Technical Support Document

Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors

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Background and Overview

In 2013, the Agency published a Technical Support Document (TSD) (U.S. EPA 2013) describing an approach for estimating the average avoided human health impacts, and monetized benefits related to emissions of $PM_{2.5}$ and $PM_{2.5}$ precursors including NO_x and SO_2 from 17 sectors using the results of source apportionment photochemical modeling. The Agency periodically updates the demographic and economic input parameters used to quantify the incidence and dollar value of air pollution-related effects. In 2017, EPA released a new version of its environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) tool that incorporated new demographic and economic parameters; these are summarized below and described in greater detail in a memorandum available here.

Using this new version of BenMAP-CE, we re-calculated the $PM_{2.5}$ benefit per-ton values (BPT). When calculating these new BPT values, we used the same emission and air quality input parameters as was used in the 2013 TSD (U.S. EPA 2013) and a published manuscript (Fann et al. 2012). Below we describe: our approach to calculating a BPT value; the new demographic and economic datasets we incorporated into BenMAP-CE; and, the limitations and uncertainties associated with application of these estimates. Finally, we summarize the benefit per ton estimates for each of the 17 emission sectors. Readers interested in learning more about the emissions and air quality input parameters may refer to a separate TSD detailing the modeling or the two published manuscripts that detail the photochemical modeling simulations (Fann et al. 2013, 2012; U.S. EPA 2011).

Approach to Calculating Benefit Per-Ton Values

The procedure for calculating benefit per ton coefficients follows three steps, shown graphically in Figure 1:

1. Using source apportionment photochemical modeling, predict annual average ambient concentrations of primary $PM_{2.5}$, nitrate and sulfate attributable to each of 17 emission sectors across the Continental U.S.; see below for a summary of the sectors modeled.

2. For each sector, estimate the health impacts, and the economic value of these impacts, associated with the attributable ambient concentrations of primary $PM_{2.5}$, sulfate and nitrate $PM_{2.5}$ using the environmental Benefits Mapping and Analysis Program-Community Edition (BenMAP v1.3.71).[1]

[1] In this stage we estimate the $PM_{2.5}$-related impacts associated with changes in directly emitted $PM_{2.5}$, nitrate

3. For each sector, divide the $PM_{2.5}$-related health impacts attributable to each type of $PM_{2.5}$, and the monetary value of these impacts, by the level of associated precursor emissions. That is, primary $PM_{2.5}$ benefits are divided by direct $PM_{2.5}$ emissions, sulfate benefits are divided by SO_2 emissions, and nitrate benefits are divided by NO_x emissions.

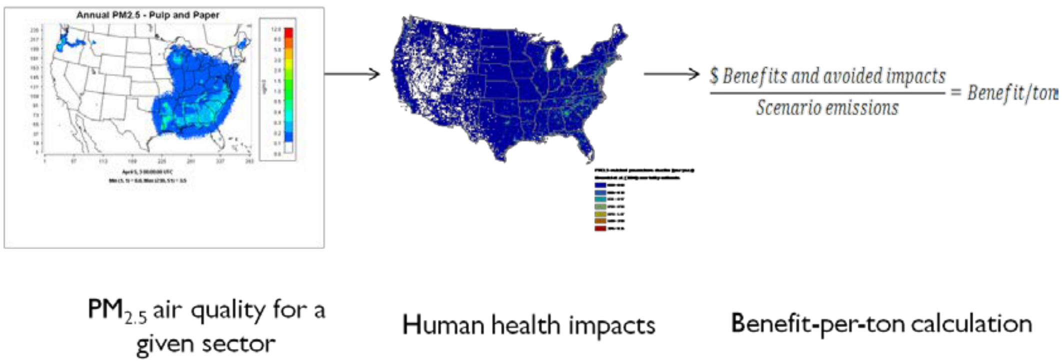


Figure 1. Conceptual overview of the steps for calculating benefit per-ton estimates

Sectors Analyzed

The example above depicts the total $PM_{2.5}$ contribution from the pulp and paper sector, though we repeat this process for each of the 17 sectors, which include:

1. Locomotives and marine vessels[2]
2. Area sources
3. Cement kilns
4. Coke ovens
5. Electric arc furnaces
6. Electricity generating units
7. Ferroalloy facilities
8. Industrial point sources
9. Integrated iron and steel facilities
10. Iron and steel facilities
11. Non-road mobile sources
12. Ocean-going vessels
13. On-road mobile sources
14. Pulp and paper facilities

and sulfate separately, so that we may ultimately calculate the benefit per ton reduced of the corresponding $PM_{2.5}$ precursor, or directly emitted $PM_{2.5}$, in step 3. When estimating these impacts we apply effect coefficients that relate changes in total $PM_{2.5}$ mass to the risk of adverse health outcomes; we do not apply effect coefficients that are differentiated by $PM_{2.5}$ specie.

[2] The prior version of this TSD specified this sector as "Air, Locomotive and Marine Vessels." The Agency subsequently learned that, due to an emissions processing error, this sector omits Aircraft emissions.

15. Refineries
16. Residential wood combustion
17. Taconite mines

The "Area sources" and "Industrial point sources" categories are an agglomeration of emission sectors that were not otherwise specified elsewhere. When selecting a benefit per ton estimate for use with a sector not specifically modeled, it is necessary to determine which composite sector is the best match with respect to the source characteristics that would affect the level of benefits. These attributes include the proximity to receptor populations, the geographic distribution of sources, and the release parameters of the source (e.g., stack height).

Readers interested in a full discussion of the air quality modeling performed to generate these benefit per ton estimates may consult "Air Quality Modeling Technical Support Document: Source Sector Assessments" (U.S. EPA 2011). Ambient $PM_{2.5}$ concentrations attributable to each sector were projected from the 2005 baseline to 2016 to represent growth and the application of controls. The starting point for the projections was the 2005 v4.3 emissions platform (US EPA 2005). EGU emission estimates for 2016 are from the Integrated Planning Model (IPM). The 2016 projection included emission reductions related to the NO_x State Implementation Plan Call (US EPA 1998), the Maximum Achievable Control Technology (MACT) Standards for Industrial Boilers (US EPA 2011d) and Reciprocating Internal Combustion Engines (US EPA 2010b), and the proposed Transport Rule affecting emissions from Electricity Generating Units (US EPA 2010c). Control and growth factors, including known plant shut-downs and economic growth in some sectors, were applied to a subset of the 2005 industrial point sources and area sources to create the 2016 projection. Other North American emissions are based on a 2006 Canadian inventory and 1999 Mexican inventory, which are not grown or controlled when used as part of future year baseline inventories (US EPA 2011b; US EPA 2011c). Global emissions are included in the modeling system through boundary condition inflow to the 36 km CAMx simulation. The initial and boundary conditions for the 36 km CAMx simulation are based on 3-hourly output from an annual 2005 GEOS-CHEM simulation (standard version 7-04-11). Table 1 summarizes the total precursor emissions attributable to each sector in 2016. Appendix B of this TSD includes plots of the $PM_{2.5}$ levels attributed to each of these sectors for which we estimated benefit per-ton metrics.

Table 1. 2016 emissions by sector (tons per year)

Sector	*VOC*	*NO_x*	*$PM_{2.5}$*[a]	*SO_2*	*NH_3*
Aircraft, locomotives and marine vessels	43,547	1,342,849	35,604	9,087	940
Area sources	9,380,925	1,633,261	325,820	1,243,154	126,802
Cement kilns	3,059	130,536	1,106	48,737	679
Coke ovens	7,821	16,110	368	27,952	1,084
Electric arc furnaces	3,560	15,707	622	6,088	119
Electricity generating units	63,198	1,826,582	30,078	3,793,362	36,706
Ferroalloy facilities	150	3,412	201	4,580	510
Industrial point sources	1,259,745	1,263,276	67,614	877,620	140,948
Integrated iron and steel facilities	9,620	31,925	2,856	29,045	167
Iron and steel facilities	14,384	5,867	1,366	3,590	166
Non-road mobile sources	1,953,067	1,259,578	106,975	2,879	2,345
Ocean-going vessels	66,093	1,534,234	7,407	439,987	0
On-road mobile sources	2,357,108	4,239,971	118,986	26,786	82,094
Pulp and paper facilities	121,597	240,139	10,067	170,393	10,859
Refineries	111,391	118,206	7,379	132,337	3,556
Residential wood combustion	538,466	33,786	192,492	4,720	6,586
Taconite mines	606	41,350	884	8,823	4

[a] This value includes elemental and organic carbon, which were used for the benefit per ton calculations.

The photochemical modeling used here also produced estimates of ozone levels attributable to each sector. However, the complex non-linear chemistry governing ozone formation prevented us from developing a complementary array of ozone benefit per ton values. This limitation notwithstanding, we anticipate that the ozone-related benefits associated with reducing emissions of NO_x and VOC for many of these sectors could be substantial.

While most VOCs emitted are oxidized to carbon dioxide (CO_2) rather than to PM, a portion of VOC emission contributes to ambient $PM_{2.5}$ levels as organic carbon aerosols (U.S. EPA 2009). Therefore, reducing VOC emissions would reduce the level of $PM_{2.5}$ formed in the atmosphere, human exposure to $PM_{2.5}$, and the incidence of $PM_{2.5}$-related health effects. However, we have not quantified VOC benefit per ton estimates in this analysis. Uncertainties in both the origin and quantity of emissions contributing to secondary organic aerosol on regional scales limit the quality of regional scale modeling of secondary organic carbon. Modeling and monitoring the relative amount of organic particles that are formed through secondary processes, versus primarily emitted organic particles, is highly uncertain. While the relative contributions of different sources to regional sulfate and nitrate can be quantified with certainty, the contributions from different sources to secondary organic aerosol are less clear. Carbonaceous aerosol reflects a complex mixture of hundreds to thousands of organic carbon compounds, many of which have not been successfully quantified. Despite progress that has been made in understanding the origin, properties, and key formation processes of SOA, it remains the least understood component of $PM_{2.5}$ (U.S. EPA 2004).

Below we provide an expanded discussion of each of the latter two steps to the calculation—estimating health impacts and economic value of $PM_{2.5}$ attributable to each sector and calculating the benefit per ton coefficients. The discussion of these topics is not intended to be exhaustive, and readers interested in learning more about our approach to performing an air pollution health impact and benefits analysis may consult the PM NAAQS RIA (US EPA 2012).

Estimating the number of $PM_{2.5}$-related health impacts attributable to each sector

In this stage of the analysis we performed a Health Impact Assessment (HIA), which quantifies the changes in the incidence of adverse health impacts resulting from changes in human exposure to $PM_{2.5}$ from each sector. HIAs are a well-established approach for estimating the retrospective or prospective change in adverse health impacts expected to result from population-level changes in exposure to pollutants (Hubbell et al. 2009b, 2009a). PC-based tools such as the environmental Benefits Mapping and Analysis Program (BenMAP) can systematize health impact analyses by applying a database of key input parameters, including health impact functions and population projections (US EPA). Analysts have applied the HIA approach to estimate human health impacts resulting from hypothetical changes in pollutant levels(Davidson et al. 2007; Hubbell et al. 2004; Tagaris et al. 2009).

The HIA approach used in this analysis involves three basic steps: (1) utilizing CAMx--generated estimates of $PM_{2.5}$ levels attributed to each sector; (2) determining the subsequent change in population-level exposure; (3) calculating health impacts by applying concentration-response relationships drawn from the epidemiological literature to this change in population exposure (Hubbell et al. 2004).

This procedure is operationalized within BenMAP using a health impact function (Eq 1). We estimated the number of $PM_{2.5}$-related total deaths and illnesses (y_{ij}) during each year *i* (i=2016, 2020, 2025, 2030) among populations in each 12km by 12km air quality model grid cell *j* (j=1,…,J where J is the total number of grids) as

$$y_{ij} = \boldsymbol{\Sigma}_a \, y_{ija}$$

$$y_{ija} = m0_{ija} \times (e^{\beta \cdot C_j} - 1) \times P_{ija}, \quad \text{Eq[1]}$$

where β is the risk coefficient for all-cause mortality for adults in association with $PM_{2.5}$ exposure, m_{0ija} is the baseline all-cause mortality or morbidity rate for populations aged *a* in grid cell *j* in year *i* stratified in 10-year age bins, C_{ij} is annual mean $PM_{2.5}$ concentration in grid cell *j*, and P_{ija} is the number of individuals aged *a* in grid cell *j* in year *i* stratified into 5-year age bins.

Tools such as BenMAP can systematize the HIA calculation process, allowing users to draw upon a library of existing air quality monitoring data, population data and health impact functions.

Figure 2 provides a simplified overview of this approach, using $PM_{2.5}$-related premature mortality as an example, though the procedure is generally the same for other health endpoints. This sequence of steps is performed for each of the 17 sectors for each $PM_{2.5}$ component (primary $PM_{2.5}$, sulfate and nitrate). The $PM_{2.5}$ health endpoints quantified and the health impact functions applied in this analysis are consistent with the PM NAAQS RIA (US EPA 2012). That RIA includes a detailed discussion of each of the data inputs, analytical assumptions and sources of uncertainty. In the interest of brevity, we do not repeat these here in detail. However, it is worth noting that we exclude the value of several important non-health endpoints, including recreational and residential visibility, climate-related impacts and ecological endpoints. Table 2 below summarizes the endpoints quantified in this benefit per ton TSD.

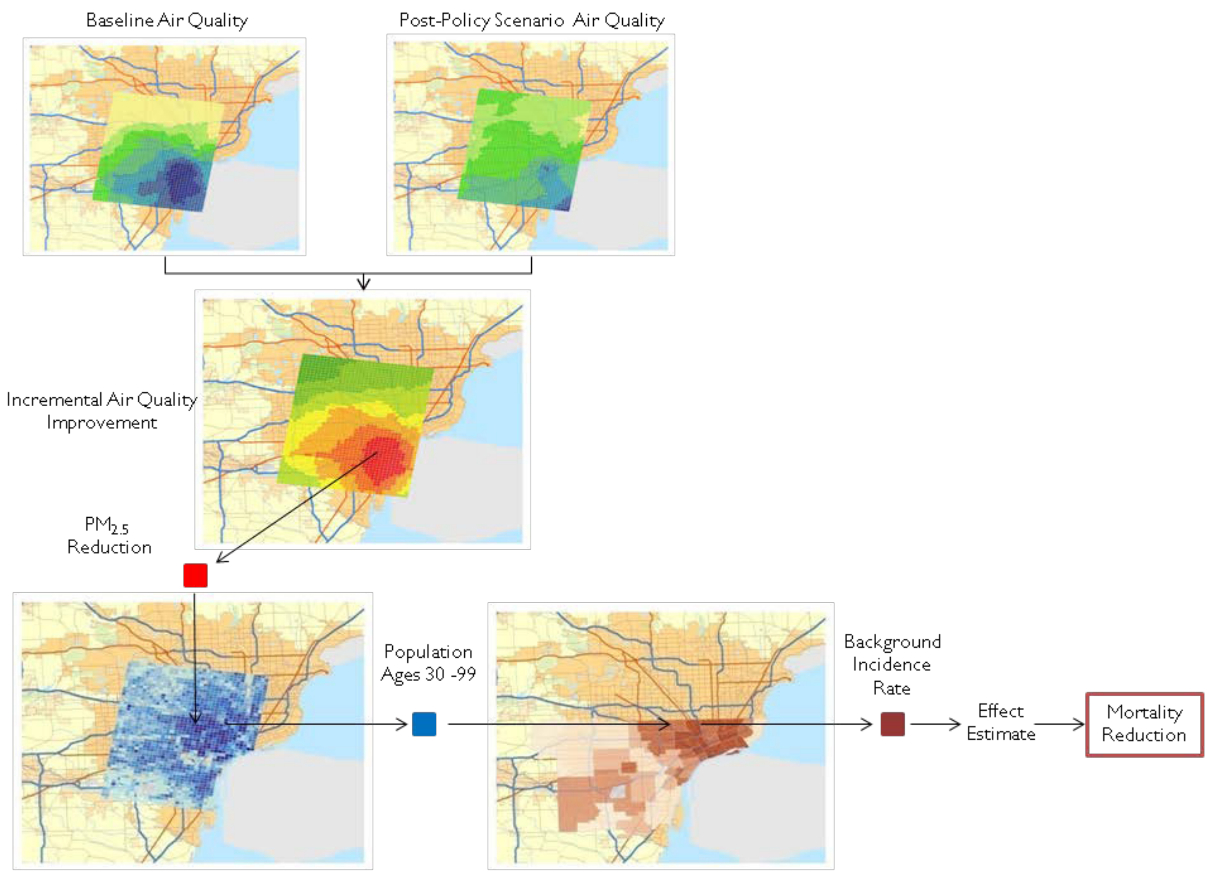


Figure 2. Illustration of the BenMAP-CE Approach to Calculating Cases of Air Pollution-Related Effects

Table 2. Human health effects of $PM_{2.5}$ quantified and not quantified in this analysis

Category	*Effect*	*Quantified*	*Monetized*	*More Information in PM NAAQS RIA*
Improved Human Health				
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age >25 or age >30)	✓	✓	Section 5.6
	Infant mortality (age <1)	✓	✓	Section 5.6
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Non-fatal heart attacks (age > 18)	✓	✓	Section 5.6
	Hospital admissions—respiratory (all ages)	✓	✓	Section 5.6
	Hospital admissions—cardiovascular (age >20)	✓	✓	Section 5.6
	Emergency room visits for asthma (all ages)	✓	✓	Section 5.6
	Acute bronchitis (age 8-12)	✓	✓	Section 5.6
	Lower respiratory symptoms (age 7-14)	✓	✓	Section 5.6
	Upper respiratory symptoms (asthmatics age 9-11)	✓	✓	Section 5.6
	Asthma exacerbation (asthmatics age 6-18)	✓	✓	Section 5.6
	Lost work days (age 18-65)	✓	✓	Section 5.6
	Minor restricted-activity days (age 18-65)	✓	✓	Section 5.6
	Chronic Bronchitis (age >26)	--[1]	--[1]	Section 5.6
	Emergency room visits for cardiovascular effects (all ages)	--[1]	--[1]	Section 5.6
	Strokes and cerebrovascular disease (age 50-79)	--[1]	--[1]	Section 5.6
	Other cardiovascular effects (e. g., other ages)	--	--	PM ISA[2]
	Other respiratory effects (e.g., pulmonary function, non- a ER visits, non-bronchitis chronic diseases, other ages and populations)	--	--	PM ISA[2]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc)	--	--	PM ISA[2,3]
	Cancer, mutagenicity, and genotoxicity effects	--	--	PM ISA[2,3]

[1] We assess these benefits qualitatively due to time and resource limitations for this analysis. In the PM NAAQS RIA, these benefits were quantified in a sensitivity analysis, but not in the core analysis.

[2] We assess these benefits qualitatively because we do not have sufficient confidenc e in available data or methods.

[3] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

Estimating the economic value of health impacts attributable to each sector

After quantifying the number of adverse air pollution-attributable impacts, the next step is to estimate the economic value of these events. The appropriate economic value for a change in a health effect depends on whether the health effect is viewed *ex ante* (before the effect has occurred) or *ex post* (after the effect has occurred). Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. The appropriate economic measure is therefore *ex ante* Willingness to Pay (WTP) for changes in risk. However, epidemiological studies generally provide estimates of the relative risks of a particular health effect avoided due to a reduction in air pollution. A convenient way to use this data in a consistent framework is to convert probabilities to units of avoided statistical incidences. This measure is calculated by dividing individual WTP for a risk reduction by the related observed change in risk. For example, suppose a measure is able to reduce the risk of premature mortality from 2 in 10,000 to 1 in 10,000 (a reduction of 1 in 10,000). If individual WTP for this risk reduction is $100, then the WTP for an avoided statistical premature mortality amounts to $1 million ($100/0.0001 change in risk). Using this approach, the size of the affected population is automatically taken into account by the number of incidences predicted by epidemiological studies applied to the relevant population. The same type of calculation can produce values for statistical incidences of other health endpoints.

