BenMAP-CE Version 1.3 Sensitivity Analysis:
Documenting and Quantifying the Database Updates in the Latest Version

Contents

Introduction

The Benefits Team recently updated key input parameters in the BenMAP-CE program: population, baseline incidence (death, hospital and emergency department visits); and, income growth. This memo explores the influence of these new input parameters on the size of the estimated air pollution cases of death and illness, and the economic value of these outcomes.

Before evaluating the new input data, we first compared the results of versions 1.1 and 1.3 of the program. Using input parameters that were identical between the two programs (e.g. 2010 Population and 2010 Mortality Rates), we confirmed that each version produced the same counts of premature deaths and illnesses. This initial test confirmed that the algorithms the program(s) used to quantify cases of air pollution impacts were identical.

We next systematically tested each new input dataset: Population, Baseline Mortality Rates, Baseline Morbidity Rates, and Income Elasticity. For each evaluation, we used the same air quality surface: $PM_{2.5}$ source apportionment model predictions for the wildfire sector in the year 2016.

We conclude that: (1) the new input data are valid and appropriate to use for regulatory analyses; (2) the size and distribution of the incidence and economic values changed between v1.1 and v.3 in concert with the new input parameters. We are now confident that the updates in this latest software release will produce results that differ from RIA analyses in ways that we can explain. **Table 1** provides a summary of the changes in the health outcomes and dollar amounts if we ran the same analysis in 1.3 with the updated database for (A) Population, (B) Mortality, (C) Morbidity, and (D) Income Growth. Detailed results of our comprehensive testing are reported in the following sections.

Table 1. Comparative analysis of Point Estimate and Valuation between the updated datasets built into BenMAP-CE Version 1.3 in relation to the older datasets from Version 1.1. These results assume all the same variables between the versions except for the parameter being evaluated.

A. Population Projections	Projection Year	Version 1.1	Version 1.3

All-Cause Mortality Age 30-99 (Krewski)	2025	7,640 $67.3B	7,840 $70.4B
	2030	8,770 $77.2B	9,030 $81.1B
	2035	10,110 $89.0B	10,410 $93.5B

Population

To compare the population estimates between BenMAP version 1.3 (v1.3) and v1.1, we first compared

B. Mortality Projections	Projection Year	Version 1.1	Version 1.3
All-Cause Mortality Age 30-99 (Krewski)	2025	4,592 $40.4B	4,698 $42.2B
	2050	3,609 $31.8B	3,605 $32.4B

C. Morbidity Rates	Version 1.1 (2007 Baseline)	Version 1.3 (2014 Baseline)
All Cause Cardiovascular Disease Ages 65-99 (Zanobetti)	637 $56.9M	479 $42.8M
All Cause Respiratory Disease Ages 65-99 (Zanobetti)	1,209 $38.4M	1,131 $34.2M

the total nationwide population counts for the years 2010, 2020, 2030, and 2040 using the 2009 Krewski

D. Income Growth	Growth Year	Version 1.1	Version 1.3
All-Cause Mortality Age 30-99 (Krewski)	2020	$51.3B	$50.0B
	2024	$52.6B	$50.8B

PM-mediated mortality function (**Fig. 1**). Please note that the Krewski function applies only to adults age 30-99, so national estimates may appear smaller than the total U.S. population. The two versions estimate identical U.S. population counts for 2010, and remain similar through 2040. Interestingly, v1.3 estimates a slightly higher population in 2030 and 2040, whereas v1.1 estimates a slightly higher population in 2020. Exact numbers can be found in **Table 2**, which includes the 2050 population, available only from v1.3.

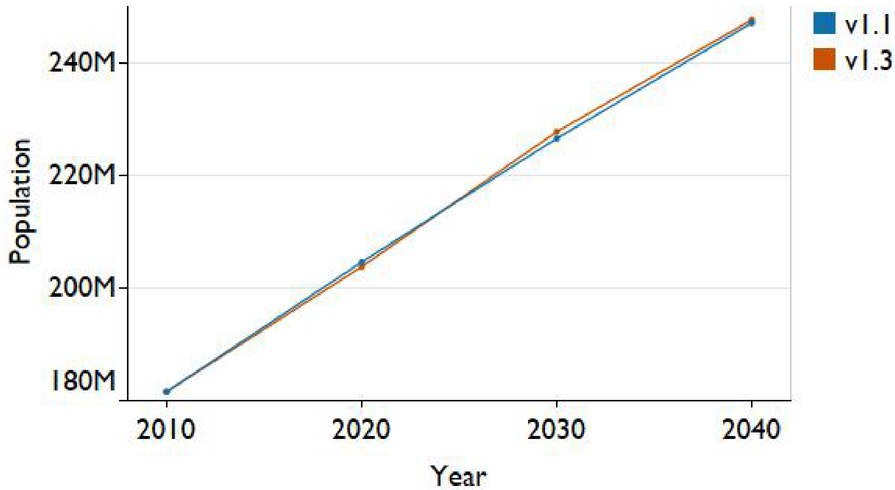


Figure 1. U.S. population estimates from v1.1 and v1.3.

Table 2. U.S. population estimates from v1.1 and v1.3.

Year	v1.1	v1.3	Absolute Difference	Percent Difference
2010	181,568,712	181,568,712	0	0
2020	204,617,158	203,782,845	834,314	0.409413
2030	226,594,739	227,785,084	1,190,344	0.525319
2040	247,120,225	247,680,263	560,038	0.226626
2050		266,444,162		

As 2010 population counts were identical between v1.1 and v1.3, both nationally and within each 12km grid cell (data not shown), from this point onward we only present and compare population estimates for the years 2020, 2030, and 2040.

We compared the population estimates by state and county. Population estimates from v1.1 and v1.3 of each state is available in **Fig. 2**. Population estimates from v1.1 and v1.3 of the 20 most populated counties is available in **Fig. 3**.

