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ENVIRONMENTAL ASSESSMENT FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR RESIDENTIAL CENTRAL AIR CONDITIONERS AND HEAT PUMPS

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ENVIRONMENTAL ASSESSMENT FOR RESIDENTIAL CENTRAL AIR CONDITIONERS AND HEAT PUMPS

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ABBREVIATIONS AND ACRONYMS

Act or EPCA: Part B of Title III of the Energy Policy and Conservation Act, Public Law 94-163, as amended by the National Energy Conservation Policy Act, Public Law 95-619, the National Appliance Energy Conservation Act, Public Law 100-12, the National Appliance Energy Conservation Amendments of 1988, Public Law 100-357, and the Energy Policy Act of 1992, Public Law 102-486

AEO: *Annual Energy Outlook*, DOE/EIA publication

BRS: DOE's Building Research and Standards office

Btu: British thermal unit

C: carbon

DOE: Department of Energy

EA: Environmental Assessment

EIA: Energy Information Administration

EJ: exajoule (10^{18} joules)

EPCA: Energy Policy and Conservation Act

GJ: gigajoule (10^{9} joules)

GW: gigawatt (10^{9} watts)

HSPF: Heating Seasonal Performance Factor

kt/a: thousand metric tons per year

kWh: kilowatt-hour

LCC: Life-Cycle Cost

Mt/a: millions of metric tons per year

NAECA: National Appliance Energy Conservation Act

NEMS: National Energy Modeling System

NEPA: National Environmental Policy Act of 1969

NES: National Energy Savings

NOPR: Notice of Proposed Rulemaking

NO_x: nitrogen oxides

PBP: Payback period

Quad: quadrillion Btu (10^{15} Btus)

RIA: Regulatory Impact Analysis

SEER: Seasonal Energy Efficiency Ratio

SO_2: sulfur dioxide

t: metric ton

TSL: Trial Standard Level

TSD: Technical Support Document

TWh: terawatt-hour

U.S.C.: United States Code

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) prepared this central air conditioner and heat pump environmental assessment (EA) pursuant to the National Environmental Policy Act of 1969 (NEPA)(42 U.S.C. 4321 et seq.), the regulations of the Council on Environmental Quality (40 CFR parts 1500-1508), and the Department of Energy's regulations for compliance with NEPA (10 CFR part 1021).

On September 8, 1993, DOE published an Advance Notice of Proposed Rulemaking (ANOPR) announcing the Department's intention to revise the existing central air conditioner and heat pump efficiency standard. 58 FR 47326. On November 24, 1999, DOE published a Supplemental ANOPR (hereinafter referred to as the Supplemental ANOPR). 64 FR 66306. On October 5, 2000, DOE published a Notice of Proposed Rulemaking (NOPR or proposed rule) for energy efficiency standards. 65 FR 59590. For the NOPR, we analyzed the energy savings, benefits and burdens of amended energy conservation standards for residential central air conditioners and central air conditioning heat pumps (heat pumps) and shared the results of these analyses with all stakeholders. The Department proposed an energy conservation standard for residential central air conditioners and heat pumps at Trial Standard Level (TSL) 3. The Department conducted a public hearing on November 16, 2000 and based on review of oral and written comments the Department in its Final Rule decided to adopt TSL 4 rather than TSL 3 as an energy conservation standard for residential central air conditioners and heat pumps. The seasonal energy efficiency ratings for this and other TSLs reviewed is found in Section 3.3 below.

DOE adopted the residential central air conditioner and heat pump conservation standard pursuant to Part B of Title III of the Energy Policy and Conservation Act, Public Law (P.L.) 94-163, as amended by the National Energy Conservation Policy Act, P.L. 95-619, by the National Appliance Energy Conservation Act, P.L. 100-12, by the National Appliance Energy Conservation Amendments of 1988, P.L. 100-357, and the Energy Policy Act of 1992, P.L. 102-486[a] (the Act or EPCA), which created the Energy Conservation Program for Consumer Products other than Automobiles.

The proposed cental air conditioner and heat pump efficiency standard affects consumers and manufacturers of residential central air conditioners and heat pumps.

2.0 PURPOSE AND NEED

The Energy Policy and Conservation Act, as amended, specifies that the Department must

[a] Part B of Title III of the Energy Policy and Conservation Act, as amended by the National Energy Conservation Policy Act, the National Appliance Energy Conservation Act, the National Appliance Energy Conservation Amendments of 1988, and the Energy Policy Act of 1992, is referred to in this notice as the "Act." Part B of Title III is codified at 42 U.S.C. 6291 et seq. Part B of Title III of the Energy Policy and Conservation Act, as amended by the National Energy Conservation Policy Act only, is referred to in this notice as the National Energy Conservation Policy Act.

consider, for new or amended conservation standards, those standards that "achieve the maximum improvement in energy efficiency which the Secretary determines is technologically feasible and economically justified" and which will "result in significant conservation of energy." Accordingly, DOE's proposed rule would amend the energy conservation standard for residential central air conditioners and heat pumps.

Consistent with this requirement, DOE's purpose in the proposed action is to reduce the consumption of energy used by central air conditioners and heat pumps in the United States. DOE's discretion is in deciding the level for a minimum efficiency standard, not if there should be one.

A DOE central air conditioner and heat pump standard results in electrical energy being saved through an improvement in the efficiency of these units. The metric used to measure the cooling efficiency of central air conditioners and the cooling-performance of heat pumps is called the Seasonal Energy Efficiency Ratio (SEER). The metric used to measure the heating efficiency of heat pumps is called the Heating Seasonal Performance Factor (HSPF). An increase in the SEER or HSPF indicates that the central air conditioner or heat pump is more efficient. Details on the technical analysis of increased efficiency levels are provided in the Central Air Conditioner and Heat Pump Technical Support Document (TSD) that accompanies DOE's Notice of Proposed Rulemaking (NOPR) for the amended standard.[1]

In analyzing improvements in the efficiency of central air conditioners and heat pumps, five Trial Standard Levels (TSL) were created. The five TSLs consist of a combination of different SEER and HSPF levels applied to four different product classes. Of the five TSLs, DOE's Notice of Proposed Rulemaking (NOPR) proposed TSL 3 as a central air conditioner and heat pump standard, which consists of a 12 SEER standard for central air conditioners and a 13 SEER / 7.7 HSPF standard for heat pumps. However, in the Final Rule, DOE adopted TSL 4, which consists of a 13 SEER standard for central air conditioners and a 13 SEER / 7.7 HSPF for heat pumps.

3.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

3.1 No Action Alternative

Under this alternative DOE would not publish a new minimum energy efficiency standard for central air conditioners and heat pumps. By taking no action, DOE would be in violation of EPCA, which requires (1) DOE to determine whether to amend the statutory standard, and (2) that a minimum standard be set at a level that "shall be designed to achieve the maximum improvement in energy efficiency that the Secretary determines is technologically feasible and economically justified." EPCA, §325(d)(3)and (o)(2)(A), 42 U.S.C. §6295(d)(3) and (o)(2)(A). In addition to analyzing a baseline case in the TSD, a Draft Central Air Conditioner and Heat Pump Regulatory Impact Analysis (RIA) was published that examines the "no action" alternative as well as other non-mandatory efficiency standards or voluntary incentive programs. The RIA determined that the "no action" alternative would result in lower energy reductions than the proposed standard. If no action were taken, the minimum efficiency requirements would remain at their current levels: a cooling efficiency of 10 SEER for split system air conditioners and heat pumps, a cooling efficiency of 9.7 SEER for single package system air conditioners and heat pumps, a heating efficiency of 6.8 HSPF for split system heat pumps, and a heating efficiency of 6.6 HSPF for single package system heat pumps.

3.2 Proposed and Adopted Standard

The proposed standard (12 SEER standard for central air conditioners and a 13 SEER / 7.7 HSPF standard for heat pumps) as well as the adopted standard (13 SEER standard for central air conditioners and 13 SEER / 7.7 HSPF standard for heat pumps) would result in national energy savings, reduced average life-cycle costs to consumers, a likely net national benefit (i.e., monetary savings to the Nation are likely to exceed increased equipment costs to the Nation), and air-borne emissions reductions. Both the proposed and adopted standards would also result in a loss in manufacturer net present value and life-cycle cost increases for some consumers. In the NOPR and the Final Rule, DOE determined that the benefits of the proposed and adopted standards outweighed its burdens and is economically justified. DOE believes, for example, that even if the proposed or adopted standard were to result in relatively small negative national net present values (as predicted by some estimates), its benefits would outweigh its burdens. DOE concluded the proposed and adopted standards would save a significant amount of energy and is technologically feasible. The adopted standard goes into effect in the year 2006. Additional details on impacts due to the proposed and adopted standard and other trial standard levels (TSL) are provided in the Central Air Conditioner and Heat Pump TSD. The TSD is available on the DOE internet site at:
http://www.eren.doe.gov/buildings/codes_standards/applbrf/central_air_conditioner.html.

