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Environmental Assessment

for

**10 CFR Part 431 Energy Conservation Standards: Energy
Conservation Standards for Residential Water Heaters, Direct
Heating Equipment, and Pool Heaters**

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CHAPTER 16. ENVIRONMENTAL IMPACTS ANALYSIS

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CHAPTER 16. ENVIRONMENTAL IMPACTS ANALYSIS

16.1 INTRODUCTION

This chapter describes potential environmental effects that may result from amended energy conservation standards for residential heating products. The U.S. Department of Energy (DOE)'s energy conservation standards are not site-specific, and would apply to all 50 States and U.S. territories. Therefore, none of the standards would impact land uses, cause any direct disturbance to the land, or directly affect biological resources in any one area.

All of the trial standard levels (TSLs) are expected to reduce energy consumption in comparison to the base case. These changes in energy consumption are the primary drivers in analyzing environmental effects. The estimates of source energy savings that serve as inputs to the environmental assessment (EA) can be found in the utility impact analysis in chapter 13 of this technical support document (TSD).

The primary impact of the TSLs is on air emissions resulting from power plant operations and from the residential heating products themselves. Therefore, much of this chapter describes the air emissions analysis, and the latter part of the chapter describes potential impacts to other environmental resources.

16.2 AIR EMISSIONS ANALYSIS

A primary focus of the environmental analysis is the impact on air emissions of amended energy conservation standards for residential heating products. The outcomes of the environmental analysis are largely driven by changes in power plant types and quantities of electricity generated under each of the alternatives. Changes in generation are described in the utility impact analysis in chapter 13.

16.2.1 Air Emissions Descriptions

For each of the TSLs, DOE calculated total power-sector emissions based on output from the NEMS-BT model (see chapter 13 for description of the model). This analysis considers three pollutants: sulfur dioxide (SO₂), nitrogen oxides (NO_x), and mercury (Hg). An air pollutant is any substance in the air that can cause harm to humans or the environment. Pollutants may be natural or man-made (i.e., anthropogenic) and may take the form of solid particles (i.e., particulates or particulate matter), liquid droplets, or gases.^a This analysis also considers carbon dioxide (CO₂).

Sulfur Dioxide. Sulfur dioxide, or SO₂, belongs to the family of sulfur oxide gases (SO_x). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including

^a More information on air pollution characteristics and regulations is available on the U.S. Environment Protection Agent (EPA)'s website at www.epa.gov.

crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SO_x gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore. SO₂ dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.¹

DOE has determined that SO₂ emissions from affected Electric Generating Units (EGUs) are subject to nationwide and regional emissions cap and trading programs that create uncertainty about the standards' impact on SO₂ emissions. Title IV of the Clean Air Act sets an annual emissions cap on SO₂ for all affected EGUs. SO₂ emissions from 28 eastern States and the District of Columbia (D.C.) are also limited under the Clean Air Interstate Rule (CAIR), published in the *Federal Register* on May 12, 2005. 70 FR 25162 (May 12, 2005), which creates an allowance-based trading program that will gradually replace the Title IV program in those States and D.C. (The recent legal history surrounding CAIR is discussed below.) The attainment of the emissions caps is flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO₂ emission allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO₂ emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emission allowances, there would be an overall reduction in SO₂ emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO₂ emissions covered by the existing cap and trade system, the NEMS-BT modeling system that DOE plans to use to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO₂.

Even if there is no significant reduction in the overall emissions of SO₂ that results from the standard, there may still be some economic benefit from reduced demand for SO₂ emission allowances that is not fully reflected in the cost savings experienced by individual consumers. Electricity savings that decrease the overall demand for SO₂ emissions allowances could lower allowance prices and thereby result in some economic benefits for all electricity consumers, not just those that reduced their electricity use as a result of an efficiency standard. DOE does not plan to monetize this particular benefit because the effect on the SO₂ allowance price from any single energy conservation standard is likely to be small and highly uncertain.

Nitrogen Oxides. Nitrogen oxides, or NO_x, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO₂), along with particles in the air can often be seen as a reddish-brown layer over many urban areas. NO₂ is the specific form of NO_x reported in this document. NO_x is one of the main ingredients involved in the formation of ground-level ozone, which can trigger serious respiratory problems. It can contribute to the formation of acid rain, and can impair visibility in areas such as national parks. NO_x also contributes to the formation of fine particles that can impair human health.¹

Nitrogen oxides form when fossil fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_x are motor vehicles, electric utilities, and other

industrial, commercial, and residential sources that burn fossil fuels. NO_x can also be formed naturally. Electric utilities account for about 22 percent of NO_x emissions in the United States.²

Mercury. Coal-fired power plants emit mercury (Hg) found in coal during the burning process. While coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States, they contribute very little to the global Hg pool or to contamination of U.S. waters.¹ U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is then deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory.³

Carbon Dioxide. Carbon dioxide (CO₂) is not a criteria pollutant (see below), but it is of interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun's radiation inside the Earth's atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, CO₂, methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). Human activities, however, add to the levels of most of these naturally occurring gases. For example, CO₂ is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2007, over 90 percent of anthropogenic (i.e., human-made) CO₂ emissions resulted from burning fossil fuels.⁴

Concentrations of CO₂ in the atmosphere are naturally regulated by numerous processes, collectively known as the "carbon cycle." The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic CO₂ emissions produced each year, billions of metric tons are added to the atmosphere annually. In the United States, in 2007, CO₂ emissions from electricity generation accounted for 39 percent of total U.S. GHG emissions.⁴

Particulate Matter. Particulate matter (PM) also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

PM impacts are of concern due to human exposures that can impact health. Particle pollution - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including:

increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.

Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct PM emissions. Meanwhile other pollutants such as SO₂ and NO_x interact with other elements in the atmosphere to produce PM at some distance from the power plant.

In general, the relative impacts of direct PM emissions reduction compared to other pollutants on PM exposures are much more difficult to estimate than other emissions reductions. This is due to the complex interactions between PM, other power plant emissions, meteorology and atmospheric chemistry that impact human exposure to particulates. Human exposure to PM usually occurs at a significant distance from the power plants that are emitting particulates and particulate precursors. When power plant emissions travel this distance they undergo highly complex atmospheric chemical reactions and the proportion of impacts and exposures attributable to different emissions can vary dramatically for different emissions sources and types of particulate precursors. These variations in emissions impacts depend on the distance to the source, land use and land cover, and the local and regional meteorology responsible for pollutant transport, deposition and atmospheric chemistry.