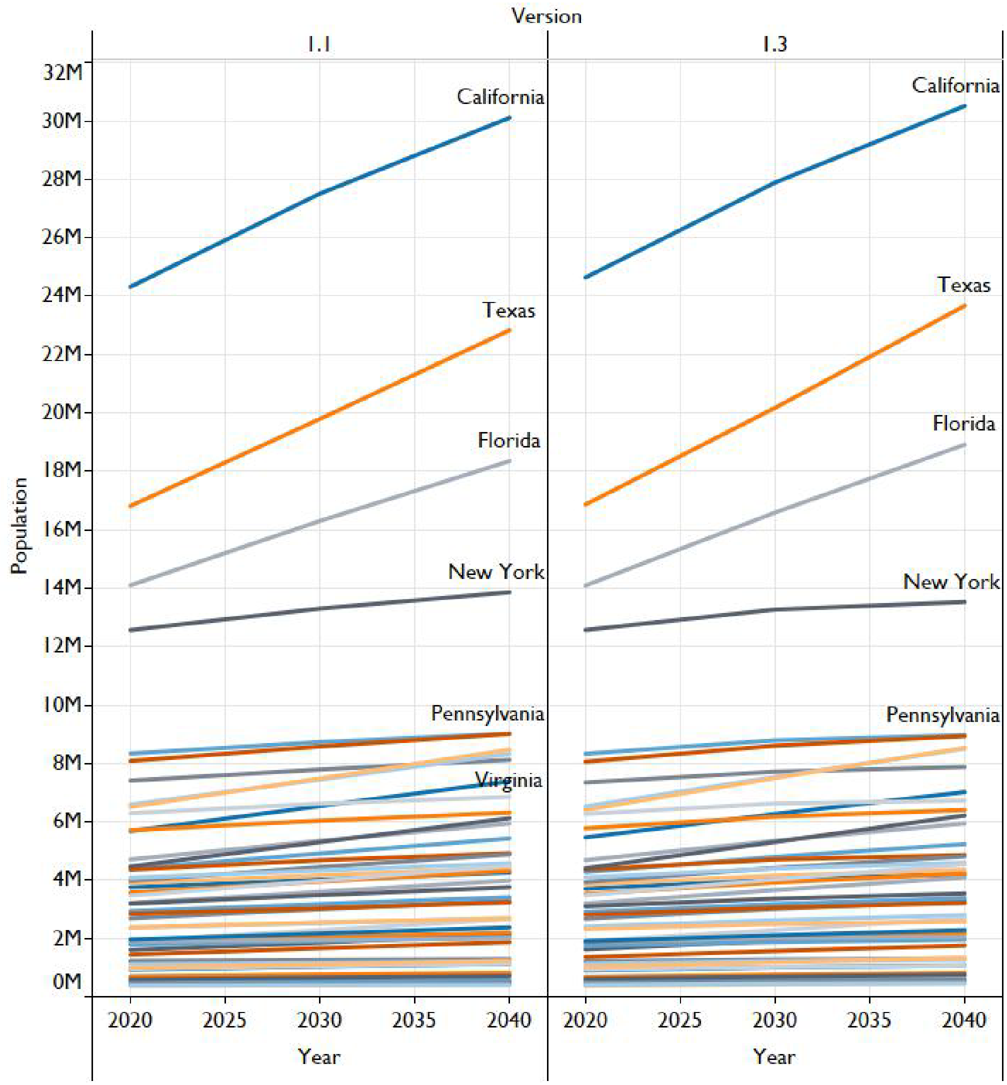


Figure 2. 2020, 2030, and 2040 population estimates split by state from BenMAP v1.1 and v1.3.

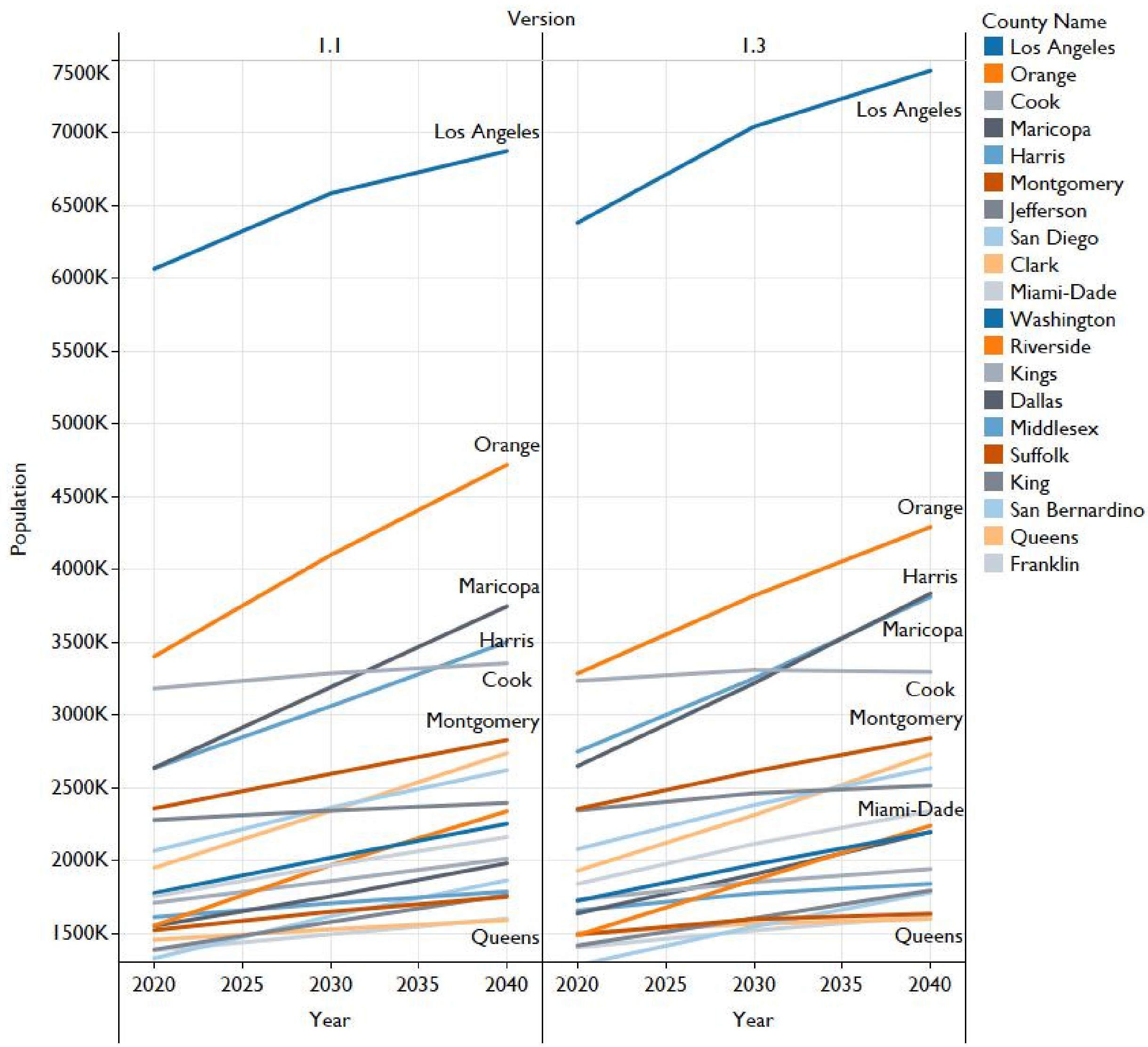


Figure 3. 2020, 2030, and 2040 population estimates of the most highly populated 20 counties from BenMAP v1.1 and v1.3.

We focused on counties that decreased in estimated population over the 2020-2040 time period from either BenMAP version, as there are very few counties that are expected to decrease in population over that 40-year time frame. The three counties that decreased the most were Wayne, Michigan, Orleans, Louisiana, and St. Louis, Missouri (**Fig. 4 and Table 3**). Of these counties Estimates from both versions display similar trends, although BenMAP v1.3 estimated higher populations than v1.1 in Orleans, Louisiana for all three years analyzed.

