CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the method for estimating the quantity and net value to consumers of future national energy savings (NES) from possible candidate standard levels. Results described here include: 1) national energy consumption and savings, 2) monetary value of energy savings to the nation due to standards, 3) increased total installed costs to the nation due to standards, and 4) the net present value (NPV) of energy savings (difference between value of energy savings and increased total installed costs).

The Department determined both the NPV and NES for all of the candidate standard levels considered for the two equipment classes of commercial unitary air conditioners. Candidate standard levels of 10.5, 11.0, 11.5, and 12.0 EER are being considered for the ≥65,000 Btu/h to <135,000 Btu/h equipment class while candidate standard levels of 10.0, 10.5, 11.0, 11.5, and 12.0 EER are being considered for the ≥135,000 Btu/h to <240,000 Btu/h equipment class. In addition, the Department determined the NES and NPV due to quick adoption of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/Illuminating Engineering Society of North America (IESNA) 90.1-1999 candidate standard levels. Quick adoption in this case is defined as an effective date of 2004 as opposed to an assumed effective date of 2008 for the more stringent standard levels currently under consideration by the Department. In this way, the Department can assess the national benefits of adopting more stringent standards at a later effective date relative to adopting the ASHRAE/IESNA 90.1-1999 standard levels almost immediately.

The Department performed all calculations using a Microsoft Excel® spreadsheet, which is accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html). Details and instructions for using the spreadsheet are discussed in Appendix R. A more detailed set of results is available in Appendix S.

The important facets of national energy consumption of commercial unitary air conditioners include: 1) shipments of the equipment, 2) customer response to changes in total installed cost (i.e., purchase price), operating expense, and business income, and 3) voluntary programs promoting higher energy efficiency of equipment.

Chapter 9 provides a detailed description of the Shipments Model that DOE used to forecast future purchases of commercial unitary air conditioners. Included in the discussion are detailed descriptions of customers' sensitivities to total installed cost, operating expense, and income (otherwise known as elasticities), and how DOE captured them within the model.

Concerning voluntary programs, although they may increase the share of energy-efficient equipment prior to the implementation date of any new standards, DOE was not able to obtain information that quantified how such programs affect equipment efficiencies on a national basis. Consequently, DOE did not explicitly incorporate the impact of market-based initiatives into the shipments forecasts detailed in Chapter 9.

10.2 NATIONAL ENERGY SAVINGS

10.2.1 NES Definition

The Department calculates annual national energy savings as the difference between two projections: a base case (without new standards) and a standards case (with new standards). Positive values of NES correspond to energy savings (i.e., national energy consumption with standards is less than national energy consumption in the base case).

$$NES_y = AEC_{base} - AEC_{standard}$$

Cumulative energy savings are the sum over a defined time period (2008 to 2035)[a] of the annual national energy savings.

$$NES_{cum} = \sum NES_y$$

The Department calculated the national annual energy consumption by multiplying the number or stock of commercial air conditioners (by vintage) by the unit energy consumption (also by vintage). The calculation of the national annual energy consumption is represented with the following equation:

$$AEC = \sum STOCK_V \cdot UEC_V$$

For the above expressions, DOE defined the following quantities as follows:

AEC = Annual national energy consumption each year in quadrillion Btus (quads), summed over vintages of commercial air conditioner stock, $STOCK_V$.

NES = Annual national energy savings (quads).

$STOCK_V$ = Stock of commercial air conditioners (millions of units) of vintage V surviving in the year for which DOE calculated annual energy consumption. Vintages range from 1 to approximately 30 years, depending on the lifetime of the equipment.

UEC_V = Annual energy consumption per commercial air conditioner (kWh). Electricity consumption is converted from site energy (kWh) to source energy (quads) by applying a time-dependent conversion factor (Btu/kWh).

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[a] For the ASHRAE 90.1-1999 standards case, the defined time period is 2004-2035.

V =	Year in which the commercial air conditioner was purchased as a new unit.
y =	Year in the forecast (e.g., 2008 to 2035).

The stock of commercial air-conditioning equipment is dependent on annual shipments and the lifetime of the equipment. As described in Chapter 9, the Department conducted shipments projections under the base case and standards cases for a variety of possible equipment efficiency scenarios and equipment efficiency growth trends. The Department determined that the shipment projections under the standards cases were lower than those in the base case projection, due to the higher installed cost of the more-efficient equipment. In other words, the Department believes that the higher installed costs would cause some customers to forego new equipment purchases. Hence, DOE used the standards-case shipments projection and, in turn, the standards case stock to determine the NES, to avoid the inclusion of savings due to displaced shipments.

10.2.2 NES Inputs

Table 10.2.1 lists the inputs for the determination of NES.

Table 10.2.1 National Energy Saving Inputs

Input
Annual Energy Consumption per Unit (*UEC*)
Shipments
Equipment Stock ($STOCK_V$)
National Annual Energy Consumption (*AEC*)
Site-to-Source Conversion Factor (*src_conv*)

10.2.2.1 Annual Energy Consumption per Unit

The annual energy consumption per unit (UEC) is the site energy consumed by a commercial air-conditioning unit per year. The annual energy consumption is directly tied to the efficiency of the unit. Thus, knowing the efficiency of a commercial air-conditioning unit enables a determination of the corresponding annual energy consumption.[b] As described below, the Department determined annual historical and forecasted shipment-weighted average equipment efficiencies that, in turn, enabled a determination of shipment-weighted annual energy consumption values.