The Environmental Protection Agency (EPA) has compiled and summarized technical studies regarding PM source apportionment.⁵ In this compilation of studies, sources are classified into seven categories: (1) Secondary sulfate/coal, (2) Secondary organic matter/mobile sources, (3) Nitrate dominated sources, (4) Biomass burning, (5) Industrial, (6) Crustal and salt (7) Other. In these studies, the PM exposures attributed to coal power plants are not disaggregated between direct particulate emissions and SO₂ emissions from these power plants. This is because both SO₂ and direct PM emissions aggregate and interact with water droplets and emissions from other sources to create final particulates that are a complex mixture of different constituents. Both the SO₂ and direct PM are emitted from the power plant at the same time and if the final aerosol particle contains both sulfur compounds and other PM components it is not possible to attribute that aerosol particle to one source or the other. Therefore, DOE is not currently able to perform modeling that can make reliable estimates of the impact of direct PM emissions on air quality at this time.

16.2.2 Air Quality Regulation

The Clean Air Act Amendments of 1990 list 188 toxic air pollutants that EPA is required to control.⁶ EPA has set national air quality standards for six common pollutants (also referred to as “criteria” pollutants), two of which are SO₂ and NO_x. Also, the Clean Air Act Amendments of 1990 gave EPA the authority to control acidification and to require operators of electric power plants to reduce emissions of SO₂ and NO_x. Title IV of the 1990 amendments established a cap-and-trade program for SO₂ intended to help control acid rain.⁶ This cap-and-trade program serves as a model for more recent programs with similar features.

In 2005, EPA issued the Clean Air Interstate Rule (CAIR) under sections 110 and 111 of the Clean Air Act (40 CFR Parts 51, 96, and 97).^{7 b} CAIR will permanently cap emissions of SO₂ and NO_x in eastern States of the United States. CAIR achieves large reductions of SO₂ and/or NO_x emissions across 28 eastern States and the District of Columbia. States must achieve the required emission reductions using one of two compliance options: 1) meet an emission budget for each regulated state by requiring power plants to participate in an EPA-administered interstate cap-and-trade system that caps emissions in two stages, or 2) meet an individual state emissions budget through measures of the state's choosing. Phase 1 caps for NO_x have been in place since 2009. Phase 1 caps for SO₂ are to be in place beginning in 2010. The Phase 2 caps for both NO_x and SO₂ are due in 2015.

Also in 2005, EPA issued the final rule entitled "Standards of Performance for New and Existing Stationary Sources: Electric Steam Generating Units," under sections 110 and 111 of the Clean Air Act (40 CFR Parts 60, 63, 72, and 75)⁸. This rule, called the Clean Air Mercury Rule (CAMR), was closely related to the CAIR and established standards of performance for Hg emissions from new and existing coal-fired electric utility steam generating units. The CAMR regulated Hg emissions from coal-fired power plants.

On February 8, 2008, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) issued its decision in State of New Jersey, et al. v. Environmental Protection Agency,^c in which the Court, among other actions, vacated the CAMR referenced above.

On July 11, 2008, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) issued its decision in North Carolina v. Environmental Protection Agency, which vacated the CAIR issued by the U.S. Environmental Protection Agency on March 10, 2005.^d CAIR was the vehicle for capping NO_x emissions.^e On December 23, 2008, the D.C. Circuit decided to allow CAIR to remain in effect until it is replaced by a rule consistent with the court's earlier opinion. North Carolina v. EPA, 550 F.3d 1176 (D.C. Cir. 2008) (remand of vacatur).^f

16.2.3 Global Climate Change

Climate change has evolved into a matter of global concern because it is expected to have widespread, adverse effects on natural resources and systems. A growing body of evidence points to anthropogenic sources of greenhouse gases, such as carbon dioxide (CO₂), as major contributors to climate change. Because this Rule, if finalized, will likely decrease CO₂ emission rates from the fossil fuel sector in the United States, the Department here examines the impacts

^b See <http://www.epa.gov/cleanairinterstaterule/>.

^c 517 F.3d 574, 583 (D.C. Cir. 2008).

^d See <http://www.epa.gov/cleanairinterstaterule/>.

^e *See id.* at 903.

^f *State of North Carolina, et al. v. Environmental Protection Agency*, 550 F.3d 1176 (D.C. Cir. 2008).

and causes of climate change and then the potential impact of the Rule on CO₂ emissions and global warming.

Impacts of Climate Change on the Environment. Climate is usually defined as the average weather, over a period ranging from months to many years. Climate change refers to a change in the state of the climate, which is identifiable through changes in the mean and/or the variability of its properties (e.g., temperature or precipitation) over an extended period, typically decades or longer.⁹

The World Meteorological Organization and United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about climate change. According to the IPCC Fourth Assessment Report (IPCC Report), published in 2007, climate change is consistent with observed changes to the world's natural systems; the IPCC expects these changes to continue.⁹

Changes that are consistent with warming include warming of the world's oceans to a depth of 3000 meters; global average sea level rise at an average rate of 1.8 mm per year from 1961 to 2003; loss of annual average Arctic sea ice at a rate of 2.7 percent per decade, changes in wind patterns that affect extra-tropical storm tracks and temperature patterns, increases in intense precipitation in some parts of the world, as well as increased drought and more frequent heat waves in many locations worldwide, and numerous ecological changes.⁹

Looking forward, the IPCC describes continued global warming of about 0.2 °C per decade for the next two decades under a wide range of emission scenarios for carbon dioxide (CO₂), other greenhouse gases (GHGs), and aerosols. After that period, the rate of increase is less certain. The IPCC Report describes increases in average global temperatures of about 1.1 °C to 6.4 °C at the end of the century relative to today. These increases vary depending on the model and emissions scenarios.⁹

The IPCC Report describes incremental impacts associated with the rise in temperature. At ranges of incremental increases to the global average temperature, IPCC reports, with either high or very high confidence, that there is likely to be an increasing degree of impacts such as coral reef bleaching, loss of wildlife habitat, loss to specific ecosystems, and negative yield impacts for major cereal crops in the tropics, but also projects that there likely will be some beneficial impacts on crop yields in temperate regions.

Causes of Climate Change. The IPCC Report states that the world has warmed by about 0.74 °C in the last 100 years. The IPCC Report finds that most of the temperature increase since the mid-20th century is very likely due to the increase in anthropogenic concentrations of CO₂ and other long-lived greenhouse gases such as methane and nitrous oxide in the atmosphere, rather than from natural causes.