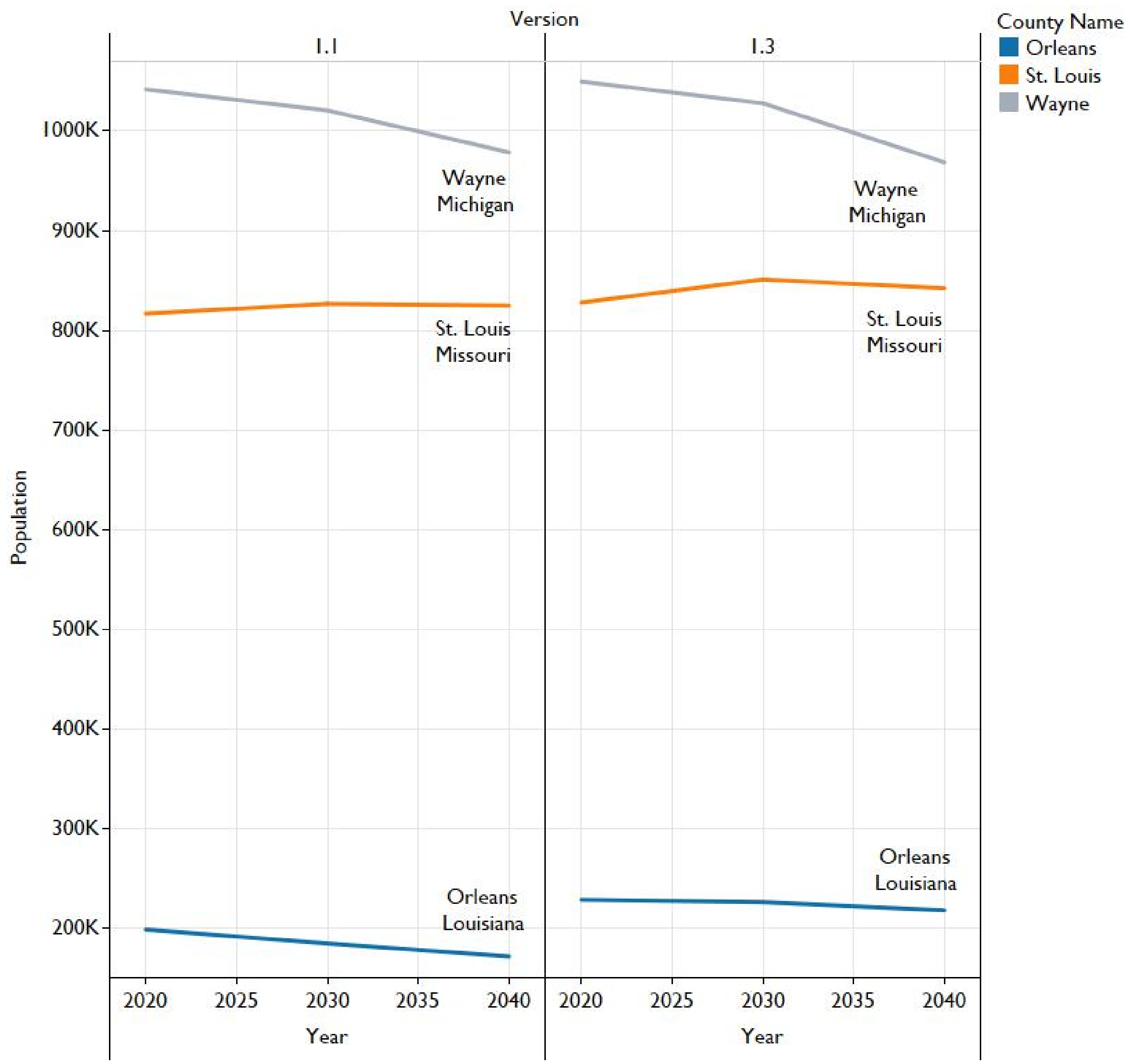


Figure 4. 2020, 2030, and 2040 population estimates of the three counties in which estimated population decreased the most BenMAP v1.1 and v1.3.

Table 3. Change in population estimates for three counties in which the population decreased over time.

State Name	**County**	**Difference between 2040 and 2020 estimates in v1.3 (% difference)**	**Difference between 2040 and 2020 estimates in v1.1 (% difference)**
Louisiana	Orleans	-10,658 (5%)	-26918 (16%)
Michigan	Wayne	-80,959 (8%)	-63100 (6%)
Missouri	St. Louis	-7,602 (4%)	-15775 (9%)

Mortality

For BenMAP mortality health impact functions, we were interested in quantifying the differences in baseline mortality incidence projections between v1.1 and v1.3. Standard EPA mortality health impact functions are derived from 8 epidemiologic studies common to BenMAP versions 1.1 and 1.3 (see table below). We used the 2010 population and a 2016 $PM_{2.5}$ wildfire air quality surface to examine changes in baseline mortality incidence from 2015 to 2050, in 5-year increments. As presented in the table below, some endpoints have health impact functions from multiple studies. Therefore, because baseline incidence is dependent on the defined population (i.e., endpoint and age range), but independent of the concentration-response function, we chose to present results for each endpoint, rather than each study. However, we previously verified that v1.3 was applying the same baseline incidences to different health impact functions for the same endpoint and age range.

List of Studies Used to Derive Mortality Health Impact Functions in BenMAP (v1.1 and v1.3)

All-Cause Endpoints	Age Range	Studies
All-Cause Mortality	0-0	Woodruff et al. (2006); Woodruff et al. (1997)
All-Cause Mortality	25-99	LePeule et al. (2012); Laden et al. (2006)
All-Cause Mortality	30-99	Krewski et al. (2009); Pope et al. (2002)
Cause Specific Endpoints (Sensitivity)		
Lung Cancer Mortality	30-99	Krewski et al. (2009)
Ischemic Heart Disease Mortality	30-99	Krewski et al. (2009)

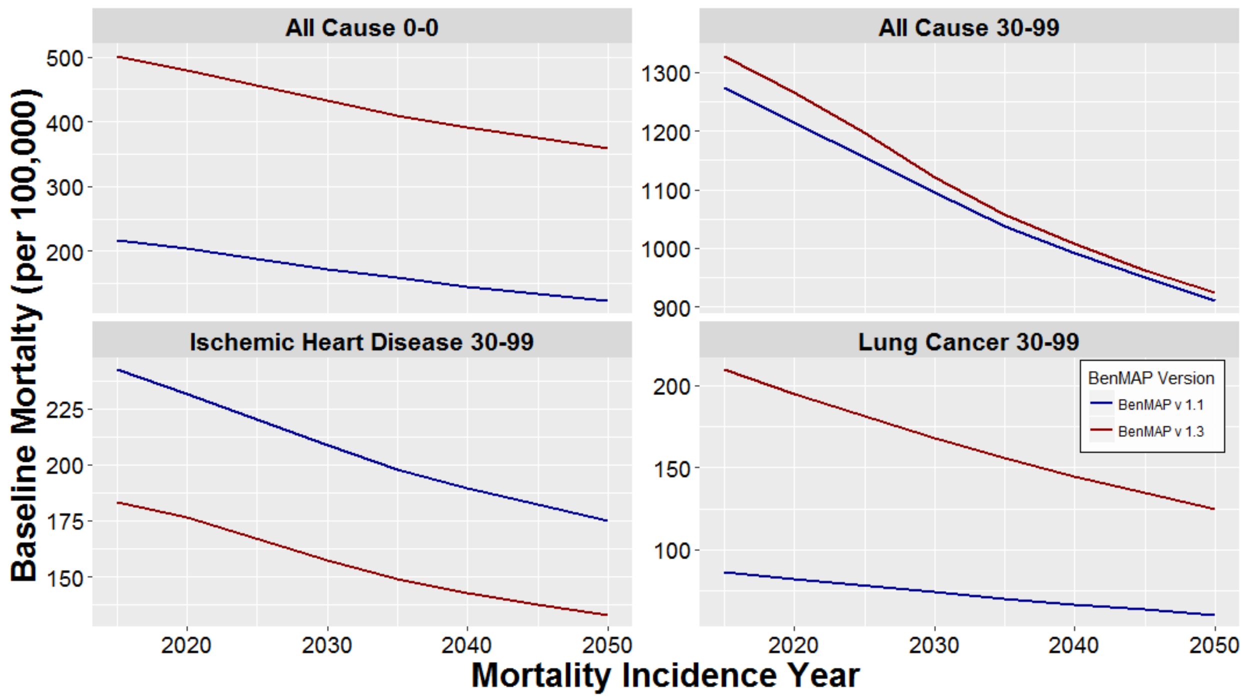
The tables below summarize the absolute and percent changes in baseline mortality for each of four main endpoints, aggregated to the national level. Below the tables, the baseline incidences are also compared graphically as a standardized rate per 100,000 people. In practice, the changes in baseline mortality between versions 1.1 and 1.3 would be reflected in estimates of air pollution-related mortalities as a fraction of the total change, dependent on the magnitude of the applied concentration-response function. The percent change in adult all-cause mortality between v1.1 and v1.3 is relatively small (< 5%) for all of the projected baseline incidence years, but there is much greater variation for each of the other endpoints. We have contacted IEc to request the underlying mortality data and programming code used to project the mortality data, so that we can validate and better understand the changes between versions 1.1 and 1.3.