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[b] Although directly tied to the efficiency of the unit, the unit's annual energy consumption was determined through a building simulation analysis and is also a function of the building type, building activity, and weather. Refer to Chapter 6 for more details on how the Department conducted the building simulation analysis.

The Department based historical shipment-weighted average efficiency trends for commercial unitary air conditioners upon a combination of 1999-2001 commercial air conditioner efficiency data and residential central air conditioner efficiency trends. Then, from those historical data and trends, DOE extrapolated future trends of commercial unitary air conditioner equipment efficiency both for a base case (i.e., without new standards) and various standards cases (i.e., with new standards). The difference in equipment efficiency between the base and standards cases was the basis for determining the reduction in per-unit annual energy consumption that could result from new standards.

Because of the limited availability of historical efficiency data for commercial unitary air conditioners,[c] the Department used the historical efficiency trends of residential central air conditioners as a basis for formulating the historical trends for commercial unitary air conditioners dating back to 1975. Figure 10.2.1 shows the historical shipment-weighted efficiencies of residential central air conditioners,[1] the shipment-weighted efficiencies of commercial unitary air conditioners for the three years for which data are available (1999 through 2001), and the estimated historical and forecasted efficiency trends for commercial unitary air conditioners. Note that the efficiency data are disaggregated into two equipment classes (≥65,000 Btu/h to <135,000 Btu/h, and ≥135,000 Btu/h to <240,000 Btu/h).

[c] The Air-Conditioning and Refrigeration Institute (ARI) provided historical efficiency data for the years 1999, 2000, and 2001.

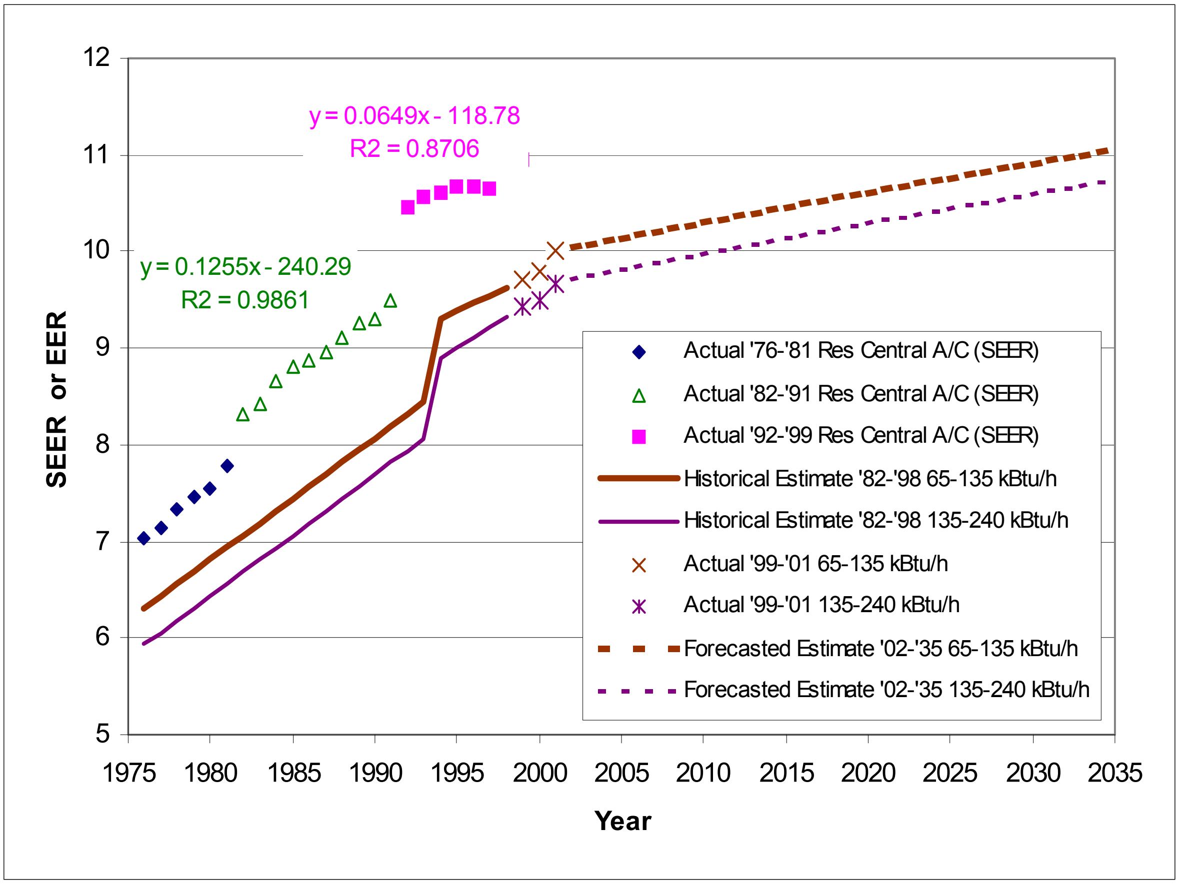

Figure 10.2.1 Residential and Commercial Air Conditioner Actual, Historical, and Forecasted Shipment-Weighted Efficiencies