Increasing the CO₂ concentration partially blocks the earth's re-radiation of captured solar energy in the infrared band, inhibits the radiant cooling of the earth, and thereby alters the energy balance of the planet, which gradually increases its average temperature. The IPCC

Report estimates that currently, CO₂ makes up about 77 percent of the total CO₂-equivalent^g global warming potential in GHGs emitted from human activities, with the vast majority (74 percent) of the CO₂ attributable to fossil fuel use.¹⁰ For the future, the IPCC Report describes a wide range of GHG emissions scenarios, but under each scenario CO₂ would continue to comprise above 70 percent of the total global warming potential.¹⁰

Stabilization of CO₂ Concentrations. Unlike many traditional air pollutants, CO₂ mixes thoroughly in the entire atmosphere and is long-lived. The residence time of CO₂ in the atmosphere is long compared to the emission processes. Therefore, the global cumulative emissions of CO₂ over long periods determine CO₂ concentrations because it takes hundreds of years for natural processes to remove the CO₂. Globally, 49 billion metric tons of CO₂–equivalent of anthropogenic (man-made) greenhouse gases are emitted every year. Of this annual total, fossil fuels contribute about 29 billion metric tons of CO₂.^{11 h}

Researchers have focused on considering atmospheric CO₂ concentrations that likely will result in some level of global climate stabilization, and the emission rates associated with achieving the “stabilizing” concentrations by particular dates. They associate these stabilized CO₂ concentrations with temperature increases that plateau in a defined range. For example, at the low end, the IPCC Report scenarios target CO₂ stabilized concentrations range between 350 ppm and 400 ppm (essentially today’s value)—because of climate inertia, concentrations in this low-end range would still result in temperatures projected to increase 2.0 °C to 2.4 °C above pre-industrial levelsⁱ (about 1.3 °C to 1.7 °C above today’s levels). To achieve concentrations between 350 ppm to 400 ppm, the IPCC scenarios present that there would have to be a rapid downward trend in total annual global emissions of greenhouse gases to levels that are 50 to 85 percent below today’s annual emission rates by no later than 2050. Since it is assumed that there would continue to be growth in global population and substantial increases in economic production, the scenarios identify required reductions in greenhouse gas emissions intensity (emissions per unit of output) of more than 90 percent. However, even at these rates, the scenarios describe some warming and some climate change is projected due to already accumulated CO₂ and GHGs in the atmosphere.¹²

The Beneficial Impact of the Rule on CO₂ Emissions. It is anticipated that the Rule will reduce energy-related CO₂ emissions, particularly those associated with energy consumption in buildings. The U.S. Energy Information Administration (EIA) reports in its 2009 Annual Energy Outlook (*AEO2009*)¹³ that U.S. annual energy-related emissions of CO₂ in 2006 were about 6.0 billion metric tons, of which 1.2 billion tons were attributed to the residential buildings sector

^g GHGs differ in their warming influence (radiative forcing) on a global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO₂, i.e., CO₂-equivalent. CO₂ equivalent emission is the amount of CO₂ emission that would cause the same- time integrated radiative forcing, over a given time horizon, as an emitted amount of other long- lived GHG or mixture of GHGs.

^h Other non-fossil fuel contributors include CO₂ emissions from deforestation and decay from agriculture biomass; agricultural and industrial emissions of methane; and emissions of nitrous oxide and fluorocarbons.

ⁱ IPCC Working Group 3 Table TS 2

(including related energy-using products such as residential heating products). Most of the greenhouse gas emissions attributed to residential buildings are emitted from fossil fuel-fired power plants that generate electricity used in this sector. In the *AEO2009* Reference Case, EIA projected that annual energy-related CO₂ emissions would grow from 5.7 billion metric tons in 2010 to 6.2 billion metric tons in 2030, an increase of 8 percent (see *AEO2009*), while residential emissions would grow to from 1.2 billion metric tons to 1.3 billion metric tons, an increase of 5 percent.

The estimated cumulative CO₂ emission reductions from a residential heating product efficiency standard (shown as a range of alternative TSLs) during this same 30-year period are indicated in Table 16.2.1. Estimated CO₂ emission reductions in Table 16.2.1 come from two sources: electricity generation (i.e., power plants) and fossil fuel-fired appliances. The estimated CO₂ emission reductions from electricity generation are calculated using the NEMS-BT model. The estimated CO₂ emission reductions from fossil fuel-fired appliances (i.e., gas heating products) are derived from emissions factors for residential natural gas combustion.

Table 16.2.1 Impact of Residential Heating Products Efficiency Standards on Cumulative Energy-Related Emissions of CO₂ between 2015 and 2045 (Million Metric Tons of CO₂)

	Trial Standard Levels							
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6	TSL 7	TSL8
Water Heaters*	-74.30	-121.67	-130.54	-137.25	-154.2	-209.5	-608.8	-1,001
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6		
Direct Heating Equipment*	-8.25	-8.84	-9.31	-17.95	-20.24	-49.94		
Pool Heaters*	-0.41	-0.75	-1.72	-2.38	-3.61	-8.89		
Total*	-82.96	-131.3	-141.6	-157.6	-178.0	-268.3		
Percent of Total Cumulative Emissions Reduction compared with the <i>AEO2009</i> Reference Case in 2015-2045	-0.108	-0.171	-0.184	-0.205	-0.231	-0.349		

* All results in million metric tons, equivalent to 1.1 short tons; negative values refer to a reduction compared with the base case.

The Incremental Impact of the Rule on Climate Change. It is difficult to correlate specific emission rates with atmospheric concentrations of CO₂ and specific atmospheric concentrations with future temperatures because the IPCC Report describes a clear lag in the climate system between any given concentration of CO₂ (even if maintained for long periods) and the subsequent average worldwide and regional temperature, precipitation, and extreme weather regimes. For example, a major determinant of climate response is “equilibrium climate sensitivity”, a measure of the climate system response to sustained radioactive forcing. It is defined as the global average surface warming following a doubling of carbon dioxide

concentrations. The IPCC Report describes its estimated, numeric value as about 3 °C, but the likely range of that value is 2 °C to 4.5 °C, with cloud feedbacks the largest source of uncertainty. Further, as illustrated above, the IPCC Report scenarios for stabilization rates are presented in terms of a range of concentrations, which then correlates to a range of temperature changes. Thus, climate sensitivity is a key uncertainty for CO₂ mitigation scenarios that aim to meet specific temperature levels.

Because of how complex global climate systems are, it is difficult to know to what extent and when particular CO₂ emissions reductions will impact global warming. However, as Table 16.2.1 indicates, the rule is expected to reduce CO₂ emissions associated with energy consumption in buildings.

16.2.4 Analytical Methods for Air Emissions

NEMS-BT incorporates capabilities to assess compliance with SO₂ restrictions specified in the Clean Air Act and its amendments. Clean Air Act provisions include New Source Performance Standards, and Revised New Source Performance Standards. The version of NEMS-BT in 2008 included provisions for the CAIR, which imposes stricter restrictions on SO₂ and NO_x for some states, and the CAMR, which imposed a national Hg constraint. As discussed earlier in section 16.2.2, on December 23, 2008, the D.C. Circuit decided to allow CAIR to remain in effect until it is replaced by a rule consistent with the court's earlier opinion. Carolina v. Environmental Protection Agency, 550 F.3d 1176 (D.C. Cir. 2008) (remand of vacatur). But , EPA has not promulgated a rule to replace CAMR, which the D.C. Circuit vacated in 2008 . Thus, the version of NEMS-BT used in this analysis does not include provisions for the CAMR.