Lung Cancer Mortality; 30-99		
Incidence Year	**Δ Baseline**	**% Δ Baseline**
2015	224,156	143.2%
2020	205,010	137.7%
2025	187,155	132.3%
2030	169,890	126.1%
2035	155,569	121.6%
2040	141,386	116.4%
2045	128,584	111.1%
2050	117,138	106.8%

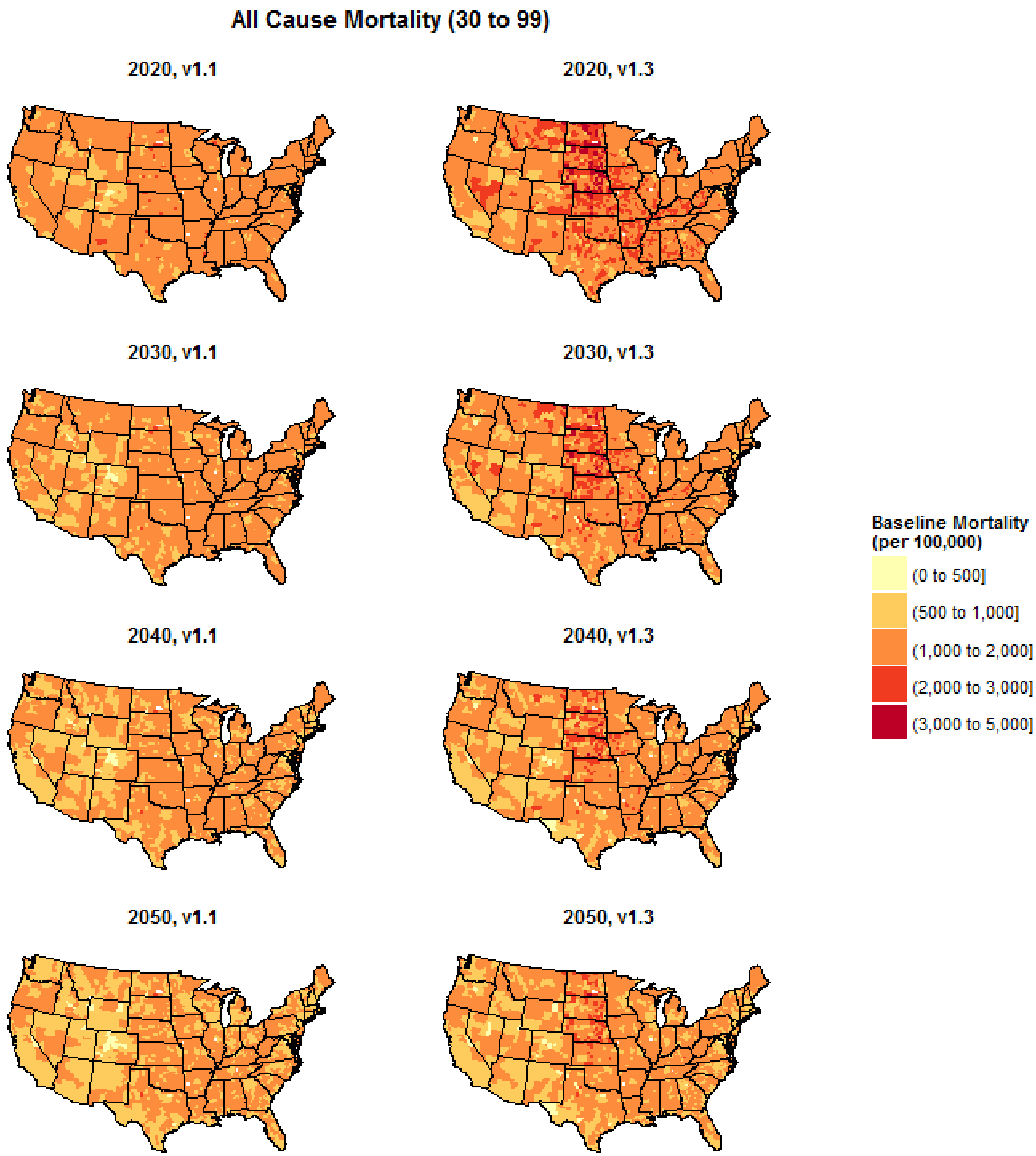
All-Cause Mortality; 0-0		
Incidence Year	**Δ Baseline**	**% Δ Baseline**
2015	11,140	131.3%
2020	10,781	134.6%
2025	10,539	143.4%
2030	10,213	151.3%
2035	9,845	158.8%
2040	9,644	169.5%
2045	9,431	180.6%
2050	9,230	192.5%

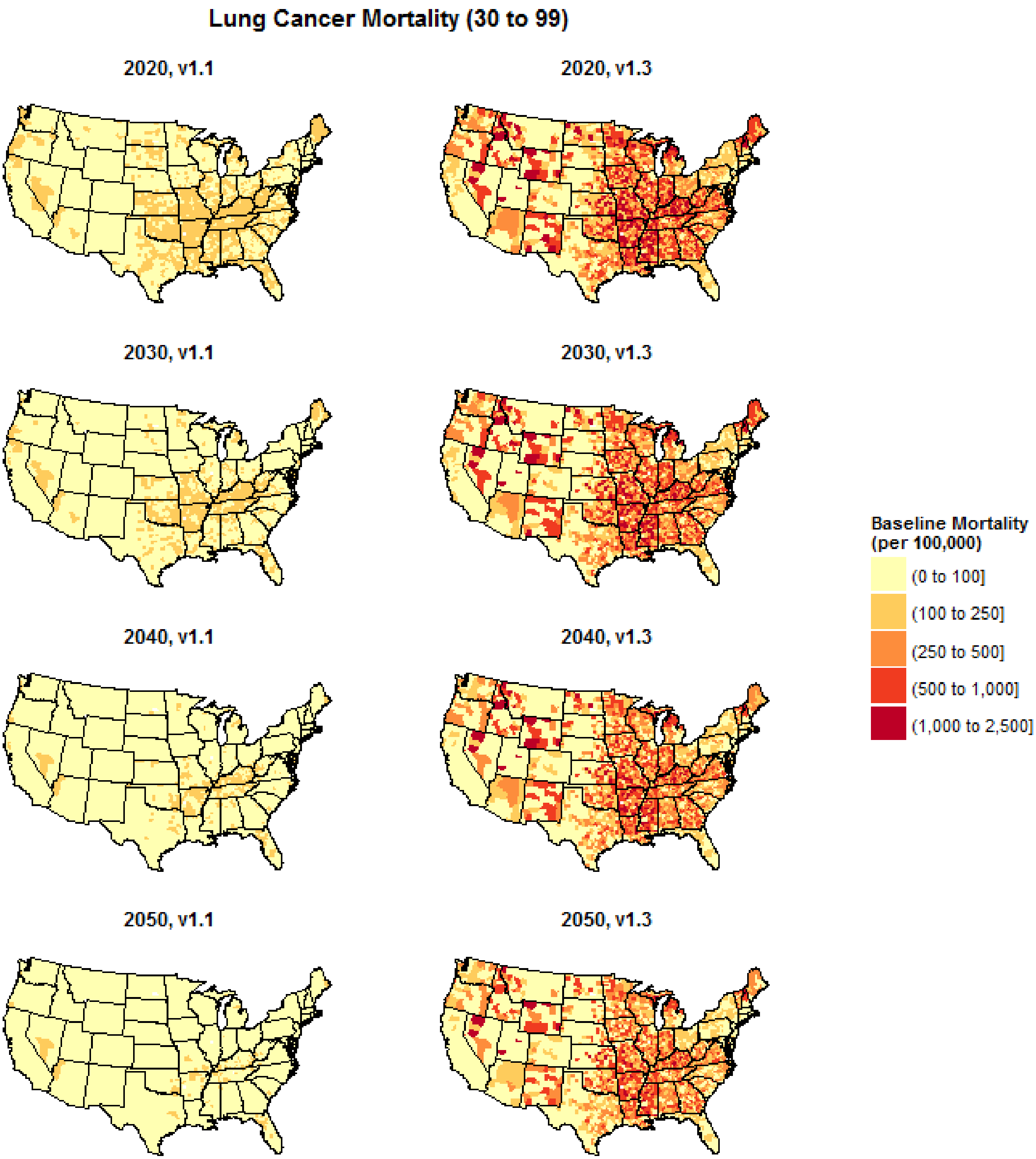
All-Cause Mortality; 30-99		
Incidence Year	**Δ Baseline**	**% Δ Baseline**
2015	98,410	4.3%
2020	93,609	4.2%
2025	73,888	3.5%
2030	46,197	2.3%
2035	36,133	1.9%
2040	27,580	1.5%
2045	20,766	1.2%
2050	26,392	1.6%