3.3 Alternative Standards

This EA presents the results of the environmental impacts from five residential central air conditioners and heat pumps efficiency standards. Each standard is an alternative action, and is compared against the no-action alternative. The no-action alternative, also referred to as the baseline case, consists of a cooling efficiency of 10 SEER for split system air conditioners and heat pumps, a cooling efficiency of 9.7 SEER for single package system air conditioners and heat pumps, a heating efficiency of 6.8 HSPF for split system heat pumps, and a heating efficiency of 6.6 HSPF for single package system heat pumps. Description of the each of the five TSL are provided below:

- **TSL 1**: 11 SEER for air conditioners and the cooling-performance of heat pumps and 7.1 HSPF for the heating-performance of heat pumps,
- **TSL 2**: 12 SEER for air conditioners and the cooling-performance of heat pumps and 7.4 HSPF for the heating-performance of heat pumps,
- **TSL 3**: 12 SEER for air conditioners and 13 SEER and 7.7 HSPF for the cooling- and heating-performances of heat pumps, respectively,
- **TSL 4**: 13 SEER for air conditioners and the cooling-performance of heat pumps and 7.7 HSPF for the heating-performance of heat pumps,

- **TSL 5**: 18 SEER for air conditioners and the cooling-performance of heat pumps and 8.8 HSPF for the heating-performance of heat pumps.

The justification for selecting the proposed standard, TSL 3, over the other trial standard levels considered is fully explained in Section VI.E, conclusions of the October 5, 2000, Federal Register Notice, page 59625.[2] The justification for adopting TSL 4 over TSL 3 is fully explained in Section V.E, conclusions of the Final Rule. The Federal Register notice and Final Rule are available on the internet at: http://www.eren.doe.gov/buildings/codes_standards/applbrf/central_air_conditioner.html under "Notice of Proposed Rulemaking"and "Final Rule."

3.4 Impacts of Proposed, Adopted, and Alternative Standards

The NOPR established that DOE determined that significant energy savings could be achieved through the adoption of an amended conservation standard for residential central air conditioners and heat pumps. DOE considers the impacts of standards beginning with the most efficient level. Table 1 includes a summary of the analysis results to aid the reader in the discussion of the benefits and burdens for the different trial standard levels. DOE proposed to set a residential central air conditioner and heat pump standard at TSL 3 but chose to adopt a residential central air conditioner and heat pump standard at TSL 4 which is felt to be technically feasible and economically justified. Additional information on the five trial standard levels is provided in Section 5 of this EA, Environmental Impacts of the Proposed Action

Table EA.1 Summary of the Analysis Results

Trial Standard Level	**5**	**4**	**3**	**2**	**1**
SEER	18	13	12 / 13[1]	12	11
Primary Energy Saved (Quads)[2]	8.6	4.2	3.4	2.9	1.5
Generation Capacity Offset (GW)[3]	28.8	15.5	12.4	10.6	6.5
Emissions					
Carbon Equivalent (Mt)[3]	63.0	32.7	27.7	23.8	13.2
NOx (kt)[3]	184.2	93.8	84.4	72.7	36.7

1 12 SEER for air conditioners and 13 SEER for heat pumps.
2 Based on reverse engineering manufacturing cost estimates, *AEO2000* Reference Case, and Roll-up Efficiency Scenario.
3 Based on reverse engineering manufacturing cost estimates, *AEO2000* Reference Case, and NAECA Efficiency Scenario with the exception of TSL 4 which is based on Roll-up Efficiency Scenario.

4.0 DESCRIPTION OF THE AFFECTED ENVIRONMENT

4.1 Geography

The central air conditioner and heat pump standard that DOE has adopted (TSL 4) would apply to all 50 states and United States territories.

4.2 Air Resources

The primary focus of the EA is the effect of proposed efficiency standards on air resources. For this analysis, the EA uses a variant of DOE, Energy Information Administration's (DOE/EIA) National Energy Modeling System (NEMS), called NEMS-BRS (BRS is DOE's Building Research and Standards office), plus some additional analysis not using NEMS -BRS.[b] The environmental analysis is similar to the utility sector analysis described in Chapter 11 of the Central Air Conditioner and Heat Pump TSD. Outputs of the environmental analysis are in a format similar to the results of the DOE/EIA's *Annual Energy Outlook 2000 (AEO2000)*.[3]

For each of the standard levels, DOE calculated total power sector emissions based on output from NEMS-BRS. The EA considers only two pollutants, nitrogen oxides (NO_x) and sulfur dioxide (SO_2), and one emission, carbon (C). Because emissions of SO_2 from power plants are capped by clean air legislation, physical emissions of this pollutant from electricity generation will be only minimally affected by possible air conditioner and heat pump standards. The maximum SO_2 allowed by law will most likely still be produced, but because SO_2 emissions are traded, and if SO_2 emissions are lowered due to less power generation, then the cost of SO_2 emission credits may decrease slightly. Therefore, the EA does not consider changes in power sector SO_2 emissions, although it does report household emissions savings. The only form of carbon tracked by NEMS-BRS is carbon dioxide (CO_2), so the carbon discussed in this analysis is only in the form of CO_2, but is reported as mass of elemental carbon, in keeping with standard practice.

4.2.1 Assumptions

The EA uses the same basic assumptions as *AEO2000*[c] and models the changes resulting from standards as variations from current policy. For example, the emissions characteristics of an electricity generating plant in the environmental analysis are the same as those used in *AEO2000*, although the fuel mix used for generation and the construction program for new plants may deviate slightly as a result of reduced generation requirements under the standard, which in turn affects air emission results. As with the utility impact analysis in Chapter 11 of the TSD, the environmental emissions effects are assumed to be linear in the range of the standards decrements and results are extrapolated.

The EA also includes a sensitivity analysis for the proposed standard level, using the High and Low Economic Growth scenarios of NEMS-BRS. As described in Chapter 11 of the TSD, these

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[b] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000), March 2000. DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data.

[C] The *Annual Energy Outlook* (AEO), a document produced yearly by DOE/EIA, forecasts emission outputs. As part of their analysis, they analyze sensitivities for assumptions of high and low economic growth for the nation. These assumptions of economic activity in turn produce differences in fuel use and fuel prices. The Reference Case refers to the emissions predicted in *AEO2000*, i.e., without a new residential central air conditioner and heat pump standard.

scenarios cover a range of macro-economic growth assumptions. In addition, separate sensitivities based on assumptions regarding future equipment efficiencies (i.e, *efficiency scenarios*) are analyzed. The default equipment efficiency assumption is called the NAECA *efficiency scenario*. Sensitivities are performed on both the proposed standard level (TSL3) and the adopted standard level (TSL 4) with two *efficiency scenarios*: the Roll-up and Shift *efficiency scenarios*. The *efficiency scenarios* have an effect on the magnitude of central air conditioner and heat pump shipments. Sensitivities were not done for all possible standard levels as they have been eliminated based on the results of the reference scenario. Chapter 7 of the TSD describes the *efficiency scenarios* in detail.

4.2.2 Methods

4.2.2.1 Carbon

A detailed carbon module tracks carbon emissions in NEMS-BRS. The Carbon Module provides good results because it covers all sectors of the economy and their interactions. NEMS-BRS itself does not account for potential carbon savings that result from upstream processes, as described in the fuel-cycle section below.

Past experience with NEMS-BRS carbon results from power generation suggests that using marginal emissions estimates are more accurate than emissions based on simple forecast average factors for analyzing proposed appliance standards. First, the marginal fuel displaced by reduced generation as a result of proposed and adopted standards tends to be natural gas, which releases less carbon emissions than coal. Second, lowered electricity demand tends to slow down the construction of power generation capacity, thereby slowing improvement in energy conversion efficiency and emissions rates that typically result from deployment of newer technology.