For some health effects, such as hospital admissions, WTP estimates are generally not available. In these cases, we use the cost of treating or mitigating the effect as a primary estimate. For example, for the valuation of hospital admissions we use the avoided medical costs as an estimate of the value of avoiding the health effects causing the admission. These cost of illness (COI) estimates generally (although not in every case) understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect.

Avoided premature deaths account for 98% of monetized PM-related benefits. The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economics and public policy analysis community. Following the advice of the SAB's Environmental Economics Advisory Committee (SAB-EEAC), the EPA currently uses the value of statistical life (VSL) approach in calculating estimates of mortality benefits, because we believe this calculation provides the most reasonable single estimate of an individual's willingness to trade off money for reductions in mortality risk (U.S. EPA Science Advisory Board 2000). The VSL approach is a summary measure for the value of small changes in mortality risk experienced by a large number of people.

EPA continues work to update its guidance on valuing mortality risk reductions, and the Agency consulted several times with the SAB-EEAC on the issue. Until updated guidance is available, the Agency determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, EPA has decided to apply the VSL that was vetted and endorsed by the SAB in the *Guidelines for Preparing Economic Analyses* (U.S. EPA 2000) while the Agency continues its efforts to update its guidance on this issue.[2] This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$).[3] We then adjust this VSL to account for the currency year used for the analysis and to account for income growth from 1990 to the analysis year. Table 3 shows the adjusted VSL estimates for currency years 2000-2015 for the income growth years used in the source apportionment benefit per ton calculations.

Table 3. Value of a Statistical Life Estimate Adjusted for Currency and Income Growth Years

		VSL with Income Growth to:		
Currency Year	**Base VSL**	*2016*	*2020*	*2026*
2000	$6.3	$7.3	$7.4	$7.5
2001	$6.5	$7.5	$7.6	$7.7
2002	$6.6	$7.6	$7.7	$7.9
2003	$6.7	$7.8	$7.9	$8.0
2004	$6.9	$8.0	$8.1	$8.3
2005	$7.1	$8.2	$8.4	$8.5
2006	$7.4	$8.5	$8.6	$8.8
2007	$7.6	$8.7	$8.9	$9.1
2008	$7.9	$9.1	$9.2	$9.4
2009	$7.8	$9.0	$9.2	$9.4
2010	$8.0	$9.2	$9.3	$9.5
2011	$8.2	$9.5	$9.6	$9.8
2012	$8.4	$9.7	$9.8	$10.0
2013	$8.5	$9.8	$10.0	$10.2
2014	$8.7	$10.0	$10.1	$10.3
2015	$8.7	$10.0	$10.2	$10.4

2 In the updated *Guidelines for Preparing Economic Analyses* (US EPA 2010), EPA retained the VSL endorsed by the SAB with the understanding that further updates to the mortality risk valuation guidance would be forthcoming in the near future.

3 In 1990$, this VSL is $4.8 million.

In valuing premature mortality, we discount the value of premature mortality occurring in future years using rates of 3% and 7% (OMB 2003). We assume that there is a "cessation" lag between changes in PM exposures and the total realization of changes in health effects. Although the structure of the lag is uncertain, the EPA follows the advice of the SAB-HES to assume a segmented lag structure characterized by 30% of mortality reductions in the first year, 50% over years 2 to 5, and 20% over the years 6 to 20 after the reduction in $PM_{2.5}$ (U.S. EPA Science Advisory Board 2004). Changes in the cessation lag assumptions do not change the total number of estimated deaths but rather the timing of those deaths.

We express the economic value of the avoided impacts using constant year 2015 dollars, adjusted for growth in real income out to the analysis year using projections provided by the Congressional Budget Office. However, these projections are only available to 2026, so the 2030 estimates use income growth to 2026. Economic theory suggests that WTP for most goods (such as environmental protection) will increase if real income increases. Many of the valuation studies used in this analysis were conducted in the late 1980s and early 1990s. Because real income has grown since the studies were conducted, people's willingness to pay for reductions in the risk of premature death and disease likely has grown as well. We did not adjust cost of illness-based values because they are based on current costs. For these two reasons, the cost of illness estimates may underestimate the economic value of avoided health impacts in each analysis year. As with the selection of health studies, the economic valuation estimates applied in this analysis are consistent with those used in the PM NAAQS RIA.

Calculating the benefit per ton estimate

The final step is to divide the incidence of adverse health outcomes, and the economic value of those outcomes, associated with the primary $PM_{2.5}$, nitrate and sulfate attributable to each sector by the sector emissions of directly emitted $PM_{2.5}$, NO_x and SO_2. The result is a suite of incidence per ton and $ benefit per ton estimates for each sector. Below we summarize the total $ per ton estimates for each of the 17 sectors, with more detailed health impacts per ton for each sector provided in Appendix A. The results for four analysis years (2016, 2020, 2025 and 2030) are presented.

Table 4. Data used for Benefit per Ton Estimates

Analysis Year	Population Year	Mortality Incidence Year	Income Growth Year	Currency Year	Emissions Year
2016	2016	2015	2016		
2020	2020	2020	2020	2015	2016
2025	2025	2025	2025		
2030	2030	2030	2026		

Demographic and Socioeconomic Input Parameters Updated in 2017

In 2017, the Agency updated four key input parameters in the BenMAP-CE tool:

1. *Projected population*. The program projects census-reported 2010 population counts to future years using projected population counts from the Woods & Poole corporation. We procured projections developed in the year 2015, which replaced projections last updated in 2012.
2. *Baseline and projected death rates*. We replaced the existing baseline cause-specific death rates from the years 2004-2006 with rates from the years 2012-2014. We projected these cause-specific rates to the year 2060 using life tables provided by the U.S. Census Bureau.
3. *Baseline hospital admission rates*. We replaced the baseline rates of hospital admissions and emergency department visits procured from the Healthcare Cost and Utilization Program (HCUP) for the year 2007 with rates for the year 2014.
4. *Estimated changes in future income*. We substituted projected data from the Congressional Budget Office for the existing Standard and Poors data and projected personal income for each year from 1990 to 2026.

The overall influence on the size of the estimated incidence and economic value of air quality changes of these four changes is fairly modest; further information may be found in EPA (2017), linked here.

Results

Table 5. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2016 (2015$, 3% discount rate)[A]

	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
Sector	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$260,000	$89,000	$7,800	$590,000	$200,000	$18,000
Area sources	$350,000	$54,000	$8,600	$800,000	$120,000	$19,000
Cement kilns	$390,000	$48,000	$6,300	$890,000	$110,000	$14,000
Coke ovens	$510,000	$58,000	$12,000	$1,200,000	$130,000	$27,000
Electric arc furnaces	$480,000	$89,000	$11,000	$1,100,000	$200,000	$25,000
Electricity generating units	$140,000	$40,000	$6,000	$330,000	$92,000	$14,000
Ferroalloy facilities	$320,000	$50,000	$5,100	$720,000	$110,000	$12,000
Industrial point sources	$540,000	$97,000	$15,000	$1,200,000	$220,000	$35,000
Integrated iron and steel	$560,000	$450,000	$18,000	$1,300,000	$1,000,000	$41,000
Iron and steel facilities	$340,000	$47,000	$7,400	$760,000	$110,000	$17,000
Non-road mobile sources	$290,000	$45,000	$7,000	$660,000	$100,000	$16,000
Ocean-going vessels	$48,000	$13,000	$2,000	$110,000	$29,000	$4,400
On-road mobile sources	$400,000	$21,000	$8,300	$900,000	$48,000	$19,000
Pulp and paper facilities	$170,000	$50,000	$4,200	$380,000	$120,000	$9,500
Refineries	$350,000	$73,000	$7,300	$790,000	$170,000	$17,000
Residential wood combustion	$400,000	$110,000	$15,000	$900,000	$250,000	$33,000
Taconite mines	$95,000	$38,000	$6,900	$220,000	$87,000	$16,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 6. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2016 (2015$, 7% discount rate)[A]

	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
Sector	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$240,000	$80,000	$7,000	$540,000	$180,000	$16,000
Area sources	$320,000	$48,000	$7,700	$720,000	$110,000	$18,000
Cement kilns	$350,000	$43,000	$5,700	$810,000	$99,000	$13,000
Coke ovens	$460,000	$52,000	$11,000	$1,000,000	$120,000	$25,000
Electric arc furnaces	$440,000	$81,000	$9,800	$990,000	$180,000	$22,000
Electricity generating units	$130,000	$36,000	$5,400	$300,000	$83,000	$12,000
Ferroalloy facilities	$290,000	$45,000	$4,600	$650,000	$100,000	$10,000
Industrial point sources	$490,000	$88,000	$14,000	$1,100,000	$200,000	$31,000
Integrated iron and steel	$500,000	$410,000	$16,000	$1,100,000	$930,000	$37,000
Iron and steel facilities	$300,000	$43,000	$6,700	$690,000	$97,000	$15,000
Non-road mobile sources	$260,000	$41,000	$6,300	$600,000	$93,000	$14,000
Ocean-going vessels	$44,000	$11,000	$1,800	$99,000	$26,000	$4,000
On-road mobile sources	$360,000	$19,000	$7,500	$810,000	$43,000	$17,000
Pulp and paper facilities	$150,000	$46,000	$3,800	$350,000	$100,000	$8,600
Refineries	$310,000	$66,000	$6,600	$710,000	$150,000	$15,000
Residential wood combustion	$360,000	$98,000	$13,000	$810,000	$220,000	$30,000
Taconite mines	$86,000	$34,000	$6,300	$200,000	$78,000	$14,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 7. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2020 (2015$, 3% discount rate)[A]

	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
Sector	*Directly emitted $PM_{2.5}$*	*SO_2*	*NO_x*	*Directly emitted $PM_{2.5}$*	*SO_2*	*NO_x*
Aircraft, locomotives and marine vessels	$280,000	$96,000	$8,100	$620,000	$220,000	$18,000
Area sources	$370,000	$56,000	$9,000	$840,000	$130,000	$20,000
Cement kilns	$420,000	$50,000	$6,500	$950,000	$110,000	$15,000
Coke ovens	$520,000	$60,000	$12,000	$1,200,000	$140,000	$28,000
Electric arc furnaces	$500,000	$93,000	$11,000	$1,100,000	$210,000	$26,000
Electricity generating units	$150,000	$42,000	$6,200	$350,000	$96,000	$14,000
Ferroalloy facilities	$330,000	$52,000	$5,200	$750,000	$120,000	$12,000
Industrial point sources	$560,000	$100,000	$16,000	$1,300,000	$230,000	$36,000
Integrated iron and steel	$580,000	$470,000	$19,000	$1,300,000	$1,100,000	$43,000
Iron and steel facilities	$360,000	$51,000	$7,800	$810,000	$120,000	$18,000
Non-road mobile sources	$310,000	$47,000	$7,300	$700,000	$110,000	$17,000
Ocean-going vessels	$52,000	$14,000	$2,100	$120,000	$31,000	$4,700
On-road mobile sources	$420,000	$23,000	$8,700	$950,000	$52,000	$20,000
Pulp and paper facilities	$180,000	$53,000	$4,400	$400,000	$120,000	$9,900
Refineries	$360,000	$77,000	$7,700	$830,000	$180,000	$17,000
Residential wood combustion	$420,000	$110,000	$15,000	$960,000	$260,000	$35,000
Taconite mines	$99,000	$40,000	$7,200	$230,000	$90,000	$16,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 8. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2020 (2015$, 7% discount rate)[A]

	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
Sector	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$250,000	$87,000	$7,300	$560,000	$200,000	$17,000
Area sources	$340,000	$51,000	$8,100	$760,000	$120,000	$18,000
Cement kilns	$380,000	$46,000	$5,900	$850,000	$100,000	$13,000
Coke ovens	$470,000	$54,000	$11,000	$1,100,000	$120,000	$25,000
Electric arc furnaces	$450,000	$84,000	$10,000	$1,000,000	$190,000	$23,000
Electricity generating units	$140,000	$38,000	$5,600	$310,000	$86,000	$13,000
Ferroalloy facilities	$300,000	$47,000	$4,700	$680,000	$110,000	$11,000
Industrial point sources	$500,000	$91,000	$14,000	$1,100,000	$210,000	$32,000
Integrated iron and steel	$520,000	$420,000	$17,000	$1,200,000	$960,000	$39,000
Iron and steel facilities	$320,000	$46,000	$7,000	$730,000	$100,000	$16,000
Non-road mobile sources	$280,000	$43,000	$6,600	$630,000	$97,000	$15,000
Ocean-going vessels	$47,000	$12,000	$1,900	$110,000	$28,000	$4,200
On-road mobile sources	$380,000	$21,000	$7,800	$850,000	$47,000	$18,000
Pulp and paper facilities	$160,000	$48,000	$3,900	$360,000	$110,000	$8,900
Refineries	$330,000	$70,000	$6,900	$750,000	$160,000	$16,000
Residential wood combustion	$380,000	$100,000	$14,000	$860,000	$230,000	$31,000
Taconite mines	$89,000	$36,000	$6,500	$200,000	$81,000	$15,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 9. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2025 (2015$, 3% discount rate)[A]

	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
Sector	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$300,000	$110,000	$8,800	$680,000	$240,000	$20,000
Area sources	$410,000	$61,000	$9,700	$920,000	$140,000	$22,000
Cement kilns	$460,000	$55,000	$7,100	$1,000,000	$120,000	$16,000
Coke ovens	$550,000	$65,000	$13,000	$1,300,000	$150,000	$30,000
Electric arc furnaces	$540,000	$100,000	$12,000	$1,200,000	$230,000	$27,000
Electricity generating units	$170,000	$46,000	$6,700	$370,000	$100,000	$15,000
Ferroalloy facilities	$350,000	$56,000	$5,600	$800,000	$130,000	$13,000
Industrial point sources	$590,000	$110,000	$17,000	$1,300,000	$240,000	$38,000
Integrated iron and steel	$620,000	$500,000	$20,000	$1,400,000	$1,100,000	$46,000
Iron and steel facilities	$390,000	$57,000	$8,400	$880,000	$130,000	$19,000
Non-road mobile sources	$330,000	$51,000	$7,900	$760,000	$120,000	$18,000
Ocean-going vessels	$57,000	$15,000	$2,300	$130,000	$34,000	$5,200
On-road mobile sources	$460,000	$25,000	$9,400	$1,000,000	$57,000	$21,000
Pulp and paper facilities	$190,000	$58,000	$4,700	$440,000	$130,000	$11,000
Refineries	$400,000	$85,000	$8,400	$900,000	$190,000	$19,000
Residential wood combustion	$460,000	$130,000	$17,000	$1,000,000	$280,000	$38,000
Taconite mines	$110,000	$43,000	$7,700	$240,000	$97,000	$17,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 10. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2025 (2015$, 7% discount rate)[A]

Sector	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
	Directly emitted $PM_{2.5}$	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$270,000	$97,000	$8,000	$610,000	$220,000	$18,000
Area sources	$370,000	$55,000	$8,800	$830,000	$120,000	$20,000
Cement kilns	$410,000	$49,000	$6,400	$940,000	$110,000	$14,000
Coke ovens	$500,000	$58,000	$12,000	$1,100,000	$130,000	$27,000
Electric arc furnaces	$480,000	$90,000	$11,000	$1,100,000	$210,000	$25,000
Electricity generating units	$150,000	$41,000	$6,000	$340,000	$93,000	$14,000
Ferroalloy facilities	$320,000	$51,000	$5,100	$720,000	$120,000	$12,000
Industrial point sources	$540,000	$97,000	$15,000	$1,200,000	$220,000	$34,000
Integrated iron and steel	$560,000	$460,000	$18,000	$1,300,000	$1,000,000	$42,000
Iron and steel facilities	$350,000	$51,000	$7,600	$790,000	$120,000	$17,000
Non-road mobile sources	$300,000	$46,000	$7,100	$680,000	$100,000	$16,000
Ocean-going vessels	$51,000	$14,000	$2,100	$120,000	$30,000	$4,700
On-road mobile sources	$410,000	$23,000	$8,500	$930,000	$52,000	$19,000
Pulp and paper facilities	$170,000	$52,000	$4,200	$390,000	$120,000	$9,600
Refineries	$360,000	$76,000	$7,500	$810,000	$170,000	$17,000
Residential wood combustion	$420,000	$110,000	$15,000	$940,000	$260,000	$34,000
Taconite mines	$96,000	$38,000	$6,900	$220,000	$87,000	$16,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 11. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2030 (2015$, 3% discount rate)[A]

Sector	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
	Directly emitted $PM_{2.5}$	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$330,000	$120,000	$9,600	$740,000	$270,000	$22,000
Area sources	$450,000	$67,000	$11,000	$1,000,000	$150,000	$24,000
Cement kilns	$510,000	$60,000	$7,700	$1,100,000	$130,000	$17,000
Coke ovens	$590,000	$70,000	$14,000	$1,300,000	$160,000	$32,000
Electric arc furnaces	$580,000	$110,000	$13,000	$1,300,000	$250,000	$29,000
Electricity generating units	$180,000	$49,000	$7,200	$410,000	$110,000	$16,000
Ferroalloy facilities	$380,000	$61,000	$6,000	$850,000	$140,000	$14,000
Industrial point sources	$630,000	$120,000	$18,000	$1,400,000	$260,000	$41,000
Integrated iron and steel	$670,000	$540,000	$22,000	$1,500,000	$1,200,000	$50,000
Iron and steel facilities	$430,000	$63,000	$9,200	$970,000	$140,000	$21,000
Non-road mobile sources	$370,000	$56,000	$8,500	$830,000	$130,000	$19,000
Ocean-going vessels	$63,000	$17,000	$2,600	$140,000	$38,000	$5,800
On-road mobile sources	$500,000	$28,000	$10,000	$1,100,000	$64,000	$23,000
Pulp and paper facilities	$210,000	$63,000	$5,100	$470,000	$140,000	$12,000
Refineries	$430,000	$93,000	$9,100	$980,000	$210,000	$21,000
Residential wood combustion	$510,000	$140,000	$18,000	$1,100,000	$310,000	$41,000
Taconite mines	$120,000	$46,000	$8,300	$260,000	$100,000	$19,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Table 12. Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor reduced by each of 17 sectors in 2030 (2015$, 7% discount rate)[A]

	Krewski et al. (2009) mortality estimate[B]			Lepeule et al. (2012) mortality estimate[B]		
Sector	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***	***Directly emitted $PM_{2.5}$***	***SO_2***	***NO_x***
Aircraft, locomotives and marine vessels	$290,000	$110,000	$8,700	$660,000	$240,000	$20,000
Area sources	$400,000	$60,000	$9,500	$910,000	$140,000	$21,000
Cement kilns	$460,000	$54,000	$6,900	$1,000,000	$120,000	$16,000
Coke ovens	$530,000	$63,000	$13,000	$1,200,000	$140,000	$29,000
Electric arc furnaces	$520,000	$98,000	$12,000	$1,200,000	$220,000	$27,000
Electricity generating units	$160,000	$45,000	$6,500	$370,000	$100,000	$15,000
Ferroalloy facilities	$340,000	$55,000	$5,500	$770,000	$130,000	$12,000
Industrial point sources	$570,000	$100,000	$16,000	$1,300,000	$240,000	$37,000
Integrated iron and steel	$610,000	$490,000	$20,000	$1,400,000	$1,100,000	$45,000
Iron and steel facilities	$390,000	$57,000	$8,300	$870,000	$130,000	$19,000
Non-road mobile sources	$330,000	$50,000	$7,700	$750,000	$110,000	$17,000
Ocean-going vessels	$57,000	$15,000	$2,300	$130,000	$34,000	$5,200
On-road mobile sources	$450,000	$25,000	$9,200	$1,000,000	$57,000	$21,000
Pulp and paper facilities	$190,000	$57,000	$4,600	$430,000	$130,000	$10,000
Refineries	$390,000	$84,000	$8,200	$880,000	$190,000	$19,000
Residential wood combustion	$460,000	$120,000	$16,000	$1,000,000	$280,000	$37,000
Taconite mines	$100,000	$42,000	$7,500	$240,000	$94,000	$17,000

[A] These values represent a national average $/ton of total emissions for each sector; the $/ton for a given location (e.g. state or county) may be higher or lower than the value reported here. Estimates do not capture important differences in marginal $/ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant.