IHD Mortality; 30-99		
Incidence Year	**Δ Baseline**	**% Δ Baseline**
2015	-106,842	-24.3%
2020	-100,085	-23.8%
2025	-96,076	-24.0%
2030	-93,500	-24.6%
2035	-88,531	-24.7%
2040	-84,650	-24.6%
2045	-81,044	-24.5%
2050	-75,795	-23.9%

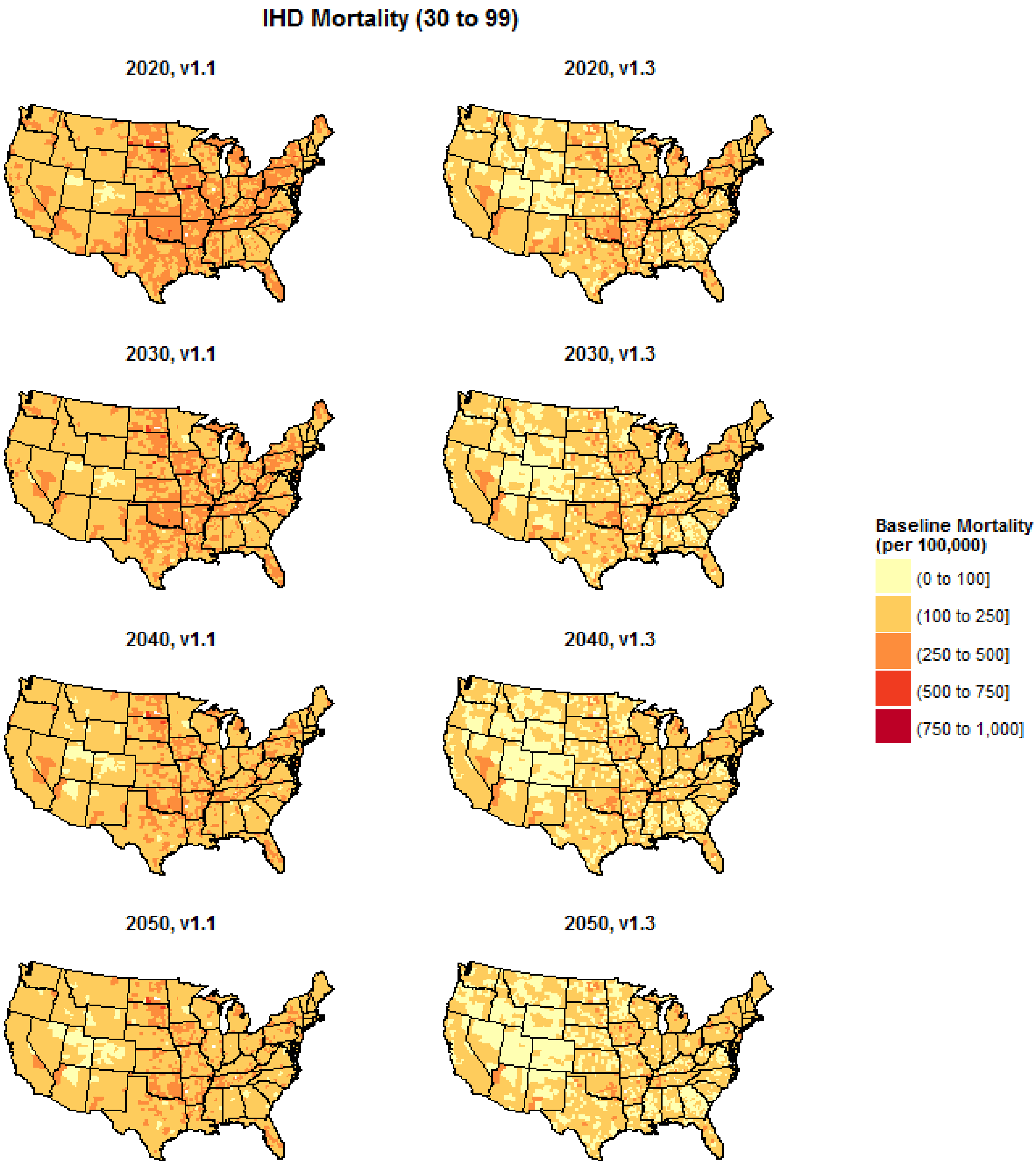


In addition to a national comparison of baseline mortality incidence, we also mapped the standardized county-level rates to examine spatial patterns in baseline incidence and changes in baseline incidence between the two versions of BenMAP. The following series of maps compare standardized baseline mortality incidence in v1.1 and v1.3 for each of the major mortality endpoints.