4.2.2.2 Power Sector NO_x

NEMS-BRS reports the two airborne pollutant emissions: NO_x and SO_2. Power sector NO_x results are based on forecasts of compliance with existing legislation and have proven stable and reasonable.

4.2.2.3 Power Sector SO_2

The Clean Air Act Amendments of 1990 set an SO_2 emissions cap on all power generation, but permits flexibility among generators through the use of emissions allowances and tradable permits. SO_2 trading tends to imply that physical emissions effects of a standard will be zero because emissions will always be at, or near, the ceiling. There is virtually no real possible SO_2 environmental benefit from electricity conservation as long as there is enforcement of the emissions ceiling. A slight economic benefit may result only if coal generation falls and the reduced demand for SO_2 emission allowances lowers the allowance price. Because the effects considered here are too small to deliver reasonable estimates, the EA does not consider this possibility.

4.2.2.4 Fuel-Cycle Emissions

NEMS-BRS does not account for upstream emissions from energy losses during coal and natural gas production. The upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. Appendix EA.1 shows upstream emissions factors for carbon, SO_2, and NO_x, along with the percentage of upstream emissions relative to power plants emissions. The Appendix also provides a detailed description of the methodology used to derive these estimates. Although DOE does not report actual estimates of the effects of standards on upstream emissions, the material in Appendix EA.1 provides the reader with a feel for the possible magnitude effects. According to the study by M.A. DeLuchi, approximately 8% of total coal fuel cycle carbon, NO_x, or SO_2 emissions are attributed to upstream coal production. The equivalent value for gas is 14%.

4.2.2.5 Interpolation

Because the size of the energy savings from standards are too small to produce stable power sector results in NEMS-BRS, it is necessary to estimate results in the range of the standard levels' effects using interpolation. Appendix EA.2 describes the interpolation methodology in detail. A series of cases is executed in which the residential central air conditioner and heat pump's electricity load is reduced at incrementally higher savings than the standards levels. Actual standard level savings are then derived from these outputs.

4.2.2.6 Extrapolation

The current time horizon of NEMS-BRS is 2020 (modeling a 15-year period, 2006-2020), yet other parts of the appliance energy-efficiency work reach 2030. As described in the utility analysis in Chapter 11 of the TSD, it is not feasible to extend the forecast period of NEMS-BRS for the purposes of this analysis, nor does EIA have an approved method for extrapolation of many outputs beyond 2020; therefore, to ensure consistency, all extrapolations beyond 2020 presented here are simple replications of year 2020 results. As with the *AEO2000* Reference Case in general, the implicit assumption is that the regulatory environment does not change from the current, known situation during the extrapolation period. Only changes that have been announced with date-certain introduction are included in NEMS-BRS. To emphasize the extrapolated results wherever they appear, they are shaded in grey to distinguish them from actual NEMS-BRS output.

4.3 Socioeconomics

As part of the rulemaking process, the socioeconomic effect on low-income consumers has been analyzed. Analysis included determining the differences in life-cycle cost as well as the payback periods for the standard levels analyzed. Chapter 10 of the TSD provides more details on the consumer analysis.

4.4 Environmental Justice

A consideration of Environmental Justice is made pursuant to the Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The Executive Order requires federal agencies to assess whether a proposed federal action causes any disproportionately high and adverse human health or environmental effects on low-income or minority populations. The proposed action causes no such adverse impacts.

4.5 Energy Consumption

Equipment cost data were obtained from two different sources: manufacturers provided cost data through the Air-Conditioning & Refrigeration Institute (ARI) and the Department conducted it own reverse-engineering cost analysis. Both sets of cost data are used as input to a National Energy Saving (NES)/Shipments spreadsheet model that forecasted shipments of central air conditioners and heat pumps to the year 2030 and determined the savings of energy consumption to the nation both annually and cumulatively. Chapter 4 of the TSD discusses in detail the cost data provided by manufacturers and the reverse-engineering data. Chapters 6 and 7 of the TSD provide more details on the national energy savings and shipments analyses.

A sophisticated NES/Shipments spreadsheet model was used to determine national energy savings as a result of increases in the minimum efficiency standard. This spreadsheet model forecasts the national shipments and energy use of central air conditioners and heat pumps with and without new standards. The NES and shipments analyses are described in detail in Chapters 6 and 7 of the TSD.

5.0 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

5.1 Air Quality/Emissions Impacts

5.1.1 Power Sector Emissions

Tables EA.2 and EA.3 show total power sector carbon and NO_x emissions for each of the five central air conditioner and heat pump standard trial standard levels. The results in Table EA.2 are based on manufacturing cost estimates determined from the reverse engineering analysis while the results in Table EA.3 are based on shipment-weighted mean estimates provided by ARI. Chapter 4 of the TSD provides a complete description of the reverse engineering and ARI mean manufacturing cost estimates.

The annual carbon emissions reductions range up to 6.8 Mt/a in 2020. NO_x emissions reductions reach up to 27.0 kt/a by 2015. Tables EA.4 and EA.5 list cumulative emissions savings for the power sector based on reverse engineering and ARI mean manufacturing cost estimates, respectively, over the 15-year period modeled for the central air conditioner and heat pump analyses.

Tables EA.6 and EA.7 show the results for the cumulative emissions reductions through 2030 for carbon and NOx based on reverse engineering and ARI mean manufacturing cost estimates, respectively.

All of the TSLs considered by DOE, including the proposed standard (TSL 3) and the adopted standard (TSL 4) are shown in Tables EA.2 through EA.7. In this analysis, the reference case refers to cases with respect to the AEO2000 Reference Case. All TSLs are compared to the reference case which represents the no action alternative. This is also referred to as the baseline case, a cooling efficiency of 10 SEER for split system air conditioners and heat pumps, a cooling efficiency of 9.7 SEER for single package system air conditioners and heat pumps, a heating efficiency of 6.8 HSPF for split system heat pumps, and a heating efficiency of 6.6 HSPF for single package system heat pumps.

Also note that in Tables EA.2 through EA.7 sensitivities based on assumptions regarding future equipment efficiencies (i.e, *efficiency scenarios*) are presented. The default equipment efficiency assumption is called the NAECA *efficiency scenario*. Sensitivities were performed on the adopted standard level with two *efficiency scenarios*: the Roll-up and Shift *efficiency scenarios*. The *efficiency scenarios* have an effect on the magnitude of central air conditioner and heat pump shipments. Chapter 7 of the TSD describes the *efficiency scenarios* in detail. The effect of the Roll-up *efficiency scenario* is to lower emission reductions while the effect of the Shift *efficiency scenario* is to increase emission reductions.

Also reported are equivalent results for the Low and High Economic Growth cases for the the adopted standard (TSL 4) in Tables EA.8 and EA.9. The results in Table EA.8 are based on reverse engineering manufacturing cost estimates while the results in Table EA.9 are based on ARI mean estimates. The cumulative effect of the Low and High Economic Growth cases and the alternative *efficiency scenarios* are also presented. The outcome of the analysis is shown as both total power sector emissions and deviations from the *AEO2000* result. Generally, the carbon savings for the Low Economic Growth cases are slightly lower than those reported for the comparable Reference Case standards scenario while the savings for the High Economic Growth cases are slightly higher than those reported for the Reference Case. The differences between the reference and sensitivity cases are due not only to changes in the macroeconomic assumptions of NEMS-BRS but also to variations in the assumptions used when calculating savings with the NES model.