[B] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates rounded to two significant figures in this table, but all calculations are performed with the unrounded estimates.

Lowest Measured Air Quality Level Exposure Assessment

Assessments quantifying $PM_{2.5}$ related health impacts generally find that cases of avoided mortality represent the majority of the monetized benefits. For this reason, EPA has historically performed a series of analyses that characterize the uncertainty associated with the PM-mortality relationship and the economic value of reducing the risk of premature death (Mansfield and Henrion 2009; Roman et al. 2008; US EPA 2012). Here we focus on the level of uncertainty associated with the avoided premature deaths estimated to occur due to air quality improvements below the lowest levels of $PM_{2.5}$ observed in the epidemiological studies used to quantify such risks.

In general, we are more confident in the magnitude of the risks we estimate from simulated $PM_{2.5}$ concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated $PM_{2.5}$ concentrations that fall below the bulk of the observed data in these studies. Concentration benchmark analyses (e.g., lowest measured level [LML] or one standard deviation below the mean of the air quality data in the study) allow readers to determine the portion of population exposed to annual mean $PM_{2.5}$ levels at or above different concentrations, which provides some insight into the level of uncertainty in the estimated $PM_{2.5}$ mortality benefits. There are uncertainties inherent in identifying any particular point at which our confidence in reported associations becomes appreciably less, and the scientific evidence provides no clear dividing line. However, the EPA does not view these concentration benchmarks as a concentration threshold below which we would not quantify health benefits of air quality improvements.[4] Rather, the benefits estimates reported are the best available estimates because they reflect the full range of air quality concentrations associated with the emission reduction strategies and because the current body of scientific literature indicates that a no-threshold model provides the best estimate of PM-related long-term mortality. In other words, although we may have less confidence in the magnitude of the risk at concentrations below these benchmarks, we still have high confidence that $PM_{2.5}$ is causally associated with risk at those lower air quality concentrations.

For a benefit per ton analysis, policy-specific air quality data is not available due to time or resource limitations. For rules using benefit per ton estimates, we are unable to estimate the percentage of premature mortality associated with that rule's emission reductions at each $PM_{2.5}$ level. However, we believe that it is still important to characterize

4 For a summary of the scientific review statements regarding the lack of a threshold in the $PM_{2.5}$-mortality relationship, see the Technical Support Document (TSD) entitled *Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for $PM_{2.5}$-related Mortality* (US EPA 2010d).

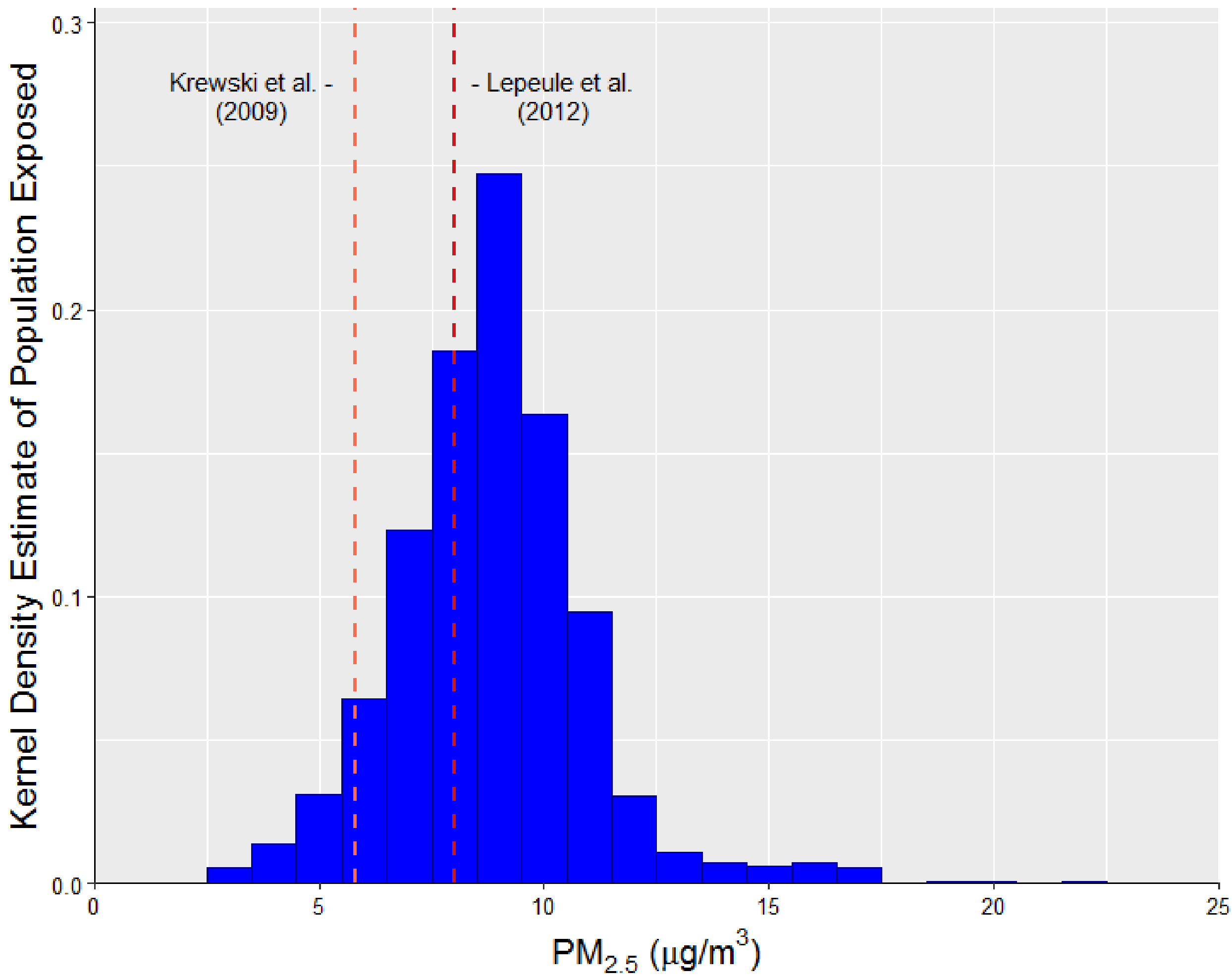
the distribution of exposure to baseline air quality levels as a representation of the starting point for any marginal reductions in air pollution as a result of sector specific emissions reductions. As a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each $PM_{2.5}$ level in the baseline of the source apportionment modeling used to calculate the benefit-per-ton estimates for this sector. It is important to note that baseline exposure is only one parameter in the health impact function, along with baseline incidence rates population, and change in air quality. In other words, the percentage of the population exposed to air pollution below the LML is not the same as the percentage of the population experiencing health impacts as a result of a specific emission reduction policy. The most important aspect, which we are unable to quantify for rules without rule-specific air quality modeling, is the shift in exposure associated with a specific rule. Therefore, caution is warranted when interpreting the LML assessment for any particular sector rule because these results are not consistent with results from rules that had air quality modeling.

Table 13 provides the percentage of the population exposed above and below two concentration benchmarks (i.e., LML and 1 standard deviation below the mean) in the modeled baseline. Figure 3 shows a bar chart of the percentage of the population exposed to various air quality levels in the baseline, and Figure 4 shows a cumulative distribution function of the same data. Both figures identify the LML for each of the major cohort studies.

Table 13. Population Exposure in the Baseline Above and Below Various Concentration Benchmarks in the Underlying Epidemiology Studies[a]

Epidemiology Study	Below 1 Std. Dev. Below AQ Mean	At or Above 1 Std. Dev. Below AQ Mean	Below LML	At or Above LML
Krewski et al. (2009)	**89%**	**11%**	**7%**	**93%**
Lepeule et al. (2012)	**N/A**	**N/A**	**23%**	**67%**

[a] One standard deviation below the mean is equivalent to the middle of the range between the 10th and 25th percentile. For Krewski, the LML is 5.8 µg/ m³ and one standard deviation below the mean is 11.0 µg/m³. For Lepeule et al., the LML is 8 µg/ m³ and we do not have the data for one standard deviation below the mean. It is important to emphasize that although we have lower levels of confidence in levels below the LML for each study, the scientific evidence does not support the existence of a level below which health effects from e xposure to $PM_{2.5}$ do not occur.

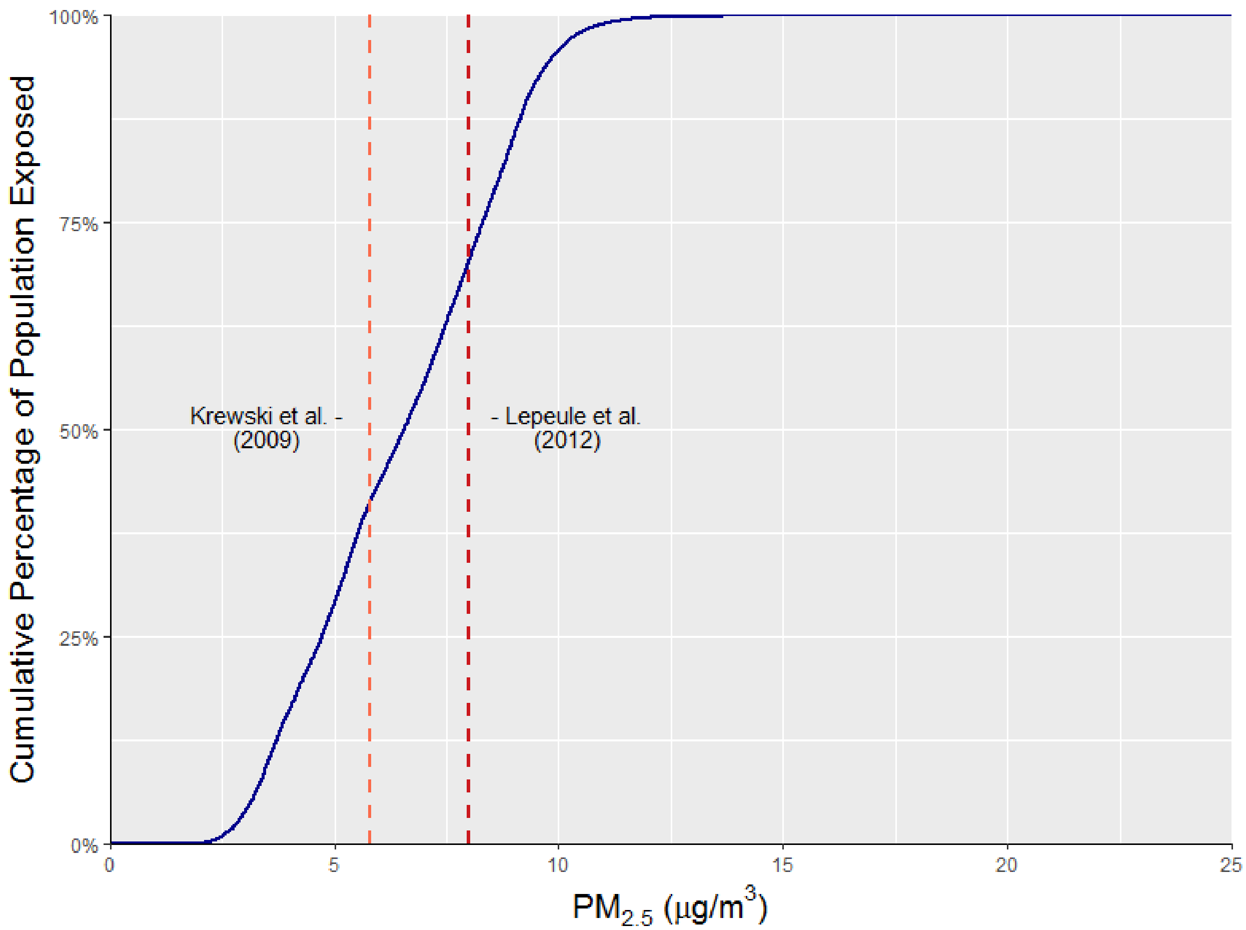


Among the populations exposed to $PM_{2.5}$ in the baseline:

93% are exposed to $PM_{2.5}$ levels at or above the LML of the Krewski et al. (2009) study

67% are exposed to $PM_{2.5}$ levels at or above the LML of the Lepeule et al. (2012) study

Figure 3. Percentage of Adult Population by Annual Mean $PM_{2.5}$ Exposure in the Baseline



Among the populations exposed to $PM_{2.5}$ in the baseline:

93% are exposed to $PM_{2.5}$ levels at or above the LML of the Krewski et al. (2009) study

67% are exposed to $PM_{2.5}$ levels at or above the LML of the Lepeule et al. (2012) study

Figure 4. Cumulative Distribution of Adult Population by Annual Mean $PM_{2.5}$ Exposure in the Baseline

Limitations and Uncertainties

This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, health effect estimates from epidemiology studies, and economic data for monetizing benefits. Each of these inputs may be uncertain and would affect the benefits estimate. When the uncertainties from each stage of the analysis are compounded, small uncertainties can have large effects on the total quantified benefits. This analysis does not include the type of detailed uncertainty assessment found in the PM NAAQS RIA (EPA 2014; US EPA 2012). However, the results of the Monte Carlo analyses of the health and welfare benefits presented in the PM RIAs can provide some evidence of the uncertainty surrounding the benefits results presented in this analysis.

In this analysis we assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from EGUs may differ significantly from direct $PM_{2.5}$ released from other industrial sources. However, the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. We also assume that the health impact function for fine particles is linear down to the lowest air quality levels modeled in this analysis. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including regions that are in attainment with fine particle standard.

It is also important to note that the monetized benefit per ton estimates used here reflect specific geographic patterns of emissions and specific air quality and benefits modeling assumptions. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these are all based on national emission reduction assumptions and therefore represent an average benefit per ton over the entire United States. The benefit per ton for emission reductions in specific locations may be very different from the estimates presented here. In addition, estimates do not capture important differences in marginal benefit per ton that may exist due to different combinations of reductions (i.e., all other sectors are held constant) or nonlinearities within a particular pollutant (e.g., non-zero second derivatives with respect to emissions). The maps in Appendix B provide an indication of the location of the facilities that were modeled as well as the associated $PM_{2.5}$ levels.

When using these benefit per ton estimates in analyses, care should be taken to not overstate the accuracy of the total benefits estimates or estimates of avoided incidence. For this reason, it is EPA practice to round total benefits estimates to two significant digits and to round estimates of avoided incidence to the nearest whole number.

Appendix A: Detailed Results for Each Sector

2016 Analysis Year

Table 1: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the cement kilns sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,300	$48,000	$390,000
Lepeule et al. (2012)	$14,000	$110,000	$890,000
		7% Discount Rate	
Krewski et al. (2009)	$5,700	$43,000	$350,000
Lepeule et al. (2012)	$13,000	$99,000	$810,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 2: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the cement kilns sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000680	0.005200	0.042000
Lepeule et al. (2012)	0.001500	0.012000	0.097000
Morbidity			
Respiratory emergency room visits	0.000370	0.002800	0.023000
Acute bronchitis	0.000960	0.006700	0.063000
Lower respiratory symptoms	0.012000	0.086000	0.810000
Upper respiratory symptoms	0.017000	0.120000	1.200000
Minor Restricted Activity Days	0.510000	3.700000	33.000000
Work loss days	0.086000	0.610000	5.500000
Asthma exacerbation	0.020000	0.140000	1.400000
Cardiovascular hospital admissions	0.000160	0.001200	0.009900
Respiratory hospital admissions	0.000150	0.001200	0.009000
Non-fatal heart attacks (Peters)	0.000630	0.004900	0.041000
Non-fatal heart attacks (All others)	0.000068	0.000530	0.004400

Table 3: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the pulp and paper facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$4,200	$50,000	$170,000
Lepeule et al. (2012)	$9,500	$120,000	$380,000
		7% Discount Rate	
Krewski et al. (2009)	$3,800	$46,000	$150,000
Lepeule et al. (2012)	$8,600	$100,000	$350,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 4: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the pulp and paper facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000450	0.005500	0.018000
Lepeule et al. (2012)	0.001000	0.013000	0.042000
Morbidity			
Respiratory emergency room visits	0.000230	0.002700	0.008300
Acute bronchitis	0.000580	0.006800	0.023000
Lower respiratory symptoms	0.007400	0.087000	0.290000
Upper respiratory symptoms	0.011000	0.120000	0.410000
Minor Restricted Activity Days	0.320000	3.700000	12.000000
Work loss days	0.053000	0.620000	2.000000
Asthma exacerbation	0.012000	0.150000	0.480000
Cardiovascular hospital admissions	0.000100	0.001300	0.004400
Respiratory hospital admissions	0.000095	0.001200	0.004100
Non-fatal heart attacks (Peters)	0.000410	0.005300	0.018000
Non-fatal heart attacks (All others)	0.000044	0.000570	0.001900

Table 5: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the refineries sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,300	$73,000	$350,000
Lepeule et al. (2012)	$17,000	$170,000	$790,000
		7% Discount Rate	
Krewski et al. (2009)	$6,600	$66,000	$310,000
Lepeule et al. (2012)	$15,000	$150,000	$710,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 6: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the refineries sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000790	0.007900	0.037000
Lepeule et al. (2012)	0.001800	0.018000	0.085000
Morbidity			
Respiratory emergency room visits	0.000420	0.004400	0.022000
Acute bronchitis	0.001200	0.012000	0.058000
Lower respiratory symptoms	0.016000	0.160000	0.730000
Upper respiratory symptoms	0.022000	0.220000	1.000000
Minor Restricted Activity Days	0.660000	6.600000	31.000000
Work loss days	0.110000	1.100000	5.200000
Asthma exacerbation	0.026000	0.260000	1.200000
Cardiovascular hospital admissions	0.000190	0.001900	0.008800
Respiratory hospital admissions	0.000180	0.001800	0.008200
Non-fatal heart attacks (Peters)	0.000750	0.007600	0.035000
Non-fatal heart attacks (All others)	0.000080	0.000820	0.003800