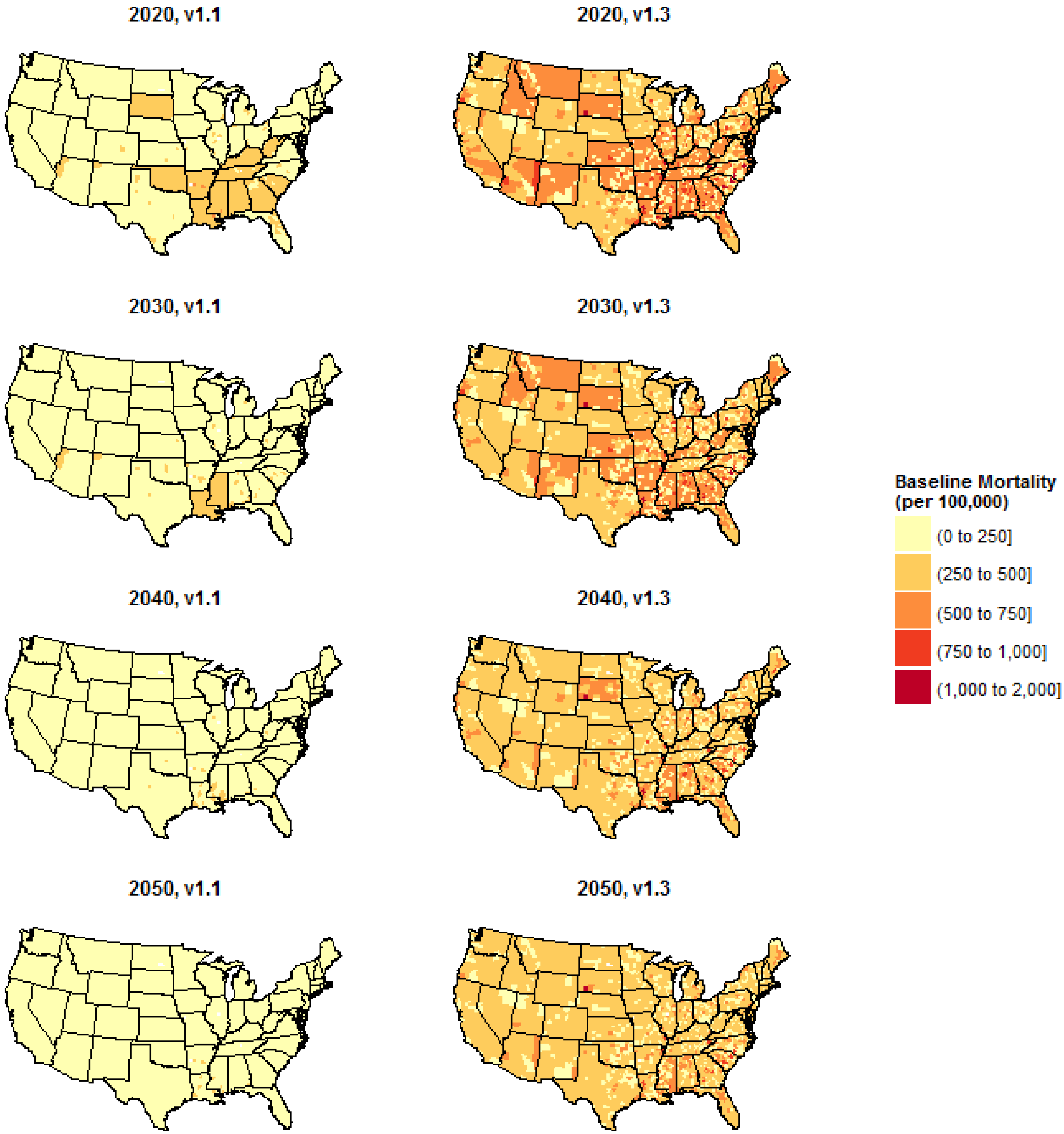

All Cause Mortality (30 to 99)
2020, v1.1
2020, v1.3
2030, v1.1
2030, v1.3
2040, v1.1
2040, v1.3
2050, v1.1
2050, v1.3
Baseline Mortality (per 100,000)
(0 to 500]
(500 to 1,000]
(1,000 to 2,000]
(2,000 to 3,000]
(3,000 to 5,000]



Lung Cancer Mortality (30 to 99)
2020, v1.1
2020, v1.3
2030, v1.1
2030, v1.3
2040, v1.1
2040, v1.3
2050, v1.1
2050, v1.3
Baseline Mortality
(per 100,000)
(0 to 100]
(100 to 250]
(250 to 500]
(500 to 1,000]
(1,000 to 2,500]


IHD Mortality (30 to 99)
2020, v1.1
2020, v1.3
2030, v1.1
2030, v1.3
2040, v1.1
2040, v1.3
2050, v1.1
2050, v1.3
Baseline Mortality (per 100,000)
(0 to 100]
(100 to 250]
(250 to 500]
(500 to 750]
(750 to 1,000]

All Cause Mortality (0 to 0)



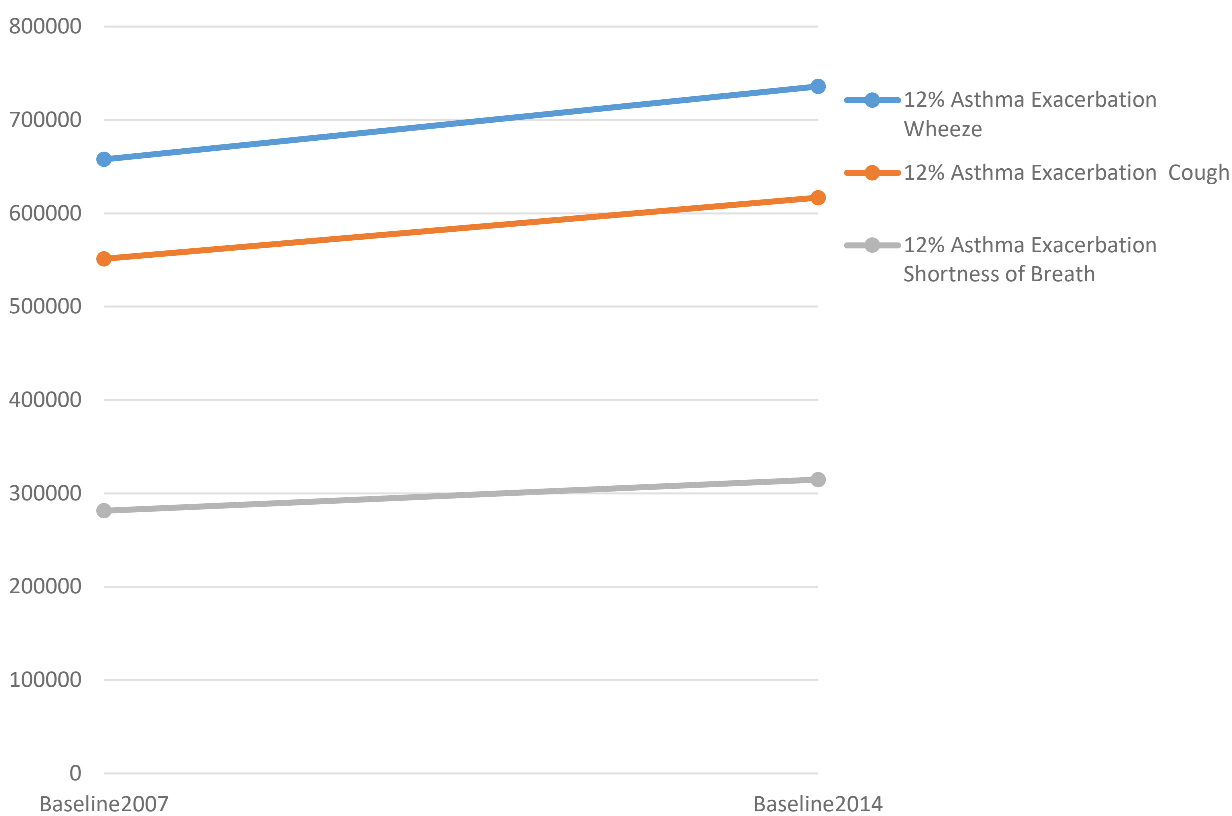
Morbidity

Morbidity rates are taken from Healthcare Cost and Utilization Project (HCUP) within the Department of Health and Human Services. Version 1.1 used 2007 HCUP rates whereas Version 1.3 now has 2014 updated rates imbedded in the database.

We first performed a nationwide analysis to see if any observable changes occurred in the rate of incidence. There are only 23 unique $PM_{2.5}$-related health endpoints being used: 12 rates increased, 5 decreased and 6 health outcome rates remained unchanged between 2007 and 2014.