Coal-fired electric generation is the single largest source of electricity in the United States. Because the mix of coals used significantly affects the emissions produced, the model includes a detailed representation of coal supply. The model considers the rank of the coal as well as the sulfur contents of the fuel used when determining optimal dispatch.¹⁴

Within the NEMS-BT model, planning options for achieving emissions restrictions in the Clean Air Act Amendments include installing pollution control equipment on existing power plants and building new power plants with low emission rates. These methods for reducing emission are compared to dispatching options such as fuel switching and allowance trading. Environmental regulations also affect capacity expansion decisions. For instance, new plants are not allocated SO₂ emissions allowances according to the Clean Air Act Amendments. Consequently, the decision to build a particular capacity type must consider the cost (if any) of obtaining sufficient allowances. This could involve purchasing allowances or over complying at an existing unit.

DOE's analysis assumed the presence of nationwide emission caps on SO₂ and caps on NO_x emissions in the 28 States covered by the CAIR. The NEMS-BT modeling system that DOE plans to use to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO₂. However, remaining uncertainty prevents DOE from estimating or reporting SO₂ reductions from energy conservation standards at this time. It

should be noted that the standards could put slight downward pressure on the prices of emissions allowances in cap-and-trade markets.

In contrast to the modeling forecasts of NEMS-BT that SO₂ emissions reductions will remain at the cap, during the years 2007 and 2008, SO₂ emissions have been below the trading cap. The difference between the emissions levels that NEMS-BT forecasts and those that EPA forecasts is an indicator of the uncertainties associated with long-range energy sector forecasts. Because of such uncertainties, DOE is unable to estimate the economic and physical benefit from SO₂ emissions reductions at this time.

As noted in chapter 13, NEMS-BT model forecasts end in year 2030. Emissions impacts beyond 2030 were assumed to be equal to the impacts in 2030.

16.2.5 Effects on Power Plant Emissions

Table 16.2.2 shows *AEO2009* reference case power plant emissions in selected years. The Reference Case emissions are the emissions shown by the NEMS-BT model to result if none of the TSLs are promulgated (the base case).

Table 16.2.2 Power Sector Emissions Forecast from *AEO2009* Reference Case

NEMS-BT Results*	2005	2010	2015	2020	2025	2030
CO ₂ (Million metric tons/year)**	2,397	2,343	2,381	2,466	2,535	2,636
NO _x (Million metric tons/year) [†]	3.30	2.08	1.87	1.88	1.88	1.91
Hg (metric tons/year) [†]	51.5	43.8	29.5	28.9	29.3	28.7

* All results in metric tons, equivalent to 1.1 short tons and negative values refer to a reduction compared with the Base Case

** Comparable to Table A17 of *AEO2009*: Electric Generators

[†] Comparable to Table A8 of *AEO2009*: Emissions

Table 16.2.3 through Table 16.2.5 show the estimated changes in power plant emissions in selected years for each of the TSLs. Changes in CO₂, NO_x, and Hg emissions from power plants are shown in these tables.

Table 16.2.3 Power Sector Emissions Impact Forecasts for Water Heaters

NEMS-BT Results*	Difference from AEO2009 Reference Case							
	2015	2020	2025	2030	Extapolation			Total
					2035	2040	2044	2015-2045
Standard Level 1								
CO ₂ (Mt/a)	-0.112	-0.804	-1.368	-1.474	-1.474	-1.474	-1.474	-37.2
NO _x (kt/a)	-0.088	-0.612	-1.013	-1.065	-1.065	-1.065	-1.065	-27.3
Hg (t/a)	0.000	0.000	-0.003	0.002	0.002	0.002	0.002	-0.056
Standard Level 2								
CO ₂ (Mt/a)	-0.182	-1.294	-2.195	-2.359	-2.359	-2.359	-2.359	-59.6
NO _x (kt/a)	-0.143	-0.985	-1.626	-1.705	-1.705	-1.705	-1.705	-43.7
Hg (t/a)	0.000	0.000	-0.005	0.003	0.003	0.003	0.003	-0.090
Standard Level 3								
CO ₂ (Mt/a)	-0.207	-1.479	-2.512	-2.699	-2.699	-2.699	-2.699	-68.2
NO _x (kt/a)	-0.163	-1.126	-1.861	-1.951	-1.951	-1.951	-1.951	-50.0
Hg (t/a)	0.000	0.000	-0.006	0.004	0.004	0.004	0.004	-0.103
Standard Level 4								
CO ₂ (Mt/a)	-0.227	-1.624	-2.760	-2.965	-2.965	-2.965	-2.965	-74.9
NO _x (kt/a)	-0.178	-1.237	-2.044	-2.143	-2.143	-2.143	-2.143	-54.9
Hg (t/a)	0.000	0.000	-0.007	0.004	0.004	0.004	0.004	-0.113
Standard Level 5								
CO ₂ (Mt/a)	0.985	-2.026	-4.192	-4.769	-4.769	-4.769	-4.769	-111
NO _x (kt/a)	0.773	-1.543	-3.105	-3.447	-3.447	-3.447	-3.447	-81.0
Hg (t/a)	-0.010	-0.016	-0.026	-0.009	-0.009	-0.009	-0.009	-0.553
Standard Level 6								
CO ₂ (Mt/a)	1.27	-2.59	-5.34	-6.07	-6.07	-6.07	-6.07	-141
NO _x (kt/a)	0.99	-1.97	-3.96	-4.39	-4.39	-4.39	-4.39	-103
Hg (t/a)	-0.013	-0.020	-0.033	-0.012	-0.012	-0.012	-0.012	-0.704
Standard Level 7								
CO ₂ (Mt/a)	4.08	-8.46	-17.60	-20.10	-20.10	-20.10	-20.10	-467
NO _x (kt/a)	3.20	-6.44	-13.04	-14.53	-14.53	-14.53	-14.53	-341
Hg (t/a)	-0.042	-0.067	-0.110	-0.039	-0.039	-0.039	-0.039	-2.32
Standard Level 8								
CO ₂ (Mt/a)	6.38	-13.13	-27.21	-31.01	-31.01	-31.01	-31.01	-721
NO _x (kt/a)	5.00	-10.00	-20.16	-22.41	-22.41	-22.41	-22.41	-526
Hg (t/a)	-0.066	-0.103	-0.171	-0.061	-0.061	-0.061	-0.061	-3.59

*All results in metric tons (t), equivalent to 1.1 short tons

Table 16.2.4 Power Sector Emissions Impact Forecasts for Direct Heating Equipment