In Figure 10.2.1, DOE provides linear fits (and their corresponding correlation coefficients) for the residential central air conditioner shipment-weighted efficiency trends from 1982 to 1991 and 1992 to 1999. The Department used the growth rates (i.e., the slopes) from the linear fits to estimate the historical efficiency trends for commercial unitary air conditioners. It attributed the jump in residential central air-conditioner efficiency observed between 1991 and 1992 to Federal energy conservation standards for this equipment, which became effective in 1991. The Department assumed that an equivalent percentage jump in shipment-weighted commercial air conditioner efficiency occurred when minimum standards for this equipment became effective in 1994. Thus, the Department used the rate of increase from 1992 to 1999 for residential air conditioners to estimate the historical efficiency trend from 1994 to 1998 for commercial air conditioners.

The Department chose a growth rate for its forecasted base case efficiency trends to be one-half of the growth rate observed from the historical residential air conditioner efficiency trend during 1992 through 1999. The Department made this decision based on observed trends in the historical commercial air-conditioner efficiency data. The three years' worth of commercial air conditioner efficiency data revealed a significant shift to higher equipment efficiencies from the year 2000 to 2001. Although the ASHRAE/IESNA 90.1-1999 standards are not mandatory, it appears that their effect has been to move the commercial air conditioner market to higher equipment efficiencies. The ASHRAE/IESNA 90.1-1999 standards' impact on transforming the market is assumed to be most significant in the short term. Therefore, the growth rate of the efficiency trend in the long term (i.e., for years after 2001) should be much lower than the shift in equipment efficiencies observed between 2000 and 2001. Because the Department believes that future commercial air conditioner efficiencies will grow at a modest rate, a growth rate equal to one-half of the historical residential equipment's efficiency trend was chosen. Appendix T provides the energy efficiency ratio (EER) values corresponding to the historical and forecasted base case efficiency trends shown in Figure 10.2.1.

The Department based its standards case forecasts (i.e., forecasts of efficiency trends after standards take effect) on the use of a roll-up efficiency scenario and parallel growth trend. Under a roll-up scenario all equipment at efficiency levels below a prospective standard are moved or rolled-up to the minimum efficiency level allowed under the new standard. The distribution of equipment at efficiency levels above the prospective standards is unaffected (i.e., this equipment remains at its pre-standard efficiency levels). The roll-up efficiency scenario dictates how DOE determined efficiency distributions in the first year a new standard takes effect, but does not define how equipment efficiency will be distributed in the future. Under the parallel growth trend, the Department assumed that the standards case efficiency trend parallels the base case efficiency trend. In other words, the initial jump in shipment-weighted efficiency that occurs when the standard first becomes effective is maintained throughout the forecast.

The 11.5 EER and 12.0 EER standards case efficiency trends are notable exceptions to the use of the parallel growth trend for the entire time span of the forecast (i.e., through 2035). As noted in Chapter 5, the maximum technologically feasible design, otherwise known as "max tech," is 12.0 EER. Because "max tech" is 12.0 EER, the maximum shipment-weighted efficiency for any given year is 12.0 EER. As a result, because the efficiency trend for the 11.5 EER standards case achieves a shipment-weighted efficiency of 12.0 EER in the year 2023, the forecasted efficiency trend remains flat from the year 2023 through 2035. In the case of the 12.0 EER standards case, a shipment-weighted efficiency of 12.0 EER is realized immediately after the standard becomes effective. Thus, the efficiency trend is flat (i.e., stays fixed at 12.0 EER) through out the entire forecast.

Figures 10.2.2 and 10.2.3 show the forecasted efficiency trends for the base case and all standards cases, including the ASHRAE/IESNA 90.1-1999 standards case.

