

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

OTC Modeling Committee
October 12, 2017



Executive Summary

In 2015, the 8-hour ozone National Ambient Air Quality Standard (NAAQS) was lowered to 70 ppb. This was the high end of the range recommended by the Clean Air Scientific Advisory Committee (CASAC) originally and in the rule proposal by Administrator McCarthy. The lower end of the range proposed by EPA was 65 ppb. Additionally, recent research has shown health effects from ozone occur at even lower levels. Given that health effects could be caused at levels closer to what is considered background we decided to also look at 40 ppb which close to a level considered to be United States Background (USB). As a result three levels of ozone were investigated in this analysis: 70 ppb, 65 ppb, and 40 ppb.

Each year that air quality does not meet the NAAQS the health of the populations exposed to the poor air quality are impacted. OTC began examining the potential health impacts of these levels of exposure starting in 2013 and as of writing 2016 is the most recent year for which data is available. As a result the analysis will focus on each ozone season for which data has been processed, 2013-2016, with the intention of adding new information annually.

Several states in the Ozone Transport Region (OTR) exceed the NAAQS set by EPA, which were set to a level to adequately protect the public health. This implies that populations in the OTR would receive a health benefit if the entire OTR were to meet the NAAQS. Additionally, even more monitors have values above the other thresholds discussed.

This paper looks at the benefits that would have occurred each year from 2013-2016, using monitored data had the entire OTR met ozone levels of 70 ppb, 65 ppb, and 40 ppb as estimated using health benefit and economic functions that came from peer reviewed sources employed by EPA in many studies processed with BenMAP.

We estimated that approximately 600 – 1,700 persons would have not died prematurely in a given year 2013-2016 had the OTR air quality attained a level that met the 70 ppb Ozone NAAQS with even more persons that would not have died if ozone levels were even lower.

As a point comparison in 2014 about 2,600 people died of homicide in the OTR and all of Virginia, 1,500 of HIV/AIDS, and 1,300 of Hepatitis C, which places deaths from ozone exposure among other notable health crises.

Additionally, we estimated that there would have been economic benefit to the region in the range of \$4-10 billion in all health impacts from reducing ozone to 70 ppb in any given year.

Estimated reduced mortality in the OTR from meeting different ozone levels

| Ozone Level | 2013 | 2014 | 2015 | 2016 |
|---------------|-------|-------|-------|-------|
| 70 ppb | 1,012 | 637 | 1,716 | 1,698 |
| 65 ppb | 1,858 | 1,378 | 2,142 | 2,266 |
| 40 ppb | 2,280 | 2,162 | 2,677 | 2,620 |

Selected causes of mortality in the OTR and VA from 2014

| Health Endpoint | Rank | Mortalities |
|--------------------|------|-------------|
| Homicide | 34 | 2,599 |
| HIV/AIDS | 38 | 1,547 |
| Hepatitis C | 41 | 1,266 |

Estimated economic benefit (billions) reduced health effects in the OTR from meeting different ozone levels

| Ozone Level | 2013 | 2014 | 2015 | 2016 |
|-------------|--------|--------|--------|--------|
| 70 | \$5.2 | \$3.7 | \$8.8 | \$10.0 |
| 65 | \$9.5 | \$8.1 | \$11.0 | \$13.4 |
| 40 | \$11.7 | \$12.7 | \$13.8 | \$15.5 |

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Introduction

In 2015, the 8-hour ozone National Ambient Air Quality Standard (NAAQS) was lowered to 70 ppb.¹ This was the high end of the range recommended by the Clean Air Scientific Advisory Committee (CASAC) originally and in the rule proposal by Administrator McCarthy. The lower end of the range proposed by EPA was 65 ppb. Additionally, recent research has shown health effects from ozone occur at even lower levels.² Given that health effects could be caused at levels closer to what is considered background we decided to also look at 40 ppb which close to a level considered to be United States Background (USB). As a result three levels of ozone were investigated in this analysis: 70 ppb, 65 ppb, and 40 ppb.

Each year that air quality does not meet the NAAQS the health of the populations exposed to the poor air quality are impacted. OTC began examining the potential health impacts of these levels of exposure starting in 2013 and as of writing 2016 is the most recent year for which data is available. As a result the analysis will focus on each ozone season for which data has been processed, 2013-2016, with the intention of adding new information annually.

Several states in the Ozone Transport Region (OTR) had monitored design values that were above the standard set by EPA. Given that the primary NAAQS are set to a level to adequately protect the public health, this implies that populations in the OTR would receive a health benefit if the entire OTR were to meet the NAAQS. This paper looks at the benefits that would have occurred each year from 2013-2016 had the entire OTR met ozone levels of 70 ppb, 65 ppb, and 40 ppb as estimated by the Environmental Benefits Mapping and Analysis Program (BenMAP) Community Edition (CE) program.³

Methods

Overview of the Health Impact Functions

BenMAP CE v1.3.52 was employed to process the health impact functions. These functions are developed to calculate the change in health incidence for a given population due to a change in air quality. The health impact functions typically consist of four variables: change in air quality, population, baseline incidence rate, and effect estimates that are drawn from epidemiological literature. The health impact functions used in the analysis were all functions provided in the downloadable version of BenMAP CE. The typical health impact function (Δy) is log-linear as follows:

$$\Delta y = y_0(e^{\beta\Delta q}-1)pop$$

where y_0 is the baseline incidence rate, β is the effect estimate, Δq is the change in air quality, and pop is the population.

¹ US EPA, "2015 National Ambient Air Quality Standards for Ozone."

² Di et al., "Air Pollution and Mortality in the Medicare Population."

³ US EPA, "Environmental Benefits Mapping and Analysis Program – Community Edition: User's Manual."

Change in Air Quality

Monitored ozone data were obtained throughout the entire OTR and the states that border the region (Ohio, West Virginia, and the remainder of Virginia) for 2013-2016 from the Air Quality System (AQS) monitor network and the data was originally compiled by staff at the Maine Department of Environmental Protection. The Voronoi Neighborhood Averaging (VNA) inverse distance interpolation squared technique was used to interpolate to grid cells between monitors. The bordering states were included so that the VNA would not result in inappropriate values along the western and southern borders of the OTR. Monitored ozone data was not available from Canada, so VNA may create unexpected results along the northern border, but exceedances are less common in that region so the monitors would not be rolled back anyway. The national CMAQ grid was used rather than the grid clipped to the United States boundaries since using the latter resulting in data missing in many grid cells in Maine.

Annual ozone season data was imported, but in many cases monitors only are operated during a shorter time period when conditions are conducive to ozone formation as defined in federal regulations (see Table 1). Furthermore, BenMap requires that a certain thresholds to be met for the data at a particular monitor to be considered acceptable. The default time spans for data to be considered are too stringent since several monitors with 4th high 8-hour ozone values above 70 ppb would be excluded so the time span of April 1 – October 31 was used. 4th high 8-hour ozone data for each year seen in Figure 1 though Figure 4 and data for the 20 worst monitors in the OTR can be seen in Table 2.

Table 1: Ozone monitoring season requirements (40 CFR 58 Appendix D (4)(i))

| State | Start Date | End Date |
|----------------------|------------|--------------|
| Connecticut | March 1 | September 30 |
| Delaware | March 1 | October 31 |
| District of Columbia | March 1 | October 31 |
| Maine | April 1 | September 30 |
| Maryland | March 1 | October 31 |
| Massachusetts | March 1 | September 30 |
| New Hampshire | March 1 | September 30 |
| New Jersey | March 1 | October 31 |
| New York | March 1 | October 31 |
| Pennsylvania | March 1 | October 31 |
| Rhode Island | March 1 | September 30 |
| Vermont | April 1 | September 30 |
| Virginia | March 1 | October 31 |

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Figure 1: 4th high monitored 8-hour ozone values for 2013

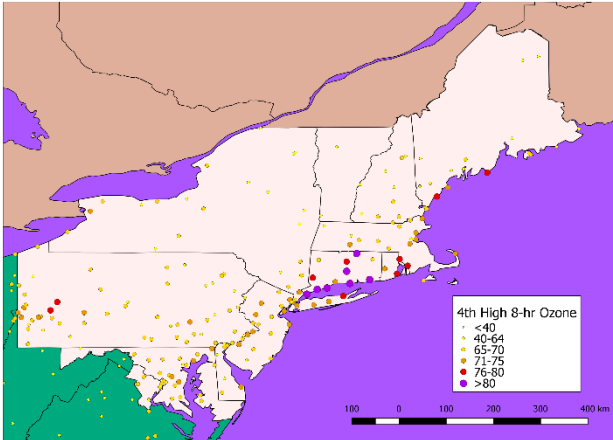


Figure 2: 4th high monitored 8-hour ozone values for 2014

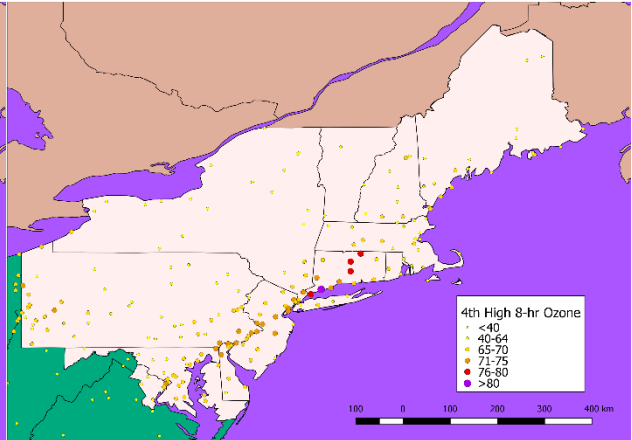


Figure 3: 4th high monitored 8-hour ozone values for 2015

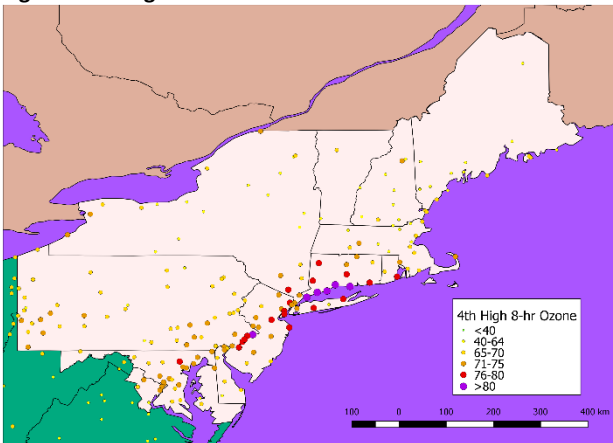


Figure 4: 4th high monitored 8-hour ozone values for 2016

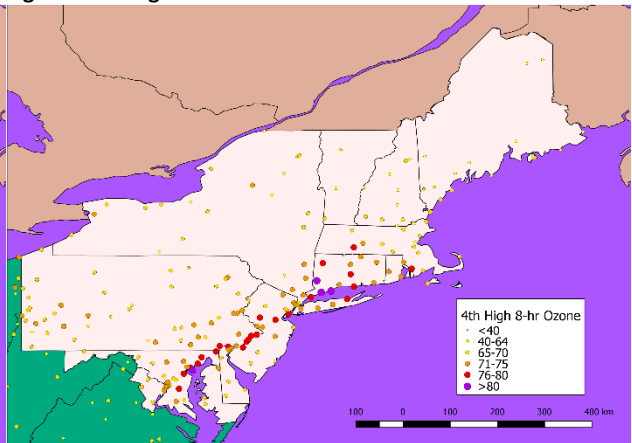


Table 2: 4th Highest 8-hour Ozone Concentrations from 2013 - 2016

| Agency | Site Name | AQ5 Code | 4th Highest 8-hr Ozone Concentrations | | | | Average 2013-16 4th High |
|--------|------------------------------|-----------|---------------------------------------|------|------|------|-----------------------------|
| | | | 2013 | 2014 | 2015 | 2016 | |
| CT | Westport | 90019003 | 86 | 81 | 87 | 87 | 85 |
| CT | Stratford | 90013007 | 90 | 74 | 86 | 83 | 83 |
| CT | Greenwich | 90010017 | 82 | 78 | 84 | 79 | 81 |
| CT | Middletown | 90070007 | 82 | 80 | 78 | 80 | 80 |
| CT | Madison-combined (3002 9002) | 90099002 | 85 | 69 | 81 | 80 | 79 |
| CT | Danbury | 90011123 | 76 | 74 | 79 | 81 | 78 |
| PA | Bristol | 420170012 | 73 | 71 | 82 | 80 | 77 |
| CT | East Hartford | 90031003 | 77 | 77 | 75 | 75 | 76 |
| CT | New Haven-B | 90090027 | 75 | 72 | 81 | 75 | 76 |
| CT | Groton Fort Griswold | 90110124 | 85 | 65 | 77 | 75 | 76 |
| CT | Stafford | 90131001 | 81 | 77 | 72 | 72 | 76 |
| MD | Fair Hill | 240150003 | 72 | 74 | 74 | 80 | 75 |
| NY | NYC-Susan Wagner HS | 360850067 | 71 | 72 | 79 | 77 | 75 |
| PA | NEA | 421010024 | 68 | 72 | 79 | 80 | 75 |
| NJ | Leonias | 340030006 | 74 | 73 | 76 | 75 | 75 |
| NY | Riverhead | 361030004 | 78 | 64 | 76 | 78 | 74 |
| NJ | Clarksboro | 340150002 | 73 | 70 | 76 | 76 | 74 |
| NJ | Rutgers U | 340230011 | 70 | 71 | 77 | 76 | 74 |
| NY | White Plains | 361192004 | 72 | 74 | 73 | 75 | 74 |
| MD | Edgewood | 240251001 | 72 | 67 | 74 | 79 | 73 |