Table 7: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the coke ovens sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$12,000	$58,000	$510,000
Lepeule et al. (2012)	$27,000	$130,000	$1,200,000
		7% Discount Rate	
Krewski et al. (2009)	$11,000	$52,000	$460,000
Lepeule et al. (2012)	$25,000	$120,000	$1,000,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 8: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the coke ovens sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001300	0.006300	0.055000
Lepeule et al. (2012)	0.003000	0.014000	0.130000
Morbidity			
Respiratory emergency room visits	0.000680	0.003000	0.025000
Acute bronchitis	0.001600	0.007600	0.063000
Lower respiratory symptoms	0.020000	0.097000	0.800000
Upper respiratory symptoms	0.029000	0.140000	1.100000
Minor Restricted Activity Days	0.880000	4.200000	35.000000
Work loss days	0.150000	0.700000	5.800000
Asthma exacerbation	0.034000	0.160000	1.300000
Cardiovascular hospital admissions	0.000300	0.001500	0.013000
Respiratory hospital admissions	0.000280	0.001400	0.012000
Non-fatal heart attacks (Peters)	0.001200	0.006100	0.051000
Non-fatal heart attacks (All others)	0.000130	0.000660	0.005500

Table 9: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the iron and steel facilities sector (2015$)

Mortality risk estimate[A]	Pollutant emitted: *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$18,000	$450,000	$560,000
Lepeule et al. (2012)	$41,000	$1,000,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$16,000	$410,000	$500,000
Lepeule et al. (2012)	$37,000	$930,000	$1,100,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 10: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the iron and steel facilities sector

Health Endpoint	Pollutant emitted: *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001900	0.049000	0.060000
Lepeule et al. (2012)	0.004400	0.110000	0.140000
Morbidity			
Respiratory emergency room visits	0.001100	0.024000	0.029000
Acute bronchitis	0.003000	0.063000	0.082000
Lower respiratory symptoms	0.038000	0.800000	1.000000
Upper respiratory symptoms	0.054000	1.100000	1.500000
Minor Restricted Activity Days	1.600000	35.000000	45.000000
Work loss days	0.270000	5.900000	7.500000
Asthma exacerbation	0.064000	1.300000	1.800000
Cardiovascular hospital admissions	0.000470	0.011000	0.014000
Respiratory hospital admissions	0.000440	0.011000	0.014000
Non-fatal heart attacks (Peters)	0.001900	0.047000	0.059000
Non-fatal heart attacks (All others)	0.000200	0.005000	0.006400

Table 11: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the integrated iron and steel facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$15,000	$97,000	$540,000
Lepeule et al. (2012)	$35,000	$220,000	$1,200,000
		7% Discount Rate	
Krewski et al. (2009)	$14,000	$88,000	$490,000
Lepeule et al. (2012)	$31,000	$200,000	$1,100,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 12: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the integrated iron and steel facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001600	0.011000	0.059000
Lepeule et al. (2012)	0.003800	0.024000	0.130000
Morbidity			
Respiratory emergency room visits	0.000830	0.005500	0.028000
Acute bronchitis	0.002100	0.013000	0.072000
Lower respiratory symptoms	0.026000	0.170000	0.910000
Upper respiratory symptoms	0.038000	0.240000	1.300000
Minor Restricted Activity Days	1.100000	7.200000	39.000000
Work loss days	0.190000	1.200000	6.500000
Asthma exacerbation	0.044000	0.280000	1.500000
Cardiovascular hospital admissions	0.000380	0.002500	0.014000
Respiratory hospital admissions	0.000360	0.002500	0.013000
Non-fatal heart attacks (Peters)	0.001500	0.010000	0.056000
Non-fatal heart attacks (All others)	0.000160	0.001100	0.006000

Table 13: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the electric arc furnaces sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$11,000	$89,000	$480,000
Lepeule et al. (2012)	$25,000	$200,000	$1,100,000
		7% Discount Rate	
Krewski et al. (2009)	$9,800	$81,000	$440,000
Lepeule et al. (2012)	$22,000	$180,000	$990,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 14: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the electric arc furnaces sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001200	0.009700	0.052000
Lepeule et al. (2012)	0.002700	0.022000	0.120000
Morbidity			
Respiratory emergency room visits	0.000640	0.004700	0.026000
Acute bronchitis	0.001500	0.012000	0.063000
Lower respiratory symptoms	0.019000	0.150000	0.800000
Upper respiratory symptoms	0.028000	0.210000	1.100000
Minor Restricted Activity Days	0.820000	6.400000	34.000000
Work loss days	0.140000	1.100000	5.700000
Asthma exacerbation	0.033000	0.250000	1.300000
Cardiovascular hospital admissions	0.000270	0.002300	0.013000
Respiratory hospital admissions	0.000260	0.002300	0.012000
Non-fatal heart attacks (Peters)	0.001100	0.009800	0.054000
Non-fatal heart attacks (All others)	0.000120	0.001100	0.005900

Table 15: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the taconite mines sector (2015$)

Mortality risk estimate[A]	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,900	$38,000	$95,000
Lepeule et al. (2012)	$16,000	$87,000	$220,000
		7% Discount Rate	
Krewski et al. (2009)	$6,300	$34,000	$86,000
Lepeule et al. (2012)	$14,000	$78,000	$200,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 16: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the taconite mines sector

Health Endpoint	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000750	0.004100	0.010000
Lepeule et al. (2012)	0.001700	0.009400	0.024000
Morbidity			
Respiratory emergency room visits	0.000350	0.001900	0.004300
Acute bronchitis	0.000960	0.005100	0.012000
Lower respiratory symptoms	0.012000	0.065000	0.160000
Upper respiratory symptoms	0.017000	0.093000	0.220000
Minor Restricted Activity Days	0.530000	2.800000	6.700000
Work loss days	0.088000	0.470000	1.100000
Asthma exacerbation	0.020000	0.110000	0.260000
Cardiovascular hospital admissions	0.000160	0.000920	0.002200
Respiratory hospital admissions	0.000150	0.000880	0.002100
Non-fatal heart attacks (Peters)	0.000670	0.003800	0.009600
Non-fatal heart attacks (All others)	0.000072	0.000410	0.001000

Table 17: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the ferroalloy facilities sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$5,100	$50,000	$320,000
Lepeule et al. (2012)	$12,000	$110,000	$720,000
		7% Discount Rate	
Krewski et al. (2009)	$4,600	$45,000	$290,000
Lepeule et al. (2012)	$10,000	$100,000	$650,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 18: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the ferroalloy facilities sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000550	0.005400	0.034000
Lepeule et al. (2012)	0.001300	0.012000	0.079000
Morbidity			
Respiratory emergency room visits	0.000230	0.002400	0.016000
Acute bronchitis	0.000600	0.006300	0.040000
Lower respiratory symptoms	0.007700	0.081000	0.510000
Upper respiratory symptoms	0.011000	0.120000	0.730000
Minor Restricted Activity Days	0.340000	3.500000	22.000000
Work loss days	0.057000	0.580000	3.700000
Asthma exacerbation	0.013000	0.140000	0.860000
Cardiovascular hospital admissions	0.000120	0.001300	0.008100
Respiratory hospital admissions	0.000110	0.001300	0.007900
Non-fatal heart attacks (Peters)	0.000500	0.005500	0.035000
Non-fatal heart attacks (All others)	0.000054	0.000590	0.003800

Table 19: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the residential wood combustion sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$15,000	$110,000	$400,000
Lepeule et al. (2012)	$33,000	$250,000	$900,000
		7% Discount Rate	
Krewski et al. (2009)	$13,000	$98,000	$360,000
Lepeule et al. (2012)	$30,000	$220,000	$810,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 20: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the residential wood combustion sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001600	0.012000	0.043000
Lepeule et al. (2012)	0.003600	0.027000	0.098000
Morbidity			
Respiratory emergency room visits	0.000850	0.006000	0.022000
Acute bronchitis	0.002300	0.016000	0.061000
Lower respiratory symptoms	0.029000	0.210000	0.770000
Upper respiratory symptoms	0.042000	0.300000	1.100000
Minor Restricted Activity Days	1.200000	9.200000	34.000000
Work loss days	0.210000	1.500000	5.700000
Asthma exacerbation	0.049000	0.350000	1.300000
Cardiovascular hospital admissions	0.000350	0.002600	0.009600
Respiratory hospital admissions	0.000330	0.002400	0.008900
Non-fatal heart attacks (Peters)	0.001400	0.011000	0.039000
Non-fatal heart attacks (All others)	0.000160	0.001100	0.004300

Table 21: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the area sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,600	$54,000	$350,000
Lepeule et al. (2012)	$19,000	$120,000	$800,000
		7% Discount Rate	
Krewski et al. (2009)	$7,700	$48,000	$320,000
Lepeule et al. (2012)	$18,000	$110,000	$720,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 22: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the area sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000930	0.005800	0.038000
Lepeule et al. (2012)	0.002100	0.013000	0.087000
Morbidity			
Respiratory emergency room visits	0.000520	0.003400	0.022000
Acute bronchitis	0.001400	0.007900	0.054000
Lower respiratory symptoms	0.017000	0.100000	0.690000
Upper respiratory symptoms	0.025000	0.150000	0.990000
Minor Restricted Activity Days	0.720000	4.400000	30.000000
Work loss days	0.120000	0.740000	5.100000
Asthma exacerbation	0.029000	0.170000	1.200000
Cardiovascular hospital admissions	0.000210	0.001400	0.009100
Respiratory hospital admissions	0.000200	0.001300	0.008600
Non-fatal heart attacks (Peters)	0.000860	0.005500	0.036000
Non-fatal heart attacks (All others)	0.000092	0.000600	0.003900

Table 23: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the industrial point sources sector (2015$)

Mortality risk estimate[A]	Pollutant emitted: *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,000	$45,000	$290,000
Lepeule et al. (2012)	$16,000	$100,000	$660,000
		7% Discount Rate	
Krewski et al. (2009)	$6,300	$41,000	$260,000
Lepeule et al. (2012)	$14,000	$93,000	$600,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 24: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the industrial point sources sector

Health Endpoint	Pollutant emitted: *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000760	0.004900	0.031000
Lepeule et al. (2012)	0.001700	0.011000	0.072000
Morbidity			
Respiratory emergency room visits	0.000400	0.002600	0.017000
Acute bronchitis	0.001100	0.006400	0.044000
Lower respiratory symptoms	0.014000	0.082000	0.560000
Upper respiratory symptoms	0.020000	0.120000	0.800000
Minor Restricted Activity Days	0.570000	3.500000	24.000000
Work loss days	0.096000	0.580000	4.000000
Asthma exacerbation	0.023000	0.140000	0.940000
Cardiovascular hospital admissions	0.000170	0.001200	0.007600
Respiratory hospital admissions	0.000170	0.001100	0.007200
Non-fatal heart attacks (Peters)	0.000710	0.004700	0.031000
Non-fatal heart attacks (All others)	0.000076	0.000510	0.003300

Table 25: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the aircraft, locomotives and marine vessels sector (2015$)

Mortality risk estimate[A]	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,800	$89,000	$260,000
Lepeule et al. (2012)	$18,000	$200,000	$590,000
		7% Discount Rate	
Krewski et al. (2009)	$7,000	$80,000	$240,000
Lepeule et al. (2012)	$16,000	$180,000	$540,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 26: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the aircraft, locomotives and marine vessels sector

Health Endpoint	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000840	0.009600	0.028000
Lepeule et al. (2012)	0.001900	0.022000	0.064000
Morbidity			
Respiratory emergency room visits	0.000430	0.005200	0.016000
Acute bronchitis	0.001200	0.017000	0.040000
Lower respiratory symptoms	0.016000	0.220000	0.520000
Upper respiratory symptoms	0.022000	0.310000	0.740000
Minor Restricted Activity Days	0.660000	9.600000	23.000000
Work loss days	0.110000	1.600000	3.900000
Asthma exacerbation	0.026000	0.370000	0.870000
Cardiovascular hospital admissions	0.000200	0.002500	0.006800
Respiratory hospital admissions	0.000190	0.002200	0.006400
Non-fatal heart attacks (Peters)	0.000800	0.009500	0.027000
Non-fatal heart attacks (All others)	0.000086	0.001000	0.002900

Table 27: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the non-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,400	$47,000	$340,000
Lepeule et al. (2012)	$17,000	$110,000	$760,000
		7% Discount Rate	
Krewski et al. (2009)	$6,700	$43,000	$300,000
Lepeule et al. (2012)	$15,000	$97,000	$690,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 28: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the non-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000800	0.005100	0.036000
Lepeule et al. (2012)	0.001800	0.012000	0.083000
Morbidity			
Respiratory emergency room visits	0.000440	0.002800	0.022000
Acute bronchitis	0.001200	0.008700	0.053000
Lower respiratory symptoms	0.016000	0.110000	0.680000
Upper respiratory symptoms	0.022000	0.160000	0.970000
Minor Restricted Activity Days	0.650000	4.300000	30.000000
Work loss days	0.110000	0.730000	5.000000
Asthma exacerbation	0.026000	0.180000	1.100000
Cardiovascular hospital admissions	0.000190	0.001100	0.008900
Respiratory hospital admissions	0.000180	0.001000	0.008300
Non-fatal heart attacks (Peters)	0.000760	0.004500	0.035000
Non-fatal heart attacks (All others)	0.000082	0.000490	0.003800

Table 29: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the on-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,300	$21,000	$400,000
Lepeule et al. (2012)	$19,000	$48,000	$900,000
		7% Discount Rate	
Krewski et al. (2009)	$7,500	$19,000	$360,000
Lepeule et al. (2012)	$17,000	$43,000	$810,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 30: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the on-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000890	0.002300	0.043000
Lepeule et al. (2012)	0.002000	0.005200	0.097000
Morbidity			
Respiratory emergency room visits	0.000490	0.001200	0.025000
Acute bronchitis	0.001300	0.003800	0.064000
Lower respiratory symptoms	0.016000	0.048000	0.810000
Upper respiratory symptoms	0.024000	0.069000	1.200000
Minor Restricted Activity Days	0.690000	1.900000	35.000000
Work loss days	0.120000	0.330000	5.900000
Asthma exacerbation	0.028000	0.081000	1.400000
Cardiovascular hospital admissions	0.000210	0.000500	0.010000
Respiratory hospital admissions	0.000200	0.000480	0.009800
Non-fatal heart attacks (Peters)	0.000840	0.002000	0.041000
Non-fatal heart attacks (All others)	0.000091	0.000220	0.004500

Table 31: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the electricity generating units sector (2015$)

Mortality risk estimate[A]	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,000	$40,000	$140,000
Lepeule et al. (2012)	$14,000	$92,000	$330,000
		7% Discount Rate	
Krewski et al. (2009)	$5,400	$36,000	$130,000
Lepeule et al. (2012)	$12,000	$83,000	$300,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 32: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the electricity generating units sector

Health Endpoint	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000650	0.004400	0.016000
Lepeule et al. (2012)	0.001500	0.010000	0.036000
Morbidity			
Respiratory emergency room visits	0.000320	0.002200	0.008800
Acute bronchitis	0.000850	0.005400	0.021000
Lower respiratory symptoms	0.011000	0.070000	0.270000
Upper respiratory symptoms	0.016000	0.100000	0.390000
Minor Restricted Activity Days	0.450000	3.000000	12.000000
Work loss days	0.076000	0.500000	1.900000
Asthma exacerbation	0.018000	0.120000	0.450000
Cardiovascular hospital admissions	0.000150	0.001000	0.003700
Respiratory hospital admissions	0.000140	0.001000	0.003500
Non-fatal heart attacks (Peters)	0.000600	0.004200	0.015000
Non-fatal heart attacks (All others)	0.000064	0.000460	0.001600

Table 33: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the ocean-going vessels sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
	3% Discount Rate		
Krewski et al. (2009)	$2,000	$13,000	$48,000
Lepeule et al. (2012)	$4,400	$29,000	$110,000
	7% Discount Rate		
Krewski et al. (2009)	$1,800	$11,000	$44,000
Lepeule et al. (2012)	$4,000	$26,000	$99,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 34: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2016 from the ocean-going vessels sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000210	0.001400	0.005200
Lepeule et al. (2012)	0.000480	0.003100	0.012000
Morbidity			
Respiratory emergency room visits	0.000130	0.000760	0.002900
Acute bronchitis	0.000360	0.001900	0.007500
Lower respiratory symptoms	0.004600	0.024000	0.095000
Upper respiratory symptoms	0.006600	0.034000	0.140000
Minor Restricted Activity Days	0.200000	1.100000	4.300000
Work loss days	0.034000	0.180000	0.720000
Asthma exacerbation	0.007800	0.040000	0.160000
Cardiovascular hospital admissions	0.000054	0.000340	0.001300
Respiratory hospital admissions	0.000050	0.000320	0.001200
Non-fatal heart attacks (Peters)	0.000210	0.001300	0.005000
Non-fatal heart attacks (All others)	0.000023	0.000140	0.000540

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Table 35: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the cement kilns sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,500	$50,000	$420,000
Lepeule et al. (2012)	$15,000	$110,000	$950,000
		7% Discount Rate	
Krewski et al. (2009)	$5,900	$46,000	$380,000
Lepeule et al. (2012)	$13,000	$100,000	$850,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 36: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the cement kilns sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000700	0.005400	0.044000
Lepeule et al. (2012)	0.001600	0.012000	0.100000
Morbidity			
Respiratory emergency room visits	0.000380	0.002800	0.023000
Acute bronchitis	0.000960	0.006800	0.064000
Lower respiratory symptoms	0.012000	0.086000	0.810000
Upper respiratory symptoms	0.017000	0.120000	1.200000
Minor Restricted Activity Days	0.520000	3.700000	34.000000
Work loss days	0.088000	0.620000	5.700000
Asthma exacerbation	0.020000	0.140000	1.400000
Cardiovascular hospital admissions	0.000170	0.001300	0.011000
Respiratory hospital admissions	0.000160	0.001300	0.009900
Non-fatal heart attacks (Peters)	0.000670	0.005300	0.044000
Non-fatal heart attacks (All others)	0.000072	0.000570	0.004800

Table 37: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the pulp and paper facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$4,400	$53,000	$180,000
Lepeule et al. (2012)	$9,900	$120,000	$400,000
		7% Discount Rate	
Krewski et al. (2009)	$3,900	$48,000	$160,000
Lepeule et al. (2012)	$8,900	$110,000	$360,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 38: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the pulp and paper facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000460	0.005700	0.019000
Lepeule et al. (2012)	0.001100	0.013000	0.043000
Morbidity			
Respiratory emergency room visits	0.000240	0.002800	0.008600
Acute bronchitis	0.000580	0.006900	0.023000
Lower respiratory symptoms	0.007400	0.088000	0.290000
Upper respiratory symptoms	0.011000	0.130000	0.420000
Minor Restricted Activity Days	0.320000	3.800000	12.000000
Work loss days	0.054000	0.640000	2.100000
Asthma exacerbation	0.012000	0.150000	0.480000
Cardiovascular hospital admissions	0.000110	0.001400	0.004700
Respiratory hospital admissions	0.000100	0.001400	0.004500
Non-fatal heart attacks (Peters)	0.000440	0.005700	0.019000
Non-fatal heart attacks (All others)	0.000047	0.000620	0.002100

Table 39: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the refineries sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,700	$77,000	$360,000
Lepeule et al. (2012)	$17,000	$180,000	$830,000
		7% Discount Rate	
Krewski et al. (2009)	$6,900	$70,000	$330,000
Lepeule et al. (2012)	$16,000	$160,000	$750,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 40: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the refineries sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000820	0.008200	0.039000
Lepeule et al. (2012)	0.001900	0.019000	0.088000
Morbidity			
Respiratory emergency room visits	0.000440	0.004500	0.022000
Acute bronchitis	0.001200	0.012000	0.059000
Lower respiratory symptoms	0.016000	0.160000	0.750000
Upper respiratory symptoms	0.023000	0.220000	1.100000
Minor Restricted Activity Days	0.660000	6.700000	31.000000
Work loss days	0.110000	1.100000	5.300000
Asthma exacerbation	0.026000	0.260000	1.200000
Cardiovascular hospital admissions	0.000200	0.002100	0.009500
Respiratory hospital admissions	0.000190	0.002000	0.008900
Non-fatal heart attacks (Peters)	0.000800	0.008200	0.038000
Non-fatal heart attacks (All others)	0.000087	0.000890	0.004100