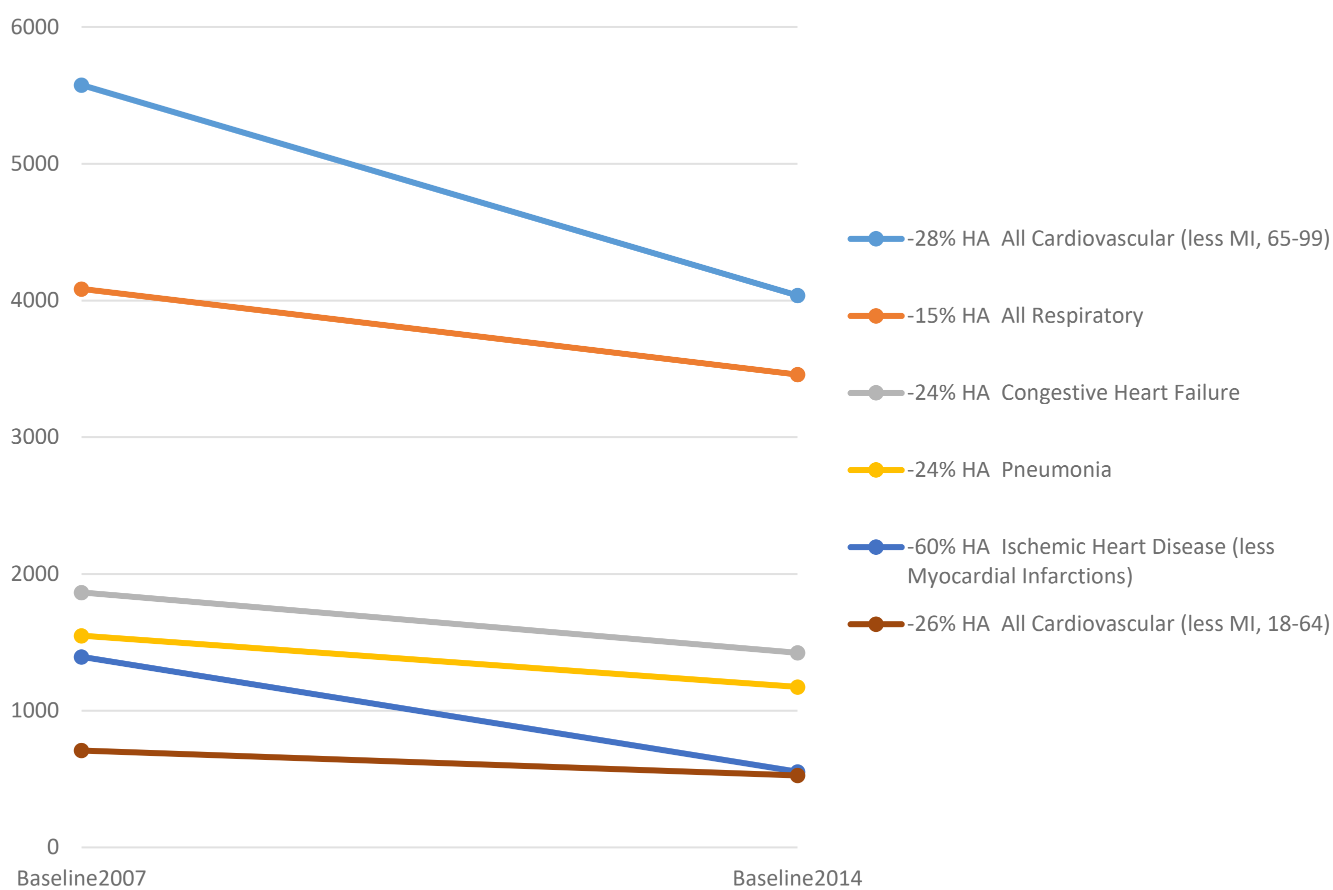
The following baseline incidence rates increased from 2007 to 2014 with a subset plotted below. It appears as if the evaluation of asthma exacerbation is the only substantial increase due to the updated asthma prevalence rate in 2014.

Endpoint	Start Age	End Age	Baseline 2007	Baseline 2014	% Change
Asthma Exacerbation, Wheeze	6	18	657,748	735,873	12%
Asthma Exacerbation, Cough	6	18	551,291	616,776	12%
Asthma Exacerbation, Shortness of Breath	6	18	281,349	314,769	12%
Emergency Room Visits, Asthma	0	99	551	581	5%
HA, Chronic Lung Disease (less Asthma)	18	64	112	113	1%

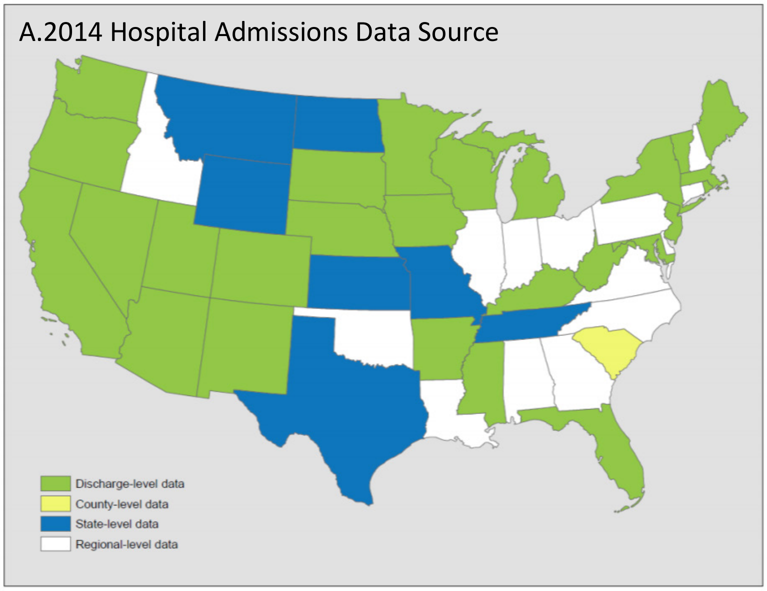


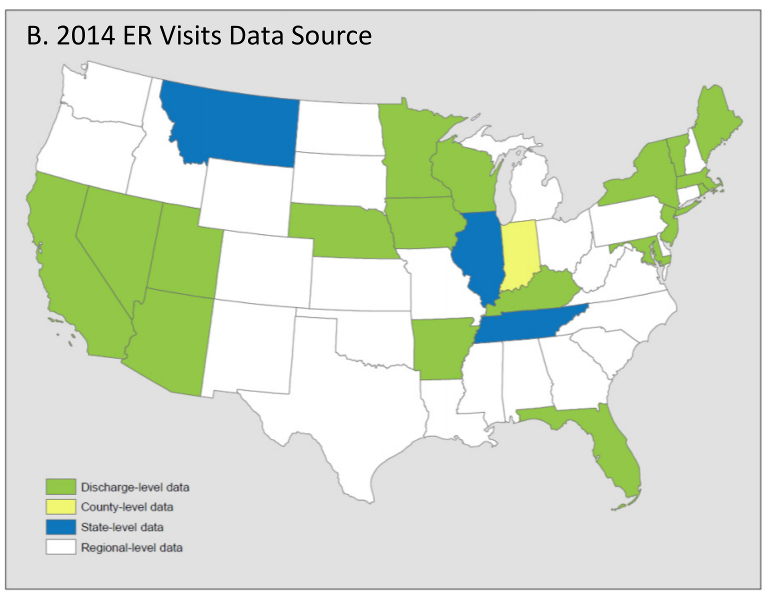
The following health outcome rate (per 100,000) decreased from 2007 to 2014. The significant drops in some of the outcomes were checked on the HCUP website to confirm these trends are in fact accurate.

Endpoint	Start Age	End Age	Baseline 2007	Baseline 2014	%Diff
HA, All Cardiovascular (less MI)	65	99	5,576	4,037	-28%
HA, All Respiratory	65	99	4,084	3,458	-15%
HA, Congestive Heart Failure	65	99	1,865	1,423	-24%
HA, Pneumonia	65	99	1,549	1,174	-24%
HA, Ischemic Heart Disease (less MI)	65	99	1,394	554	-60%
HA, Dysrhythmia	65	99	1,270	1,072	-16%
HA, Chronic Lung Disease	65	99	1,215	1,048	-14%
HA, All Cardiovascular (less MI)	18	64	708	526	-26%
Acute Myocardial Infarction, Nonfatal	18	99	254	231	-9%
HA, Chronic Lung Disease	18	64	210	200	-5%
Acute Myocardial Infarction, Nonfatal	0	99	193	175	-9%
HA, Asthma	0	17	167	137	-18%