After importing each year's monitored ozone data, BenMAP CE was employed to conduct an analysis termed "roll back." In this approach a mathematical technique is used to reduce the ozone values at the monitors so that each meets a threshold, in these cases a 4th highest daily maximum 8-hour ozone average concentration of 70 ppb, 65 ppb, or 40 ppb. Technically to demonstrate compliance with the 8-hour ozone NAAQS, the average of 3 years of the 4th highest daily maximum 8-hour ozone averages is calculated and referred to as a design value (DV) This is necessary since BenMAP CE only accepts one year worth of air quality data in an analysis. After the "roll back" is complete, the monitor data was then interpolated geographically using an inverse distance weighting technique.

There are three techniques for rolling back the monitored values to the standard: percentage reduction, incremental, and peak shaving that need to be applied to the inter-day and intra-day rollback. The peak shaving technique was employed for the inter-day rollback so values meeting the standard would not have reductions applied, which would result in more conservative results. The percentage technique was employed for the intra-day rollback since it best reflected the implementation of measures that would affect each hour of the day equally.

In conducting the analysis, including a background rate was necessary to prevent monitors from being lowered below what would occur absent anthropogenic emissions. There are a variety of estimates for background, and even several values considered background (e.g., United States Background (USB) and North American Background (NAB)). For this aspect of the modeling a value of 30 ppb was used which is associated with lower levels of NAB found in the Eastern United States in the summer time as was presented in Figure 3-9 of EPA's Integrated Scientific Assessment for the 2015 Ozone NAAQS.⁴ Peak shaving was used as the inter-day rollback method and percentage reduction was used as the intra-day rollback method. In both cases 30 ppb was used for the background level.

One potential flaw with the rollback approach is that only monitors that have 4th highest values above 70 ppb were rolled back to the standard. However, in a case where controls are put on to achieve such a monitored level, downwind areas would also have reduced ozone concentrations even though their monitors are already below the standard. As a result, the health effects downwind, in New England in particular, are lower than what would be experienced in a real world scenario.

Population

US population data were based on estimates of populations in the corresponding year projected from 2010 block-level US Census data. The geographic extent of population was limited to the population that lives in the 12 full states in the OTR, the District of Columbia and the nine cities/counties in Virginia that are considered part of the OTR. However, not all health incidence are evaluated against the entire population of the OTR, some are evaluated only against sub populations based on age. The total

⁴ Lin Zhang et al., "Improved Estimate of the Policy-Relevant Background Ozone in the United States Using the GEOS-Chem Global Model with 1/2° × 2/3° Horizontal Resolution over North America"; US EPA, *Integrated Science Assessment for Ozone and Related Photochemical Oxidants*.

population used for each year and various age cohorts as well as the health endpoint group associated with the age cohort is in Table 3.

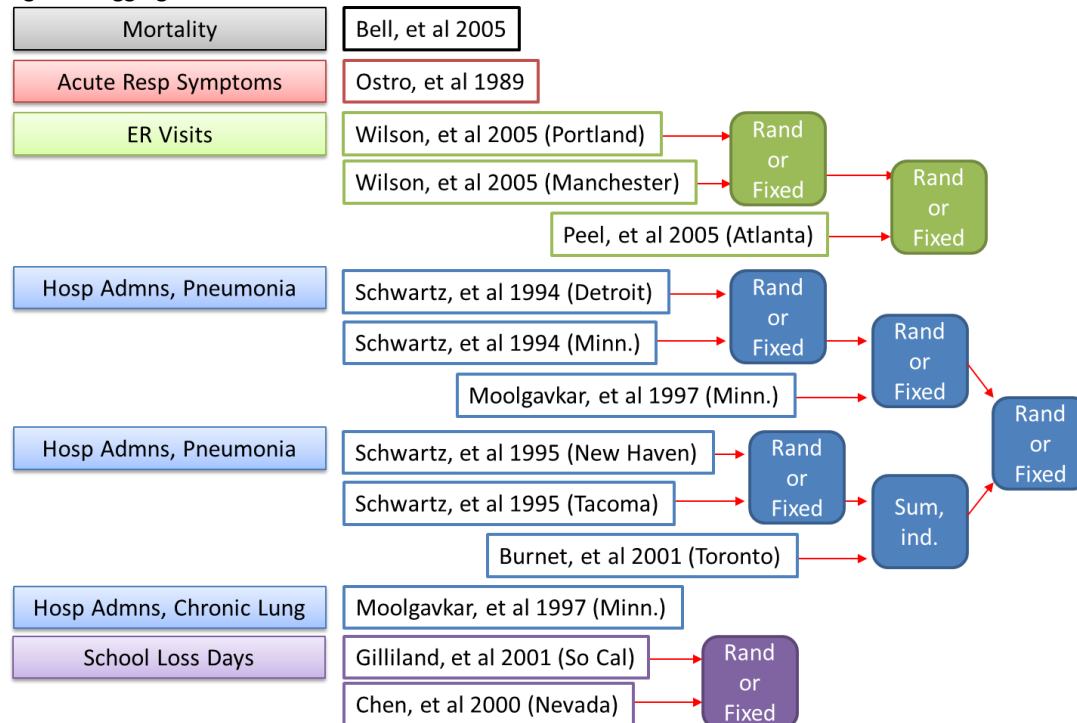
Table 3: Population for each age cohort by year analyzed

| Population | Health Endpoint Group | 2013 | 2014 | 2015 | 2016 |
|-------------|----------------------------------|------------|------------|------------|------------|
| Total | Mortality, Emergency Room Visits | 66,403,000 | 66,610,000 | 66,928,000 | 67,301,000 |
| 18-64 | Acute Respiratory Symptoms | 42,120,000 | 42,152,000 | 42,246,000 | 42,321,000 |
| 0-1 and 65+ | Hospital Admissions | 9,651,000 | 9,899, 000 | 10,167,000 | 10,437,000 |
| 5-17 | School Loss Days | 10,682,000 | 10,592,000 | 10,504,000 | 10,463,000 |

Selection of Health Impact Functions

There is evidence of a relationship between long-term exposure to concentrations of ozone and premature respiratory mortality, which is one of a few studies that detect an increase in mortality from long-term ozone exposure.⁵ However there remain questions as to whether long-term mortality has the same direct relationship to ozone exposure as short-term mortality does since this is a newer finding in the literature, so this paper will only examine short-term mortality. Additionally, several functions representing morbidity, including acute respiratory symptoms, respiratory hospital admissions, respiratory emergency rooms visits, and school loss days, were used, which are functions typically used in EPA studies. The process to aggregate the results of the health studies is in Figure 5.

Figure 5: Aggregation of health effects studies



⁵ Jerrett et al., "Long-Term Ozone Exposure and Mortality."

Baseline Incidence Rates

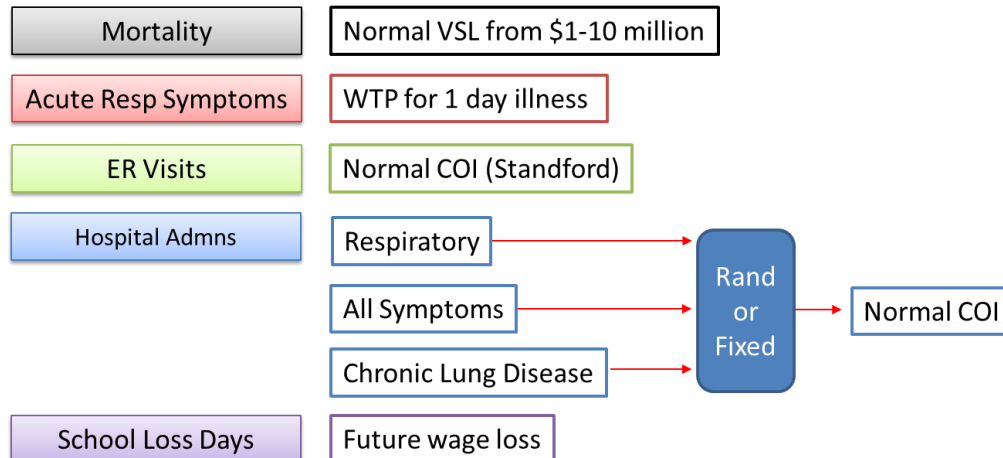
Baseline incidence rates that are part of EPA’s dataset were used in this analysis. Incidence rate data sets are not available for every year so selections of which year to use are largely made based on the proximity of the year the incidence data set is for to the year of the monitored data being evaluated. Projections of mortality incidence rates were available in five year increments and 2015, which coincided with one of the years analyzed, was determined to be the most appropriate data set to use with the mortality health impact functions. Only one incidence data set was available for the other health endpoints so the incidence estimates for 2014 were used for the other health endpoints excepting school loss days where 2000 was the only data set available and acute respiratory systems which has a slightly different form than the other functions, so baseline incidence rates are not included in the equation.

Economic Analysis

In order to quantify the impact of the health benefits the reduced incidence is multiplied by a valuation estimated through one of several techniques. In the case of mortality, the Value of Statistical Life (VSL) based upon a normal distribution was used. The VSL uses differences in salaries and the inherent risk of a job to infer the rate at which life is valued. A Willingness to Pay (WTP) estimate was used to monetize acute respiratory symptoms. WTP relies on survey data to determine how much people value not having an adverse health effect. Cost of Illness (COI) estimates were used to value emergency room visits and hospital admissions. COI totals up the amount spent on medicine, hospital visits, etc. due to an adverse health effect. Since the VSL is based on hedonic economic analysis it best characterizes the complete value of the effect, with the WTP estimates characterizing less of the true cost, and COI capturing the least of the true cost. The process undertaken to aggregate the economic results are in Figure 6.

Additionally, income effects were adjusted to the year analyzed and all valuations are in 2010 U.S. Dollars, inflated using the Consumer Price Index (CPI) and Employer Costs for Employee Compensation (ECEC).