Table EA.2 Power Sector Emissions for all Standards based on Reverse Engineering Manufacturing Cost Estimates

NEMS-BRS Results						Difference from AEO2000 Reference							
	2000	**2005**	**2010**	**2015**	**2020**		**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
AEO2000 Reference Case -- NO ACTION ALTERNATIVE												Extrapolation	
Carbon (Mt/a)[1,3]	589.4	645.5	681.0	725.9	757.8	Carbon (Mt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx (kt/a)[2,3]	4,563.1	4,989.5	5,134.7	5,325.2	5,379.6	NOx (kt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Level 1 (SEER 11)													
Carbon (Mt/a)	589.4	645.5	680.2	724.8	756.4	Carbon (Mt/a)	0.0	0.0	-0.8	-1.1	-1.4	-1.4	-1.4
NOx (kt/a)	4,563.1	4,989.5	5,129.3	5,320.3	5,381.4	NOx (kt/a)	0.0	0.0	-5.4	-4.9	1.8	1.8	1.8
Standard Level 2 (SEER 12)													
Carbon (Mt/a)	589.4	645.5	679.4	723.8	755.3	Carbon (Mt/a)	0.0	0.0	-1.6	-2.1	-2.5	-2.5	-2.5
NOx (kt/a)	4,563.1	4,989.5	5,123.4	5,316.3	5,381.9	NOx (kt/a)	0.0	0.0	-11.2	-8.9	2.3	2.3	2.3
Standard Level 3 (SEER 12/13) -- PROPOSED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.1	723.5	754.9	Carbon (Mt/a)	0.0	0.0	-1.9	-2.4	-2.9	-2.9	-2.9
NOx (kt/a)	4,563.1	4,989.5	5,121.6	5,314.8	5,382.3	NOx (kt/a)	0.0	0.0	-13.0	-10.3	2.7	2.7	2.7
Standard Level 4 (SEER 13) -- ADOPTED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.3	723.0	754.3	Carbon (Mt/a)	0.0	0.0	-1.7	-2.9	-3.5	-3.5	-3.5
NOx (kt/a)	4,563.1	4,989.5	5,124.8	5,313.4	5,383.0	NOx (kt/a)	0.0	0.0	-9.9	-11.8	3.4	3.4	3.4
Standard Level 5 (SEER 18)													
Carbon (Mt/a)	589.4	645.5	677.5	720.3	751.0	Carbon (Mt/a)	0.0	0.0	-3.5	-5.6	-6.8	-6.8	-6.8
NOx (kt/a)	4,563.1	4,989.5	5,111.9	5,298.2	5,388.5	NOx (kt/a)	0.0	0.0	-22.8	-27.0	8.9	8.9	8.9
Standard Level 4 Roll-Up (SEER 13) -- ADOPTED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.2	723.0	754.4	Carbon (Mt/a)	0.0	0.0	-1.8	-2.9	-3.4	-3.4	-3.4
NOx (kt/a)	4,563.1	4,989.5	5,124.3	5,314.4	5,383.0	NOx (kt/a)	0.0	0.0	-10.3	-10.8	3.4	3.4	3.4
Standard Level 4 Shift (SEER 13) -- ADOPTED STANDARD													
Carbon (Mt/a)	589.4	645.5	678.7	722.7	754.0	Carbon (Mt/a)	0.0	0.0	-2.3	-3.2	-3.8	-3.8	-3.8
NOx (kt/a)	4,563.1	4,989.5	5,119.2	5,311.2	5,384.7	NOx (kt/a)	0.0	0.0	-15.5	-14.0	5.1	5.1	5.1

[1] Comparable to Table A17 of AEO2000: Electric Generators

[2] Comparable to Table A8 of AEO2000: Emissions

[3] All results in metric tons (t), equivalent to 1.1 short tons

Table EA.3 Power Sector Emissions for all Standards based on ARI Mean Manufacturing Cost Estimates

NEMS-BRS Results	2000	2005	2010	2015	2020	Difference from AEO2000 Reference	2000	2005	2010	2015	2020	2025	2030
AEO2000 Reference Case -- NO ACTION ALTERNATIVE												Extrapolation	
Carbon (Mt/a)[1,3]	589.4	645.5	681.0	725.9	757.8	Carbon (Mt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx (kt/a)[2,3]	4,563.1	4,989.5	5,134.7	5,325.2	5,379.6	NOx (kt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Level 1 (SEER 11)													
Carbon (Mt/a)	589.4	645.5	680.2	724.7	756.4	Carbon (Mt/a)	0.0	0.0	-0.8	-1.2	-1.4	-1.4	-1.4
NOx (kt/a)	4,563.1	4,989.5	5,129.6	5,320.7	5,381.0	NOx (kt/a)	0.0	0.0	-5.0	-4.5	1.4	1.4	1.4
Standard Level 2 (SEER 12)													
Carbon (Mt/a)	589.4	645.5	679.3	723.9	755.4	Carbon (Mt/a)	0.0	0.0	-1.7	-2.0	-2.4	-2.4	-2.4
NOx (kt/a)	4,563.1	4,989.5	5,123.2	5,317.2	5,381.9	NOx (kt/a)	0.0	0.0	-11.4	-8.0	2.3	2.3	2.3
Standard Level 3 (SEER 12/13) -- PROPOSED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.0	723.5	755.0	Carbon (Mt/a)	0.0	0.0	-2.0	-2.4	-2.8	-2.8	-2.8
NOx (kt/a)	4,563.1	4,989.5	5,121.4	5,315.9	5,382.3	NOx (kt/a)	0.0	0.0	-13.3	-9.3	2.7	2.7	2.7
Standard Level 4 (SEER 13) -- ADOPTED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.1	722.9	754.3	Carbon (Mt/a)	0.0	0.0	-1.9	-3.0	-3.5	-3.5	-3.5
NOx (kt/a)	4,563.1	4,989.5	5,122.7	5,311.9	5,384.4	NOx (kt/a)	0.0	0.0	-12.0	-13.3	4.8	4.8	4.8
Standard Level 5 (SEER 18)													
Carbon (Mt/a)	589.4	645.5	677.2	720.1	751.2	Carbon (Mt/a)	0.0	0.0	-3.8	-5.8	-6.6	-6.6	-6.6
NOx (kt/a)	4,563.1	4,989.5	5,112.7	5,300.7	5,386.8	NOx (kt/a)	0.0	0.0	-22.0	-24.5	7.2	7.2	7.2
Standard Level 4 Roll-Up (SEER 13) -- ADOPTED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.4	723.2	754.4	Carbon (Mt/a)	0.0	0.0	-1.6	-2.7	-3.4	-3.4	-3.4
NOx (kt/a)	4,563.1	4,989.5	5,125.6	5,313.4	5,382.9	NOx (kt/a)	0.0	0.0	-9.0	-11.8	3.3	3.3	3.3
Standard Level 4 Shift (SEER 13) -- ADOPTED STANDARD													
Carbon (Mt/a)	589.4	645.5	679.4	722.7	754.1	Carbon (Mt/a)	0.0	0.0	-1.6	-3.2	-3.7	-3.7	-3.7
NOx (kt/a)	4,563.1	4,989.5	5,126.0	5,311.3	5,383.2	NOx (kt/a)	0.0	0.0	-8.7	-13.9	3.6	3.6	3.6

[1]Comparable to Table A17 of AEO2000: Electric Generators

[2]Comparable to Table A8 of AEO2000: Emissions

[3]All results in metric tons (t), equivalent to 1.1 short tons

Table EA.4 Cumulative Emissions Reductions through 2020 based on Reverse Engineering Manufacturing Cost Estimates: Power Sector

	Standard Level						
Emission	**1**	**2**	**3**	**4**	**5**	**4 (Roll-up)**	**4 (Shift)**
Carbon (Mt)	-13.2	-23.8	-27.7	-32.6	-63.0	-32.7	-36.0
NOx (kt)	-36.7	-72.7	-84.4	-85.8	-184.2	-93.8	-107.1

Table EA.5 Cumulative Emissions Reductions through 2030 based on Reverse Engineering Manufacturing Cost Estimates: Power Sector

	Standard Level						
Emission	**1**	**2**	**3**	**4**	**5**	**4 (Roll-up)**	**4 (Shift)**
Carbon (Mt)	-27.2	-48.9	-56.8	-67.3	-131.2	-67.1	-73.8
NOx (kt)	-18.5	-49.5	-57.6	-51.6	-95.0	-59.9	-56.4

Table EA.6 Cumulative Emissions Reductions through 2020 based on ARI Mean Manufacturing Cost Estimates: Power Sector

	Standard Level						
Emission	**1**	**2**	**3**	**4**	**5**	**4 (Roll-up)**	**4 (Shift)**
Carbon (Mt)	-13.4	-23.7	-27.4	-33.6	-63.7	-31.3	-34.9
NOx (kt)	-37.2	-67.9	-78.8	-102.5	-193.7	-87.5	-97.9

Table EA.7 Cumulative Emissions Reductions through 2030 based on ARI Mean Manufacturing Cost Estimates: Power Sector

	Standard Level						
Emission	**1**	**2**	**3**	**4**	**5**	**4 (Roll-up)**	**4 (Shift)**
Carbon (Mt)	-27.6	-48.1	-55.8	-68.7	-130.2	-65.1	-72.3
NOx (kt)	-23.0	-44.9	-52.0	-54.3	-121.7	-54.7	-61.9