NEMS-BT Results*	Difference from AEO2009 Reference Case									
	2013	2014	2015	2020	2025	2030	Extapolation			Total
							2035	2040	2042	2013-2043
Standard Level 1										
CO ₂ (Mt/a)	0.003	0.024	0.024	0.043	0.107	0.139	0.139	0.139	0.139	2.93
NO _x (kt/a)	0.003	0.021	0.019	0.033	0.080	0.100	0.100	0.100	0.100	2.15
Hg (t/a)	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.012
Standard Level 2										
CO ₂ (Mt/a)	0.004	0.026	0.026	0.046	0.116	0.149	0.149	0.149	0.149	3.15
NO _x (kt/a)	0.003	0.023	0.020	0.035	0.086	0.108	0.108	0.108	0.108	2.31
Hg (t/a)	0.002	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.013
Standard Level 3										
CO ₂ (Mt/a)	0.004	0.028	0.027	0.049	0.122	0.158	0.158	0.158	0.158	3.32
NO _x (kt/a)	0.003	0.024	0.022	0.037	0.090	0.114	0.114	0.114	0.114	2.43
Hg (t/a)	0.002	-0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.014
Standard Level 4										
CO ₂ (Mt/a)	0.005	0.054	0.065	0.090	0.263	0.329	0.329	0.329	0.329	6.84
NO _x (kt/a)	0.004	0.047	0.051	0.069	0.195	0.237	0.237	0.237	0.237	5.01
Hg (t/a)	0.003	-0.001	0.000	0.000	-0.004	0.001	0.001	0.001	0.001	-0.029
Standard Level 5										
CO ₂ (Mt/a)	0.005	0.061	0.074	0.102	0.297	0.369	0.369	0.369	0.369	7.69
NO _x (kt/a)	0.005	0.053	0.058	0.078	0.220	0.267	0.267	0.267	0.267	5.63
Hg (t/a)	0.003	-0.001	0.000	0.000	-0.005	0.002	0.002	0.002	0.002	-0.033
Standard Level 6										
CO ₂ (Mt/a)	0.013	0.155	0.188	0.260	0.754	0.939	0.939	0.939	0.939	19.6
NO _x (kt/a)	0.012	0.134	0.148	0.198	0.559	0.679	0.679	0.679	0.679	14.3
Hg (t/a)	0.008	-0.003	0.000	0.000	-0.012	0.004	0.004	0.004	0.004	-0.084

*All results in metric tons (t), equivalent to 1.1 short tons

Table 16.2.5 Power Sector Emissions Impact Forecasts for Pool Heaters

NEMS-BT Results*	Difference from AEO2009 Reference Case								
	2013	2015	2020	2025	2030	Extapolation			Total
						2035	2040	2042	2013-2043
Standard Level 1									
CO ₂ (Mt/a)	0.000	0.001	0.003	0.005	0.006	0.006	0.006	0.006	0.133
NO _x (kt/a)	0.000	0.001	0.002	0.004	0.005	0.005	0.005	0.005	0.098
Hg (t/a)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standard Level 2									
CO ₂ (Mt/a)	0.000	0.002	0.005	0.009	0.011	0.011	0.011	0.011	0.241
NO _x (kt/a)	0.000	0.002	0.003	0.007	0.008	0.008	0.008	0.008	0.177
Hg (t/a)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
Standard Level 3									
CO ₂ (Mt/a)	0.000	0.005	0.010	0.020	0.025	0.025	0.025	0.025	0.540
NO _x (kt/a)	0.000	0.004	0.008	0.015	0.018	0.018	0.018	0.018	0.396
Hg (t/a)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
Standard Level 4									
CO ₂ (Mt/a)	0.000	0.006	0.009	0.020	0.027	0.027	0.027	0.027	0.570
NO _x (kt/a)	0.000	0.005	0.007	0.015	0.019	0.019	0.019	0.019	0.418
Hg (t/a)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standard Level 5									
CO ₂ (Mt/a)	0.000	0.009	0.014	0.031	0.041	0.041	0.041	0.041	0.869
NO _x (kt/a)	0.000	0.007	0.010	0.023	0.029	0.029	0.029	0.029	0.636
Hg (t/a)	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000
Standard Level 6									
CO ₂ (Mt/a)	0.001	0.023	0.034	0.077	0.101	0.101	0.101	0.101	2.16
NO _x (kt/a)	0.001	0.018	0.026	0.057	0.073	0.073	0.073	0.073	1.58
Hg (t/a)	0.001	0.001	0.000	-0.001	0.002	0.002	0.002	0.002	-0.001

*All results in metric tons (t), equivalent to 1.1 short tons

16.2.6 Effects on Site Emissions

For residential heating products, DOE also accounts for impacts from household emissions at the site (i.e., the residential building). NEMS-BT does not account for these emissions at the site. The estimates given here are based on exogenous emissions factors for residential natural gas combustion derived by the EPA’s AP-42 report, in conjunction with the site energy savings predicted by the national impacts analysis (NIA) model.¹⁵

The emissions factors DOE used are derived from what is reported in the AP-42 for residential water heaters because no explicit listing was provided for the other heating products. Given that emissions rates from end-use combustion are small compared to other emissions

sources, it is not uncommon to see emissions factors from residential end uses reported in one general rate.¹⁶ For these reasons, the Department opted to simply use the water heating emissions factor for all of the heating products. It acknowledges that these estimates are only general approximations.

Tables 16.2.6 through 16.2.8 show the estimated changes in site emissions in selected years for each of the water heater, direct heating equipment, and pool heater TSLs.