Table 41: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the coke ovens sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$12,000	$60,000	$520,000
Lepeule et al. (2012)	$28,000	$140,000	$1,200,000
		7% Discount Rate	
Krewski et al. (2009)	$11,000	$54,000	$470,000
Lepeule et al. (2012)	$25,000	$120,000	$1,100,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 42: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the coke ovens sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001300	0.006400	0.056000
Lepeule et al. (2012)	0.003000	0.015000	0.130000
Morbidity			
Respiratory emergency room visits	0.000690	0.003100	0.025000
Acute bronchitis	0.001600	0.007600	0.062000
Lower respiratory symptoms	0.020000	0.096000	0.800000
Upper respiratory symptoms	0.028000	0.140000	1.100000
Minor Restricted Activity Days	0.870000	4.200000	34.000000
Work loss days	0.150000	0.700000	5.800000
Asthma exacerbation	0.033000	0.160000	1.300000
Cardiovascular hospital admissions	0.000310	0.001600	0.013000
Respiratory hospital admissions	0.000300	0.001600	0.013000
Non-fatal heart attacks (Peters)	0.001200	0.006500	0.054000
Non-fatal heart attacks (All others)	0.000130	0.000700	0.005800

Table 43: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the iron and steel facilities sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$19,000	$470,000	$580,000
Lepeule et al. (2012)	$43,000	$1,100,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$17,000	$420,000	$520,000
Lepeule et al. (2012)	$39,000	$960,000	$1,200,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 44: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the iron and steel facilities sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.002000	0.050000	0.062000
Lepeule et al. (2012)	0.004600	0.110000	0.140000
Morbidity			
Respiratory emergency room visits	0.001100	0.024000	0.030000
Acute bronchitis	0.003000	0.063000	0.082000
Lower respiratory symptoms	0.038000	0.800000	1.000000
Upper respiratory symptoms	0.055000	1.100000	1.500000
Minor Restricted Activity Days	1.600000	35.000000	45.000000
Work loss days	0.270000	5.900000	7.600000
Asthma exacerbation	0.064000	1.300000	1.800000
Cardiovascular hospital admissions	0.000510	0.012000	0.015000
Respiratory hospital admissions	0.000480	0.012000	0.015000
Non-fatal heart attacks (Peters)	0.002000	0.050000	0.063000
Non-fatal heart attacks (All others)	0.000220	0.005400	0.006800

Table 45: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the integrated iron and steel facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$16,000	$100,000	$560,000
Lepeule et al. (2012)	$36,000	$230,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$14,000	$91,000	$500,000
Lepeule et al. (2012)	$32,000	$210,000	$1,100,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 46: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the integrated iron and steel facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001700	0.011000	0.059000
Lepeule et al. (2012)	0.003800	0.024000	0.140000
Morbidity			
Respiratory emergency room visits	0.000840	0.005600	0.029000
Acute bronchitis	0.002100	0.013000	0.071000
Lower respiratory symptoms	0.026000	0.170000	0.900000
Upper respiratory symptoms	0.037000	0.240000	1.300000
Minor Restricted Activity Days	1.100000	7.100000	38.000000
Work loss days	0.190000	1.200000	6.500000
Asthma exacerbation	0.044000	0.280000	1.500000
Cardiovascular hospital admissions	0.000400	0.002700	0.015000
Respiratory hospital admissions	0.000390	0.002600	0.014000
Non-fatal heart attacks (Peters)	0.001600	0.011000	0.059000
Non-fatal heart attacks (All others)	0.000170	0.001200	0.006300

Table 47: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the electric arc furnaces sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$11,000	$93,000	$500,000
Lepeule et al. (2012)	$26,000	$210,000	$1,100,000
		7% Discount Rate	
Krewski et al. (2009)	$10,000	$84,000	$450,000
Lepeule et al. (2012)	$23,000	$190,000	$1,000,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 48: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the electric arc furnaces sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001200	0.009900	0.053000
Lepeule et al. (2012)	0.002700	0.023000	0.120000
Morbidity			
Respiratory emergency room visits	0.000650	0.004800	0.026000
Acute bronchitis	0.001500	0.012000	0.063000
Lower respiratory symptoms	0.019000	0.150000	0.800000
Upper respiratory symptoms	0.028000	0.210000	1.100000
Minor Restricted Activity Days	0.830000	6.500000	34.000000
Work loss days	0.140000	1.100000	5.800000
Asthma exacerbation	0.032000	0.250000	1.300000
Cardiovascular hospital admissions	0.000290	0.002500	0.013000
Respiratory hospital admissions	0.000280	0.002400	0.013000
Non-fatal heart attacks (Peters)	0.001200	0.010000	0.057000
Non-fatal heart attacks (All others)	0.000120	0.001100	0.006200

Table 49: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the taconite mines sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,200	$40,000	$99,000
Lepeule et al. (2012)	$16,000	$90,000	$230,000
		7% Discount Rate	
Krewski et al. (2009)	$6,500	$36,000	$89,000
Lepeule et al. (2012)	$15,000	$81,000	$200,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 50: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the taconite mines sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000770	0.004200	0.011000
Lepeule et al. (2012)	0.001800	0.009600	0.024000
Morbidity			
Respiratory emergency room visits	0.000360	0.002000	0.004400
Acute bronchitis	0.000950	0.005100	0.012000
Lower respiratory symptoms	0.012000	0.065000	0.160000
Upper respiratory symptoms	0.017000	0.092000	0.220000
Minor Restricted Activity Days	0.520000	2.800000	6.700000
Work loss days	0.088000	0.470000	1.100000
Asthma exacerbation	0.020000	0.110000	0.260000
Cardiovascular hospital admissions	0.000170	0.000990	0.002400
Respiratory hospital admissions	0.000160	0.000950	0.002300
Non-fatal heart attacks (Peters)	0.000710	0.004100	0.010000
Non-fatal heart attacks (All others)	0.000076	0.000440	0.001100

Table 51: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the ferroalloy facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$5,200	$52,000	$330,000
Lepeule et al. (2012)	$12,000	$120,000	$750,000
		7% Discount Rate	
Krewski et al. (2009)	$4,700	$47,000	$300,000
Lepeule et al. (2012)	$11,000	$110,000	$680,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 52: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the ferroalloy facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000560	0.005600	0.035000
Lepeule et al. (2012)	0.001300	0.013000	0.080000
Morbidity			
Respiratory emergency room visits	0.000230	0.002500	0.016000
Acute bronchitis	0.000600	0.006400	0.040000
Lower respiratory symptoms	0.007700	0.081000	0.510000
Upper respiratory symptoms	0.011000	0.120000	0.730000
Minor Restricted Activity Days	0.340000	3.500000	22.000000
Work loss days	0.058000	0.590000	3.700000
Asthma exacerbation	0.013000	0.140000	0.860000
Cardiovascular hospital admissions	0.000130	0.001400	0.008600
Respiratory hospital admissions	0.000120	0.001400	0.008500
Non-fatal heart attacks (Peters)	0.000530	0.005900	0.037000
Non-fatal heart attacks (All others)	0.000058	0.000630	0.004000

Table 53: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the residential wood combustion sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$15,000	$110,000	$420,000
Lepeule et al. (2012)	$35,000	$260,000	$960,000
		7% Discount Rate	
Krewski et al. (2009)	$14,000	$100,000	$380,000
Lepeule et al. (2012)	$31,000	$230,000	$860,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 54: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the residential wood combustion sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001600	0.012000	0.045000
Lepeule et al. (2012)	0.003700	0.028000	0.100000
Morbidity			
Respiratory emergency room visits	0.000870	0.006200	0.023000
Acute bronchitis	0.002300	0.017000	0.061000
Lower respiratory symptoms	0.029000	0.210000	0.780000
Upper respiratory symptoms	0.042000	0.300000	1.100000
Minor Restricted Activity Days	1.200000	9.300000	34.000000
Work loss days	0.210000	1.600000	5.800000
Asthma exacerbation	0.049000	0.350000	1.300000
Cardiovascular hospital admissions	0.000380	0.002800	0.010000
Respiratory hospital admissions	0.000350	0.002600	0.009700
Non-fatal heart attacks (Peters)	0.001600	0.012000	0.043000
Non-fatal heart attacks (All others)	0.000170	0.001200	0.004600

Table 55: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the area sources sector (2015$)

Mortality risk estimate[A]	Pollutant emitted: *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$9,000	$56,000	$370,000
Lepeule et al. (2012)	$20,000	$130,000	$840,000
		7% Discount Rate	
Krewski et al. (2009)	$8,100	$51,000	$340,000
Lepeule et al. (2012)	$18,000	$120,000	$760,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 56: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the area sources sector

Health Endpoint	Pollutant emitted: *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000950	0.006000	0.040000
Lepeule et al. (2012)	0.002200	0.014000	0.090000
Morbidity			
Respiratory emergency room visits	0.000530	0.003500	0.023000
Acute bronchitis	0.001400	0.008000	0.054000
Lower respiratory symptoms	0.017000	0.100000	0.700000
Upper respiratory symptoms	0.025000	0.150000	1.000000
Minor Restricted Activity Days	0.730000	4.500000	30.000000
Work loss days	0.120000	0.760000	5.200000
Asthma exacerbation	0.029000	0.170000	1.200000
Cardiovascular hospital admissions	0.000230	0.001500	0.009800
Respiratory hospital admissions	0.000220	0.001500	0.009400
Non-fatal heart attacks (Peters)	0.000920	0.006000	0.039000
Non-fatal heart attacks (All others)	0.000099	0.000650	0.004200

Table 57: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the industrial point sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,300	$47,000	$310,000
Lepeule et al. (2012)	$17,000	$110,000	$700,000
		7% Discount Rate	
Krewski et al. (2009)	$6,600	$43,000	$280,000
Lepeule et al. (2012)	$15,000	$97,000	$630,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 58: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the industrial point sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000780	0.005000	0.033000
Lepeule et al. (2012)	0.001800	0.011000	0.074000
Morbidity			
Respiratory emergency room visits	0.000410	0.002700	0.017000
Acute bronchitis	0.001100	0.006400	0.044000
Lower respiratory symptoms	0.014000	0.082000	0.560000
Upper respiratory symptoms	0.020000	0.120000	0.810000
Minor Restricted Activity Days	0.570000	3.500000	24.000000
Work loss days	0.097000	0.590000	4.100000
Asthma exacerbation	0.023000	0.140000	0.940000
Cardiovascular hospital admissions	0.000190	0.001300	0.008200
Respiratory hospital admissions	0.000180	0.001200	0.007900
Non-fatal heart attacks (Peters)	0.000750	0.005100	0.033000
Non-fatal heart attacks (All others)	0.000081	0.000550	0.003600

Table 59: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the aircraft, locomotives and marine vessels sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,100	$96,000	$280,000
Lepeule et al. (2012)	$18,000	$220,000	$620,000
		7% Discount Rate	
Krewski et al. (2009)	$7,300	$87,000	$250,000
Lepeule et al. (2012)	$17,000	$200,000	$560,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 60: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the aircraft, locomotives and marine vessels sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000860	0.010000	0.029000
Lepeule et al. (2012)	0.002000	0.023000	0.067000
Morbidity			
Respiratory emergency room visits	0.000450	0.005400	0.016000
Acute bronchitis	0.001200	0.018000	0.041000
Lower respiratory symptoms	0.016000	0.220000	0.520000
Upper respiratory symptoms	0.022000	0.320000	0.750000
Minor Restricted Activity Days	0.670000	9.800000	23.000000
Work loss days	0.110000	1.700000	3.900000
Asthma exacerbation	0.026000	0.370000	0.880000
Cardiovascular hospital admissions	0.000210	0.002700	0.007300
Respiratory hospital admissions	0.000200	0.002500	0.007000
Non-fatal heart attacks (Peters)	0.000860	0.010000	0.029000
Non-fatal heart attacks (All others)	0.000092	0.001100	0.003100

Table 61: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the non-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,800	$51,000	$360,000
Lepeule et al. (2012)	$18,000	$120,000	$810,000
		7% Discount Rate	
Krewski et al. (2009)	$7,000	$46,000	$320,000
Lepeule et al. (2012)	$16,000	$100,000	$730,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 62: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the non-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000820	0.005400	0.038000
Lepeule et al. (2012)	0.001900	0.012000	0.086000
Morbidity			
Respiratory emergency room visits	0.000450	0.003000	0.023000
Acute bronchitis	0.001200	0.008800	0.054000
Lower respiratory symptoms	0.016000	0.110000	0.690000
Upper respiratory symptoms	0.022000	0.160000	0.980000
Minor Restricted Activity Days	0.660000	4.500000	30.000000
Work loss days	0.110000	0.760000	5.100000
Asthma exacerbation	0.026000	0.190000	1.200000
Cardiovascular hospital admissions	0.000200	0.001200	0.009600
Respiratory hospital admissions	0.000190	0.001100	0.009000
Non-fatal heart attacks (Peters)	0.000820	0.005000	0.038000
Non-fatal heart attacks (All others)	0.000088	0.000530	0.004100

Table 63: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the on-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,700	$23,000	$420,000
Lepeule et al. (2012)	$20,000	$52,000	$950,000
		7% Discount Rate	
Krewski et al. (2009)	$7,800	$21,000	$380,000
Lepeule et al. (2012)	$18,000	$47,000	$850,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 64: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the on-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000920	0.002400	0.044000
Lepeule et al. (2012)	0.002100	0.005500	0.100000
Morbidity			
Respiratory emergency room visits	0.000500	0.001300	0.026000
Acute bronchitis	0.001300	0.003900	0.064000
Lower respiratory symptoms	0.016000	0.049000	0.820000
Upper respiratory symptoms	0.024000	0.070000	1.200000
Minor Restricted Activity Days	0.700000	2.000000	36.000000
Work loss days	0.120000	0.340000	6.100000
Asthma exacerbation	0.028000	0.082000	1.400000
Cardiovascular hospital admissions	0.000220	0.000550	0.011000
Respiratory hospital admissions	0.000210	0.000530	0.011000
Non-fatal heart attacks (Peters)	0.000900	0.002200	0.045000
Non-fatal heart attacks (All others)	0.000097	0.000240	0.004800

Table 65: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the electricity generating units sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,200	$42,000	$150,000
Lepeule et al. (2012)	$14,000	$96,000	$350,000
		7% Discount Rate	
Krewski et al. (2009)	$5,600	$38,000	$140,000
Lepeule et al. (2012)	$13,000	$86,000	$310,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 66: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the electricity generating units sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000660	0.004500	0.016000
Lepeule et al. (2012)	0.001500	0.010000	0.037000
Morbidity			
Respiratory emergency room visits	0.000320	0.002200	0.009100
Acute bronchitis	0.000850	0.005500	0.021000
Lower respiratory symptoms	0.011000	0.070000	0.270000
Upper respiratory symptoms	0.016000	0.100000	0.390000
Minor Restricted Activity Days	0.460000	3.000000	12.000000
Work loss days	0.077000	0.510000	2.000000
Asthma exacerbation	0.018000	0.120000	0.460000
Cardiovascular hospital admissions	0.000160	0.001100	0.004000
Respiratory hospital admissions	0.000150	0.001100	0.003800
Non-fatal heart attacks (Peters)	0.000630	0.004500	0.016000
Non-fatal heart attacks (All others)	0.000068	0.000490	0.001700

Table 67: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the ocean-going vessels sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
3% Discount Rate			
Krewski et al. (2009)	$2,100	$14,000	$52,000
Lepeule et al. (2012)	$4,700	$31,000	$120,000
7% Discount Rate			
Krewski et al. (2009)	$1,900	$12,000	$47,000
Lepeule et al. (2012)	$4,200	$28,000	$110,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 68: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2020 from the ocean-going vessels sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000220	0.001400	0.005500
Lepeule et al. (2012)	0.000500	0.003300	0.012000
Morbidity			
Respiratory emergency room visits	0.000130	0.000790	0.003000
Acute bronchitis	0.000370	0.001900	0.007600
Lower respiratory symptoms	0.004700	0.024000	0.097000
Upper respiratory symptoms	0.006700	0.035000	0.140000
Minor Restricted Activity Days	0.210000	1.100000	4.300000
Work loss days	0.035000	0.190000	0.740000
Asthma exacerbation	0.007800	0.041000	0.160000
Cardiovascular hospital admissions	0.000059	0.000370	0.001400
Respiratory hospital admissions	0.000054	0.000350	0.001300
Non-fatal heart attacks (Peters)	0.000230	0.001400	0.005400
Non-fatal heart attacks (All others)	0.000025	0.000150	0.000580

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Table 69: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the cement kilns sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,100	$55,000	$460,000
Lepeule et al. (2012)	$16,000	$120,000	$1,000,000
		7% Discount Rate	
Krewski et al. (2009)	$6,400	$49,000	$410,000
Lepeule et al. (2012)	$14,000	$110,000	$940,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 70: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the cement kilns sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000740	0.005700	0.048000
Lepeule et al. (2012)	0.001700	0.013000	0.110000
Morbidity			
Respiratory emergency room visits	0.000400	0.002900	0.025000
Acute bronchitis	0.001000	0.007100	0.067000
Lower respiratory symptoms	0.013000	0.090000	0.850000
Upper respiratory symptoms	0.018000	0.130000	1.200000
Minor Restricted Activity Days	0.520000	3.700000	35.000000
Work loss days	0.089000	0.640000	5.900000
Asthma exacerbation	0.021000	0.150000	1.400000
Cardiovascular hospital admissions	0.000180	0.001500	0.012000
Respiratory hospital admissions	0.000180	0.001400	0.011000
Non-fatal heart attacks (Peters)	0.000730	0.005800	0.049000
Non-fatal heart attacks (All others)	0.000079	0.000620	0.005300

Table 71: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the pulp and paper facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$4,700	$58,000	$190,000
Lepeule et al. (2012)	$11,000	$130,000	$440,000
		7% Discount Rate	
Krewski et al. (2009)	$4,200	$52,000	$170,000
Lepeule et al. (2012)	$9,600	$120,000	$390,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 72: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the pulp and paper facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000490	0.006000	0.020000
Lepeule et al. (2012)	0.001100	0.014000	0.046000
Morbidity			
Respiratory emergency room visits	0.000240	0.002900	0.009000
Acute bronchitis	0.000610	0.007200	0.024000
Lower respiratory symptoms	0.007800	0.092000	0.310000
Upper respiratory symptoms	0.011000	0.130000	0.430000
Minor Restricted Activity Days	0.320000	3.800000	12.000000
Work loss days	0.054000	0.650000	2.100000
Asthma exacerbation	0.013000	0.150000	0.510000
Cardiovascular hospital admissions	0.000120	0.001600	0.005200
Respiratory hospital admissions	0.000110	0.001500	0.005000
Non-fatal heart attacks (Peters)	0.000480	0.006300	0.021000
Non-fatal heart attacks (All others)	0.000052	0.000670	0.002300

Table 73: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the refineries sector (2015$)