Figure 6: Aggregation of economic evaluations



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Figure 7: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2013

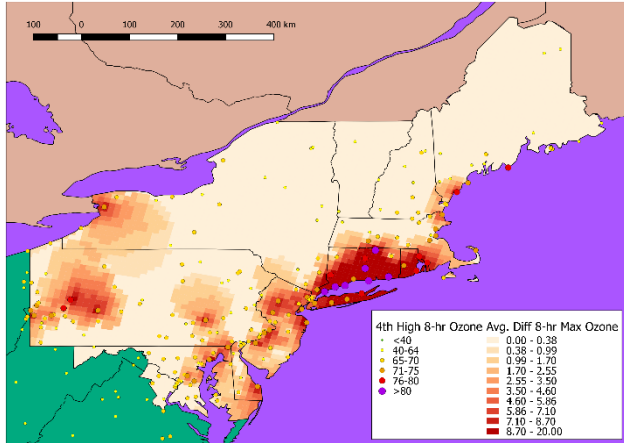


Figure 8: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2013

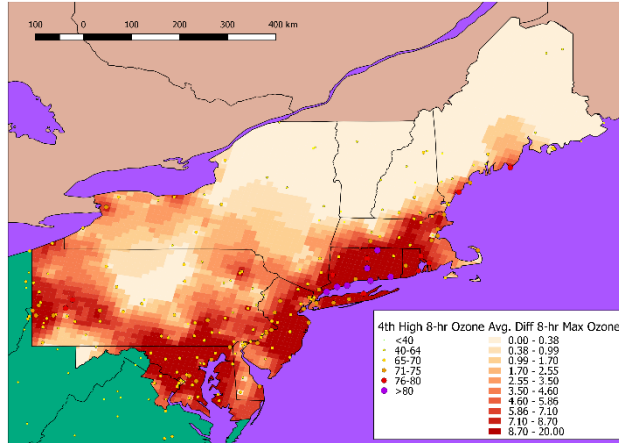


Figure 9: Change in avg. 8-hour max. ozone due to roll back to 40 ppb using data from 2013

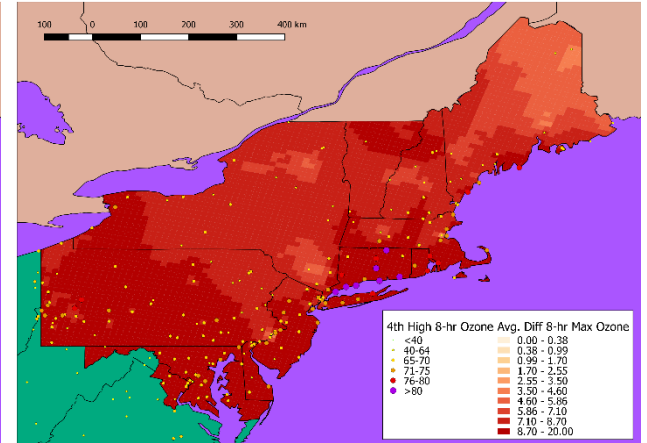


Figure 10: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2014

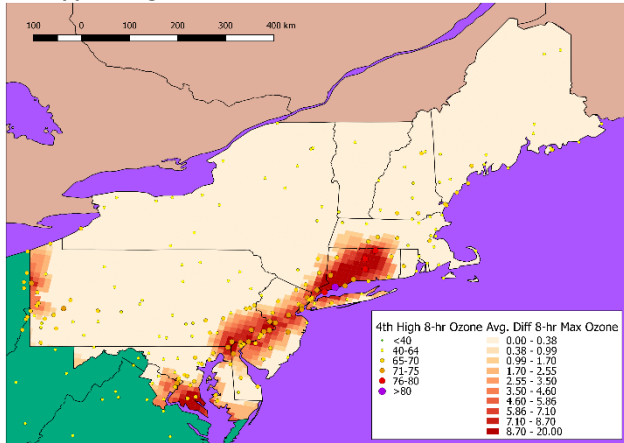


Figure 11: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2014

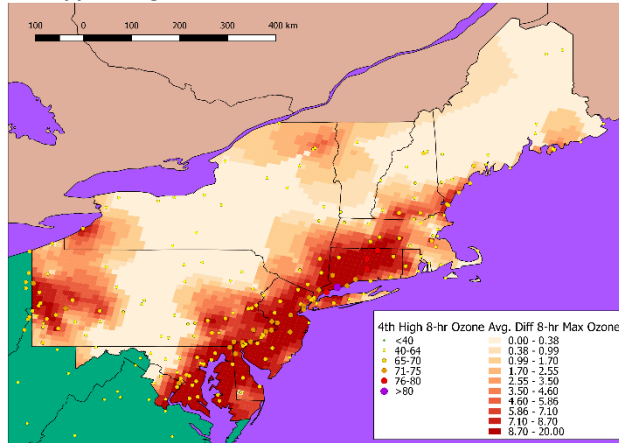
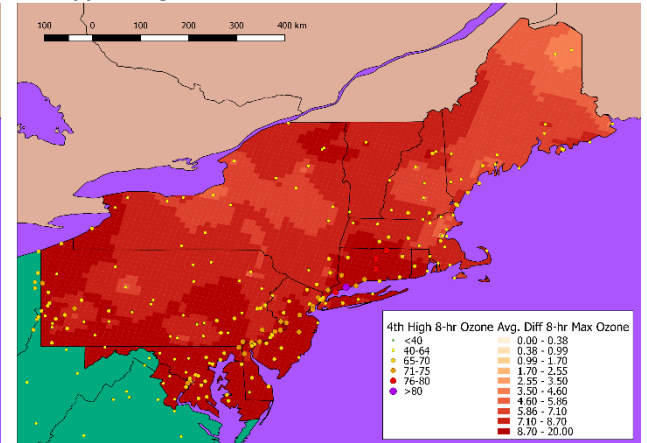


Figure 12: Change in avg. 8-hour max. ozone due to roll back to 40 ppb using data from 2014



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Figure 13: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2015

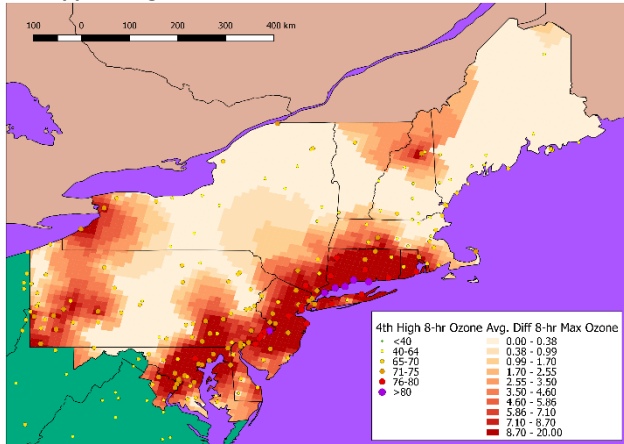


Figure 14: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2015

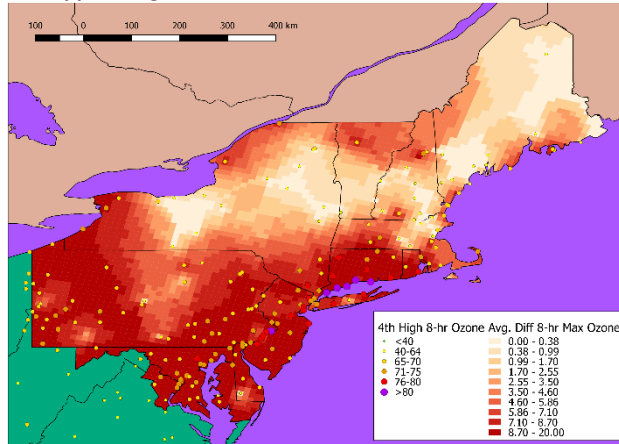


Figure 15: Change in avg. 8-hour max. ozone due to roll back to 40 ppb using data from 2015

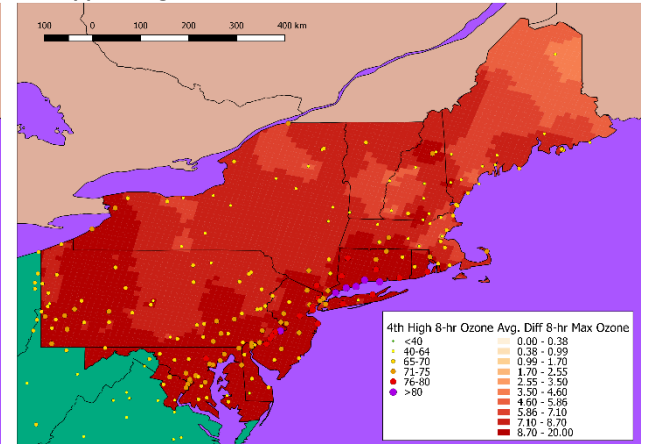


Figure 16: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2016

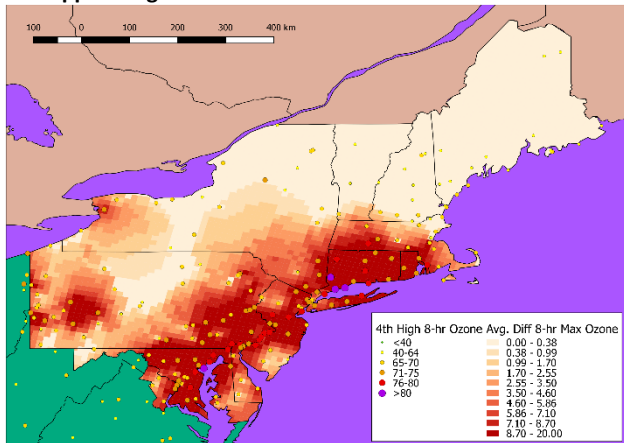


Figure 17: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2016

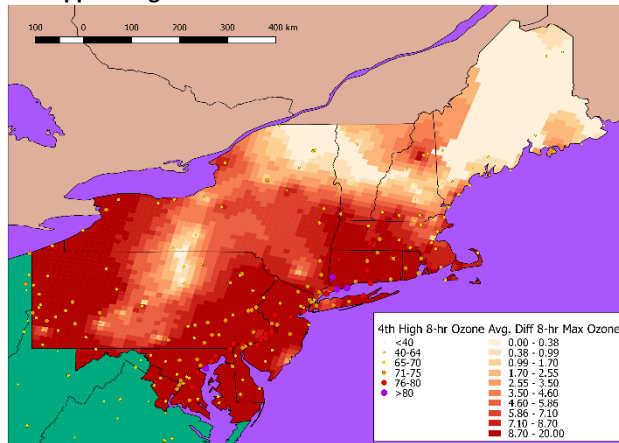
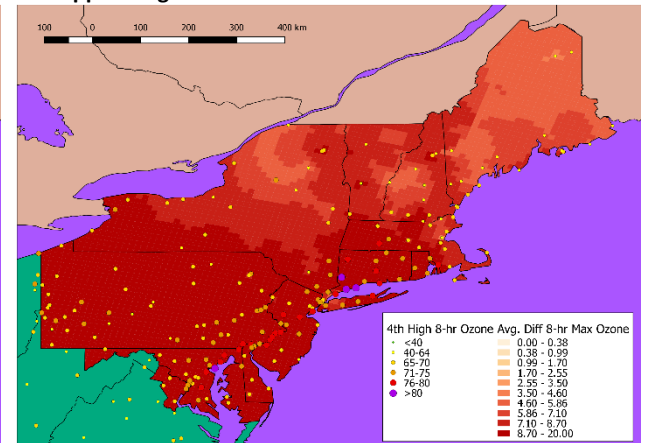


Figure 18: Change in avg. 8-hour max. ozone due to roll back to 40 ppb using data from 2016



Results

Monitor Rollback

The majority of the reductions in ozone levels in 70 ppb rollbacks occurred in the I-95 corridor between Washington, DC and New York City, NY, with smaller reductions extending north to Boston, MA. Western Pennsylvania also saw reductions in the 70 ppb rollback scenarios except in 2014. Central Pennsylvania saw reductions in 2015 and 2016. Northern New Hampshire also saw reductions in some years, though this was highly dependent on the value of a mountain monitor that is in a very rural area and can experience stratospheric intrusions, and likely is not leading to the high level of population exposures that the model suggests.

In the 65 ppb scenario the reductions were greater in the I-95 corridor and Western Pennsylvania, Eastern Pennsylvania, and Central New York saw reductions in all years. Several years also saw reductions in coastal Maine.

The entire region saw massive reductions in ozone levels in the 40 ppb rollback scenarios including many rural areas in the region.

Overview maps of the changes in average 8 hour maximum ozone concentrations in the OTR after being rolled back to 70 ppb in left most figures from Figure 7 through Figure 18 to 65 ppb in the center figures and to 40 ppb in the right most figures.

Health Impact

After processing the health impact functions, we estimated that had the entire OTR had 4th highest monitor results at or under 70 ppb it is expected that there would have been anywhere from 50 to 860 fewer short term mortalities due to ozone exposure. A similar pattern of results happened for 65 and 40 ppb rollbacks, but with higher levels of reduced mortality. Emergency room visit were not estimated to be significant different than 0. The same pattern of results occurred for the other health endpoints as mortality with the magnitude being of hospital admissions being about half of the mortality incidence, acute respiratory symptoms being roughly 2000 times, and school loss days being roughly 500 times. State level graphs showing the mean mortality for each year from 2013-2016 for having met 70 ppb, 65 ppb, and 40 ppb are in Figure 19, Figure 20, and Figure 21, respectively. A full listing of the reduced health incidence pooled for the OTR is in Table 4 with a state level breakout in Table 7.