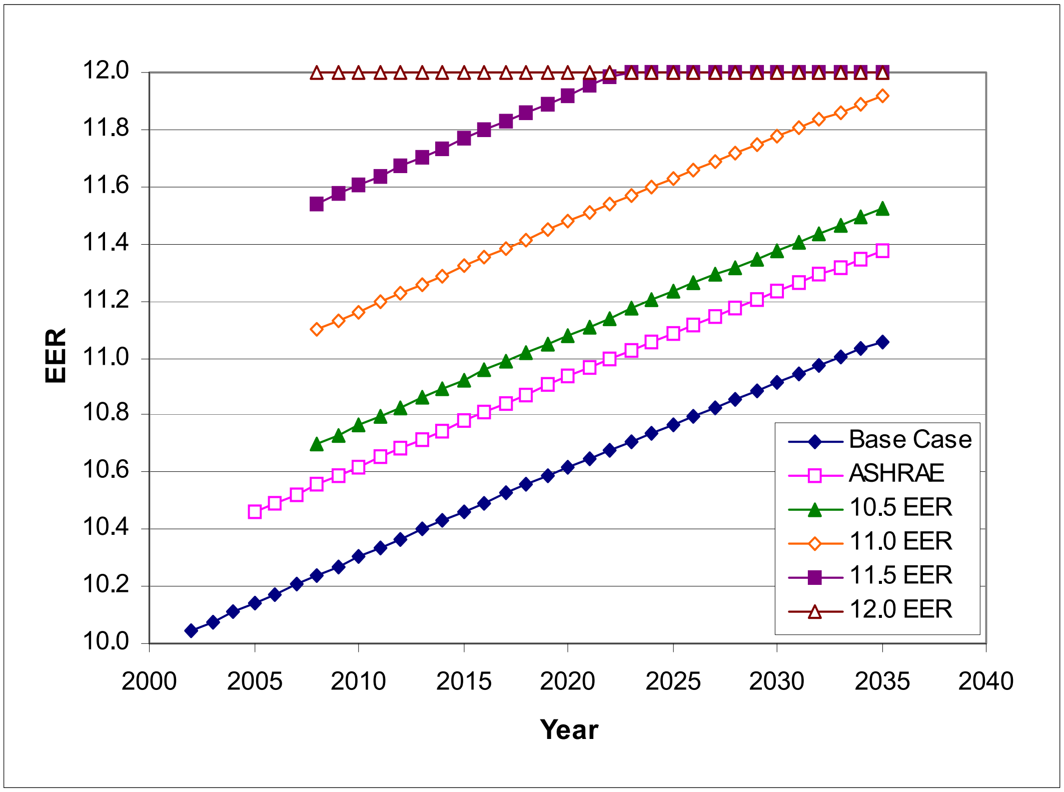

Figure 10.2.2 ≥65,000 Btu/h to <135,000 Btu/h: Base Case and Standards Case Forecasted Efficiency Trends

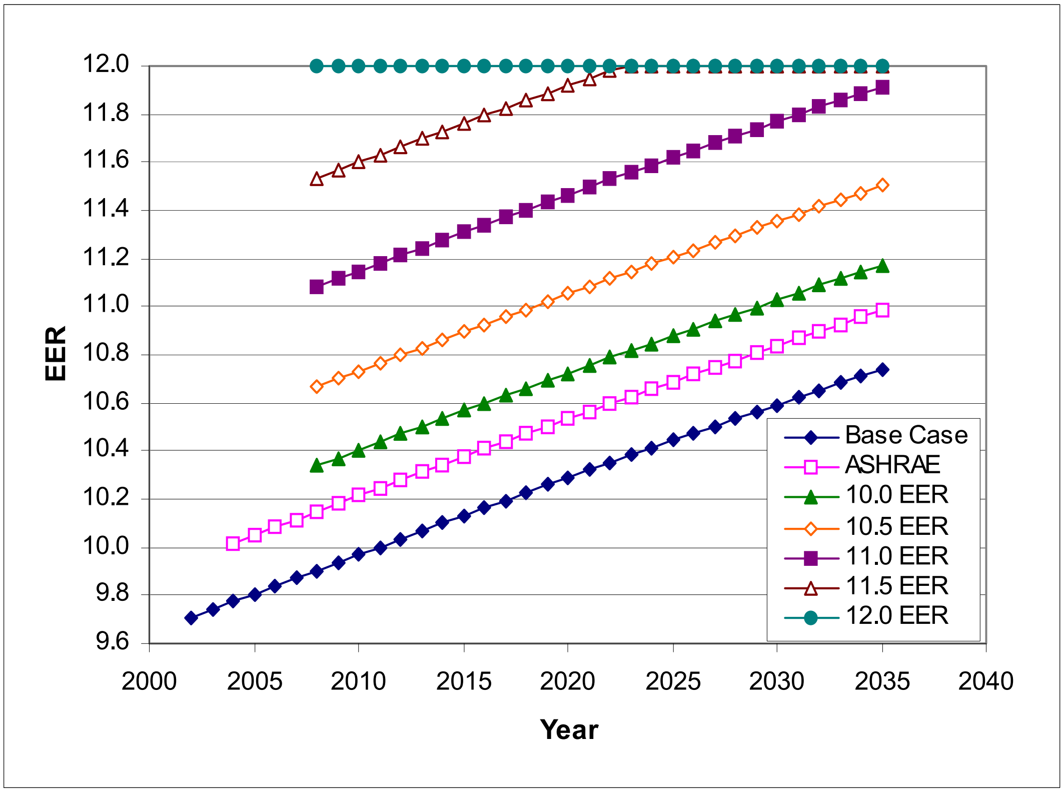

Figure 10.2.3 ≥135,000 Btu/h to <240,000 Btu/h: Base Case and Standards Case Forecasted Efficiency Trends

Appendix T provides the EER values corresponding to all the standards case efficiency trends. As noted earlier, the Department developed standards case efficiency trends for the following standards cases: ASHRAE/IESNA 90.1-1999, 10.0 EER, 10.5 EER, 11.0 EER, 11.5 EER, and 12.0 EER. Note that the Department did not analyze 10.0 EER for the ≥65,000 Btu/h to <135,000 Btu/h equipment class, because the baseline efficiency level for this class equals 10.1 EER.