Mortality risk estimate[A]	Pollutant emitted NO_x	SO_2	Directly emitted $PM_{2.5}$
		3% Discount Rate	
Krewski et al. (2009)	$8,400	$85,000	$400,000
Lepeule et al. (2012)	$19,000	$190,000	$900,000
		7% Discount Rate	
Krewski et al. (2009)	$7,500	$76,000	$360,000
Lepeule et al. (2012)	$17,000	$170,000	$810,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 74: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the refineries sector

Health Endpoint	Pollutant emitted NO_x	SO_2	Directly emitted $PM_{2.5}$
Premature mortality			
Krewski et al. (2009)	0.000870	0.008800	0.041000
Lepeule et al. (2012)	0.002000	0.020000	0.094000
Morbidity			
Respiratory emergency room visits	0.000450	0.004700	0.023000
Acute bronchitis	0.001300	0.013000	0.061000
Lower respiratory symptoms	0.016000	0.160000	0.780000
Upper respiratory symptoms	0.023000	0.230000	1.100000
Minor Restricted Activity Days	0.670000	6.800000	32.000000
Work loss days	0.110000	1.200000	5.400000
Asthma exacerbation	0.027000	0.280000	1.300000
Cardiovascular hospital admissions	0.000220	0.002300	0.010000
Respiratory hospital admissions	0.000210	0.002200	0.010000
Non-fatal heart attacks (Peters)	0.000880	0.009100	0.041000
Non-fatal heart attacks (All others)	0.000095	0.000990	0.004500

Table 75: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the coke ovens sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$13,000	$65,000	$550,000
Lepeule et al. (2012)	$30,000	$150,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$12,000	$58,000	$500,000
Lepeule et al. (2012)	$27,000	$130,000	$1,100,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 76: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the coke ovens sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001400	0.006700	0.058000
Lepeule et al. (2012)	0.003100	0.015000	0.130000
Morbidity			
Respiratory emergency room visits	0.000700	0.003200	0.025000
Acute bronchitis	0.001600	0.007900	0.065000
Lower respiratory symptoms	0.021000	0.100000	0.820000
Upper respiratory symptoms	0.029000	0.140000	1.200000
Minor Restricted Activity Days	0.860000	4.200000	34.000000
Work loss days	0.150000	0.710000	5.700000
Asthma exacerbation	0.035000	0.170000	1.400000
Cardiovascular hospital admissions	0.000340	0.001700	0.014000
Respiratory hospital admissions	0.000330	0.001700	0.014000
Non-fatal heart attacks (Peters)	0.001300	0.007000	0.057000
Non-fatal heart attacks (All others)	0.000140	0.000750	0.006100

Table 77: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the iron and steel facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$20,000	$500,000	$620,000
Lepeule et al. (2012)	$46,000	$1,100,000	$1,400,000
		7% Discount Rate	
Krewski et al. (2009)	$18,000	$460,000	$560,000
Lepeule et al. (2012)	$42,000	$1,000,000	$1,300,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 78: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the iron and steel facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.002100	0.053000	0.065000
Lepeule et al. (2012)	0.004900	0.120000	0.150000
Morbidity			
Respiratory emergency room visits	0.001100	0.025000	0.031000
Acute bronchitis	0.003100	0.066000	0.086000
Lower respiratory symptoms	0.040000	0.840000	1.100000
Upper respiratory symptoms	0.056000	1.200000	1.600000
Minor Restricted Activity Days	1.600000	35.000000	45.000000
Work loss days	0.280000	5.900000	7.700000
Asthma exacerbation	0.066000	1.400000	1.800000
Cardiovascular hospital admissions	0.000560	0.013000	0.017000
Respiratory hospital admissions	0.000530	0.013000	0.016000
Non-fatal heart attacks (Peters)	0.002200	0.054000	0.069000
Non-fatal heart attacks (All others)	0.000240	0.005800	0.007400

Table 79: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the integrated iron and steel facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$17,000	$110,000	$590,000
Lepeule et al. (2012)	$38,000	$240,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$15,000	$97,000	$540,000
Lepeule et al. (2012)	$34,000	$220,000	$1,200,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 80: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the integrated iron and steel facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001800	0.011000	0.062000
Lepeule et al. (2012)	0.004000	0.026000	0.140000
Morbidity			
Respiratory emergency room visits	0.000860	0.005700	0.029000
Acute bronchitis	0.002100	0.014000	0.073000
Lower respiratory symptoms	0.027000	0.170000	0.930000
Upper respiratory symptoms	0.038000	0.250000	1.300000
Minor Restricted Activity Days	1.100000	7.100000	38.000000
Work loss days	0.190000	1.200000	6.400000
Asthma exacerbation	0.045000	0.290000	1.600000
Cardiovascular hospital admissions	0.000440	0.002900	0.016000
Respiratory hospital admissions	0.000420	0.002900	0.015000
Non-fatal heart attacks (Peters)	0.001700	0.012000	0.063000
Non-fatal heart attacks (All others)	0.000190	0.001200	0.006800

Table 81: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the electric arc furnaces sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$12,000	$100,000	$540,000
Lepeule et al. (2012)	$27,000	$230,000	$1,200,000
		7% Discount Rate	
Krewski et al. (2009)	$11,000	$90,000	$480,000
Lepeule et al. (2012)	$25,000	$210,000	$1,100,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 82: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the electric arc furnaces sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001300	0.010000	0.056000
Lepeule et al. (2012)	0.002900	0.024000	0.130000
Morbidity			
Respiratory emergency room visits	0.000670	0.005000	0.027000
Acute bronchitis	0.001600	0.012000	0.066000
Lower respiratory symptoms	0.020000	0.160000	0.830000
Upper respiratory symptoms	0.029000	0.220000	1.200000
Minor Restricted Activity Days	0.820000	6.500000	34.000000
Work loss days	0.140000	1.100000	5.800000
Asthma exacerbation	0.034000	0.260000	1.400000
Cardiovascular hospital admissions	0.000310	0.002700	0.015000
Respiratory hospital admissions	0.000300	0.002700	0.014000
Non-fatal heart attacks (Peters)	0.001200	0.011000	0.062000
Non-fatal heart attacks (All others)	0.000130	0.001200	0.006600

Table 83: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the taconite mines sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,700	$43,000	$110,000
Lepeule et al. (2012)	$17,000	$97,000	$240,000
		7% Discount Rate	
Krewski et al. (2009)	$6,900	$38,000	$96,000
Lepeule et al. (2012)	$16,000	$87,000	$220,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 84: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the taconite mines sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000800	0.004500	0.011000
Lepeule et al. (2012)	0.001800	0.010000	0.025000
Morbidity			
Respiratory emergency room visits	0.000370	0.002000	0.004600
Acute bronchitis	0.001000	0.005300	0.013000
Lower respiratory symptoms	0.013000	0.067000	0.160000
Upper respiratory symptoms	0.018000	0.096000	0.230000
Minor Restricted Activity Days	0.520000	2.800000	6.700000
Work loss days	0.088000	0.470000	1.100000
Asthma exacerbation	0.021000	0.110000	0.270000
Cardiovascular hospital admissions	0.000190	0.001100	0.002600
Respiratory hospital admissions	0.000180	0.001000	0.002500
Non-fatal heart attacks (Peters)	0.000770	0.004400	0.011000
Non-fatal heart attacks (All others)	0.000082	0.000480	0.001200

Table 85: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the ferroalloy facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$5,600	$56,000	$350,000
Lepeule et al. (2012)	$13,000	$130,000	$800,000
		7% Discount Rate	
Krewski et al. (2009)	$5,100	$51,000	$320,000
Lepeule et al. (2012)	$12,000	$120,000	$720,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 86: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the ferroalloy facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000590	0.005900	0.037000
Lepeule et al. (2012)	0.001300	0.013000	0.084000
Morbidity			
Respiratory emergency room visits	0.000240	0.002600	0.017000
Acute bronchitis	0.000630	0.006700	0.042000
Lower respiratory symptoms	0.008000	0.085000	0.540000
Upper respiratory symptoms	0.011000	0.120000	0.760000
Minor Restricted Activity Days	0.340000	3.500000	22.000000
Work loss days	0.058000	0.600000	3.700000
Asthma exacerbation	0.013000	0.140000	0.900000
Cardiovascular hospital admissions	0.000140	0.001500	0.009400
Respiratory hospital admissions	0.000140	0.001500	0.009400
Non-fatal heart attacks (Peters)	0.000580	0.006400	0.040000
Non-fatal heart attacks (All others)	0.000062	0.000690	0.004300

Table 87: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the residential wood combustion sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$17,000	$130,000	$460,000
Lepeule et al. (2012)	$38,000	$280,000	$1,000,000
		7% Discount Rate	
Krewski et al. (2009)	$15,000	$110,000	$420,000
Lepeule et al. (2012)	$34,000	$260,000	$940,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 88: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the residential wood combustion sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001700	0.013000	0.048000
Lepeule et al. (2012)	0.004000	0.030000	0.110000
Morbidity			
Respiratory emergency room visits	0.000900	0.006500	0.024000
Acute bronchitis	0.002400	0.017000	0.064000
Lower respiratory symptoms	0.031000	0.220000	0.820000
Upper respiratory symptoms	0.044000	0.310000	1.200000
Minor Restricted Activity Days	1.300000	9.500000	35.000000
Work loss days	0.210000	1.600000	5.900000
Asthma exacerbation	0.051000	0.370000	1.400000
Cardiovascular hospital admissions	0.000420	0.003100	0.012000
Respiratory hospital admissions	0.000390	0.002900	0.011000
Non-fatal heart attacks (Peters)	0.001700	0.013000	0.047000
Non-fatal heart attacks (All others)	0.000180	0.001400	0.005100

Table 89: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the area sources sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$9,700	$61,000	$410,000
Lepeule et al. (2012)	$22,000	$140,000	$920,000
		7% Discount Rate	
Krewski et al. (2009)	$8,800	$55,000	$370,000
Lepeule et al. (2012)	$20,000	$120,000	$830,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 90: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the area sources sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001000	0.006400	0.043000
Lepeule et al. (2012)	0.002300	0.015000	0.096000
Morbidity			
Respiratory emergency room visits	0.000550	0.003700	0.024000
Acute bronchitis	0.001400	0.008400	0.057000
Lower respiratory symptoms	0.018000	0.110000	0.730000
Upper respiratory symptoms	0.026000	0.150000	1.000000
Minor Restricted Activity Days	0.730000	4.500000	31.000000
Work loss days	0.120000	0.770000	5.300000
Asthma exacerbation	0.030000	0.180000	1.200000
Cardiovascular hospital admissions	0.000250	0.001700	0.011000
Respiratory hospital admissions	0.000240	0.001600	0.011000
Non-fatal heart attacks (Peters)	0.001000	0.006500	0.043000
Non-fatal heart attacks (All others)	0.000110	0.000710	0.004700

Table 91: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the industrial point sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,900	$51,000	$330,000
Lepeule et al. (2012)	$18,000	$120,000	$760,000
		7% Discount Rate	
Krewski et al. (2009)	$7,100	$46,000	$300,000
Lepeule et al. (2012)	$16,000	$100,000	$680,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 92: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the industrial point sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000820	0.005400	0.035000
Lepeule et al. (2012)	0.001900	0.012000	0.079000
Morbidity			
Respiratory emergency room visits	0.000420	0.002800	0.018000
Acute bronchitis	0.001100	0.006800	0.047000
Lower respiratory symptoms	0.014000	0.086000	0.590000
Upper respiratory symptoms	0.020000	0.120000	0.840000
Minor Restricted Activity Days	0.580000	3.600000	25.000000
Work loss days	0.098000	0.610000	4.200000
Asthma exacerbation	0.024000	0.140000	0.990000
Cardiovascular hospital admissions	0.000200	0.001400	0.009100
Respiratory hospital admissions	0.000200	0.001400	0.008800
Non-fatal heart attacks (Peters)	0.000820	0.005500	0.036000
Non-fatal heart attacks (All others)	0.000088	0.000600	0.003900

Table 93: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the aircraft, locomotives and marine vessels sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,800	$110,000	$300,000
Lepeule et al. (2012)	$20,000	$240,000	$680,000
		7% Discount Rate	
Krewski et al. (2009)	$8,000	$97,000	$270,000
Lepeule et al. (2012)	$18,000	$220,000	$610,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 94: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the aircraft, locomotives and marine vessels sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000920	0.011000	0.031000
Lepeule et al. (2012)	0.002100	0.025000	0.071000
Morbidity			
Respiratory emergency room visits	0.000460	0.005700	0.017000
Acute bronchitis	0.001300	0.018000	0.043000
Lower respiratory symptoms	0.016000	0.230000	0.550000
Upper respiratory symptoms	0.023000	0.330000	0.780000
Minor Restricted Activity Days	0.670000	10.000000	23.000000
Work loss days	0.110000	1.700000	4.000000
Asthma exacerbation	0.027000	0.390000	0.920000
Cardiovascular hospital admissions	0.000230	0.003100	0.008100
Respiratory hospital admissions	0.000230	0.002800	0.007800
Non-fatal heart attacks (Peters)	0.000940	0.012000	0.032000
Non-fatal heart attacks (All others)	0.000100	0.001300	0.003400

Table 95: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the non-road mobile sources sector (2015$)

Mortality risk estimate[A]	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,400	$57,000	$390,000
Lepeule et al. (2012)	$19,000	$130,000	$880,000
		7% Discount Rate	
Krewski et al. (2009)	$7,600	$51,000	$350,000
Lepeule et al. (2012)	$17,000	$120,000	$790,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 96: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the non-road mobile sources sector

Health Endpoint	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000880	0.005900	0.041000
Lepeule et al. (2012)	0.002000	0.013000	0.092000
Morbidity			
Respiratory emergency room visits	0.000470	0.003200	0.024000
Acute bronchitis	0.001300	0.009300	0.057000
Lower respiratory symptoms	0.016000	0.120000	0.720000
Upper respiratory symptoms	0.023000	0.170000	1.000000
Minor Restricted Activity Days	0.670000	4.700000	31.000000
Work loss days	0.110000	0.800000	5.300000
Asthma exacerbation	0.027000	0.200000	1.200000
Cardiovascular hospital admissions	0.000220	0.001300	0.011000
Respiratory hospital admissions	0.000210	0.001300	0.010000
Non-fatal heart attacks (Peters)	0.000900	0.005600	0.041000
Non-fatal heart attacks (All others)	0.000097	0.000600	0.004500

Table 97: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the on-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
	3% Discount Rate		
Krewski et al. (2009)	$9,400	$25,000	$460,000
Lepeule et al. (2012)	$21,000	$57,000	$1,000,000
	7% Discount Rate		
Krewski et al. (2009)	$8,500	$23,000	$410,000
Lepeule et al. (2012)	$19,000	$52,000	$930,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 98: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the on-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000980	0.002600	0.048000
Lepeule et al. (2012)	0.002200	0.006000	0.110000
Morbidity			
Respiratory emergency room visits	0.000520	0.001400	0.027000
Acute bronchitis	0.001300	0.004100	0.067000
Lower respiratory symptoms	0.017000	0.052000	0.860000
Upper respiratory symptoms	0.025000	0.074000	1.200000
Minor Restricted Activity Days	0.700000	2.100000	36.000000
Work loss days	0.120000	0.350000	6.200000
Asthma exacerbation	0.029000	0.087000	1.400000
Cardiovascular hospital admissions	0.000250	0.000620	0.012000
Respiratory hospital admissions	0.000240	0.000600	0.012000
Non-fatal heart attacks (Peters)	0.000980	0.002500	0.049000
Non-fatal heart attacks (All others)	0.000110	0.000270	0.005300

Table 99: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the electricity generating units sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,700	$46,000	$170,000
Lepeule et al. (2012)	$15,000	$100,000	$370,000
		7% Discount Rate	
Krewski et al. (2009)	$6,000	$41,000	$150,000
Lepeule et al. (2012)	$14,000	$93,000	$340,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 100: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the electricity generating units sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000700	0.004800	0.017000
Lepeule et al. (2012)	0.001600	0.011000	0.039000
Morbidity			
Respiratory emergency room visits	0.000330	0.002300	0.009400
Acute bronchitis	0.000890	0.005700	0.022000
Lower respiratory symptoms	0.011000	0.073000	0.290000
Upper respiratory symptoms	0.016000	0.100000	0.410000
Minor Restricted Activity Days	0.460000	3.000000	12.000000
Work loss days	0.077000	0.520000	2.000000
Asthma exacerbation	0.019000	0.120000	0.480000
Cardiovascular hospital admissions	0.000170	0.001200	0.004400
Respiratory hospital admissions	0.000170	0.001200	0.004300
Non-fatal heart attacks (Peters)	0.000680	0.004900	0.018000
Non-fatal heart attacks (All others)	0.000074	0.000540	0.001900

Table 101: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the ocean-going vessels sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
	3% Discount Rate		
Krewski et al. (2009)	$2,300	$15,000	$57,000
Lepeule et al. (2012)	$5,200	$34,000	$130,000
	7% Discount Rate		
Krewski et al. (2009)	$2,100	$14,000	$51,000
Lepeule et al. (2012)	$4,700	$30,000	$120,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 102: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2025 from the ocean-going vessels sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000240	0.001600	0.005900
Lepeule et al. (2012)	0.000540	0.003500	0.013000
Morbidity			
Respiratory emergency room visits	0.000140	0.000840	0.003200
Acute bronchitis	0.000380	0.002000	0.008000
Lower respiratory symptoms	0.004900	0.026000	0.100000
Upper respiratory symptoms	0.007000	0.037000	0.140000
Minor Restricted Activity Days	0.210000	1.100000	4.400000
Work loss days	0.036000	0.190000	0.750000
Asthma exacerbation	0.008200	0.043000	0.170000
Cardiovascular hospital admissions	0.000066	0.000420	0.001500
Respiratory hospital admissions	0.000062	0.000400	0.001400
Non-fatal heart attacks (Peters)	0.000260	0.001600	0.006000
Non-fatal heart attacks (All others)	0.000028	0.000170	0.000650

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Table 103: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the cement kilns sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,700	$60,000	$510,000
Lepeule et al. (2012)	$17,000	$130,000	$1,100,000
		7% Discount Rate	
Krewski et al. (2009)	$6,900	$54,000	$460,000
Lepeule et al. (2012)	$16,000	$120,000	$1,000,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 104: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the cement kilns sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000780	0.006100	0.052000
Lepeule et al. (2012)	0.001800	0.014000	0.120000
Morbidity			
Respiratory emergency room visits	0.000410	0.003100	0.026000
Acute bronchitis	0.001100	0.007700	0.074000
Lower respiratory symptoms	0.014000	0.098000	0.940000
Upper respiratory symptoms	0.020000	0.140000	1.300000
Minor Restricted Activity Days	0.530000	3.800000	36.000000
Work loss days	0.090000	0.650000	6.100000
Asthma exacerbation	0.023000	0.160000	1.500000
Cardiovascular hospital admissions	0.000200	0.001600	0.013000
Respiratory hospital admissions	0.000200	0.001500	0.013000
Non-fatal heart attacks (Peters)	0.000800	0.006300	0.055000
Non-fatal heart attacks (All others)	0.000086	0.000680	0.005900