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Figure 19: Estimated state mortalities that could have been avoided by meeting the 70 ppb NAAQS from 2013-2016

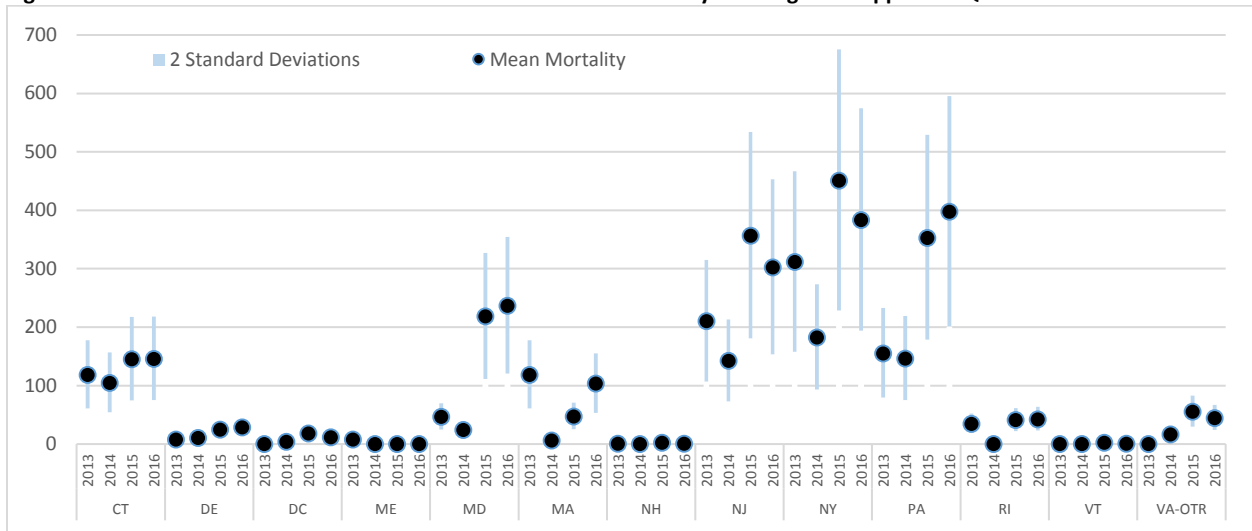


Figure 20: Estimated state mortalities that could have been avoided by meeting the 65 ppb NAAQS from 2013-2016

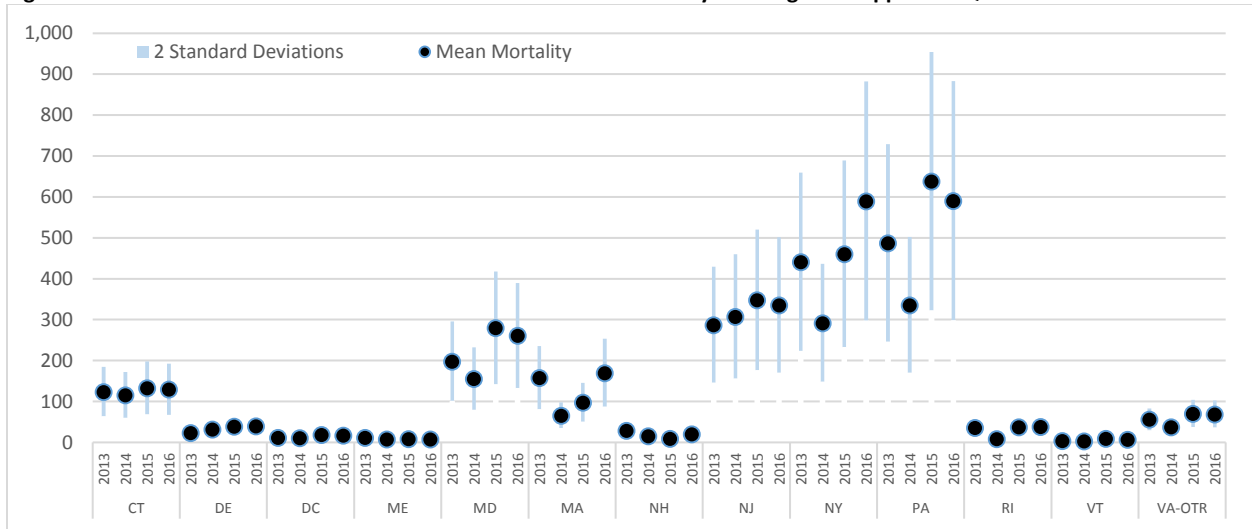
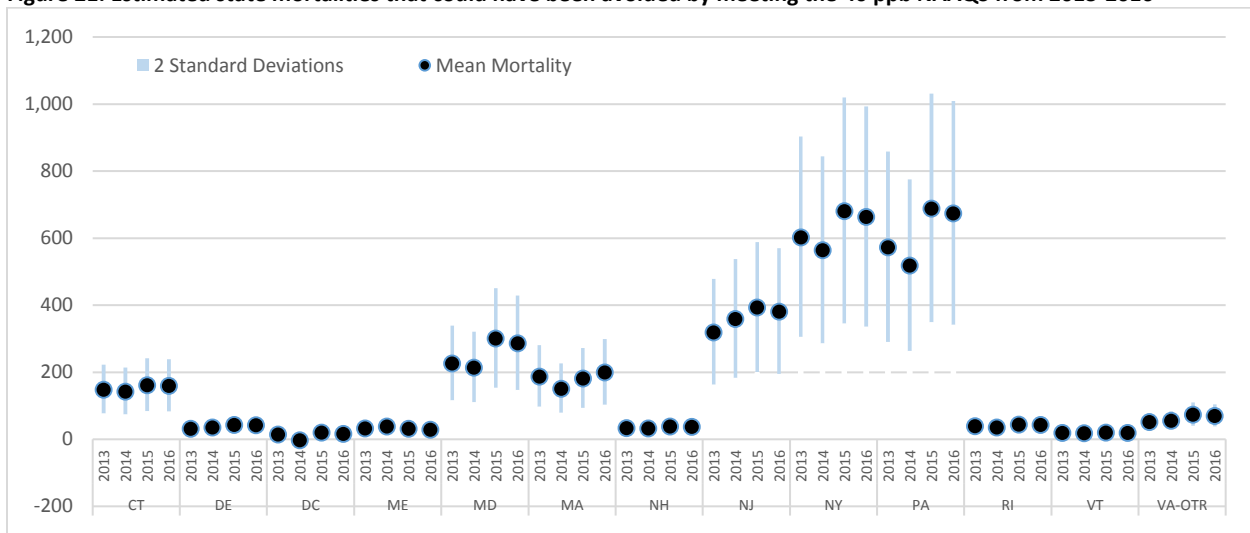


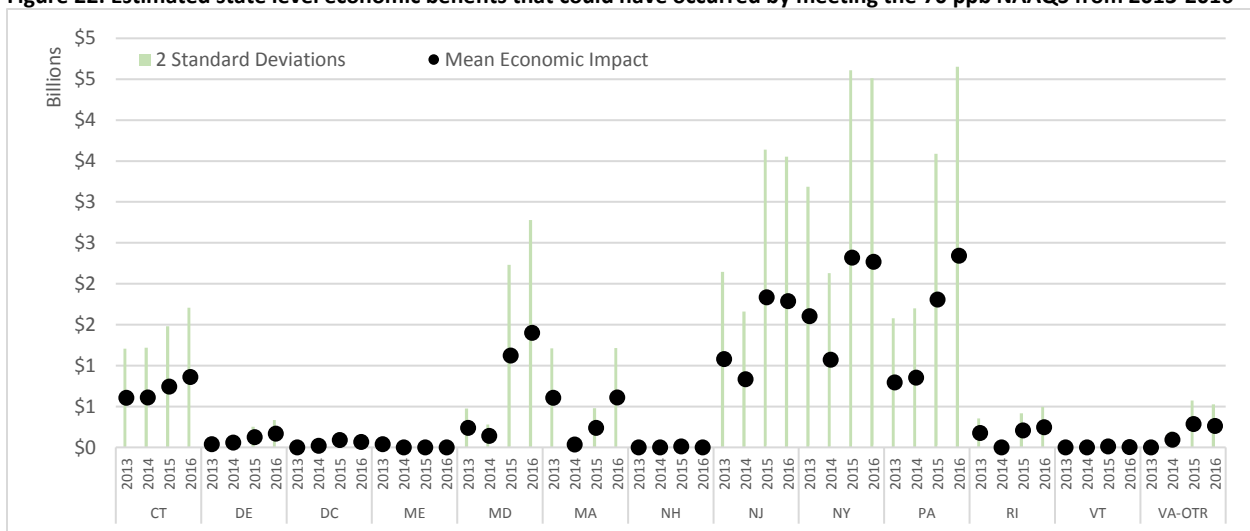
Figure 21: Estimated state mortalities that could have been avoided by meeting the 40 ppb NAAQS from 2013-2016



Economic Impact

Following analysis of the health impacts, economic impacts were estimated using the previously discussed techniques. The value of the mortalities outweigh the other economic impacts considerably, though one should consider that some economic benefits such as reduced personal suffering may not have been monetized for morbidity due to the data, such as cost of illness estimates, used in developing the cost estimates. Again emergency room visits were not found to be significantly different from zero, as were minor restricted activity days. Total economic benefits for the OTR, excluding emergency room visits and minor restricted activity days, are found for each year from 2013-2016 for having met 70 ppb, 65 ppb, and 40 ppb in Figure 22, Figure 23, and Figure 24, respectively. A full break down of the economic impacts is in Table 5 with a state level breakout in Table 8.

Figure 22: Estimated state level economic benefits that could have occurred by meeting the 70 ppb NAAQS from 2013-2016



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Figure 23: Estimated state level economic benefits that could have occurred by meeting the 65 ppb NAAQS from 2013-2016

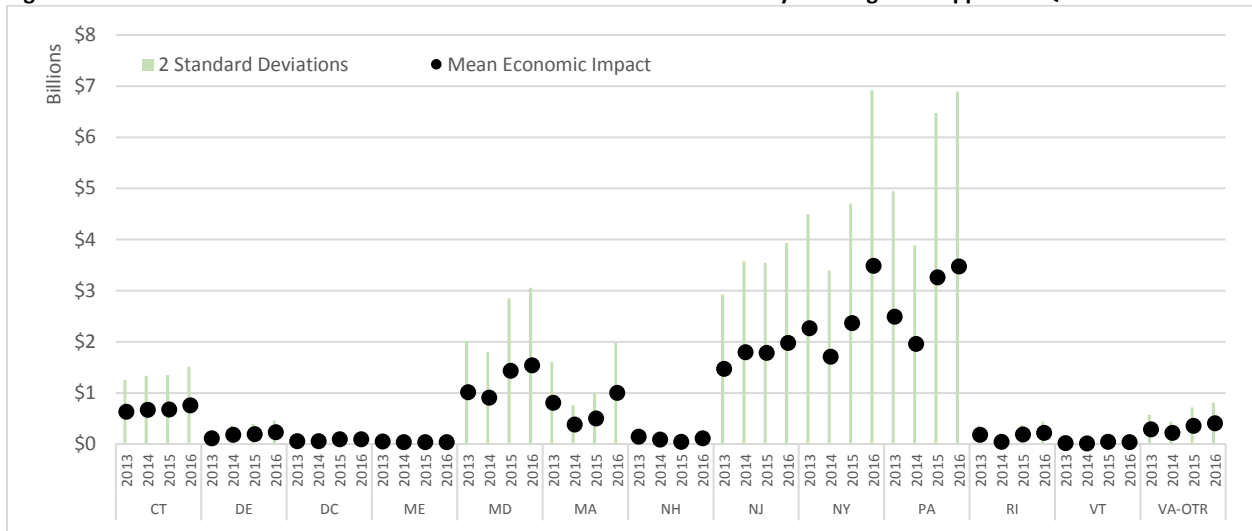
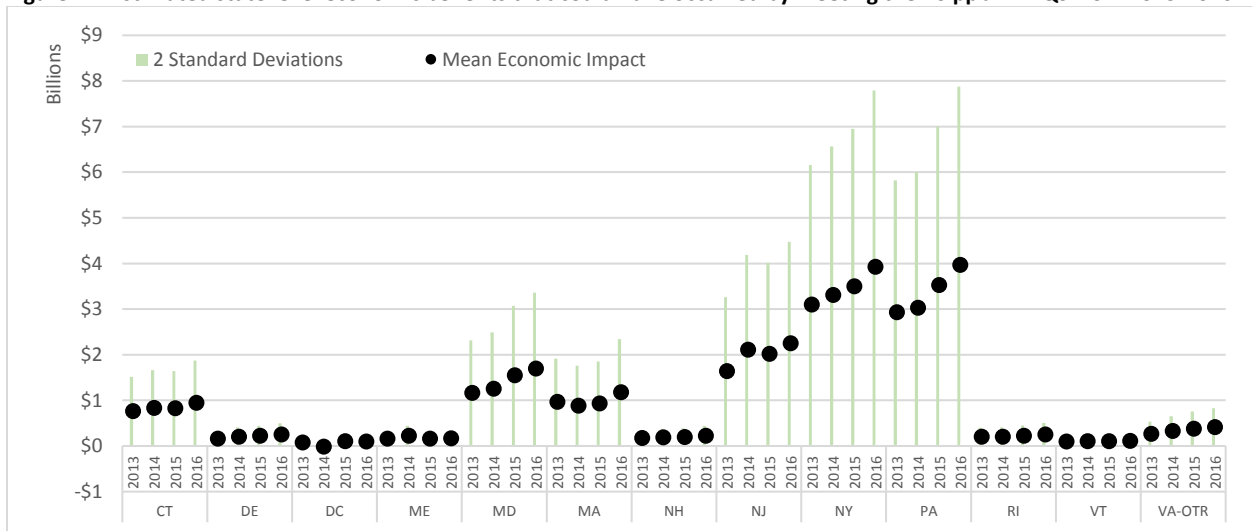