Table 16.2.6 Change in Site Emissions for Water Heaters

NEMS-BT Results*								
	2015	2020	2025	2030	Extrapolation			Total
					2035	2040	2044	2015-2045
Standard Level 1								
CO ₂ (Mt/a)	-0.128	-0.759	-1.285	-1.547	-1.547	-1.547	-1.547	-37.10
NO _x (kt/a)	-0.105	-0.619	-1.047	-1.261	-1.261	-1.261	-1.261	-30.25
Hg (t/a)	-0.004	-0.027	-0.045	-0.053	-0.053	-0.053	-0.053	-1.27
Standard Level 2								
CO ₂ (Mt/a)	-0.217	-1.277	-2.152	-2.582	-2.582	-2.582	-2.582	-62.04
NO _x (kt/a)	-0.177	-1.041	-1.755	-2.106	-2.106	-2.106	-2.106	-50.58
Hg (t/a)	-0.008	-0.048	-0.081	-0.096	-0.096	-0.096	-0.096	-2.32
Standard Level 3								
CO ₂ (Mt/a)	-0.218	-1.283	-2.162	-2.594	-2.594	-2.594	-2.594	-62.32
NO _x (kt/a)	-0.178	-1.046	-1.763	-2.115	-2.115	-2.115	-2.115	-50.81
Hg (t/a)	-0.011	-0.067	-0.112	-0.132	-0.132	-0.132	-0.132	-3.20
Standard Level 4								
CO ₂ (Mt/a)	-0.218	-1.283	-2.162	-2.594	-2.594	-2.594	-2.594	-62.32
NO _x (kt/a)	-0.178	-1.046	-1.763	-2.115	-2.115	-2.115	-2.115	-50.81
Hg (t/a)	-0.011	-0.067	-0.112	-0.132	-0.132	-0.132	-0.132	-3.20
Standard Level 5								
CO ₂ (Mt/a)	-0.150	-0.887	-1.498	-1.802	-1.802	-1.802	-1.802	-43.24
NO _x (kt/a)	-0.123	-0.723	-1.221	-1.469	-1.469	-1.469	-1.469	-35.25
SO ₂ (kt/a)	-0.011	-0.063	-0.106	-0.125	-0.125	-0.125	-0.125	-3.02
Standard Level 6								
CO ₂ (Mt/a)	-0.239	-1.406	-2.367	-2.838	-2.838	-2.838	-2.838	-68.20
NO _x (kt/a)	-0.195	-1.146	-1.929	-2.314	-2.314	-2.314	-2.314	-55.60
SO ₂ (kt/a)	-0.011	-0.068	-0.114	-0.135	-0.135	-0.135	-0.135	-3.25
Standard Level 7								
CO ₂ (Mt/a)	-0.473	-2.839	-4.866	-5.950	-5.950	-5.950	-5.950	-141.79
NO _x (kt/a)	-0.386	-2.315	-3.968	-4.852	-4.852	-4.852	-4.852	-115.61
SO ₂ (kt/a)	-0.014	-0.081	-0.137	-0.163	-0.163	-0.163	-0.163	-3.92
Standard Level 8								
CO ₂ (Mt/a)	-0.972	-5.738	-9.693	-11.662	-11.662	-11.662	-11.662	-279.84
NO _x (kt/a)	-0.793	-4.679	-7.904	-9.509	-9.509	-9.509	-9.509	-228.18
SO ₂ (kt/a)	-0.027	-0.159	-0.268	-0.318	-0.318	-0.318	-0.318	-7.66

*All results in metric tons (t), equivalent to 1.1 short tons

Table 16.2.7 Change in Site Emissions from Direct Heating Equipment

NEMS-BT Results*									
	2013	2015	2020	2025	2030	Extrapolation			Total
						2035	2040	2042	2013-2043
Standard Level 1									
CO ₂ (Mt/a)	-0.04	-0.11	-0.28	-0.43	-0.47	-0.47	-0.47	-0.47	-11.18
NO _x (kt/a)	-0.03	-0.09	-0.24	-0.38	-0.41	-0.41	-0.41	-0.41	-9.68
SO ₂ (kt/a)	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.31
Standard Level 2									
CO ₂ (Mt/a)	-0.038	-0.114	-0.301	-0.466	-0.507	-0.507	-0.507	-0.507	-11.986
NO _x (kt/a)	-0.033	-0.098	-0.260	-0.403	-0.439	-0.439	-0.439	-0.439	-10.362
SO ₂ (kt/a)	-0.001	-0.003	-0.008	-0.013	-0.014	-0.014	-0.014	-0.014	-0.325
Standard Level 3									
CO ₂ (Mt/a)	-0.040	-0.120	-0.317	-0.491	-0.535	-0.535	-0.535	-0.535	-12.631
NO _x (kt/a)	-0.035	-0.103	-0.274	-0.424	-0.462	-0.462	-0.462	-0.462	-10.909
SO ₂ (kt/a)	-0.001	-0.003	-0.009	-0.013	-0.014	-0.014	-0.014	-0.014	-0.339
Standard Level 4									
CO ₂ (Mt/a)	-0.079	-0.234	-0.622	-0.964	-1.050	-1.050	-1.050	-1.050	-24.785
NO _x (kt/a)	-0.068	-0.203	-0.538	-0.834	-0.908	-0.908	-0.908	-0.908	-21.436
SO ₂ (kt/a)	-0.002	-0.006	-0.017	-0.026	-0.029	-0.029	-0.029	-0.029	-0.676
Standard Level 5									
CO ₂ (Mt/a)	-0.090	-0.267	-0.705	-1.089	-1.180	-1.180	-1.180	-1.180	-27.932
NO _x (kt/a)	-0.078	-0.232	-0.612	-0.945	-1.024	-1.024	-1.024	-1.024	-24.247
SO ₂ (kt/a)	-0.003	-0.008	-0.020	-0.031	-0.034	-0.034	-0.034	-0.034	-0.795
Standard Level 6									
CO ₂ (Mt/a)	-0.222	-0.661	-1.751	-2.708	-2.939	-2.939	-2.939	-2.939	-69.519
NO _x (kt/a)	-0.193	-0.574	-1.519	-2.349	-2.550	-2.550	-2.550	-2.550	-60.308
SO ₂ (kt/a)	-0.006	-0.019	-0.050	-0.077	-0.083	-0.083	-0.083	-0.083	-1.964

*All results in metric tons (t), equivalent to 1.1 short tons

Table 16.2.8 Change in Site Emissions from Pool Heaters

NEMS-BT Results*									
	2013	2015	2020	2025	2030	Extrapolation			Total
						2035	2040	2042	2013-2043
Standard Level 1									
CO ₂ (Mt/a)	-0.002	-0.006	-0.016	-0.021	-0.022	-0.02	-0.02	-0.02	-0.55
NO _x (kt/a)	-0.002	-0.005	-0.014	-0.018	-0.019	-0.02	-0.02	-0.02	-0.47
SO ₂ (kt/a)	0.000	0.000	0.000	0.000	-0.001	0.00	0.00	0.00	-0.01
Standard Level 2									
CO ₂ (Mt/a)	-0.003	-0.011	-0.030	-0.038	-0.040	-0.040	-0.040	-0.040	-0.991
NO _x (kt/a)	-0.003	-0.010	-0.025	-0.033	-0.034	-0.034	-0.034	-0.034	-0.845
SO ₂ (kt/a)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.023
Standard Level 3									
CO ₂ (Mt/a)	-0.007	-0.026	-0.068	-0.087	-0.091	-0.091	-0.091	-0.091	-2.263
NO _x (kt/a)	-0.006	-0.022	-0.058	-0.074	-0.078	-0.078	-0.078	-0.078	-1.930
SO ₂ (kt/a)	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.052
Standard Level 4									
CO ₂ (Mt/a)	-0.010	-0.034	-0.088	-0.114	-0.119	-0.119	-0.119	-0.119	-2.952
NO _x (kt/a)	-0.008	-0.029	-0.075	-0.097	-0.102	-0.102	-0.102	-0.102	-2.517
SO ₂ (kt/a)	0.000	-0.001	-0.002	-0.003	-0.003	-0.003	-0.003	-0.003	-0.067
Standard Level 5									
CO ₂ (Mt/a)	-0.015	-0.051	-0.134	-0.172	-0.180	-0.180	-0.180	-0.180	-4.474
NO _x (kt/a)	-0.013	-0.044	-0.114	-0.147	-0.154	-0.154	-0.154	-0.154	-3.815
SO ₂ (kt/a)	0.000	-0.001	-0.003	-0.004	-0.004	-0.004	-0.004	-0.004	-0.102
Standard Level 6									
CO ₂ (Mt/a)	-0.036	-0.127	-0.330	-0.425	-0.446	-0.446	-0.446	-0.446	-11.047
NO _x (kt/a)	-0.031	-0.108	-0.282	-0.362	-0.380	-0.380	-0.380	-0.380	-9.419
SO ₂ (kt/a)	-0.001	-0.003	-0.008	-0.010	-0.010	-0.010	-0.010	-0.010	-0.252