Table 105: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the pulp and paper facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$5,100	$63,000	$210,000
Lepeule et al. (2012)	$12,000	$140,000	$470,000
		7% Discount Rate	
Krewski et al. (2009)	$4,600	$57,000	$190,000
Lepeule et al. (2012)	$10,000	$130,000	$430,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 106: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the pulp and paper facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000520	0.006500	0.021000
Lepeule et al. (2012)	0.001200	0.015000	0.049000
Morbidity			
Respiratory emergency room visits	0.000250	0.003000	0.009300
Acute bronchitis	0.000660	0.007800	0.026000
Lower respiratory symptoms	0.008400	0.100000	0.330000
Upper respiratory symptoms	0.012000	0.140000	0.470000
Minor Restricted Activity Days	0.320000	3.900000	13.000000
Work loss days	0.055000	0.670000	2.200000
Asthma exacerbation	0.014000	0.160000	0.540000
Cardiovascular hospital admissions	0.000130	0.001700	0.005700
Respiratory hospital admissions	0.000120	0.001700	0.005500
Non-fatal heart attacks (Peters)	0.000520	0.006800	0.023000
Non-fatal heart attacks (All others)	0.000056	0.000730	0.002500

Table 107: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the refineries sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$9,100	$93,000	$430,000
Lepeule et al. (2012)	$21,000	$210,000	$980,000
		7% Discount Rate	
Krewski et al. (2009)	$8,200	$84,000	$390,000
Lepeule et al. (2012)	$19,000	$190,000	$880,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 108: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the refineries sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000940	0.009500	0.044000
Lepeule et al. (2012)	0.002100	0.022000	0.100000
Morbidity			
Respiratory emergency room visits	0.000470	0.004900	0.024000
Acute bronchitis	0.001400	0.014000	0.066000
Lower respiratory symptoms	0.018000	0.180000	0.840000
Upper respiratory symptoms	0.025000	0.250000	1.200000
Minor Restricted Activity Days	0.680000	7.000000	33.000000
Work loss days	0.120000	1.200000	5.600000
Asthma exacerbation	0.029000	0.290000	1.400000
Cardiovascular hospital admissions	0.000250	0.002600	0.012000
Respiratory hospital admissions	0.000240	0.002500	0.011000
Non-fatal heart attacks (Peters)	0.000970	0.010000	0.045000
Non-fatal heart attacks (All others)	0.000100	0.001100	0.004900

Table 109: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the coke ovens sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$14,000	$70,000	$590,000
Lepeule et al. (2012)	$32,000	$160,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$13,000	$63,000	$530,000
Lepeule et al. (2012)	$29,000	$140,000	$1,200,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 110: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the coke ovens sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001400	0.007100	0.061000
Lepeule et al. (2012)	0.003300	0.016000	0.140000
Morbidity			
Respiratory emergency room visits	0.000710	0.003300	0.026000
Acute bronchitis	0.001700	0.008400	0.068000
Lower respiratory symptoms	0.022000	0.110000	0.870000
Upper respiratory symptoms	0.031000	0.150000	1.200000
Minor Restricted Activity Days	0.860000	4.200000	34.000000
Work loss days	0.150000	0.710000	5.700000
Asthma exacerbation	0.036000	0.180000	1.400000
Cardiovascular hospital admissions	0.000360	0.001900	0.015000
Respiratory hospital admissions	0.000360	0.001900	0.015000
Non-fatal heart attacks (Peters)	0.001400	0.007500	0.060000
Non-fatal heart attacks (All others)	0.000150	0.000810	0.006500

Table 111: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the iron and steel facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$22,000	$540,000	$670,000
Lepeule et al. (2012)	$50,000	$1,200,000	$1,500,000
		7% Discount Rate	
Krewski et al. (2009)	$20,000	$490,000	$610,000
Lepeule et al. (2012)	$45,000	$1,100,000	$1,400,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 112: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the iron and steel facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.002300	0.056000	0.069000
Lepeule et al. (2012)	0.005200	0.130000	0.160000
Morbidity			
Respiratory emergency room visits	0.001200	0.026000	0.032000
Acute bronchitis	0.003300	0.070000	0.092000
Lower respiratory symptoms	0.042000	0.900000	1.200000
Upper respiratory symptoms	0.061000	1.300000	1.700000
Minor Restricted Activity Days	1.600000	35.000000	46.000000
Work loss days	0.280000	6.000000	7.800000
Asthma exacerbation	0.070000	1.500000	1.900000
Cardiovascular hospital admissions	0.000610	0.014000	0.018000
Respiratory hospital admissions	0.000590	0.014000	0.018000
Non-fatal heart attacks (Peters)	0.002400	0.058000	0.074000
Non-fatal heart attacks (All others)	0.000260	0.006200	0.008000

Table 113: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the integrated iron and steel facilities sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$18,000	$120,000	$630,000
Lepeule et al. (2012)	$41,000	$260,000	$1,400,000
		7% Discount Rate	
Krewski et al. (2009)	$16,000	$100,000	$570,000
Lepeule et al. (2012)	$37,000	$240,000	$1,300,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 114: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the integrated iron and steel facilities sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001900	0.012000	0.065000
Lepeule et al. (2012)	0.004200	0.027000	0.150000
Morbidity			
Respiratory emergency room visits	0.000880	0.005800	0.029000
Acute bronchitis	0.002300	0.014000	0.077000
Lower respiratory symptoms	0.029000	0.180000	0.980000
Upper respiratory symptoms	0.041000	0.260000	1.400000
Minor Restricted Activity Days	1.100000	7.100000	38.000000
Work loss days	0.190000	1.200000	6.400000
Asthma exacerbation	0.047000	0.300000	1.600000
Cardiovascular hospital admissions	0.000470	0.003100	0.017000
Respiratory hospital admissions	0.000460	0.003100	0.017000
Non-fatal heart attacks (Peters)	0.001900	0.012000	0.066000
Non-fatal heart attacks (All others)	0.000200	0.001300	0.007200

Table 115: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the electric arc furnaces sector (2015$)

Mortality risk estimate[A]	Pollutant emitted NO_x	SO_2	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$13,000	$110,000	$580,000
Lepeule et al. (2012)	$29,000	$250,000	$1,300,000
		7% Discount Rate	
Krewski et al. (2009)	$12,000	$98,000	$520,000
Lepeule et al. (2012)	$27,000	$220,000	$1,200,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 116: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the electric arc furnaces sector

Health Endpoint	Pollutant emitted NO_x	SO_2	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001300	0.011000	0.059000
Lepeule et al. (2012)	0.003000	0.025000	0.130000
Morbidity			
Respiratory emergency room visits	0.000690	0.005200	0.028000
Acute bronchitis	0.001700	0.013000	0.070000
Lower respiratory symptoms	0.022000	0.170000	0.900000
Upper respiratory symptoms	0.031000	0.240000	1.300000
Minor Restricted Activity Days	0.830000	6.600000	35.000000
Work loss days	0.140000	1.100000	5.900000
Asthma exacerbation	0.036000	0.280000	1.500000
Cardiovascular hospital admissions	0.000340	0.002900	0.016000
Respiratory hospital admissions	0.000330	0.002900	0.016000
Non-fatal heart attacks (Peters)	0.001300	0.012000	0.066000
Non-fatal heart attacks (All others)	0.000140	0.001300	0.007100

Table 117: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the taconite mines sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,300	$46,000	$120,000
Lepeule et al. (2012)	$19,000	$100,000	$260,000
		7% Discount Rate	
Krewski et al. (2009)	$7,500	$42,000	$100,000
Lepeule et al. (2012)	$17,000	$94,000	$240,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 118: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the taconite mines sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000850	0.004700	0.012000
Lepeule et al. (2012)	0.001900	0.011000	0.027000
Morbidity			
Respiratory emergency room visits	0.000380	0.002100	0.004700
Acute bronchitis	0.001100	0.005700	0.014000
Lower respiratory symptoms	0.014000	0.072000	0.180000
Upper respiratory symptoms	0.019000	0.100000	0.250000
Minor Restricted Activity Days	0.520000	2.800000	6.700000
Work loss days	0.088000	0.480000	1.100000
Asthma exacerbation	0.022000	0.120000	0.290000
Cardiovascular hospital admissions	0.000200	0.001200	0.002800
Respiratory hospital admissions	0.000190	0.001200	0.002800
Non-fatal heart attacks (Peters)	0.000820	0.004800	0.012000
Non-fatal heart attacks (All others)	0.000089	0.000520	0.001300

Table 119: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the ferroalloy facilities sector (2015$)

Mortality risk estimate[A]	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$6,000	$61,000	$380,000
Lepeule et al. (2012)	$14,000	$140,000	$850,000
		7% Discount Rate	
Krewski et al. (2009)	$5,500	$55,000	$340,000
Lepeule et al. (2012)	$12,000	$130,000	$770,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 120: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the ferroalloy facilities sector

Health Endpoint	Pollutant emitted *NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000620	0.006300	0.039000
Lepeule et al. (2012)	0.001400	0.014000	0.088000
Morbidity			
Respiratory emergency room visits	0.000250	0.002700	0.017000
Acute bronchitis	0.000680	0.007200	0.045000
Lower respiratory symptoms	0.008600	0.092000	0.580000
Upper respiratory symptoms	0.012000	0.130000	0.820000
Minor Restricted Activity Days	0.340000	3.600000	22.000000
Work loss days	0.058000	0.610000	3.800000
Asthma exacerbation	0.014000	0.150000	0.950000
Cardiovascular hospital admissions	0.000150	0.001700	0.010000
Respiratory hospital admissions	0.000150	0.001700	0.010000
Non-fatal heart attacks (Peters)	0.000620	0.006900	0.043000
Non-fatal heart attacks (All others)	0.000067	0.000740	0.004600

Table 121: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the residential wood combustion sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$18,000	$140,000	$510,000
Lepeule et al. (2012)	$41,000	$310,000	$1,100,000
		7% Discount Rate	
Krewski et al. (2009)	$16,000	$120,000	$460,000
Lepeule et al. (2012)	$37,000	$280,000	$1,000,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 122: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the residential wood combustion sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001900	0.014000	0.052000
Lepeule et al. (2012)	0.004200	0.032000	0.120000
Morbidity			
Respiratory emergency room visits	0.000930	0.006800	0.025000
Acute bronchitis	0.002600	0.019000	0.070000
Lower respiratory symptoms	0.033000	0.240000	0.890000
Upper respiratory symptoms	0.047000	0.340000	1.300000
Minor Restricted Activity Days	1.300000	9.700000	35.000000
Work loss days	0.220000	1.600000	6.000000
Asthma exacerbation	0.054000	0.400000	1.500000
Cardiovascular hospital admissions	0.000450	0.003400	0.013000
Respiratory hospital admissions	0.000430	0.003200	0.012000
Non-fatal heart attacks (Peters)	0.001800	0.014000	0.051000
Non-fatal heart attacks (All others)	0.000200	0.001500	0.005600

Table 123: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the area sources sector (2015$)

Mortality risk estimate[A]	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$11,000	$67,000	$450,000
Lepeule et al. (2012)	$24,000	$150,000	$1,000,000
		7% Discount Rate	
Krewski et al. (2009)	$9,500	$60,000	$400,000
Lepeule et al. (2012)	$21,000	$140,000	$910,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 124: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the area sources sector

Health Endpoint	Pollutant emitted		
	NO_x	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001100	0.006800	0.046000
Lepeule et al. (2012)	0.002400	0.015000	0.100000
Morbidity			
Respiratory emergency room visits	0.000570	0.003800	0.025000
Acute bronchitis	0.001500	0.009000	0.062000
Lower respiratory symptoms	0.020000	0.120000	0.790000
Upper respiratory symptoms	0.028000	0.170000	1.100000
Minor Restricted Activity Days	0.740000	4.600000	32.000000
Work loss days	0.130000	0.790000	5.400000
Asthma exacerbation	0.032000	0.190000	1.300000
Cardiovascular hospital admissions	0.000270	0.001800	0.012000
Respiratory hospital admissions	0.000270	0.001800	0.012000
Non-fatal heart attacks (Peters)	0.001100	0.007100	0.047000
Non-fatal heart attacks (All others)	0.000120	0.000770	0.005100

Table 125: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the industrial point sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$8,500	$56,000	$370,000
Lepeule et al. (2012)	$19,000	$130,000	$830,000
		7% Discount Rate	
Krewski et al. (2009)	$7,700	$50,000	$330,000
Lepeule et al. (2012)	$17,000	$110,000	$750,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 126: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the industrial point sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000880	0.005700	0.037000
Lepeule et al. (2012)	0.002000	0.013000	0.085000
Morbidity			
Respiratory emergency room visits	0.000430	0.002900	0.019000
Acute bronchitis	0.001200	0.007300	0.050000
Lower respiratory symptoms	0.015000	0.093000	0.640000
Upper respiratory symptoms	0.022000	0.130000	0.920000
Minor Restricted Activity Days	0.580000	3.600000	25.000000
Work loss days	0.099000	0.620000	4.300000
Asthma exacerbation	0.025000	0.150000	1.100000
Cardiovascular hospital admissions	0.000220	0.001500	0.010000
Respiratory hospital admissions	0.000220	0.001500	0.009800
Non-fatal heart attacks (Peters)	0.000890	0.006000	0.040000
Non-fatal heart attacks (All others)	0.000096	0.000650	0.004300

Table 127: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the aircraft, locomotives and marine vessels sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$9,600	$120,000	$330,000
Lepeule et al. (2012)	$22,000	$270,000	$740,000
		7% Discount Rate	
Krewski et al. (2009)	$8,700	$110,000	$290,000
Lepeule et al. (2012)	$20,000	$240,000	$660,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 128: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the aircraft, locomotives and marine vessels sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000980	0.012000	0.033000
Lepeule et al. (2012)	0.002200	0.028000	0.076000
Morbidity			
Respiratory emergency room visits	0.000480	0.006000	0.018000
Acute bronchitis	0.001400	0.020000	0.046000
Lower respiratory symptoms	0.018000	0.250000	0.590000
Upper respiratory symptoms	0.025000	0.360000	0.840000
Minor Restricted Activity Days	0.680000	10.000000	24.000000
Work loss days	0.120000	1.700000	4.100000
Asthma exacerbation	0.029000	0.410000	0.980000
Cardiovascular hospital admissions	0.000260	0.003500	0.008900
Respiratory hospital admissions	0.000250	0.003200	0.008600
Non-fatal heart attacks (Peters)	0.001000	0.013000	0.035000
Non-fatal heart attacks (All others)	0.000110	0.001400	0.003800

Table 129: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the non-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$9,200	$63,000	$430,000
Lepeule et al. (2012)	$21,000	$140,000	$970,000
		7% Discount Rate	
Krewski et al. (2009)	$8,300	$57,000	$390,000
Lepeule et al. (2012)	$19,000	$130,000	$870,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 130: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the non-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000940	0.006500	0.044000
Lepeule et al. (2012)	0.002100	0.015000	0.099000
Morbidity			
Respiratory emergency room visits	0.000480	0.003400	0.025000
Acute bronchitis	0.001400	0.010000	0.061000
Lower respiratory symptoms	0.018000	0.130000	0.780000
Upper respiratory symptoms	0.025000	0.190000	1.100000
Minor Restricted Activity Days	0.680000	4.900000	32.000000
Work loss days	0.120000	0.840000	5.400000
Asthma exacerbation	0.029000	0.210000	1.300000
Cardiovascular hospital admissions	0.000250	0.001500	0.012000
Respiratory hospital admissions	0.000240	0.001500	0.011000
Non-fatal heart attacks (Peters)	0.000980	0.006200	0.045000
Non-fatal heart attacks (All others)	0.000110	0.000670	0.004900

Table 131: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the on-road mobile sources sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$10,000	$28,000	$500,000
Lepeule et al. (2012)	$23,000	$64,000	$1,100,000
		7% Discount Rate	
Krewski et al. (2009)	$9,200	$25,000	$450,000
Lepeule et al. (2012)	$21,000	$57,000	$1,000,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 132: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the on-road mobile sources sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.001000	0.002900	0.051000
Lepeule et al. (2012)	0.002400	0.006500	0.120000
Morbidity			
Respiratory emergency room visits	0.000530	0.001500	0.028000
Acute bronchitis	0.001400	0.004500	0.073000
Lower respiratory symptoms	0.018000	0.057000	0.930000
Upper respiratory symptoms	0.026000	0.082000	1.300000
Minor Restricted Activity Days	0.710000	2.100000	37.000000
Work loss days	0.120000	0.370000	6.300000
Asthma exacerbation	0.031000	0.094000	1.500000
Cardiovascular hospital admissions	0.000270	0.000700	0.014000
Respiratory hospital admissions	0.000260	0.000680	0.013000
Non-fatal heart attacks (Peters)	0.001100	0.002800	0.054000
Non-fatal heart attacks (All others)	0.000110	0.000300	0.005800

Table 133: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the electricity generating units sector (2015$)

	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$7,200	$49,000	$180,000
Lepeule et al. (2012)	$16,000	$110,000	$410,000
		7% Discount Rate	
Krewski et al. (2009)	$6,500	$45,000	$160,000
Lepeule et al. (2012)	$15,000	$100,000	$370,000

[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

Table 134: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the electricity generating units sector

	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000740	0.005100	0.018000
Lepeule et al. (2012)	0.001700	0.011000	0.042000
Morbidity			
Respiratory emergency room visits	0.000340	0.002400	0.009800
Acute bronchitis	0.000960	0.006200	0.024000
Lower respiratory symptoms	0.012000	0.079000	0.310000
Upper respiratory symptoms	0.017000	0.110000	0.440000
Minor Restricted Activity Days	0.460000	3.100000	12.000000
Work loss days	0.078000	0.530000	2.100000
Asthma exacerbation	0.020000	0.130000	0.510000
Cardiovascular hospital admissions	0.000180	0.001400	0.004800
Respiratory hospital admissions	0.000180	0.001300	0.004700
Non-fatal heart attacks (Peters)	0.000740	0.005300	0.019000
Non-fatal heart attacks (All others)	0.000079	0.000580	0.002100

Table 135: Dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the ocean-going vessels sector (2015$)

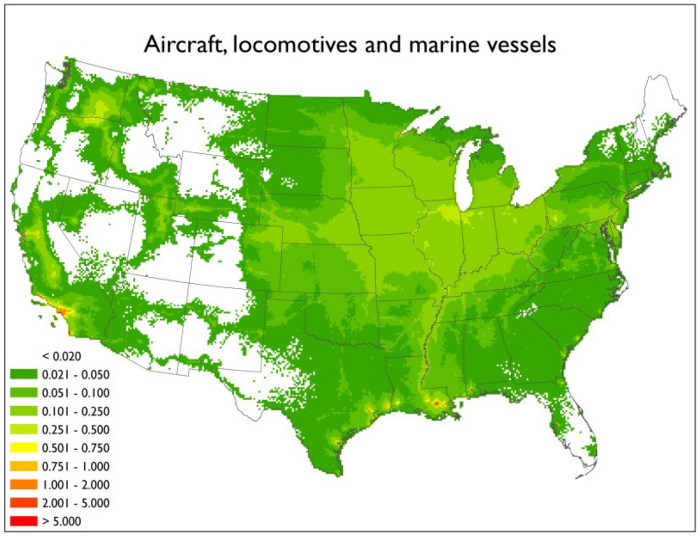
	Pollutant emitted		
Mortality risk estimate[A]	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
		3% Discount Rate	
Krewski et al. (2009)	$2,600	$17,000	$63,000
Lepeule et al. (2012)	$5,800	$38,000	$140,000
		7% Discount Rate	
Krewski et al. (2009)	$2,300	$15,000	$57,000
Lepeule et al. (2012)	$5,200	$34,000	$130,000

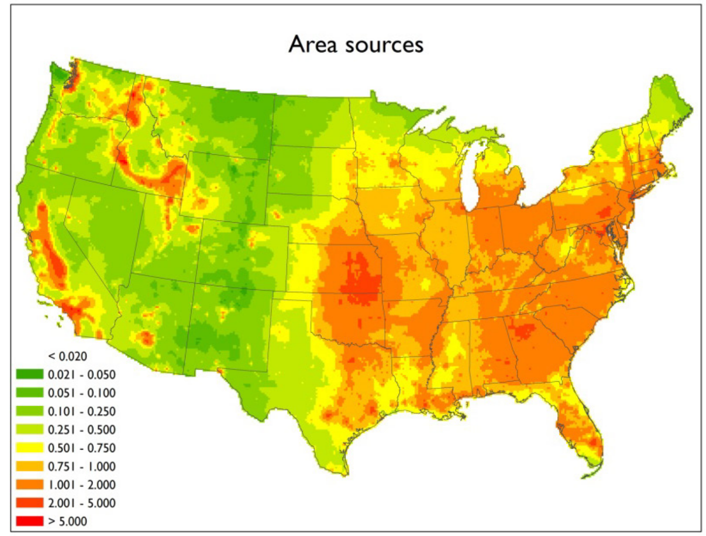
[A] Value represents sum of the value of avoided morbidity impacts and mortality impacts quantified using the $PM_{2.5}$ mortality risk estimate noted. Estimates are rounded to two significant digits in this table, but all calculations are performed with the unrounded estimates.