As stated earlier, annual energy per-unit values are tied directly to the efficiency of the equipment. Table 10.2.2 provides weighted-average annual energy consumption values for specific EER levels for both equipment classes. As detailed in Chapter 6, the Department conducted whole-building simulations on a representative sample of commercial buildings that use commercial unitary air-conditioning equipment. From that representative set of buildings, DOE performed a weighted-average calculation to arrive at the values presented in Table 10.2.2. The Department based the weighting not only on the representativeness of the building, but also on the representativeness of the electric utility to which the building was assigned, as well as the number of air-conditioning units that would be required to meet the simulated cooling load. Table 10.2.2 presents the annual energy per-unit values according to three different metrics: annual electricity use per year in kilowatt-hours (kWh/year), annual electricity use per ton per year (kWh/ton/year), and annual electricity use per building square foot per year (kWh/sq.ft./year). The last metric, electricity use per square foot, is how DOE expressed the annual energy per unit in the NES spreadsheet model. Because projections of commercial floor space (expressed in square feet) and business income (expressed as leased dollars per square foot) are two primary drivers used to estimate future air conditioner shipments, DOE calculated the national energy expense by expressing the per unit annual energy use on a square-footage basis.

Table 10.2.2 Average Annual Energy Consumption per Unit

EER	Annual Energy per unit ≥65,000 to <135,000 *kWh/year*	 ≥135,000 to <240,000 *kWh/year*	Annual Energy per unit per ton* *kWh/ton/year*	Annual Energy per unit per floor area* *kWh/sq.ft./year*
9.5	-	33,953	2186	5.74
10.0	-	32,442	2091	5.49
10.1	16,079	-	2073	5.44
10.5	15,543	31,085	2005	5.26
11.0	14,927	29,854	1928	5.06
11.5	14,366	28,733	1857	4.87
12.0	13,857	27,714	1793	4.70

* Values are the same for both commercial air conditioner equipment classes.

For the annual shipment-weighted efficiency levels specified in the base case and standards case efficiency trends, the Department assigned the appropriate annual energy per-unit value from Table 10.2.2. When necessary, the Department used interpolation and extrapolation to assign the appropriate energy use value, based on the regression fits presented in Figure 10.2.4 for each of the two equipment classes.

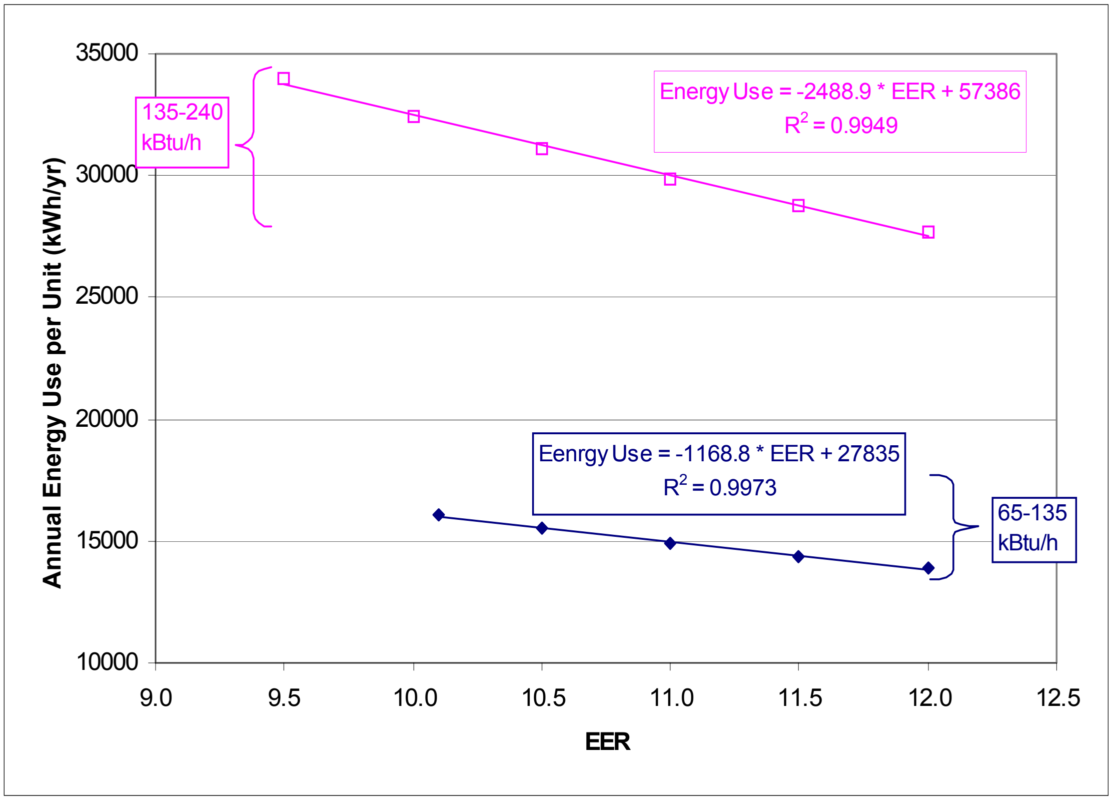

Figure 10.2.4 Average Annual Energy Consumption per Unit

10.2.2.2 Shipments

The Department forecasted shipments for the base case and all standards cases (see Chapter 9). Several factors, including total installed costs, business income, operating cost, and equipment lifetime, all impact forecasted shipments. Of the above factors, total installed costs were the primary driver in forecasting the impact of standards on shipments. As noted earlier, the increased installed cost of more-efficient equipment causes some customers to forego equipment purchases. Consequently, shipments forecasted under the standards cases are lower than under the base case. An extensive description of the methodology for conducting and generating the shipments forecasts can be found in Chapter 9.