Table EA.8 Power Sector Emissions based on Reverse Engineering Manufacturing Cost Estimates: Low and High Economic Growth

NEMS-BRS Results

	2000	2005	2010	2015	2020		2000	2005	2010	2015	2020	2025	2030
AEO2000 Lmac Reference Case						**Difference from Low Economic Growth**						Extrapolation	
Carbon (Mt/a)[1,3]	584.4	633.3	661.6	695.0	715.5	Carbon (Mt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx (kt/a)[2,3]	4,526.9	4,907.9	5,016.7	5,161.9	5,234.5	NOx (kt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Level 4 Low Economic Growth -- ADOPTED STANDARD													
Carbon (Mt/a)	584.4	633.3	659.5	693.1	712.5	Carbon (Mt/a)	0.0	0.0	-2.1	-1.9	-3.0	-3.0	-3.0
NOx (kt/a)	4,526.9	4,907.9	5,004.5	5,158.6	5,234.5	NOx (kt/a)	0.0	0.0	-12.3	-3.3	0.0	0.0	0.0
AEO2000 Hmac Reference Case						**Difference from High Economic Growth**							
Carbon (Mt/a)[1,3]	594.7	663.4	711.0	765.9	816.6	Carbon (Mt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx (kt/a)[2,3]	4,599.4	5,098.4	5,316.1	5,452.2	5,461.3	NOx (kt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Level 4 High Economic Growth -- ADOPTED STANDARD													
Carbon (Mt/a)	594.7	663.4	709.1	762.3	811.8	Carbon (Mt/a)	0.0	0.0	-1.9	-3.6	-4.8	-4.8	-4.8
NOx (kt/a)	4,599.4	5,098.4	5,303.3	5,444.4	5,467.6	NOx (kt/a)	0.0	0.0	-12.9	-7.8	6.3	6.3	6.3

[1]Comparable to Table A17 of AEO2000: Electric Generators

[2]Comparable to Table A8 of AEO2000: Emissions

[3]All results in metric tons (t), equivalent to 1.1 short tons

Table EA.9 Power Sector Emissions based on ARI Mean Manufacturing Cost Estimates: Low and High Economic Growth

NEMS-BRS Results

	2000	2005	2010	2015	2020		2000	2005	2010	2015	2020	2025	2030
AEO2000 Lmac Reference Case						**Difference from Low Economic Growth**						Extrapolation	
Carbon (Mt/a)1,3	584.4	633.3	661.6	695.0	715.5	Carbon (Mt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx (kt/a)2,3	4,526.9	4,907.9	5,016.7	5,161.9	5,234.5	NOx (kt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Level 4 Low Economic Growth													
Carbon (Mt/a)	584.4	633.3	659.9	693.1	712.6	Carbon (Mt/a)	0.0	0.0	-1.7	-1.9	-2.9	-2.9	-2.9
NOx (kt/a)	4,526.9	4,907.9	5,007.2	5,157.8	5,233.6	NOx (kt/a)	0.0	0.0	-9.5	-4.1	-0.9	-0.9	-0.9
AEO2000 Hmac Reference Case						**Difference from High Economic Growth**							
Carbon (Mt/a)1,3	594.7	663.4	711.0	765.9	816.6	Carbon (Mt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx (kt/a)2,3	4,599.4	5,098.4	5,316.1	5,452.2	5,461.3	NOx (kt/a)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Level 4 High Economic Growth													
Carbon (Mt/a)	594.7	663.4	708.9	762.2	811.7	Carbon (Mt/a)	0.0	0.0	-2.1	-3.7	-4.9	-4.9	-4.9
NOx (kt/a)	4,599.4	5,098.4	5,301.4	5,444.1	5,466.9	NOx (kt/a)	0.0	0.0	-14.7	-8.1	5.7	5.7	5.7

[1]Comparable to Table A17 of AEO2000: Electric Generators

[2]Comparable to Table A8 of AEO2000: Emissions

[3]All results in metric tons (t), equivalent to 1.1 short tons

5.1.2 Fuel-Cycle Emissions

The effects of standards on upstream emissions are not reported here. Please refer to Appendix EA.1 for a general description of the possible magnitude of these effects.

5.2 Wetlands / Endangered and Threatened Species / Cultural Resources

As this action is not a site-specific action, nor would it change land disturbance due to heat pump/air conditioner placement, impacts to these resources are not expected. Therefore, this action is not expected to impact the quality of wetlands, or threatened or endangered species. This action is not expected to impact cultural resources such as historical or archaeological sites.

5.3 Socioeconomic Impacts

Analysis has shown that the possible increase in the first cost of purchasing a more efficient central air conditioner or heat pump at both the proposed standard level and the adopted standard level are on average offset by a reduction in the life-cycle cost of owning a more efficient piece of equipment. Although the proposed standard may increase the initial cost, the proposed standard level results in either a significant decrease or an insignificant change in life-cycle cost (due to reduced energy costs) for 75% of split system air conditioner consumers, 94% of split system heat pump consumers, 91% of packaged system air conditioner consumers, and 88% of packaged system heat pump consumers. The adopted standard level results in either a significant decrease or an insiginificant change in life-cycle cost (due to reduced energy costs) for 61% of split system air conditioner consumers, 94% of split system heat pump consumers, 48% of packaged system air conditiner consumers, and 88% of packaged system heat pump consumers.[d] See Chapter 5 of the TSD for details.

5.4 Environmental Justice Impacts

Both the proposed action and the adopted action, new minimum efficiency standards for central air conditioners and heat pumps, would not cause any adverse environmental impacts, and therefore would not cause any disproportionately high and adverse human health or environmental impacts. Positive impacts, such as decreased air emissions, would be equally shared among all populations. However, the Department did conduct a consumer analysis that looked at economic impacts to low-income populations. For a complete discussion see Chapter 10 of the TSD on the internet at:
http://www.eren.doe.gov/buildings/codes_standards/applbrf/central_air_conditioner.html.

[d] For both the proposed and adopted standards, the percent of consumers with either a significant decrease or insignificant change in life-cycle cost are based on reverse engineering manufacturing cost estimates.

5.5 Energy Consumption Impacts

The proposed standard level of 12 SEER for air conditioners and 13 SEER / 7.7 HSPF for heat pumps (TSL 3) and the adopted standard level of 13 SEER for both air conditioners and heat pumps (TSL 4) would result in the national energy savings shown in Table EA.10. Energy savings for the other three standard levels (TSL 1, 2, and 5) are also provided.

Table EA.10 Cumulative Energy Savings from Standards

	Cumulative Energy Savings in Quads[1]				
from 2006	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
to 2010	0.09	0.18	0.21	0.27	0.51
to 2020	0.65	1.22	1.43	1.80	3.57
to 2030	1.51	2.86	3.35	4.22	8.55

[1] Energy Savings based on Reverse Engineering manufacturing costs, *AEO2000* Reference Case, and Roll-up Efficiency Scenario

5.6 Summary of Environmental Impacts

This EA provides information on the effects new central air conditioner and heat pump standards would have on pollutants and other emissions. Analysis of carbon and NO_x emissions from the power sector and households indicates that each of the Trial Standard Levels would have a positive impact on the environment. Cumulative power sector emissions reductions through 2020 for the TSLs range from 13.2 to 63.7 Mt for carbon and 36.7 to 193.7 kt for NO_x. Through 2030, the cumulative emissions reductions range from 27.2 to 131.2 Mt for carbon and 18.5 to 121.7 kt of NO_x.

The Department proposed to raise the energy efficiency standards for residential air conditioners and central air conditioning heat pumps (heat pumps) to 12 SEER for air conditioners and to 13 SEER/7.7 HSPF for heat pumps. However, the Department has adopted energy efficiency standards for residential central air conditioners and heat pumps of 13 SEER. The adopted standards would apply to all covered products offered for sale in the United States, effective on January 1, 2006.