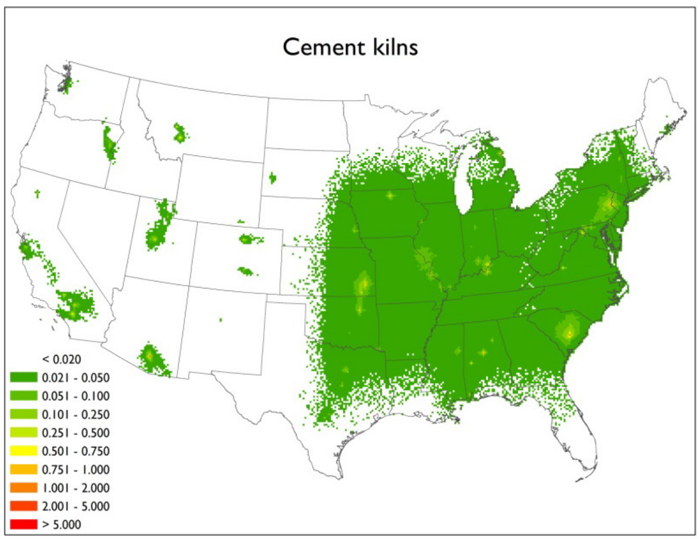
Table 136: Incidence of avoided mortalities and morbidities per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced in 2030 from the ocean-going vessels sector

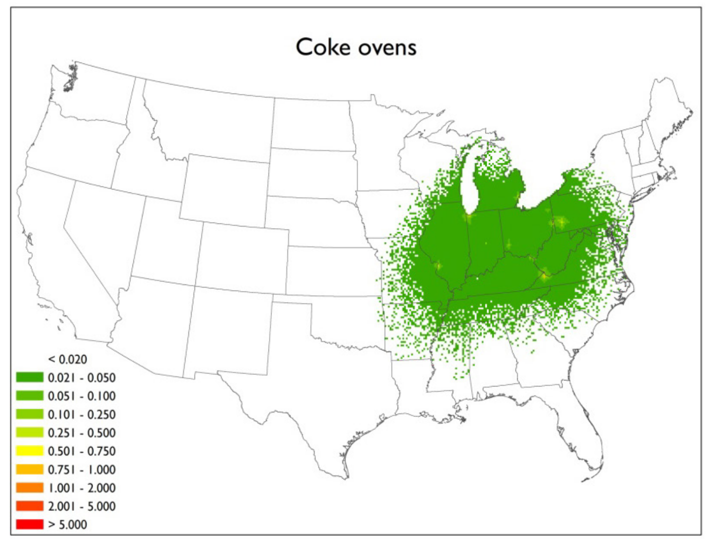
	Pollutant emitted		
Health Endpoint	*NO_x*	*SO_2*	*Directly emitted $PM_{2.5}$*
Premature mortality			
Krewski et al. (2009)	0.000260	0.001700	0.006400
Lepeule et al. (2012)	0.000590	0.003900	0.015000
Morbidity			
Respiratory emergency room visits	0.000140	0.000880	0.003300
Acute bronchitis	0.000410	0.002200	0.008600
Lower respiratory symptoms	0.005200	0.028000	0.110000
Upper respiratory symptoms	0.007500	0.040000	0.160000
Minor Restricted Activity Days	0.210000	1.200000	4.500000
Work loss days	0.036000	0.200000	0.770000
Asthma exacerbation	0.008600	0.046000	0.180000
Cardiovascular hospital admissions	0.000074	0.000470	0.001700
Respiratory hospital admissions	0.000070	0.000450	0.001600
Non-fatal heart attacks (Peters)	0.000280	0.001800	0.006600
Non-fatal heart attacks (All others)	0.000031	0.000190	0.000710

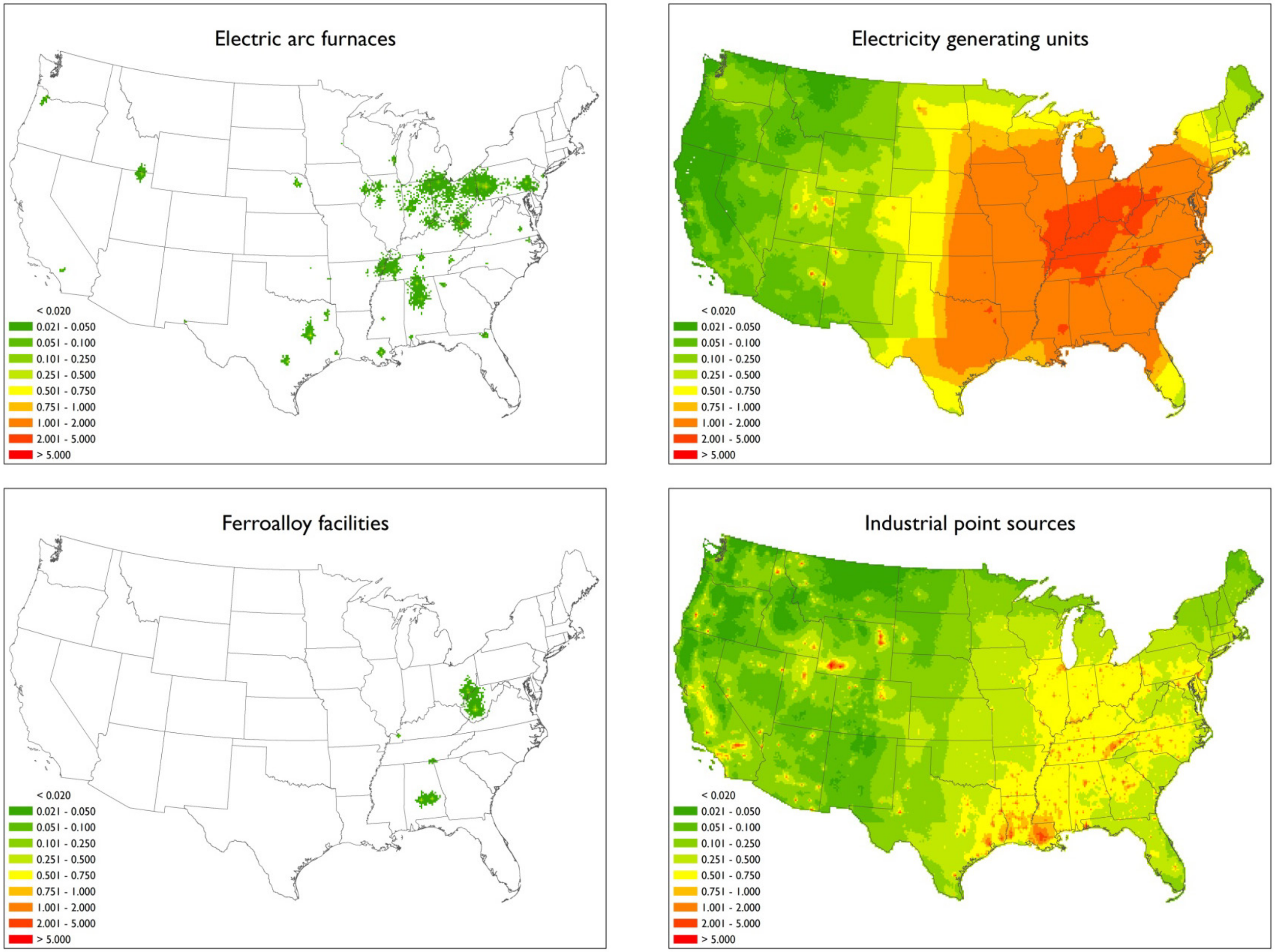
Appendix B: Modeled annual mean $PM_{2.5}$ levels attributable to sectors in 2016


Aircraft, locomotives and marine vessels
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000

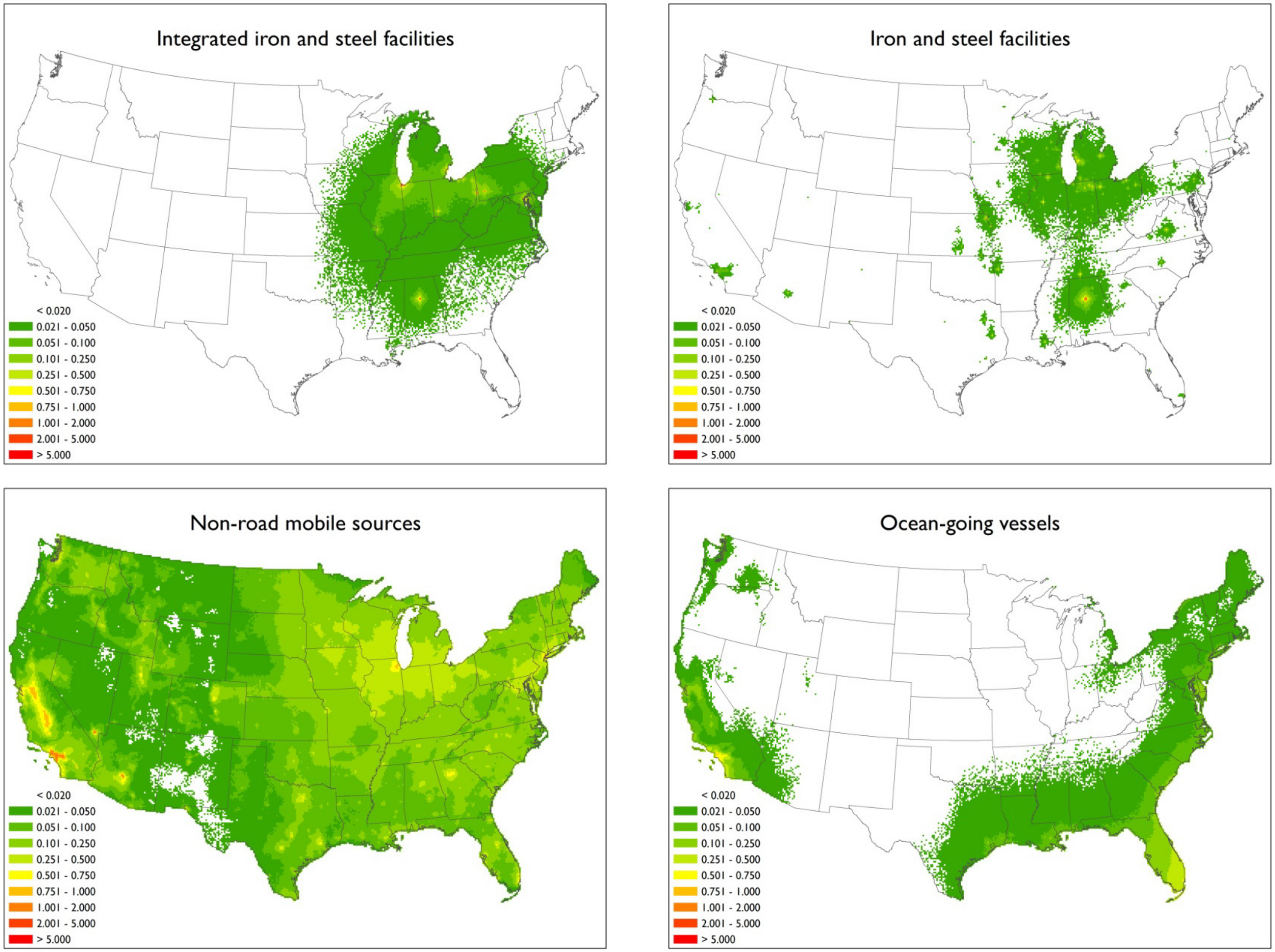

Area sources
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000

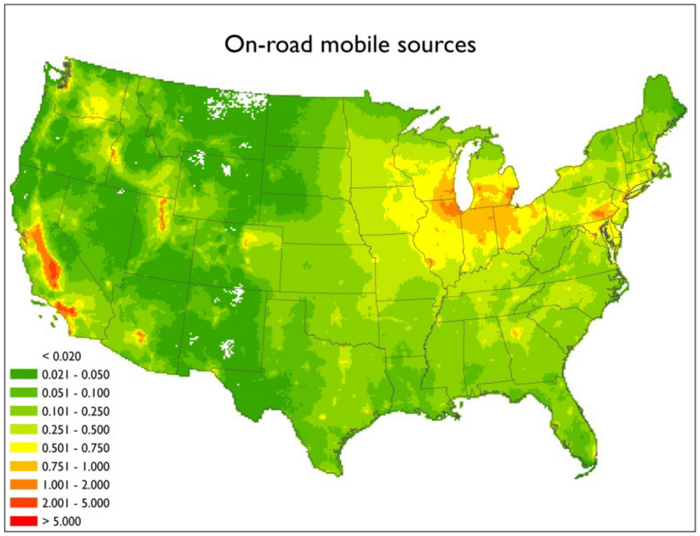

Cement kilns
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000

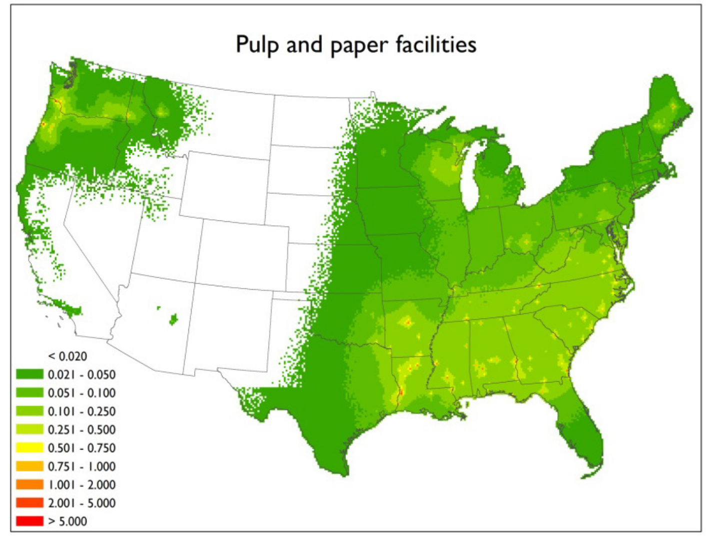

Coke ovens
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000

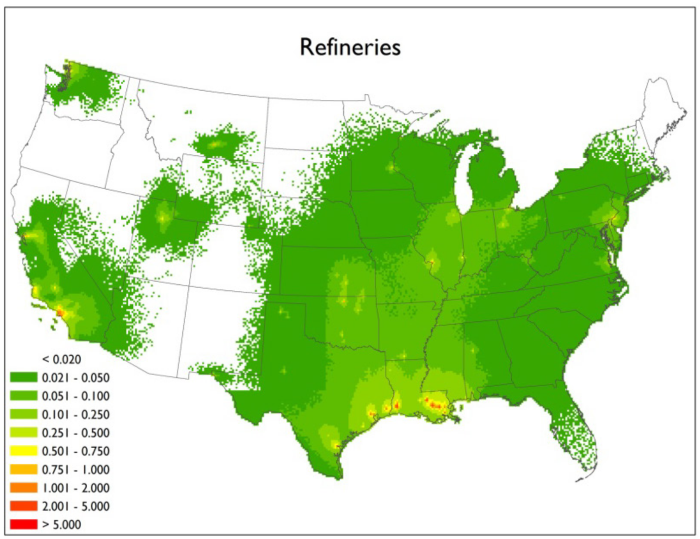


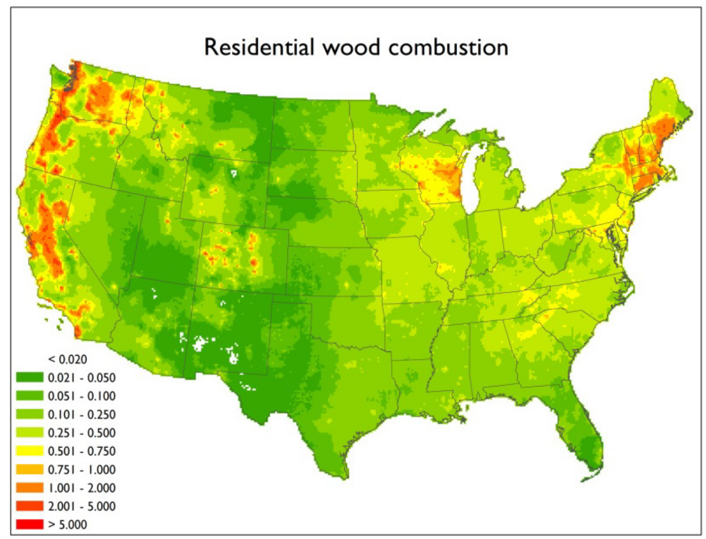
Electric arc furnaces
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000
Electricity generating units
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000
Ferroalloy facilities
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000
Industrial point sources
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000

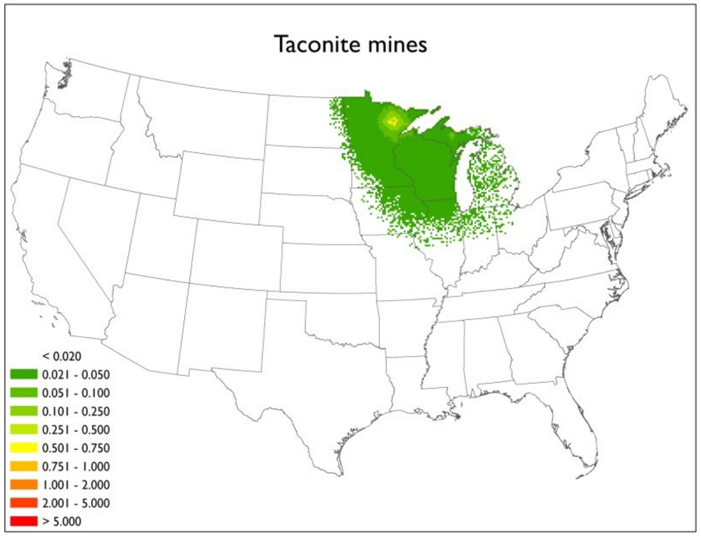

Integrated iron and steel facilities
Iron and steel facilities
Non-road mobile sources
Ocean-going vessels
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000


On-road mobile sources
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000


Pulp and paper facilities
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000


Refineries
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000


Residential wood combustion
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000



Taconite mines
< 0.020
0.021 - 0.050
0.051 - 0.100
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 2.000
2.001 - 5.000
> 5.000

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