Figure 24: Estimated state level economic benefits that could have occurred by meeting the 40 ppb NAAQS from 2013-2016



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Table 4: Estimated ozone-related health impacts following monitor rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR

| | Mortality, All Causes ⁶ | | | Emergency Room Visits Respiratory ^{7,8} | | | Hospital Admissions Respiratory ^{9,10,11,12,13} | | | Acute Respiratory Symptoms ¹⁴ | | | School Loss Days ^{15,16} | | |
|-------------|------------------------------------|-------|-------|--|------|-------|--|-----|-------|--|-----------|-----------|-----------------------------------|---------|-----------|
| | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ |
| 2013 | | | | | | | | | | | | | | | |
| 40 | 2,280 | 1,146 | 3,415 | 2,247 | -449 | 4,944 | 1,284 | 377 | 2,191 | 4,197,816 | 1,892,705 | 6,502,927 | 1,202,964 | 486,281 | 1,919,647 |
| 65 | 1,620 | 813 | 2,427 | 1,689 | -339 | 3,717 | 927 | 274 | 1,581 | 3,075,827 | 1,381,628 | 4,770,027 | 890,618 | 360,100 | 1,421,135 |
| 70 | 817 | 410 | 1,224 | 911 | -184 | 2,006 | 466 | 142 | 789 | 1,610,165 | 721,417 | 2,498,912 | 456,384 | 184,554 | 728,213 |
| 2014 | | | | | | | | | | | | | | | |
| 40 | 2,193 | 1,101 | 3,284 | 2,175 | -435 | 4,786 | 1,246 | 365 | 2,127 | 4,045,310 | 1,822,237 | 6,268,383 | 1,152,382 | 465,887 | 1,838,876 |
| 65 | 1,378 | 692 | 2,065 | 1,535 | -308 | 3,378 | 788 | 237 | 1,339 | 2,648,090 | 1,188,791 | 4,107,388 | 752,984 | 304,483 | 1,201,484 |
| 70 | 97 | 48 | 145 | 111 | -16 | 237 | 57 | 16 | 98 | 194,477 | 85,659 | 303,295 | 54,890 | 22,216 | 87,563 |
| 2015 | | | | | | | | | | | | | | | |
| 40 | 2,642 | 1,331 | 3,953 | 2,601 | -511 | 5,713 | 1,489 | 449 | 2,530 | 4,747,440 | 2,164,519 | 7,330,360 | 1,374,614 | 485,734 | 2,263,494 |
| 65 | 2,142 | 1,076 | 3,207 | 2,164 | -432 | 4,760 | 1,205 | 367 | 2,043 | 3,877,164 | 1,748,947 | 6,005,381 | 1,098,322 | 444,039 | 1,752,605 |
| 70 | 1,716 | 862 | 2,570 | 1,928 | -384 | 4,240 | 978 | 299 | 1,657 | 3,299,106 | 1,489,185 | 5,109,027 | 928,840 | 375,517 | 1,482,164 |
| 2016 | | | | | | | | | | | | | | | |
| 40 | 2,620 | 1,317 | 3,923 | 2,545 | -506 | 5,595 | 1,501 | 446 | 2,557 | 4,677,157 | 2,115,095 | 7,239,219 | 1,311,394 | 530,069 | 2,092,719 |
| 65 | 2,266 | 1,139 | 3,394 | 2,276 | -454 | 5,006 | 1,294 | 384 | 2,204 | 4,099,376 | 1,849,093 | 6,349,658 | 1,147,950 | 464,077 | 1,831,822 |
| 70 | 1,698 | 853 | 2,543 | 1,736 | -347 | 3,819 | 983 | 301 | 1,665 | 3,132,862 | 1,410,641 | 4,855,084 | 880,268 | 355,906 | 1,404,630 |

⁶ Bell, Dominici, and Samet, "A Meta-Analysis of Time-Series Studies of Ozone and Mortality with Comparison to the National Morbidity, Mortality, and Air Pollution Study."

⁷ Peel et al., "Ambient Air Pollution and Respiratory Emergency Department Visits."

⁸ Wilson et al., "Air Pollution, Weather, and Respiratory Emergency Room Visits in Two Northern New England Cities: An Ecological Time-Series Study"; Peel et al., "Ambient Air Pollution and Respiratory Emergency Department Visits."

⁹ Moolgavkar, Luebeck, and Anderson, "Air Pollution and Hospital Admissions for Respiratory Causes in Minneapolis-St. Paul and Birmingham"; Schwartz, "PM10 Ozone, and Hospital Admissions for the Elderly in Minneapolis-St. Paul, Minnesota"; Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Detroit, Michigan."

¹⁰ Schwartz, "PM10 Ozone, and Hospital Admissions for the Elderly in Minneapolis-St. Paul, Minnesota."

¹¹ Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Detroit, Michigan."

¹² Schwartz, "Short Term Fluctuations in Air Pollution and Hospital Admissions of the Elderly for Respiratory Disease."

¹³ Burnett et al., "Association between Ozone and Hospitalization for Acute Respiratory Diseases in Children Less than 2 Years of Age."

¹⁴ Ostro and Rothschild, "Air Pollution and Acute Respiratory Morbidity: An Observational Study of Multiple Pollutants."

¹⁵ Chen et al., "Elementary School Absenteeism and Air Pollution."

¹⁶ Gilliland et al., "The Effects of Ambient Air Pollution on School Absenteeism due to Respiratory Illnesses."

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Table 5: Estimated ozone-related economic impacts (2010\$) following monitor rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR

| | Mortality, All Causes | | | Emergency Room Visits, Asthma | | | Hospital Admissions Respiratory | | |
|-------------|---------------------------------------|---------------|------------------|-------------------------------|--------------|---------------|---------------------------------|-------------|--------------|
| | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ |
| 2013 | | | | | | | | | |
| 40 | \$11,519,485,792 | \$170,072,048 | \$22,868,899,536 | \$509,316 | -\$101,640 | \$1,120,272 | \$21,681,375 | \$5,500,972 | \$37,861,779 |
| 65 | \$9,384,812,704 | \$136,750,106 | \$18,632,875,302 | \$427,626 | -\$85,729 | \$940,981 | \$17,854,061 | \$4,591,009 | \$31,117,112 |
| 70 | \$5,113,000,701 | \$73,367,741 | \$10,152,633,661 | \$238,148 | -\$48,003 | \$524,299 | \$9,966,407 | \$2,500,940 | \$17,431,873 |
| 2014 | | | | | | | | | |
| 40 | \$12,471,234,255 | \$163,240,374 | \$24,779,228,136 | \$495,992 | -\$99,509 | \$1,091,493 | \$20,674,349 | \$5,382,028 | \$35,966,671 |
| 65 | \$7,950,936,124 | \$114,978,588 | \$15,786,893,660 | \$347,812 | -\$69,830 | \$765,455 | \$13,264,398 | \$3,388,041 | \$23,140,755 |
| 70 | \$3,676,306,592 | \$52,454,418 | \$7,300,158,766 | \$189,667 | -\$38,234 | \$417,568 | \$6,147,040 | \$1,604,490 | \$10,689,590 |
| 2015 | | | | | | | | | |
| 40 | \$13,526,233,880 | \$202,842,248 | \$26,849,625,512 | \$600,523 | -\$119,090 | \$1,320,137 | \$25,622,879 | \$6,657,492 | \$44,588,266 |
| 65 | \$10,819,146,524 | \$160,019,168 | \$21,478,273,880 | \$490,483 | -\$97,806 | \$1,078,773 | \$20,357,843 | \$5,265,817 | \$35,449,868 |
| 70 | \$8,669,561,586 | \$128,426,438 | \$17,210,696,734 | \$436,934 | -\$86,989 | \$960,857 | \$16,439,036 | \$4,315,551 | \$28,562,521 |
| 2016 | | | | | | | | | |
| 40 | \$15,255,727,776 | \$228,054,912 | \$30,283,400,640 | \$576,679 | -\$114,542 | \$1,267,901 | \$25,314,355 | \$6,567,577 | \$44,061,133 |
| 65 | \$13,196,190,772 | \$194,904,888 | \$26,197,476,656 | \$515,766 | -\$102,811 | \$1,134,343 | \$21,806,648 | \$5,638,167 | \$37,975,128 |
| 70 | \$9,887,347,069 | \$145,099,195 | \$19,629,594,943 | \$393,345 | -\$78,685 | \$865,375 | \$16,638,993 | \$4,292,512 | \$28,985,474 |
| | Minor Restricted Activity Days | | | School Loss Days | | | | | |
| 2013 | | | | | | | | | |
| 40 | \$93,033,327 | -\$29,589,066 | \$215,655,720 | \$81,691,996 | \$33,186,346 | \$130,197,645 | | | |
| 65 | \$77,393,080 | -\$24,668,140 | \$179,454,300 | \$68,301,008 | \$27,746,898 | \$108,855,117 | | | |
| 70 | \$42,458,928 | -\$13,567,426 | \$98,485,281 | \$36,864,577 | \$14,976,270 | \$58,752,884 | | | |
| 2014 | | | | | | | | | |
| 40 | \$92,449,008 | -\$29,624,650 | \$214,522,666 | \$79,107,465 | \$27,295,867 | \$130,919,064 | | | |
| 65 | \$61,688,814 | -\$19,686,569 | \$143,064,197 | \$51,134,326 | \$20,773,428 | \$81,495,224 | | | |
| 70 | \$30,452,374 | -\$9,742,403 | \$70,647,150 | \$24,993,965 | \$10,154,098 | \$39,833,831 | | | |
| 2015 | | | | | | | | | |
| 40 | \$107,488,235 | -\$34,076,689 | \$249,053,160 | \$92,946,422 | \$37,758,059 | \$148,134,785 | | | |
| 65 | \$85,925,006 | -\$27,316,821 | \$199,166,833 | \$74,585,860 | \$30,300,006 | \$118,871,715 | | | |
| 70 | \$73,112,556 | -\$23,230,578 | \$169,455,690 | \$63,076,564 | \$25,624,412 | \$100,528,715 | | | |
| 2016 | | | | | | | | | |
| 40 | \$109,304,954 | -\$34,676,755 | \$253,286,663 | \$89,055,374 | \$36,177,323 | \$141,933,425 | | | |
| 65 | \$95,810,665 | -\$30,462,266 | \$222,083,595 | \$77,956,033 | \$31,668,925 | \$124,243,140 | | | |
| 70 | \$73,226,288 | -\$23,313,403 | \$169,765,979 | \$59,778,074 | \$24,284,628 | \$95,271,519 | | | |