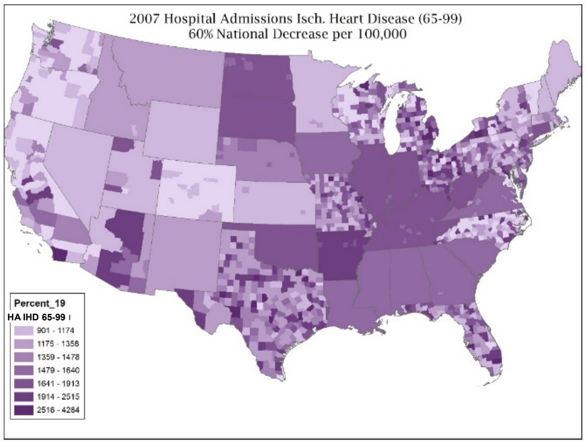


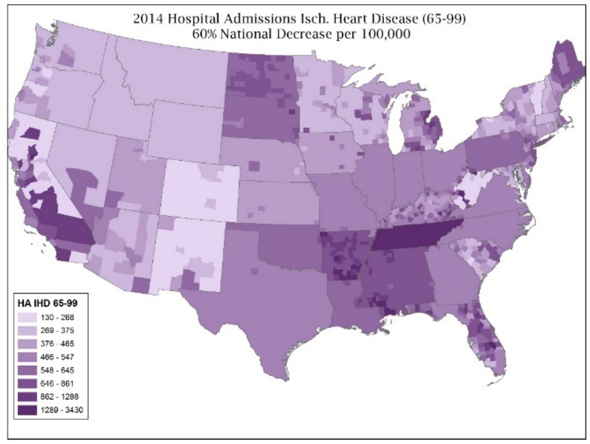
Another concern was the change in the spatial variability morbidity rates for of between 2007 and 2014. We observed that county-wide data values for some states (e.g. TX, MO, PA, OH and NC) were no longer used in 2014; whereas other states like KT, SC, AR and MS (HA only) are now using higher spatially resolved morbidity data. The source of each state's 2014 (A) Hospital Admissions, and (B) ER Visits are mapped below (taken from BenMAP-CE Appendix D).

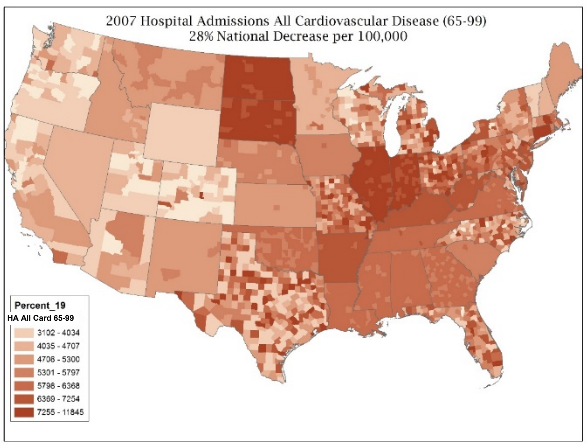


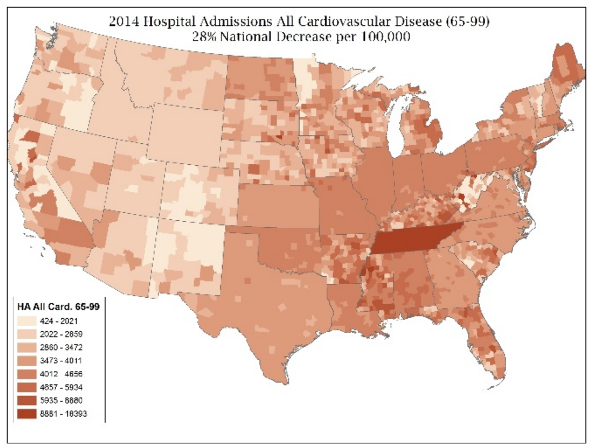


We then performed an illustrative evaluation to show where the changes are distributed between the two functions with the greatest decrease from the 2007 to 2014 datasets: HA, Ischemic Heart Disease, 65-99 (-60%), HA All Cause Cardiovascular (-28%). With the exception of TN , there seems to be an evenly distributed reduction in morbidity across the states between 2007 and 2014.

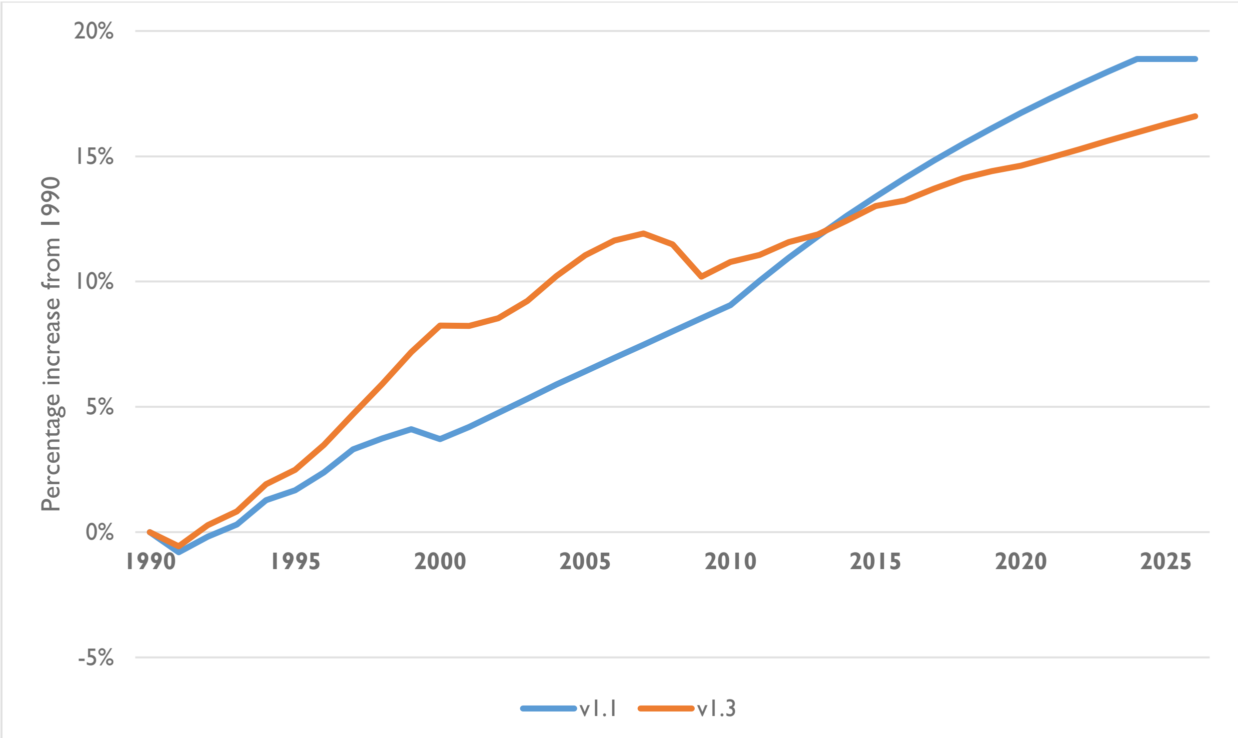








Income Growth



Why do we adjust for income growth?

- Following SAB advice, we account for the influence of changes in personal income on the willingness to pay to reduce the risk of death and other adverse outcomes.
- This relationship is a function of:
    1. The income elasticity—the percentage change in WTP per percentage change in income
    2. The change in future income

What did and did not change between versions 1.1 and 1.3?

- We *did not* alter the income elasticity values
    - We proposed to the SAB/EEAC that we apply new elasticity values calculated using newer literature
    - The SAB/EEAC:
        - Expressed concern that changes in personal income over the past two decades were not equitably distributed across the population and thus we were not capturing the change in WTP among lower-income population groups
        - Suggested we explore alternative approaches to deriving changes in personal income
        - Did not recommend we stop adjusting WTP for income
- We *did* substitute newer/better data to calculate GDP per capita
    - Version 1.1 and prior: Standard & Poor's projected income, divided by Woods & Poole population projection
    - Version 1.3: Congressional Budget Office 10-year projection of GDP, divided by Woods & Poole projected population