10.2.2.3 Equipment Stock ($STOCK_V$)

The commercial unitary air-conditioner stock in a given year is the number of unitary air conditioners shipped from earlier years and which survive in the given year. The NES spreadsheet model keeps track of the number of commercial unitary air conditioners shipped each year. The Department assumes that commercial unitary air conditioners have an increasing probability of retiring as they age. The probability of survival as a function of years-since-purchase is the survival function. Commercial unitary air-conditioner lifetimes range from one to approximately 30 years, with an average lifetime of 15.4 years (see Chapter 8, section 8.2.3.9, Lifetime, for further details). Note that the stock of unitary air conditioners under all standards cases is less than the stock under the base case because of the lower number of shipments forecasted for the standards cases.

10.2.2.4 National Annual Energy Consumption (*AEC*)

The national energy consumption is the product of the annual energy consumption per air conditioner and the number of commercial unitary air conditioners of each vintage. This approach accounts for differences in unit energy consumption from year to year. The equation for determining the annual energy consumption of unitary air conditioners was shown above and is repeated below.

$$AEC = \sum STOCK_V \cdot UEC_V$$

In determining national annual energy consumption, DOE initially calculated the annual energy consumption at the site (i.e., electricity in kWh consumed by the commercial unitary air-conditioning unit within the building it is serving). The Department then calculated primary energy consumption from site energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity.

10.2.2.5 Site-to-Source Conversion Factor (*src_conv*)

The source conversion factor is the multiplicative factor used for converting site energy consumption, expressed in kWh, into primary or source energy consumption, expressed in quads. The source conversion factor accounts for losses in generation, transmission, and distribution.

The Department used annual source conversion factors based on U.S. average values for the commercial sector, calculated from the *2003 Annual Energy Outlook (AEO),* Table A4.[2] As shown in Table 10.2.3, the average conversion factors vary over time, due to projected changes in generation sources (i.e., the power plant types projected to provide electricity to the country).

Table 10.2.3 Site-to-Source Conversion Factors

Year	Site-to-Source Conversion Factor *Btu/kWh*
2000	11,180
2001	11,031
2002	10,852
2003	10,797
2004	10,759
2005	10,744
2006	10,722
2007	10,700
2008	10,647
2009	10,589
2010	10,523
2011	10,463
2012	10,397
2013	10,354
2014	10,298
2015	10,260
2016	10,231
2017	10,191
2018	10,153
2019	10,120
2020	10,098
2021	10,057
2022	10,022
2023	9,981
2024	9,948
2025	9,917

For analyses conducted for the Notice of Proposed Rulemaking (NOPR), the Department intends to use marginal conversion factors specific to the type of generation sources (e.g., power plants) displaced, due to decreases in national energy consumption that would result from the use of more-efficient commercial unitary air conditioners. To derive marginal conversion factors, DOE would use the following methodology:

1. Start with an integrated projection of electricity supply and demand (e.g., the National Energy Modeling System (NEMS) *AEO* Reference Case), and extract the source energy consumption.

2. Estimate projected energy savings and system load impacts as a result of possible standards for each year (e.g., using the NES spreadsheet model).

3. Enter these energy savings and system load impacts back into NEMS as a new scenario—specifically, a deviation from the Reference Case—to obtain the corresponding source energy consumption.

4. Obtain the difference between source energy consumption using this standards-level scenario and the Reference Case.

5. Divide the source energy savings in Btu, adjusted for transmission and distribution losses, by the site energy savings in kWh, to provide the time series of conversion factors in Btu per kWh.

Because NEMS cannot adjust for class-specific transmission losses, this information would be gathered from sources outside of NEMS. For commercial electricity customers, transmission losses might be three percent (from the site of the electricity generation to a substation) and distribution losses might be seven percent (from that substation to a particular house). For the above case, the conversion factor would be the site-to-source conversion factor, otherwise called the marginal heat rate,[d] multiplied by 1.10 (the extra 10 percent due to the addition of transmission (three percent) and distribution (seven percent) losses).

The resulting conversion factors will change over time, and will account for the displacement of generation sources. Furthermore, the NES spreadsheet models will include a clearly defined column of conversion factors, one for each year of the projection.

10.3 NET PRESENT VALUE

10.3.1 Net Present Value Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is described by the equation:

$$NPV = PVS - PVC$$

where:

PVS = present value of operating cost savings (including electricity, repair, and maintenance costs), and

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[d] The marginal heat rate is another name for the site-to-source conversion factor. As just described, the marginal heat rate is calculated by imposing a load reduction to the end-use of the appliance being analyzed in NEMS and observing the change in primary energy use.

PVC = present value of increased total installed costs (including equipment and installation).

The *PVS* and *PVC* are determined according to the following expressions:

$$PVS = \sum OCS_y \cdot DF_y$$

$$PVC = \sum TIC_y \cdot DF_y$$

where:

OCS = total annual operating cost savings,
TIC = total annual installed cost increases,
DF = discount factor, and
y = year for which *PVS* and *PVC* are determined.