The proposed standard for split system air conditioners, the most common type of residential air conditioning equipment represents a 20% improvement in energy efficiency. For split system heat pumps, the proposed standard represents a 30% improvement in cooling efficiency and a 13% improvement in heating efficiency. The proposed standard would also increase the efficiency of packaged air conditioners by 24% and increase the cooling and heating efficiencies of packaged heat pumps by 34% and 17%, respectively. The proposed standard would save a significant amount of energy and, as a result of less electricity being produced, result in a cleaner environment. If the proposed standard became effective, the nation would save over 3.4 Quads of primary energy, equivalent to all the energy consumed by nearly 18 million American households in a single year. These energy savings would also significantly reduce the emissions of air pollutants and greenhouse gases associated with electricity production, by avoiding the emission of 56 million tons (Mt) of Carbon and 57 thousand tons (kt) nitrogen oxides (NO_x). Also, the proposed standard would be expected to eliminate the need for the construction of approximately 31 (4 coal-fired and 27 natural gas-fired) new large 400 mega Watt (MW) power plants in 2020.

The adopted standard for split system air conditioners, the most common type of residential air conditioning equipment represents a 30% improvement in energy efficiency. For split system heat pumps, the new standards would represent a 30% improvement in cooling efficiency and a 13% improvement in heating efficiency. The adopted standard would also increase the efficiency of packaged air conditioners by 34% and increase the cooling and heating efficiencies of packaged heat pumps by 34% and 17%, respectively. The adopted standard would save an even greater amount of energy and, as a result of less electricity being produced, resulting in a cleaner environment. In the 25-year period after the new standard becomes effective, the nation would save approximately 4.2 Quads of primary energy, equivalent to all the energy consumed by nearly 26 million American households in a single year. These energy savings would even more significantly reduce the emissions of air pollutants and greenhouse gases associated with electricity production, by avoiding the emission of 67 Mt of Carbon and 52 kt nitrogen oxides (NO_x). Also, the new standards are expected to eliminate the need for the construction of approximately 39 (5 coal-fired and 34 natural gas-fired) new large 400 MW power plants in 2020.

APPENDIX EA.1: UPSTREAM EMISSION FACTORS FROM COAL AND NATURAL GAS PRODUCTION

Tracking of pollutant emissions by NEMS-BRS is incomplete, with thorough treatment of some aspects and scant treatment of others. The approach is also somewhat different between emissions. Overall, the coverage of carbon emissions is most complete because these are estimated based on elemental carbon released as CO_2 from hydrocarbon combustion in all sectors. This is in contrast to NO_x and SO_2 emissions, which are only counted in the power sector. However, even for carbon, some energy-use effects of proposed standards are not tracked by NEMS-BRS. For example, the effect of lower residential electricity consumption on generation is estimated, but not the second order effect on energy consumed in coal transportation to power plants. In general, the amount of energy used to perform the upstream processes in coal and petroleum production is not linked to the downstream consumption of these fuels.

Because NEMS-BRS tracks only NO_x and SO_2 emissions from power generation, other sources of these emissions that may be affected by proposed standards are therefore missed. Two notable sources of NO_x and SO_2 emissions not considered are household emissions from the combustion of natural gas, liquefied petroleum gas (LPG), and heating fuel oil and emissions associated with fuel extraction and delivery to the point of combustion.

In addition to carbon, this analysis considers two uncounted emissions from coal and natural gas production and delivery, SO_2 and NO_x. These emissions include those due to the mining of coal or extraction of natural gas, the physical processes involved in preparing or cleaning the fossil fuel, and the transportation of the fuel from the mine to the power plant.

Studies addressing upstream emissions are very limited. Thus, the reliability of the exact measurements can be easily criticized. The values presented here are only intended to provide a coarse estimate of the magnitude of upstream emissions not accounted for in NEMS-BRS. In general, emissions from mining, cleaning, or transporting fossil fuels are small compared to the emissions that result from their combustion.

Upstream emissions estimates for carbon and NO_x are taken from a thorough study conducted by M.A. DeLuchi at Argonne National Laboratory in 1993. DeLuchi provides estimates of full fuel-cycle emissions factors for emissions of CO_2, methane (CH_4), carbon monoxide (CO), non-methane organic compounds (NMOC), and NO_x from coal and natural gas production.[4] The emission factor for SO_2 is taken from the Environmental Protection Agency (EPA) AP-42.[5] This source notes that coal cleaning is the primary source for upstream SO_2 emissions from coal production, so the emission factor for SO_2 only reflects the coal cleaning process. Transportation is not addressed in EPA's study.

For this reason, changes in upstream emissions due to proposed standards are not counted in NEMS-BRS. The amount of energy used to transport natural gas to the end-use consumer is 3.5% of the total natural gas produced and made available to end-use customers as estimated for the year

2000. According to M.A. DeLuchi, the amount of energy used to mine and clean the coal is minimal, amounting to less than 1% of the energy available in the coal. The amount of energy required to transport the coal using trains, trucks, and pipelines is estimated to be approximately 0.156 EJ/yr (0.148 Quads/yr) in for the year 2020. Based on the *AEO2000* projected energy consumption of coal from electric generation, this corresponds to 0.7% of the total energy required by electric generators. For extraction of crude oil, the relative percentage is only 2.8%. For all of those fuels, the upstream losses are small relative to the total amount of energy embodied in the coal, oil, and natural gas and, therefore, changes due to proposed standards are also likely to be small. Natural gas is treated somewhat differently in NEMS-BRS than either coal or oil and its upstream emissions of carbon are counted for both extraction and pipeline losses.

Emission factor estimates and corresponding percentage contributions of the upstream emissions relative to power plant emissions are shown in Table EA-1.1 for carbon, SO_2, and NO_x from coal and natural gas production. The relative percentage to power plant emissions is provided so an estimate of upstream emission savings based on the savings from the power plant could be easily estimated. The values shown in Table EA-1.1 represent emissions from upstream processes as mass (g) per deliverable energy (GJ) to end-use consumers.

Table EA-1.1 Estimated Upstream Emission Factors and Relative Percentages To Direct Power Plant Combustion Emissions

	Coal		**Natural Gas**	
	Emission Factor (*g/GJ*)	**% of Combustion Emissions**	**Emission Factor (*g/GJ*)**	**% of Combustion Emissions**
Carbon	2222	2.7	5456	11.9
SO_2	29.2	0.9	0	0
NO_x	41.7	5.8	153	40

DeLuchi's analysis reveals that upstream processes in coal production relative to power plant emissions account for 5.8% of NO_x and 2.7% of carbon. The AP-42 indicates that less than 1% of SO_2 emissions result upstream relative to those from coal power plant emissions. Upstream coal processes, therefore, account for at most 6% of relative power plant emissions for carbon, SO_2, and NO_x.

For natural gas production, the upstream SO_2 emissions are negligible. The upstream emissions from NO_x, however, are quite significant, accounting for 40.0% of emissions relative to those from the power plant. This relative difference can be partially attributed to the fact that total natural gas combustion NO_x emissions from the power plant are only half those from coal, while emissions upstream processes are four times those of coal. Carbon emissions are nearly 12% of power plant emissions with an emission factor of 5456 g/GJ of deliverable energy; however, as noted, changes to these emissions are counted by NEMS-BRS.

Relative to the entire fuel cycle, DeLuchi estimates that approximately 8% by mass of all emissions from coal production are due to mining, preparation, and transport from the mine to the plant. Transportation emissions include those resulting from the use of fuel by the modes of transportation used to move the fuel from the site of extraction to fuel production facilities. For natural gas production, 14% of total emissions are estimated to result from upstream processes. Based on Table EA-1.1, this higher loss factor in natural gas production is likely due to the higher NO_x contribution.

Thus, emissions factors and their relation to power plant emissions are provided to reveal the relatively small proportion of energy losses attributable to upstream processes. With the exception of NO_x emissions from natural gas production, all emissions are less than 12% of power plant emissions.

APPENDIX EA.2: INTERPOLATION OF UTILITY AND ENVIRONMENTAL RESULTS FROM NEMS-BRS OUTPUT

The effects of proposed central air conditioner and heat pump energy-efficiency standards on the electricity and gas industries were analyzed using a variant of U.S. DOE/EIA's National Energy Modeling System (NEMS) called NEMS-BRS, together with some exogenous calculations.[e] Because the relative size of the energy savings being implemented in NEMS-BRS is too small to be seen in the context of the whole electricity and gas utility sector, NEMS-BRS is not used directly. Rather, exploratory runs are conducted to estimate marginal effects, which are then used to calculate the small effects due to each proposed trial standard level.