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Table 6: Top causes of death according to 2014 CDC data for the OTR and all of Virginia

| Health Endpoint | Rank | Mortalities | Health Endpoint | Rank | Mortalities |
|------------------------|------|-------------|-----------------------|------|-------------|
| Coronary Heart Disease | 1 | 91,148 | Homicide | 33 | 2,599 |
| Lung Cancers | 2 | 34,976 | Stomach Cancer | 34 | 2,592 |
| Stroke | 3 | 27,908 | Diarrhoeal diseases | 35 | 2,442 |
| Lung Disease | 4 | 27,039 | Oral Cancer | 36 | 1,763 |
| Diabetes Mellitus | 5 | 16,138 | HIV/AIDS | 37 | 1,547 |
| Hypertension | 6 | 15,474 | Alcohol | 38 | 1,492 |
| Alzheimers | 7 | 15,175 | Congenital Anomalies | 39 | 1,440 |
| Influenza & Pneumonia | 8 | 13,774 | Hepatitis C | 40 | 1,266 |
| Colon-Rectum Cancers | 9 | 12,017 | Low Birth Weight | 41 | 1,077 |
| Kidney Disease | 10 | 11,559 | Skin Disease | 42 | 995 |
| Blood Poisoning | 11 | 10,816 | Multiple Sclerosis | 43 | 798 |
| Breast Cancer | 12 | 9,842 | Asthma | 44 | 728 |
| Pancreas Cancer | 13 | 9,823 | Cervical Cancer | 45 | 722 |
| Poisoning | 14 | 9,748 | Anaemia | 46 | 652 |
| Endocrine Disorders | 15 | 9,176 | Rheumatic/Heart | 47 | 617 |
| Lymphomas | 16 | 7,882 | Malnutrition | 48 | 404 |
| Suicide | 17 | 7,779 | Drug Use | 49 | 293 |
| Inflammatory/Heart | 18 | 7,233 | Peptic Ulcer Disease | 50 | 273 |
| Falls | 19 | 6,799 | Birth Trauma | 51 | 218 |
| Liver Disease | 20 | 6,632 | Rheumatoid Arthritis | 52 | 208 |
| Prostate Cancer | 21 | 6,522 | Fires | 53 | 135 |
| Parkinson's Disease | 22 | 5,811 | Drownings | 54 | 68 |
| Liver Cancer | 23 | 5,304 | Diphtheria | 55 | - |
| Road Traffic Accidents | 24 | 5,197 | Measles | 55 | - |
| Leukemia | 25 | 5,173 | Osteoarthritis | 55 | - |
| Other Injuries | 26 | 4,753 | Meningitis | 55 | - |
| Bladder Cancer | 27 | 4,010 | Oral conditions | 55 | - |
| Other Neoplasms | 28 | 3,698 | Pertussis | 55 | - |
| Oesophagus Cancer | 29 | 3,608 | Tetanus | 55 | - |
| Ovary Cancer | 30 | 3,319 | Prostatic Hypertrophy | 55 | - |
| Skin Cancers | 31 | 2,720 | War | 55 | - |
| Uterin Cancer | 32 | 2,609 | Appendicitis | 55 | - |

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Table 7: Estimated ozone-related health impacts following monitor rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR by State

| Year | Level | State | Mortality | | | Emergency Room Visits Respiratory | | | Hospital Admissions Respiratory | | | Acute Respiratory Symptoms | | | School Loss Days | | | |
|-----------------|-----------------|-----------------|------------|------------|--------------|-----------------------------------|--------------|--------------|---------------------------------|--------------|------------------|----------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | | | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | |
| 2013 | 40 | CT | 64 | -4 | 132 | 150 | -30 | 329 | 86 | 24 | 148 | 270,339 | 122,480 | 418,198 | 81,539 | 32,973 | 130,104 | |
| | | DE | 14 | 0 | 29 | 24 | -5 | 53 | 20 | 6 | 33 | 55,722 | 25,092 | 86,352 | 16,545 | 6,686 | 26,403 | |
| | | DC | 6 | 0 | 13 | 14 | -3 | 30 | 8 | 2 | 13 | 36,432 | 16,422 | 56,442 | 7,676 | 3,102 | 12,249 | |
| | | ME | 13 | -3 | 28 | 1 | 0 | 2 | 21 | 5 | 36 | 43,484 | 19,458 | 67,511 | 11,548 | 4,670 | 18,425 | |
| | | MD | 98 | -5 | 201 | 239 | -48 | 526 | 128 | 37 | 219 | 446,526 | 201,270 | 691,781 | 129,580 | 52,368 | 206,793 | |
| | | MA | 80 | -6 | 166 | 149 | -30 | 328 | 135 | 39 | 231 | 351,452 | 158,136 | 544,768 | 99,127 | 40,082 | 158,172 | |
| | | NH | 13 | -3 | 29 | 30 | -6 | 67 | 18 | 5 | 31 | 58,949 | 26,422 | 91,476 | 16,452 | 6,651 | 26,253 | |
| | | NJ | 147 | 3 | 290 | 342 | -68 | 753 | 184 | 56 | 311 | 633,307 | 285,843 | 980,772 | 185,396 | 74,939 | 295,853 | |
| | | NY | 287 | 12 | 563 | 742 | -148 | 1,632 | 332 | 101 | 563 | 1,217,842 | 549,514 | 1,886,171 | 343,969 | 139,055 | 548,883 | |
| | | PA | 249 | -12 | 510 | 449 | -90 | 988 | 288 | 88 | 489 | 816,993 | 367,992 | 1,265,995 | 234,480 | 94,773 | 374,186 | |
| | | RI | 17 | -1 | 35 | 28 | -6 | 62 | 23 | 7 | 39 | 66,416 | 29,983 | 102,848 | 18,560 | 7,504 | 29,617 | |
| | | VT | 7 | -2 | 17 | 8 | -2 | 18 | 9 | 1 | 16 | 27,283 | 12,219 | 42,346 | 7,400 | 2,993 | 11,806 | |
| | | VA | 20 | -4 | 45 | 71 | -14 | 156 | 34 | 8 | 60 | 173,071 | 77,875 | 268,267 | 50,694 | 20,484 | 80,904 | |
| | | 40 Total | | | -27 | 2,059 | 2,247 | -449 | 4,944 | 1,284 | 378 | 2,191 | 4,197,816 | 1,892,705 | 6,502,927 | 1,202,964 | 486,281 | 1,919,647 |
| | | 65 | CT | 53 | -4 | 109 | 123 | -25 | 272 | 71 | 19 | 123 | 223,639 | 100,748 | 346,531 | 67,003 | 27,097 | 106,910 |
| | DE | | 10 | 0 | 21 | 17 | -3 | 38 | 14 | 4 | 24 | 40,115 | 17,992 | 62,238 | 11,610 | 4,693 | 18,527 | |
| | DC | | 5 | 0 | 10 | 10 | -2 | 22 | 6 | 2 | 10 | 27,616 | 12,401 | 42,832 | 5,706 | 2,306 | 9,106 | |
| | ME | | 4 | -1 | 9 | 1 | 0 | 1 | 7 | 2 | 12 | 14,138 | 6,282 | 21,993 | 3,633 | 1,470 | 5,796 | |
| | MD | | 85 | -5 | 176 | 202 | -41 | 445 | 112 | 32 | 192 | 401,530 | 180,658 | 622,401 | 117,320 | 47,423 | 187,217 | |
| | MA | | 67 | -5 | 140 | 124 | -25 | 273 | 114 | 32 | 197 | 294,404 | 132,091 | 456,718 | 84,749 | 34,273 | 135,225 | |
| | NH | | 12 | -2 | 25 | 28 | -6 | 62 | 16 | 4 | 28 | 54,624 | 24,512 | 84,737 | 15,448 | 6,248 | 24,649 | |
| | NJ | | 132 | 3 | 261 | 308 | -62 | 678 | 166 | 50 | 281 | 571,485 | 257,372 | 885,598 | 168,046 | 67,941 | 268,152 | |
| | NY | | 213 | 10 | 415 | 584 | -117 | 1,286 | 245 | 75 | 415 | 914,001 | 410,606 | 1,417,396 | 258,868 | 104,657 | 413,079 | |
| | PA | | 212 | -10 | 434 | 386 | -77 | 849 | 247 | 75 | 419 | 700,787 | 314,978 | 1,086,595 | 201,700 | 81,542 | 321,857 | |
| | RI | | 15 | -1 | 31 | 25 | -5 | 56 | 20 | 6 | 34 | 59,246 | 26,667 | 91,825 | 16,528 | 6,683 | 26,373 | |
| | VT | | 1 | 0 | 3 | 1 | 0 | 3 | 2 | 0 | 3 | 4,614 | 2,036 | 7,192 | 1,265 | 512 | 2,018 | |
| | VA | | 22 | -5 | 48 | 76 | -15 | 167 | 37 | 9 | 64 | 185,552 | 83,686 | 287,418 | 53,897 | 21,788 | 86,006 | |
| | 65 Total | | | -19 | 1,681 | 1,887 | -379 | 4,152 | 1,056 | 310 | 1,803 | 3,491,750 | 1,570,027 | 5,413,474 | 1,005,774 | 406,632 | 1,604,915 | |
| | 70 | | CT | 52 | -7 | 110 | 121 | -24 | 266 | 69 | 20 | 118 | 218,396 | 98,421 | 338,371 | 65,567 | 26,521 | 104,614 |
| | | DE | 4 | 0 | 8 | 5 | -1 | 11 | 5 | 2 | 9 | 12,110 | 5,381 | 18,838 | 3,210 | 1,297 | 5,123 | |
| | | DC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 248 | 110 | 387 | 66 | 27 | 105 | |
| | | ME | 3 | -1 | 7 | 0 | 0 | 0 | 5 | 1 | 8 | 10,440 | 4,628 | 16,252 | 2,644 | 1,070 | 4,218 | |
| | | MD | 20 | -3 | 44 | 50 | -10 | 110 | 27 | 8 | 45 | 90,787 | 40,284 | 141,290 | 26,154 | 10,569 | 41,740 | |
| MA | | 52 | -7 | 110 | 94 | -19 | 208 | 87 | 24 | 150 | 216,184 | 96,740 | 335,629 | 61,031 | 24,685 | 97,377 | | |
| NH | | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1,255 | 552 | 1,957 | 352 | 142 | 561 | | |
| NJ | | 98 | -4 | 200 | 219 | -44 | 482 | 122 | 38 | 205 | 411,724 | 184,422 | 639,026 | 120,062 | 48,541 | 191,584 | | |
| NY | | 156 | 2 | 310 | 421 | -85 | 926 | 175 | 55 | 295 | 681,661 | 306,103 | 1,057,219 | 188,785 | 76,342 | 301,228 | | |
| PA | | 69 | -8 | 145 | 115 | -23 | 254 | 78 | 23 | 134 | 213,914 | 95,366 | 332,462 | 58,629 | 23,701 | 93,557 | | |
| RI | | 15 | -2 | 32 | 25 | -5 | 54 | 20 | 6 | 34 | 58,711 | 26,430 | 90,991 | 16,352 | 6,614 | 26,090 | | |
| VT | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 4 | 1 | 0 | 1 | | |
| VA | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 70 Total | | | -29 | 968 | 1,051 | -212 | 2,314 | 588 | 177 | 999 | 1,915,432 | 858,439 | 2,972,426 | 542,853 | 219,507 | 866,199 | | |