*All results in metric tons (t), equivalent to 1.1 short tons

16.2.7 Effects on Upstream Fuel-Cycle Emissions

Upstream fuel-cycle emissions refer to the emissions associated with the amount of energy used in the upstream production and downstream consumption of electricity, including energy used at the power plant.¹⁷ Upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. The NEMS-BT does a thorough accounting of emissions at the power plant due to downstream energy consumption, but does not account for upstream emissions (i.e., emissions from energy losses during coal and natural gas production). Thus, this analysis reports only power plant emissions.

However, previous DOE environmental assessment documents have developed approximate estimates of effects on upstream fuel-cycle emissions. These emissions factors provide the reader with a sense of the possible magnitude of upstream effects. These upstream emissions would be in addition to emissions from direct combustion.

Relative to the entire fuel cycle, estimates based on the work of Dr. Mark DeLuchi, and reported in earlier DOE environmental assessment documents, find that an amount approximately equal to eight percent, by mass, of emissions (including SO₂) from coal production are due to mining, preparation that includes cleaning the coal, and transportation from the mine to the power plant.¹⁸ Transportation emissions include emissions from the fuel used by the mode of transportation that moves the coal from the mine to the power plant. In addition, based on Dr. DeLuchi's work, DOE estimated that an amount equal to approximately 14 percent of emissions from natural gas production result from upstream processes.

Emission factor estimates and corresponding percentages of contributions of upstream emissions from coal and natural gas production, relative to power plant emissions, are shown in Table 16.2.9 for CO₂ and NO_x. The percentages provide a means to estimate upstream emission savings based on changes in emissions from power plants. This approach does not address Hg emissions.

Table 16.2.9 Estimated Upstream Emissions of Air Pollutants as a Percentage of Direct Power Plant Combustion Emissions

Pollutant	Percent of Coal Combustion Emissions	Percent of Natural Gas Combustion Emissions
CO ₂	2.7	11.9
NO _x	5.8	40

16.3 SOCIAL COST OF CARBON DIOXIDE EMISSIONS

Under Executive Order 12866, agencies are required, to the extent permitted by law, “to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” The purpose of the Social Cost of Carbon (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO₂) emissions into cost-benefit analyses of regulatory actions that have small, or “marginal,” impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. Appendix 16-A presents the interagency report “Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866,” which provides further information.

Table 16.3.1 Social Cost of CO₂, 2010 – 2050 (in 2007 dollars)

Year	Discount Rate			
	5%	3%	2.5%	3%
	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

16.3.1 Monetizing Carbon Dioxide Emissions

The “social cost of carbon” (SCC) is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the social cost of carbon are provided in dollars per metric ton of carbon dioxide.^j

^j In this document, DOE presents all values of the SCC as the cost per metric ton of CO₂ emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO₂ and the mass of carbon is 3.67 (the molecular weight of CO₂ divided by the molecular weight of carbon = 44/12 = 3.67).

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (*Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. National Academies Press, 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Under Executive Order 12866, agencies are required, to the extent permitted by law, “to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or “marginal,” impacts on cumulative global emissions. Most federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socio-economic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO₂ in 2015 and \$26 per ton of CO₂ in 2020. See Appendix A of this chapter for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

16.3.2 Social Cost of Carbon Values Used in Past Regulatory Analyses

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a “domestic” SCC value of \$2 per ton of CO₂ and a “global” SCC value of \$33 per ton of CO₂ for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at \$80 per ton of CO₂. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of \$7 per ton CO₂ (in 2006 dollars) for 2011 emission reductions (with a range of \$0-\$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton CO₂ for 2007 emission reductions (in 2007 dollars). In addition, EPA’s 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as “very preliminary” SCC estimates subject to revision. EPA’s global mean values were \$68 and \$40 per ton CO₂ for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO₂ emissions. The interagency group did not undertake

any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of \$55, \$33, \$19, \$10, and \$5 per ton of CO₂. The \$33 and \$5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The \$55 and \$10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The \$19 value was chosen as a central value between the \$5 and \$33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO₂ tailpipe emission proposed rules.

16.3.3 Approach and Key Assumptions

Since the release of the interim values, interagency group reconvened on a regular basis to generate improved SCC estimates considered for this final rule. Specifically, the group considered public comments and further explored the technical literature in relevant fields.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. There are a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

In summary, in considering the potential global benefits resulting from reduced CO₂ emissions, DOE used the most recent values identified by the interagency process, adjusted to 2009\$ using the standard GDP deflator values for 2008 and 2009. For each of the four cases

specified, the values for emissions in 2010 used were approximately \$5, \$22, \$36, and \$67 per metric ton avoided (values expressed in 2009\$). To monetize the CO₂ emissions reductions expected to result from amended standards for small electric motors in 2015–2045, DOE used the values identified in Table A1 of the “Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866,” which is reprinted as Appendix A to this chapter, appropriately escalated to 2009\$.

16.4 WETLAND, ENDANGERED AND THREATENED SPECIES, AND CULTURAL RESOURCES

Because residential heating products are not water-consuming products, more efficient heating would not reduce the amount of water discharged into the waste stream. As a result, heating product energy conservation standards do not have the effect of improving the quality of wetlands, nor threatened or endangered species that reside in these wetlands. This action is also not expected to impact cultural resources such as historical or archaeological sites.

16.5 SOCIOECONOMIC IMPACTS

DOE's analysis has shown that the increase in the first cost of purchasing more efficient water heaters, direct heating equipment, and pool heaters at the standard levels is completely offset by a reduction in the life-cycle cost (LCC) of owning a more efficient product for the average consumer. In other words, the consumer will pay less operating costs over the life of the product even through the first cost increases. The complete LCC analysis and its conclusions are presented in chapter 8 of the TSD.

For subgroups of low-income and senior consumers that purchase heating products, DOE determined that the average LCC impact of the standards is similar to that for the full sample of consumers. Therefore, DOE concludes that the action would have no significant adverse socioeconomic impact. For a complete discussion on the LCC impacts on consumer subgroups, see chapter 11 of the TSD.