To run a simulation in NEMS-BRS, the residential central air conditioner and heat pump load is reduced annually according to the energy savings estimated by the National Energy Savings model (see Chapter 7 of this TSD) for each standard level. These electricity energy savings increase over time and differences in usage among U.S. census divisions come from data derived from the Residential Energy Consumption Survey (RECS).[6]

The magnitude of the energy decrement that would be required for NEMS-BRS to produce stable results safely out of the range of numerical noise is greater than even the most stringent standard under consideration. Therefore, it has been necessary, in both the utility and environmental analyses, to estimate results in the range of the standard levels effects using interpolation. Interpolated values are derived from a series of higher decrement simulations of the standard levels. The actual annual savings attributed to each standard level are compared between standard levels, and those with similar energy savings patterns over time are grouped together. One set of simulations is run for each of the savings groups. The standard levels for the central air conditioner and heat pump analysis were divided into four groups:

Standard Level 1: modeled independently
Standard Level 3: used to model Standard Level 2
Standard Level 4: modeled independently
Standard Level 5: modeled independently

To preserve the pattern of energy savings over time for a trial standard level, savings in each year are multiplied by the same factor. This factor varies for each standard because the magnitude of the savings changes. An appropriate set of multipliers were chosen to augment the savings to a magnitude that produces credible results. Using professional judgement, sets of three multipliers were selected for each of the four patterns as shown in Table EA-2.1.

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[e] For more information on NEMS, please refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000.* DOE/EIA-0581(2000), March 2000. DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because our analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, the name NEMS-BRS refers to the model as used here (BRS is DOE's Building Research and Standards office, under whose aegis this work has been performed).

Table EA-2.1 Set of Multipliers for Each Standard Level Pattern

Standard Level 1	5.25, 6.80, 7.64
Standard Level 3	2.77, 3.59, 4.03
Standard Level 4	2.18, 2.82, 3.17
Standard Level 5	1.18, 1.53, 1.71

The output for electricity generation and capacity by fuel type for each of the iterations (e.g., 6, 8, and 10 times the standard level) is then regressed, with the y-intercept forced through the origin, and the actual standard level forecast is interpolated along this regression line. The linear regression is forced through the origin because a zero change must be the case with no standard in place and because the target points of interpolation are close to the origin (i.e., at low energy decrements). Other trial standard levels within the same group are interpolated along this regression line by substituting the x-value in the regression equation with the ratio of energy savings between standard levels in the peak energy savings year.

Figure EA-2.1a shows an example of the interpolation approach for a central air conditioner and heat pump trial standard level X1. The magnitude of the energy savings multiplier is plotted on the x-axis against the reduction in coal installed generating capacity for each reported year, as shown by the various plotted lines. In general, results for the various NEMS-BRS runs are reasonably stable and linear, with the noisy behavior appearing below the first multiplier of the trial standard level savings decrement.

Figure EA-2.1b shows a close-up of the interpolated points for trial standard level X2 from standard X1. The heavy horizontal lines illustrate the calculated values for the difference in coal capacity in 2020. These regressions appear stable, so estimating results via interpolation toward zero seems justified. A similar approach was used to find the drop in installed generating capacity from other fuels and in generation for each fuel type in each reported year.

The estimated reduction in total fuel generation that we report at each trial standard level as determined by interpolation is then used to determine emissions savings. First, annual marginal emissions rates are calculated for each of the simulations in a savings group, based on the actual output from NEMS-BRS. Marginal emissions rates incorporate both effects of the standards—the emissions saved by the reduction in total generation and the slight change in the emissions characteristics of the whole power sector that result from the slight change in dispatch and capacity expansion plan. The net effect on the entire system is very small and, typically, the overall effect on emissions can be fully attributed to the decremental generation. The annual marginal emissions rates at the trial standard level are then extrapolated from these rates (at multipliers of the trial standard level savings) by taking a simple average.

Figure EA-2.2 shows an example of the extrapolation for NO_x emissions rates for standard level X1. In this case, marginal rates for NO_x emissions are shown for each year. As is evident in the figure, more stable results are produced at higher levels of demand decrement. At lower decrement levels (i.e., both on the left-hand side of the figure and in years with small standards impacts), the emissions rate is quite variable. The dashed plots (years 2003 - 2010) show the earlier years of the imposed standard—those in which the decrements to demand are smallest (not shown here). In most cases, these curves are so close to flat that regression of the higher decrement simulation points produces a curve very close to the simple average of values. The constant emissions rates at higher decrement levels are therefore assumed to hold in the range of small decrements commensurate with the various standard levels, and the implied marginal emissions rates are used to estimate emissions reductions. Total emissions savings in each year are the product of the annual marginal emissions rate and the reduction in thermal generation for that year (as calculated by the interpolation method described above). Marginal emissions rates for all years are derived by averaging the marginal rates of the three highest decrement levels (e.g., 2, 4, and 6 times the standard). Experience has shown that stable marginal emissions factors possess a linear trend over time.

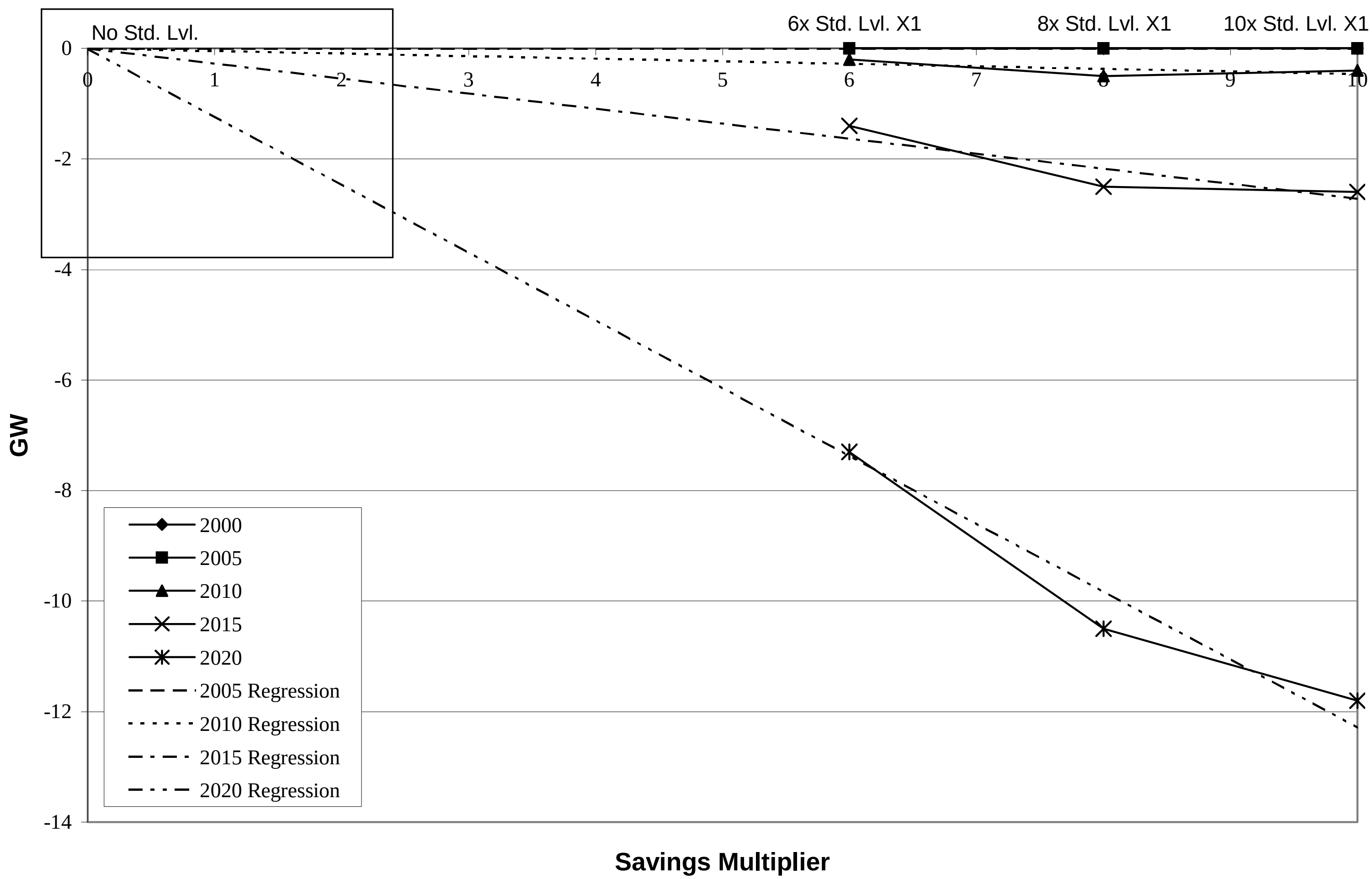

Figure EA-2.1a An Example of the Interpolation of a Trial Standard Level: Difference in Coal Capacity

