Exacerbation</b>	23,600 (-31200, 70500)	4.67 (-6.17, 13.9)	17,100 (23200, 50300)	3.39 (-4.57, 9.95)

# Results: health impacts (O<sub>3</sub>)

*Health and monetary impacts from change in O<sub>3</sub> when anthropogenic emissions from the City of Boston are eliminated.*

Endpoint	Full Domain		Suffolk County Only	
	Incidence Avoided	Economic Savings (\$2015 millions)	Incidence Avoided	Economic Savings (\$2015 millions)
<b>Mortality</b>	-28 (-36, -19)	-221 (-600,-20.6)	-23 (-31, -16)	-187 (-506, -17.4)
<b>Youth Asthma Exacerbation</b>	-6,290 (-45700, 31100)	-1.25 (-9.01, 6.13)	-5,190 (-37800, -25600)	-1.03 (-7.45, 5.04)
<b>School Loss Days</b>	-13,500 (-2200, -5130)	-1.30 (-2.10, -0.49)	-11,000 (-18000, -4200)	-1.07 (-1.73, -0.40)
<b>Emergency Room Visits, Asthma</b>	-320 (-586, -73)	-0.12 (-0.23, -0.03)	-291 (-534, -66)	-0.11 (-0.21, 0.03)
<b>Respiratory Hospital Admissions</b>	-55 (-104, -9)	-1.31 (-2.52, -0.12)	-47 (-87, -8)	-1.09 (-2.09, -0.10)
<b>Minor Restricted Activity Days</b>	-61,600 (-98300, -25200)	-3.94 (-7.31, -1.45)	-52,900 (-84500, -21600)	-3.38 (-6.28, -1.25)