The Department determined the *PVC* for each year, from the effective date of the standard to the year 2035. The *PVS* was determined for each year, from the effective date of the standard to the year when units purchased in 2035 retire.

The Department calculated costs and savings as the difference between a standards case and a base case (i.e., without new standards).

The Department calculated a discount factor from the discount rate and the number of years between the "present" (i.e., year to which the sum is being discounted) and the year in which the costs and savings occur. The net present value is the sum over time of the discounted net savings.

10.3.2 Net Present Value Inputs

Table 10.3.1 summarizes the inputs to the NPV calculation.

Table 10.3.1 Net Present Value Inputs

Input
Total Annual Installed Cost (TIC_y)
Total Annual Operating Cost Savings (OCS_y)
Discount Factor
Present Value of Costs (*PVC*)
Present Value of Savings (*PVS*)

10.3.2.1 Total Annual Installed Cost (TIC_y)

The increase in the total annual installed cost is equal to the annual change in the per-unit total installed cost (difference between base case and standards case) multiplied by the shipments forecasted in the standards case. As with the calculation of the NES, the Department used the standards case shipments forecast to avoid miscounting the reduction in shipments as a reduction in total installed costs.

The total installed cost includes both the equipment cost and the installation price. The Department based average equipment costs on average manufacturer prices (see Chapter 8, sections 8.2.2.1 and 8.2.2.2) multiplied by average overall markup values (see Chapter 8, section 8.2.2.3). The Department based average installation prices on nationally representative values of $1585 for the ≥65,000 Btu/h to <135,000 Btu/h equipment class and $2142 for the ≥135,000 and <240,000 Btu/h equipment class (see Chapter 8, Section 8.2.2.4). Table 10.3.2 shows the resulting per-unit average total installed costs for the two equipment classes of commercial unitary air conditioners The total installed cost values in Table 10.3.2 are presented not only in absolute terms but also on a per-ton and per-square-foot basis.

Table 10.3.2 Average Total Installed Cost per Unit

	≥65,000 Btu/h to <135,000 Btu/h			≥135,000 Btu/h to <240,000 Btu/h		
	Per Unit	**Per Unit per Ton**	**Per Unit per sq.ft.**	**Per Unit**	**Per Unit per Ton**	**Per Unit per sq.ft.**
EER	*2001$*	*2001$/ton*	*2001$/sq.ft.*	*kWh/year*	*2001$/ton*	*2001$/sq.ft.*
9.5	-	-	-	$11,299	$753	$2.06
10.0	-	-	-	$11,497	$766	$2.10
10.1	$6,440	$859	$2.35	-	-	-
10.5	$6,542	$872	$2.39	$11,757	$784	$2.14
11.0	$6,722	$896	$2.45	$12,121	$808	$2.21
11.5	$6,995	$933	$2.55	$12,656	$844	$2.31
12.0	$7,422	$990	$2.70	$13,472	$898	$2.45

As discussed earlier in section 10.2.2.1, the Department developed base case and standards case energy efficiency trends. The Department based its standards case forecasts (i.e., forecasts of efficiency trends after standards take effect) on the use of a roll-up efficiency scenario and parallel growth trend. For both the base case and standards case energy-efficiency trends, the Department calculated annual shipment-weighted average efficiencies. Associated with each annual shipment-weighted average efficiency value, the Department assigned a total installed cost, based on the relationship between efficiency and total installed cost. The Department based the relationship between efficiency and total installed cost for each commercial unitary air conditioner equipment class on the data in Table 10.3.2. As shown in Figure 10.3.1, DOE plotted the installed cost and efficiency data and determined regression fits to establish the relationship between installed cost and efficiency for each equipment class. The Department determined historical and forecasted average total installed costs based on the annual shipment-weighted efficiency levels specified in the base case and standards case efficiency trends.