16.6 ENVIRONMENTAL JUSTICE IMPACTS

In view of Executive Order 12898 of February 11, 1994, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” DOE examined the effect of the energy conservation standards on low-income households. As described in the LCC subgroup analysis in Chapter 11 of the TSD, DOE found that there were no disproportionately high and adverse human health or environmental effects on low-income populations that would result from the energy conservation standards.

16.7 NOISE AND AESTHETICS

Improvements in efficiency of heating products are expected to result from changes in the choice of components and other design features. These changes are described in chapter 5 of this TSD. These design changes are not expected to change noise levels in comparison to products in today's market. Products that are currently manufactured in the existing market that would meet the standards are no louder than less efficient products. Changes to the design to improve the efficiency levels are not anticipated to affect the product aesthetics.

16.8 SUMMARY OF ENVIRONMENTAL IMPACTS

Tables 16.8.1 through 16.8.3 summarize the estimated environmental impacts for each of the TSLs. The summary tables show cumulative changes in emissions for CO₂, NO_x, and Hg for 2015 to 2045 for water heaters and from 2013 to 2043 for direct heating equipment and pool heaters.

For direct heating equipment and pool heaters, cumulative CO₂, NO_x, and Hg emissions from the power sector show a slight increase under some TSLs compared to the Reference case. This result is primarily due to an increase in electricity use at the considered TSLs. The more-efficient DHE products and pool heaters save natural gas, but they also use more electricity due to electronic ignition and, for some DHE TSLs, use of a fan (see section 7.3.6 and section 7.4.4 in chapter 7). This results in higher electricity generation than in the Reference case, which leads to higher emissions. For CO₂ and NO_x, the higher emissions from the power sector are more than canceled out by lower household emissions from gas combustion, such that total emissions decrease under the considered TSLs. For Hg, this is not the case because there are no offsetting household emissions.

Upstream fuel cycle emission of CO₂ and NO_x are described but not quantified in section 16.2.7. The text describes potential reductions in fuel cycle emissions as percentage of decreases in power plant emissions. This approach suggests that upstream fuel cycle emissions would decrease and provides a sense for the magnitude of effects; however DOE does not report actual estimates of the effects.

For subgroups of low-income and senior consumers that purchase heating products, DOE determined that the average LCC impact of the standards is similar to that for the full sample of consumers. Therefore, DOE concludes that the action would have no significant adverse socioeconomic impact.

No impacts are anticipated in the areas of environmental justice, wetlands, endangered and threatened species, and cultural resources; or noise and aesthetics.

Table 16.8.1 Environmental Impact Analysis Results Summary for Water Heaters

Environmental Effects	Reference Case*	Trial Standard Level							
		1	2	3	4	5	6	7	8
Cumulative Total Emission Reductions**									
CO ₂ (million metric tons)	76,950	74.30	121.67	130.54	137.25	154.2	209.5	608.8	1,001
NO _x (thousand tons)	56,763	57.51	94.27	100.79	105.71	116.2	158.7	456.5	754.5
Hg (tons)	866	0.056	0.090	0.103	0.113	0.553	0.704	2.32	3.58
Cumulative Power Sector Emission Reductions**									
CO ₂ (million metric tons)	76,950	37.20	59.63	68.22	74.94	111.0	141.3	467.0	721.1
NO _x (thousand tons)	56,763	27.25	43.69	49.99	54.90	80.99	103.1	340.8	526.4
Hg (tons)	866	0.056	0.090	0.103	0.113	0.553	0.704	2.32	3.59
Cumulative Household Emission Reductions**									
CO ₂ (million metric tons)	-	37.10	62.04	62.32	62.32	43.24	68.20	141.8	279.8
NO _x (thousand tons)	-	30.25	50.58	50.81	50.81	35.25	55.60	115.6	228.2

* The reference case reflects total cumulative emissions (power sector only) in the absence of an amended energy conservation standard.

** Cumulative total is over 2015 to 2045 for water heaters.

Table 16.8.2 Environmental Impact Analysis Results Summary for Direct Heating Equipment

Environmental Effects	Reference Case*	Trial Standard Level					
		1	2	3	4	5	6
Cumulative Total Emission Reductions**							
CO ₂ (million metric tons)	76,445	8.25	8.84	9.31	17.95	20.24	49.94
NO _x (thousand tons)	57,080	7.53	8.06	8.47	16.43	18.62	45.98
Hg (tons)	895	(0.012)	(0.013)	(0.014)	0.029	0.033	0.084
Cumulative Power Sector Emission Reductions**							
CO ₂ (million metric tons)	76,445	(2.93)	(3.15)	(3.32)	(6.84)	(7.69)	(19.57)
NO _x (thousand tons)/	57,080	(2.15)	(2.31)	(2.43)	(5.01)	(5.63)	(14.33)
Hg (tons)	895	(0.012)	(0.013)	(0.014)	0.029	0.033	0.084
Cumulative Household Emission Reductions**							
CO ₂ (million metric tons)	-	11.18	11.99	12.63	24.79	27.93	69.52
NO _x (thousand tons)	-	9.68	10.36	10.91	21.44	24.25	60.31

* The reference case reflects total cumulative emissions (power sector only) in the absence of an amended energy conservation standard.

** Cumulative total is over 2013 to 2043 for direct heating equipment. Values in parentheses refer to emissions increase.

Table 16.8.3 Environmental Impact Analysis Results Summary for Pool Heaters

Environmental Effects	Reference Case*	Trial Standard Level					
		1	2	3	4	5	6
Cumulative Total Emission Reductions**							
CO ₂ (Million metric tons)	76,445	0.42	0.75	1.72	2.38	3.61	8.89
NO _x (Thousand tons)	57,080	0.37	0.67	1.53	2.10	3.18	7.84
Hg (tons)	895	0.000	0.001	0.001	0.000	0.000	0.001
Cumulative Power Sector Emission Reductions**							
CO ₂ (Million metric tons)	76,445	(0.13)	(0.24)	(0.54)	(0.57)	(0.87)	(2.16)
NO _x (Thousand tons)	57,080	(0.10)	(0.18)	(0.40)	(0.42)	(0.64)	(1.58)
Hg (tons)	895	0.000	0.001	0.001	0.000	0.000	0.001
Cumulative Household Emission Reductions**							
CO ₂ (Million metric tons)	-	0.55	0.99	2.26	2.95	4.47	11.05
NO _x (Thousand tons)	-	0.47	0.85	1.93	2.52	3.82	9.42

* The reference case reflects total cumulative emissions (power sector only) in the absence of an amended energy conservation standard.

** Cumulative total is over 2013 to 2043 for pool heaters. Values in parentheses refer to emissions increase.

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