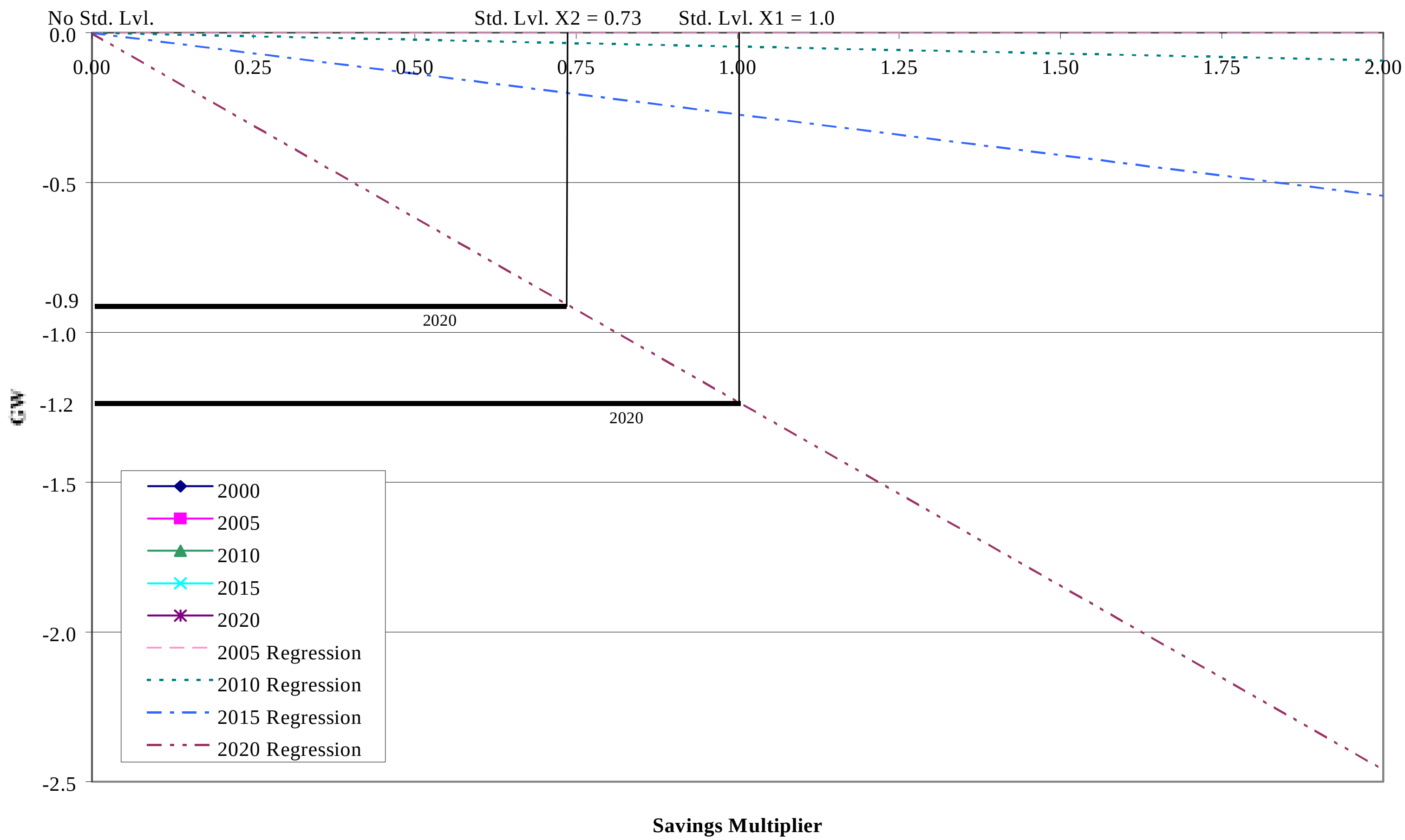

Figure EA-2.1b Close-Up of the Interpolation of Trial Standard Level X2 from X1

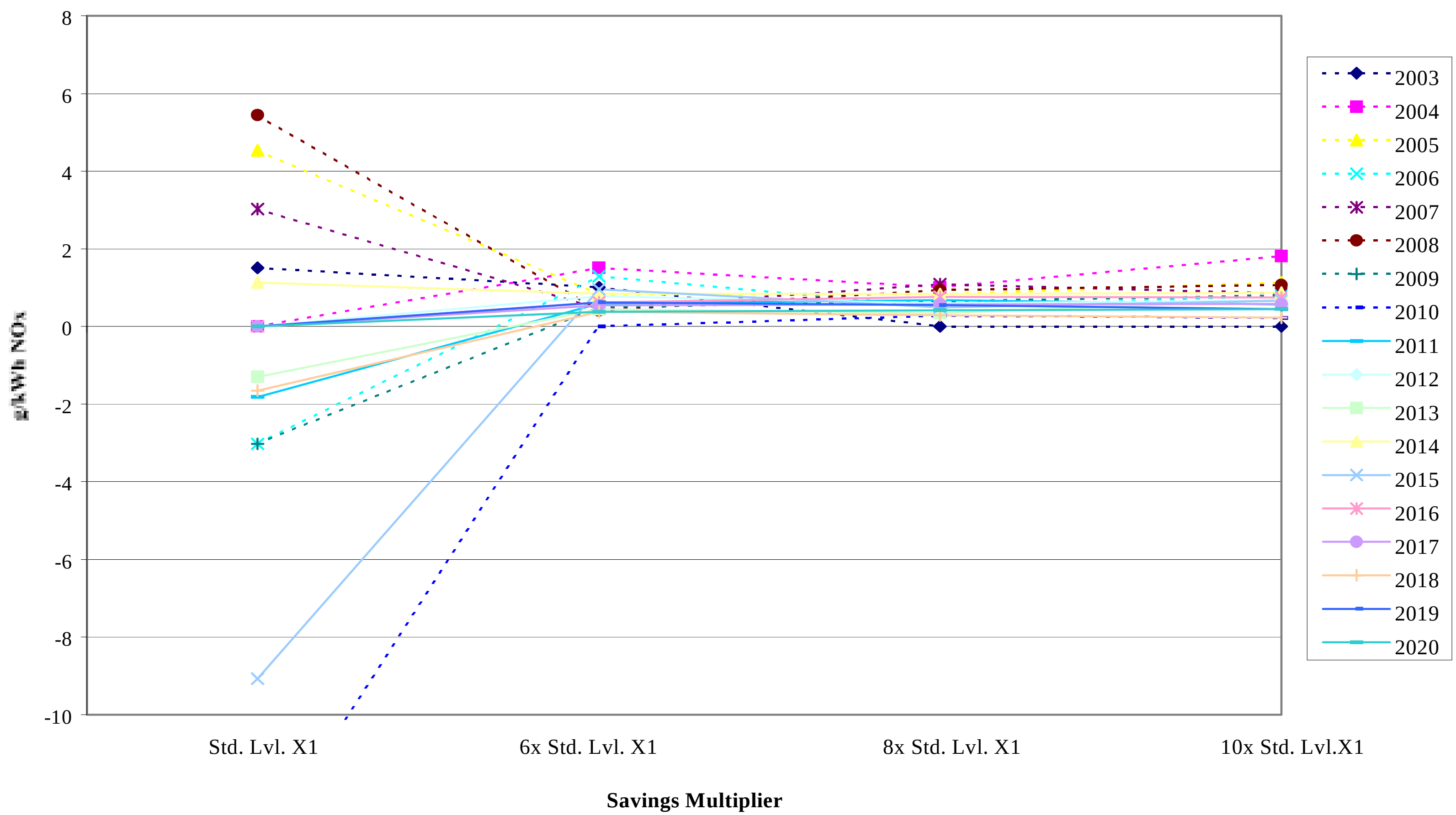

Figure EA-2.2 Example of Trial Standard Level X1: Marginal NO_x Emissions

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