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Table 7: Estimated ozone-related health impacts following monitor rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR by State

| Year | Level | State | Mortality | | | Emergency Room Visits Respiratory | | | Hospital Admissions Respiratory | | | Acute Respiratory Symptoms | | | School Loss Days | | | | |
|-----------------|-------|-----------------|-----------|-----------|--------------|-----------------------------------|--------------|--------------|---------------------------------|--------------|--------------|----------------------------|------------------|------------------|------------------|------------------|------------------|------------------|---------|
| | | | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | | |
| 2014 | 40 | CT | 61 | -4 | 127 | 142 | -28 | 313 | 83 | 23 | 143 | 256,950 | 116,906 | 396,994 | 77,959 | 27,799 | 128,119 | | |
| | | DE | 16 | 0 | 31 | 26 | -5 | 56 | 22 | 6 | 37 | 58,809 | 26,767 | 90,851 | 18,000 | 5,963 | 30,036 | | |
| | | DC | -1 | -2 | 0 | -3 | -6 | 1 | -1 | -2 | 0 | -6,247 | -10,126 | -2,367 | -1,469 | -2,892 | -46 | | |
| | | ME | 15 | -3 | 34 | 1 | 0 | 2 | 28 | 6 | 49 | 50,957 | 23,102 | 78,812 | 13,728 | 5,083 | 22,372 | | |
| | | MD | 93 | -5 | 190 | 225 | -44 | 494 | 123 | 36 | 209 | 397,871 | 180,596 | 615,146 | 121,448 | 38,440 | 204,456 | | |
| | | MA | 65 | -5 | 134 | 119 | -24 | 261 | 110 | 31 | 188 | 277,277 | 125,957 | 428,597 | 79,998 | 29,043 | 130,953 | | |
| | | NH | 13 | -2 | 28 | 29 | -6 | 63 | 17 | 5 | 30 | 55,648 | 25,214 | 86,081 | 15,675 | 5,626 | 25,723 | | |
| | | NJ | 165 | 3 | 326 | 390 | -77 | 858 | 206 | 63 | 349 | 702,299 | 319,221 | 1,085,378 | 210,090 | 71,350 | 348,830 | | |
| | | NY | 271 | 14 | 528 | 731 | -145 | 1,606 | 314 | 97 | 532 | 1,150,179 | 521,478 | 1,778,880 | 326,259 | 117,244 | 535,273 | | |
| | | PA | 225 | -12 | 461 | 421 | -83 | 925 | 260 | 81 | 439 | 760,059 | 345,046 | 1,175,073 | 223,819 | 76,879 | 370,759 | | |
| | | RI | 15 | -1 | 31 | 25 | -5 | 55 | 20 | 6 | 35 | 58,537 | 26,452 | 90,622 | 16,603 | 5,556 | 27,650 | | |
| | | VT | 7 | -2 | 16 | 7 | -1 | 16 | 8 | 1 | 15 | 25,326 | 11,427 | 39,225 | 6,842 | 2,768 | 10,916 | | |
| | | VA | 22 | -5 | 49 | 75 | -15 | 166 | 37 | 9 | 65 | 182,221 | 82,568 | 281,875 | 55,955 | 17,801 | 94,108 | | |
| | | 40 Total | | | -25 | 1,955 | 2,189 | -440 | 4,817 | 1,226 | 363 | 2,089 | 3,969,887 | 1,794,608 | 6,145,167 | 1,164,905 | 400,661 | 1,929,149 | |
| | | | 65 | CT | 49 | -3 | 102 | 115 | -23 | 254 | 68 | 20 | 116 | 209,122 | 94,228 | 324,017 | 62,106 | 25,123 | 99,089 |
| | | | | DE | 14 | 0 | 28 | 24 | -5 | 52 | 19 | 6 | 33 | 54,944 | 24,743 | 85,144 | 16,216 | 6,557 | 25,875 |
| | | | | DC | 4 | 0 | 9 | 9 | -2 | 20 | 5 | 2 | 9 | 24,970 | 11,159 | 38,782 | 5,190 | 2,098 | 8,282 |
| | | | | ME | 3 | -1 | 6 | 0 | 0 | 1 | 4 | 1 | 7 | 9,045 | 4,022 | 14,068 | 2,290 | 926 | 3,653 |
| | | | | MD | 67 | -4 | 138 | 167 | -34 | 368 | 88 | 27 | 149 | 302,491 | 135,606 | 469,375 | 86,564 | 34,992 | 138,136 |
| MA | 28 | | | -2 | 58 | 54 | -11 | 118 | 48 | 14 | 82 | 120,853 | 53,878 | 187,828 | 34,844 | 14,091 | 55,597 | | |
| NH | 6 | | | -1 | 13 | 15 | -3 | 33 | 9 | 3 | 15 | 29,128 | 12,974 | 45,282 | 8,033 | 3,249 | 12,818 | | |
| NJ | 141 | | | 3 | 279 | 333 | -66 | 732 | 177 | 55 | 300 | 610,279 | 275,172 | 945,386 | 177,501 | 71,789 | 283,214 | | |
| NY | 143 | | | 9 | 278 | 491 | -99 | 1,080 | 166 | 51 | 281 | 656,796 | 294,490 | 1,019,102 | 182,421 | 73,764 | 291,078 | | |
| PA | 147 | | | -6 | 299 | 275 | -55 | 606 | 173 | 52 | 293 | 500,530 | 224,507 | 776,552 | 142,804 | 57,742 | 227,866 | | |
| RI | 3 | | | 0 | 7 | 5 | -1 | 12 | 5 | 1 | 8 | 13,218 | 5,849 | 20,586 | 3,634 | 1,468 | 5,799 | | |
| VT | 1 | | | 0 | 2 | 1 | 0 | 2 | 1 | 0 | 2 | 3,553 | 1,567 | 5,540 | 919 | 372 | 1,466 | | |
| VA | 15 | | | -3 | 32 | 46 | -9 | 100 | 24 | 6 | 42 | 113,161 | 50,596 | 175,725 | 30,462 | 12,312 | 48,611 | | |
| 65 Total | | | | -9 | 1,251 | 1,535 | -308 | 3,378 | 787 | 237 | 1,338 | 2,648,090 | 1,188,791 | 4,107,388 | 752,984 | 304,483 | 1,201,484 | | |
| | 70 | | | CT | 46 | -6 | 98 | 108 | -22 | 237 | 63 | 18 | 107 | 194,637 | 87,700 | 301,574 | 58,141 | 23,526 | 92,755 |
| | | | | DE | 5 | -1 | 10 | 9 | -2 | 20 | 6 | 2 | 10 | 21,457 | 9,595 | 33,320 | 6,346 | 2,567 | 10,126 |
| | | | | DC | 2 | 0 | 4 | 4 | -1 | 8 | 2 | 1 | 4 | 9,732 | 4,304 | 15,160 | 1,959 | 792 | 3,127 |
| | | | | ME | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | MD | 10 | -2 | 22 | 20 | -4 | 44 | 14 | 4 | 24 | 50,147 | 22,290 | 78,005 | 14,603 | 5,903 | 23,302 |
| | | MA | 3 | 0 | 6 | 7 | -1 | 16 | 5 | 1 | 8 | 11,070 | 4,913 | 17,226 | 3,297 | 1,333 | 5,261 | | |
| | | NH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | | NJ | 66 | -3 | 135 | 168 | -34 | 369 | 84 | 25 | 143 | 302,301 | 135,147 | 469,455 | 85,085 | 34,410 | 135,759 | | |
| | | NY | 92 | 2 | 183 | 372 | -75 | 819 | 104 | 31 | 177 | 430,264 | 192,397 | 668,132 | 117,569 | 47,552 | 187,585 | | |
| | | PA | 66 | -6 | 138 | 129 | -26 | 285 | 77 | 23 | 131 | 236,121 | 105,815 | 366,426 | 67,273 | 27,210 | 107,336 | | |
| | | RI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | | VT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | | VA | 7 | -2 | 15 | 21 | -4 | 45 | 11 | 3 | 19 | 51,361 | 22,727 | 79,995 | 13,779 | 5,569 | 21,989 | | |
| | | 70 Total | | | -18 | 610 | 837 | -169 | 1,843 | 365 | 109 | 622 | 1,307,091 | 584,888 | 2,029,295 | 368,051 | 148,862 | 587,241 | |

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Table 7: Estimated ozone-related health impacts following monitor rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR by State

| Year | Level | State | Mortality | | | Emergency Room Visits Respiratory | | | Hospital Admissions Respiratory | | | Acute Respiratory Symptoms | | | School Loss Days | | |
|-----------------|-----------------|-------|------------|--------------|--------------|-----------------------------------|--------------|--------------|---------------------------------|--------------|------------------|----------------------------|------------------|------------------|------------------|------------------|------------------|
| | | | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ |
| 2015 | 40 | CT | 69 | -4 | 143 | 158 | -31 | 348 | 94 | 26 | 163 | 287,259 | 130,352 | 444,166 | 83,952 | 33,946 | 133,958 |
| | | DE | 19 | 0 | 39 | 31 | -6 | 69 | 26 | 8 | 45 | 72,268 | 32,742 | 111,794 | 21,277 | 8,599 | 33,954 |
| | | DC | 9 | 0 | 18 | 19 | -4 | 41 | 11 | 3 | 18 | 49,379 | 22,419 | 76,339 | 10,577 | 4,275 | 16,880 |
| | | ME | 12 | -3 | 28 | 1 | 0 | 2 | 21 | 5 | 37 | 41,113 | 18,386 | 63,840 | 10,715 | 4,333 | 17,097 |
| | | MD | 131 | -6 | 268 | 314 | -62 | 690 | 171 | 50 | 292 | 575,099 | 260,865 | 889,333 | 166,138 | 67,146 | 265,129 |
| | | MA | 78 | -6 | 161 | 143 | -29 | 314 | 133 | 37 | 228 | 337,234 | 151,602 | 522,865 | 92,084 | 37,217 | 146,951 |
| | | NH | 15 | -3 | 34 | 34 | -7 | 74 | 21 | 6 | 36 | 65,103 | 29,215 | 100,992 | 17,536 | 7,088 | 27,984 |
| | | NJ | 180 | 4 | 357 | 420 | -83 | 924 | 227 | 70 | 385 | 761,751 | 345,458 | 1,178,044 | 219,447 | 88,702 | 350,193 |
| | | NY | 326 | 14 | 637 | 856 | -170 | 1,881 | 379 | 116 | 641 | 1,352,466 | 612,024 | 2,092,908 | 375,936 | 151,969 | 599,902 |
| | | PA | 301 | -13 | 614 | 539 | -107 | 1,185 | 351 | 109 | 593 | 975,341 | 441,268 | 1,509,414 | 276,046 | 111,574 | 440,518 |
| | RI | 19 | -1 | 39 | 31 | -6 | 68 | 26 | 8 | 44 | 72,940 | 32,995 | 112,885 | 19,765 | 7,990 | 31,540 | |
| | VT | 8 | -2 | 18 | 8 | -2 | 18 | 10 | 2 | 17 | 27,407 | 12,274 | 42,540 | 7,216 | 2,919 | 11,513 | |
| | VA | 29 | -6 | 64 | 96 | -19 | 212 | 49 | 12 | 86 | 233,306 | 105,660 | 360,952 | 68,005 | 27,482 | 108,528 | |
| | 40 Total | | | -27 | 2,420 | 2,650 | -526 | 5,826 | 1,519 | 452 | 2,586 | 4,850,666 | 2,195,260 | 7,506,073 | 1,368,692 | 553,237 | 2,184,147 |
| | 65 | CT | 57 | -4 | 117 | 129 | -26 | 284 | 77 | 22 | 132 | 234,948 | 105,962 | 363,935 | 68,153 | 27,559 | 108,746 |
| | | DE | 17 | 0 | 34 | 28 | -6 | 62 | 23 | 7 | 39 | 65,948 | 29,832 | 102,064 | 19,393 | 7,840 | 30,946 |
| | | DC | 8 | 0 | 16 | 17 | -3 | 37 | 10 | 3 | 16 | 44,884 | 20,314 | 69,453 | 9,598 | 3,880 | 15,316 |
| | | ME | 3 | -1 | 7 | 0 | 0 | 0 | 6 | 1 | 10 | 9,481 | 4,205 | 14,758 | 2,396 | 969 | 3,822 |
| | | MD | 121 | -6 | 248 | 289 | -57 | 635 | 158 | 49 | 268 | 536,168 | 242,646 | 829,690 | 154,801 | 62,582 | 247,021 |
| | | MA | 42 | -3 | 86 | 75 | -15 | 166 | 72 | 20 | 124 | 164,717 | 73,669 | 255,765 | 45,988 | 18,591 | 73,385 |
| | | NH | 4 | -1 | 8 | 7 | -1 | 15 | 5 | 1 | 8 | 13,705 | 6,062 | 21,348 | 3,547 | 1,435 | 5,658 |
| | | NJ | 160 | 3 | 316 | 369 | -74 | 812 | 201 | 63 | 339 | 672,882 | 303,976 | 1,041,789 | 193,135 | 78,081 | 308,189 |
| | | NY | 224 | 12 | 435 | 633 | -127 | 1,392 | 257 | 81 | 433 | 942,483 | 424,119 | 1,460,847 | 262,140 | 105,976 | 418,304 |
| | | PA | 278 | -12 | 569 | 496 | -99 | 1,090 | 325 | 100 | 550 | 896,941 | 405,020 | 1,388,861 | 254,251 | 102,794 | 405,708 |
| | RI | 16 | -1 | 33 | 25 | -5 | 56 | 21 | 7 | 36 | 60,537 | 27,246 | 93,828 | 16,322 | 6,599 | 26,046 | |
| | VT | 3 | -1 | 8 | 4 | -1 | 8 | 4 | 1 | 7 | 13,193 | 5,861 | 20,525 | 3,497 | 1,415 | 5,579 | |
| | VA | 28 | -6 | 61 | 92 | -18 | 201 | 46 | 12 | 81 | 221,277 | 100,034 | 342,519 | 65,102 | 26,318 | 103,886 | |
| | 65 Total | | | -19 | 1,938 | 2,164 | -432 | 4,760 | 1,205 | 367 | 2,043 | 3,877,164 | 1,748,947 | 6,005,381 | 1,098,322 | 444,039 | 1,752,605 |
| | 70 | CT | 64 | -8 | 135 | 143 | -28 | 313 | 86 | 25 | 147 | 259,183 | 117,235 | 401,131 | 75,447 | 30,513 | 120,381 |
| | | DE | 11 | -1 | 23 | 18 | -4 | 39 | 16 | 5 | 26 | 41,197 | 18,464 | 63,930 | 11,702 | 4,728 | 18,675 |
| | | DC | 8 | -1 | 17 | 17 | -3 | 37 | 10 | 3 | 16 | 44,229 | 20,017 | 68,441 | 9,403 | 3,801 | 15,005 |
| | | ME | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 391 | 172 | 609 | 94 | 38 | 150 |
| | | MD | 97 | -11 | 204 | 246 | -49 | 542 | 122 | 38 | 207 | 429,429 | 193,997 | 664,860 | 122,477 | 49,509 | 195,446 |
| MA | | 21 | -3 | 44 | 39 | -8 | 86 | 36 | 11 | 61 | 79,140 | 35,279 | 123,000 | 22,267 | 9,001 | 35,534 | |
| NH | | 1 | 0 | 2 | 1 | 0 | 3 | 1 | 0 | 2 | 2,522 | 1,114 | 3,931 | 614 | 249 | 979 | |
| NJ | | 166 | -7 | 339 | 388 | -77 | 854 | 207 | 64 | 350 | 704,852 | 319,175 | 1,090,529 | 202,196 | 81,753 | 322,639 | |
| NY | | 225 | 2 | 448 | 683 | -136 | 1,501 | 252 | 79 | 425 | 962,188 | 434,439 | 1,489,937 | 267,977 | 108,349 | 427,604 | |
| PA | | 159 | -15 | 332 | 292 | -59 | 643 | 184 | 56 | 313 | 528,694 | 237,829 | 819,559 | 148,792 | 60,141 | 237,442 | |
| RI | | 18 | -2 | 38 | 28 | -6 | 62 | 24 | 7 | 41 | 67,522 | 30,488 | 104,557 | 18,238 | 7,375 | 29,101 | |
| VT | | 1 | 0 | 2 | 1 | 0 | 2 | 1 | 0 | 2 | 3,098 | 1,366 | 4,829 | 829 | 336 | 1,323 | |
| VA | | 23 | -6 | 51 | 72 | -14 | 158 | 38 | 10 | 66 | 176,661 | 79,610 | 273,712 | 48,805 | 19,725 | 77,885 | |
| 70 Total | | | -52 | 1,637 | 1,928 | -384 | 4,240 | 978 | 298 | 1,657 | 3,299,106 | 1,489,185 | 5,109,027 | 928,840 | 375,517 | 1,482,164 | |

Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Table 7: Estimated ozone-related health impacts following monitor rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR by State

| Year | Level | State | Mortality | | | Emergency Room Visits Respiratory | | | Hospital Admissions Respiratory | | | Acute Respiratory Symptoms | | | School Loss Days | | | |
|-----------------|-----------------|-----------------|------------|------------|--------------|-----------------------------------|--------------|--------------|---------------------------------|--------------|--------------|----------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | | | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | Mean | -2σ | 2σ | |
| 2016 | 40 | CT | 69 | -4 | 142 | 154 | -30 | 337 | 94 | 26 | 161 | 278,435 | 126,432 | 430,439 | 80,068 | 32,379 | 127,757 | |
| | | DE | 19 | 0 | 38 | 30 | -6 | 67 | 26 | 8 | 45 | 70,242 | 31,819 | 108,666 | 20,594 | 8,323 | 32,865 | |
| | | DC | 7 | 0 | 15 | 15 | -3 | 34 | 9 | 3 | 15 | 40,758 | 18,448 | 63,068 | 8,848 | 3,575 | 14,121 | |
| | | ME | 11 | -3 | 25 | 1 | 0 | 2 | 19 | 5 | 33 | 36,367 | 16,245 | 56,488 | 9,410 | 3,805 | 15,016 | |
| | | MD | 125 | -6 | 255 | 294 | -58 | 646 | 165 | 48 | 282 | 534,767 | 242,349 | 827,185 | 154,093 | 62,275 | 245,910 | |
| | | MA | 85 | -6 | 177 | 154 | -31 | 338 | 146 | 40 | 253 | 364,039 | 163,950 | 564,129 | 98,491 | 39,818 | 157,163 | |
| | | NH | 15 | -3 | 33 | 32 | -7 | 71 | 21 | 6 | 36 | 62,919 | 28,270 | 97,568 | 16,753 | 6,773 | 26,734 | |
| | | NJ | 175 | 3 | 346 | 401 | -80 | 882 | 221 | 68 | 375 | 731,870 | 331,612 | 1,132,129 | 209,815 | 84,807 | 334,823 | |
| | | NY | 317 | 16 | 619 | 815 | -162 | 1,792 | 372 | 113 | 632 | 1,305,401 | 589,845 | 2,020,956 | 360,061 | 145,537 | 574,586 | |
| | | PA | 294 | -13 | 601 | 521 | -104 | 1,146 | 346 | 107 | 584 | 940,678 | 425,257 | 1,456,099 | 264,860 | 107,049 | 422,671 | |
| | | RI | 18 | -1 | 38 | 30 | -6 | 66 | 25 | 7 | 43 | 70,149 | 31,736 | 108,561 | 18,719 | 7,568 | 29,871 | |
| | | VT | 7 | -2 | 16 | 7 | -1 | 16 | 9 | 2 | 17 | 24,900 | 11,155 | 38,644 | 6,486 | 2,624 | 10,348 | |
| | | VA | 28 | -6 | 61 | 90 | -18 | 197 | 47 | 12 | 83 | 216,632 | 97,978 | 335,287 | 63,195 | 25,536 | 100,855 | |
| | | 40 Total | | | -25 | 2,366 | 2,545 | -506 | 5,595 | 1,502 | 444 | 2,559 | 4,677,157 | 2,115,095 | 7,239,219 | 1,311,394 | 530,069 | 2,092,719 |
| | | 65 | CT | 55 | -4 | 114 | 123 | -25 | 271 | 76 | 21 | 131 | 224,399 | 101,213 | 347,584 | 63,962 | 25,865 | 102,059 |
| | DE | | 17 | 0 | 35 | 28 | -6 | 62 | 24 | 7 | 42 | 65,337 | 29,527 | 101,148 | 19,251 | 7,782 | 30,720 | |
| | DC | | 7 | 0 | 15 | 15 | -3 | 33 | 9 | 2 | 15 | 39,517 | 17,872 | 61,162 | 8,585 | 3,470 | 13,700 | |
| | ME | | 3 | -1 | 6 | 0 | 0 | 1 | 4 | 1 | 7 | 8,620 | 3,822 | 13,418 | 2,121 | 858 | 3,385 | |
| | MD | | 113 | -5 | 232 | 265 | -53 | 584 | 150 | 44 | 256 | 490,135 | 221,521 | 758,749 | 140,955 | 56,976 | 224,933 | |
| | MA | | 73 | -5 | 150 | 126 | -25 | 278 | 124 | 34 | 213 | 298,076 | 133,854 | 462,299 | 81,835 | 33,090 | 130,581 | |
| | NH | | 8 | -1 | 17 | 17 | -4 | 39 | 11 | 3 | 19 | 34,125 | 15,199 | 53,051 | 9,138 | 3,695 | 14,580 | |
| | NJ | | 154 | 3 | 304 | 358 | -71 | 788 | 195 | 59 | 331 | 652,499 | 294,692 | 1,010,306 | 186,011 | 75,197 | 296,825 | |
| | NY | | 282 | 13 | 552 | 768 | -153 | 1,689 | 326 | 101 | 551 | 1,179,441 | 531,936 | 1,826,947 | 323,412 | 130,747 | 516,077 | |
| | PA | | 258 | -11 | 526 | 456 | -91 | 1,002 | 303 | 94 | 513 | 823,907 | 371,513 | 1,276,302 | 231,240 | 93,477 | 369,004 | |
| | RI | | 16 | -1 | 34 | 26 | -5 | 58 | 22 | 6 | 38 | 61,858 | 27,884 | 95,832 | 16,446 | 6,649 | 26,242 | |
| | VT | | 2 | -1 | 5 | 2 | 0 | 5 | 3 | 1 | 6 | 7,077 | 3,150 | 11,005 | 1,834 | 742 | 2,926 | |
| | VA | | 27 | -6 | 60 | 89 | -18 | 196 | 46 | 11 | 81 | 214,384 | 96,912 | 331,856 | 63,160 | 25,530 | 100,790 | |
| | 65 Total | | | -19 | 2,051 | 2,276 | -454 | 5,006 | 1,294 | 384 | 2,204 | 4,099,376 | 1,849,093 | 6,349,658 | 1,147,950 | 464,077 | 1,831,822 | |
| | 70 | | CT | 63 | -4 | 129 | 140 | -28 | 307 | 85 | 25 | 146 | 253,957 | 114,965 | 392,949 | 72,662 | 29,395 | 115,929 |
| | | DE | 13 | 0 | 26 | 20 | -4 | 45 | 18 | 5 | 30 | 47,383 | 21,323 | 73,443 | 13,499 | 5,457 | 21,541 | |
| | | DC | 5 | 0 | 10 | 10 | -2 | 23 | 6 | 2 | 10 | 27,884 | 12,506 | 43,262 | 5,958 | 2,408 | 9,508 | |
| | | ME | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | MD | 104 | -4 | 211 | 256 | -51 | 564 | 136 | 43 | 230 | 441,626 | 199,432 | 683,821 | 126,550 | 51,163 | 201,936 | |
| MA | | 45 | -3 | 92 | 80 | -16 | 177 | 77 | 21 | 132 | 179,241 | 80,346 | 278,135 | 50,087 | 20,254 | 79,921 | | |
| NH | | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 743 | 328 | 1,158 | 197 | 80 | 314 | | |
| NJ | | 139 | 3 | 275 | 315 | -63 | 694 | 176 | 56 | 297 | 588,563 | 265,538 | 911,588 | 168,543 | 68,148 | 268,937 | | |
| NY | | 188 | 12 | 365 | 505 | -102 | 1,111 | 220 | 69 | 370 | 806,475 | 362,406 | 1,250,544 | 221,519 | 89,558 | 353,479 | | |
| PA | | 174 | -6 | 355 | 324 | -65 | 713 | 210 | 64 | 355 | 583,926 | 262,468 | 905,385 | 166,312 | 67,233 | 265,391 | | |
| RI | | 18 | -1 | 38 | 30 | -6 | 65 | 25 | 8 | 42 | 69,289 | 31,338 | 107,241 | 18,497 | 7,482 | 29,512 | | |
| VT | | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 861 | 381 | 1,342 | 212 | 86 | 338 | | |
| VA | | 18 | -4 | 39 | 54 | -11 | 119 | 30 | 7 | 52 | 132,913 | 59,611 | 206,216 | 36,233 | 14,642 | 57,823 | | |
| 70 Total | | | 766 | -9 | 1,542 | 1,736 | -347 | 3,819 | 983 | 301 | 1,665 | 3,132,862 | 1,410,641 | 4,855,084 | 880,268 | 355,906 | 1,404,630 | |