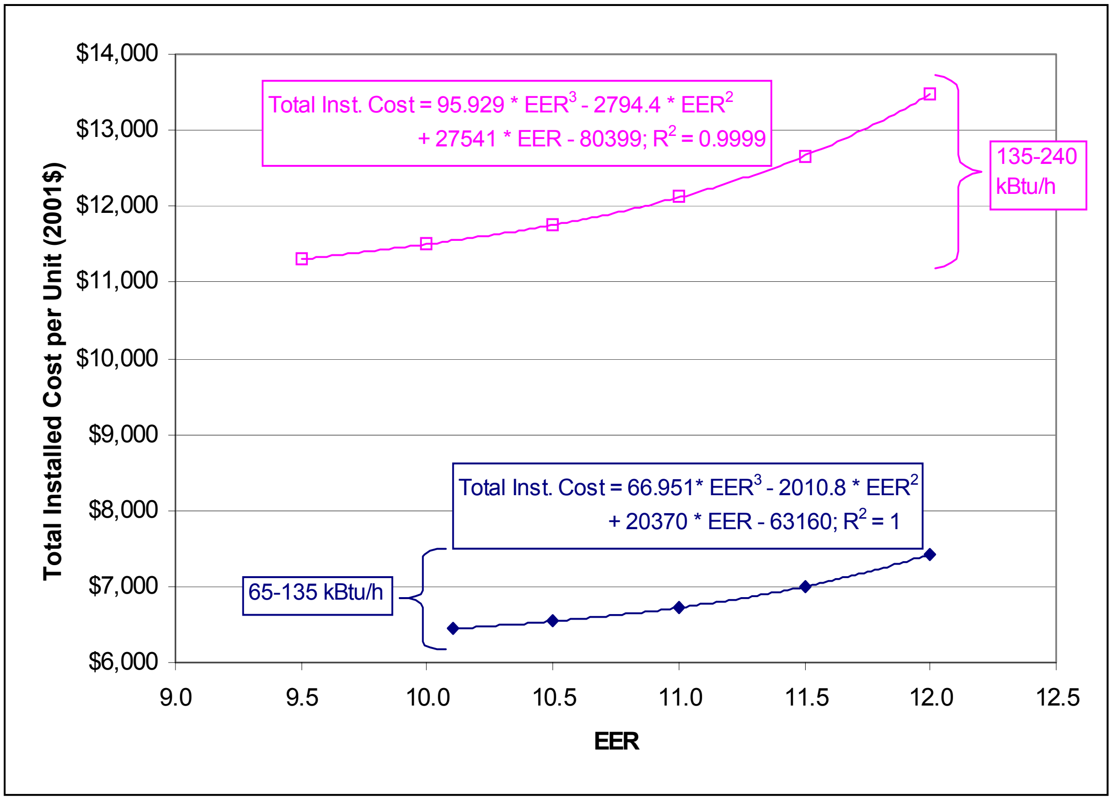

Figure 10.3.1 Average Total Installed Cost per Unit

10.3.2.2 Total Annual Operating Cost Savings (OCS_y)

The annual operating cost savings to the Nation are equal to the change in the annual operating costs (difference between base case and standards case) per unit multiplied by the shipments forecasted in the standards case. The Department used the standards case shipments forecast, in order to avoid miscounting the reduction in shipments as an operating cost savings. The annual operating cost includes electricity, repair, and maintenance costs.

Annual Electricity Cost Savings. As described in Chapter 8, section 8.2.3.1, the Department calculated annual electricity expenses based on two approaches: 1) a tariff based approach, and 2) an hourly based approach. The hourly based approach resulted in annual energy expenses which were, on average, less than one percent different than those from the tariff-based analysis (see Chapter 8, Table 8.2.14). Thus, because the resulting national customer economic impacts from the two approaches would not be significantly different, the Department decided to present only the results from the tariff-based approach.

Table 10.3.3 provides weighted-average annual energy expense values for specific EER levels for both equipment classes. As detailed in Chapter 6, the Department conducted whole-building simulations on a representative sample of commercial buildings using commercial unitary air-conditioning equipment. The Department assigned tariff-based electricity rates to each building to determine the annual energy expense for unitary air-conditioning in that building. From the representative set of buildings, DOE performed a weighted-average calculation to determine the values presented in Table 10.3.3. It based the weighting not only on the representativeness of the building, but also on the representativeness of the electric utility to which the building was assigned, as well as the number of unitary air-conditioning units that were required to meet the simulated cooling load. Table 10.3.3 presents values according to three different metrics: (1) annual electricity expense per year (2001$/year), (2) annual electricity expense per ton per year (2001$/ton/year), and (3) annual electricity expense per building square foot per year (2001$/sq.ft./year). The last metric, electricity expense per square foot, is how DOE expressed the annual energy expense per unit in the Shipments and NES spreadsheet models. Because projections of commercial floor space (expressed in square feet) and business income (expressed as leased dollars per square foot) are two of the primary drivers used to estimate future unitary air conditioner shipments, DOE calculated the national energy expense more readily by expressing the per-unit annual energy expense on square-footage basis.

Table 10.3.3 Average Annual Energy Expense per Unit

EER	Annual Energy Expense per unit		Annual Energy Expense per unit per ton	Annual Energy Expense per unit per floor area
	≥65 to <135 kBtu/h	≥135 to <240 kBtu/h		
	2001$/year	*2001$/year*	*2001$/ton/year*	*2001$/sq.ft./year*
9.5	-	$2,853	$209	$0.52
10.0	-	$2,707	$200	$0.50
10.1	$1,340	-	$198	$0.49
10.5	$1,288	$2,576	$191	$0.48
11.0	$1,228	$2,457	$183	$0.46
11.5	$1,174	$2,349	$176	$0.44
12.0	$1,125	$2,251	$169	$0.42

As with the installed cost data, the Department developed historical and forecasted annual energy expenses based on the annual shipment-weighted energy-efficiency levels specified in the base case and standards case energy-efficiency trends. For the base case efficiency trends and each of the standards case efficiency trends, DOE provides annual shipment-weighted average efficiencies. Associated with each annual shipment-weighted average energy efficiency value, the Department assigned an annual electricity expense, based on the relationship between efficiency and electricity expense. The Department based the relationship between energy efficiency and annual electricity expense on the data in Table 10.3.3 As shown in Figure 10.3.2, DOE plotted the annual electricity expense and efficiency data and determined regression fits to establish the relationship between electricity expense and energy efficiency With that relationship defined, the Department determined historical and forecasted electricity expenses for the base case and standards case efficiency trends. Because DOE characterized each possible new standard with three efficiency scenarios and three efficiency growth trends, it developed annual electricity expense trends for nine cases for each possible new standard.

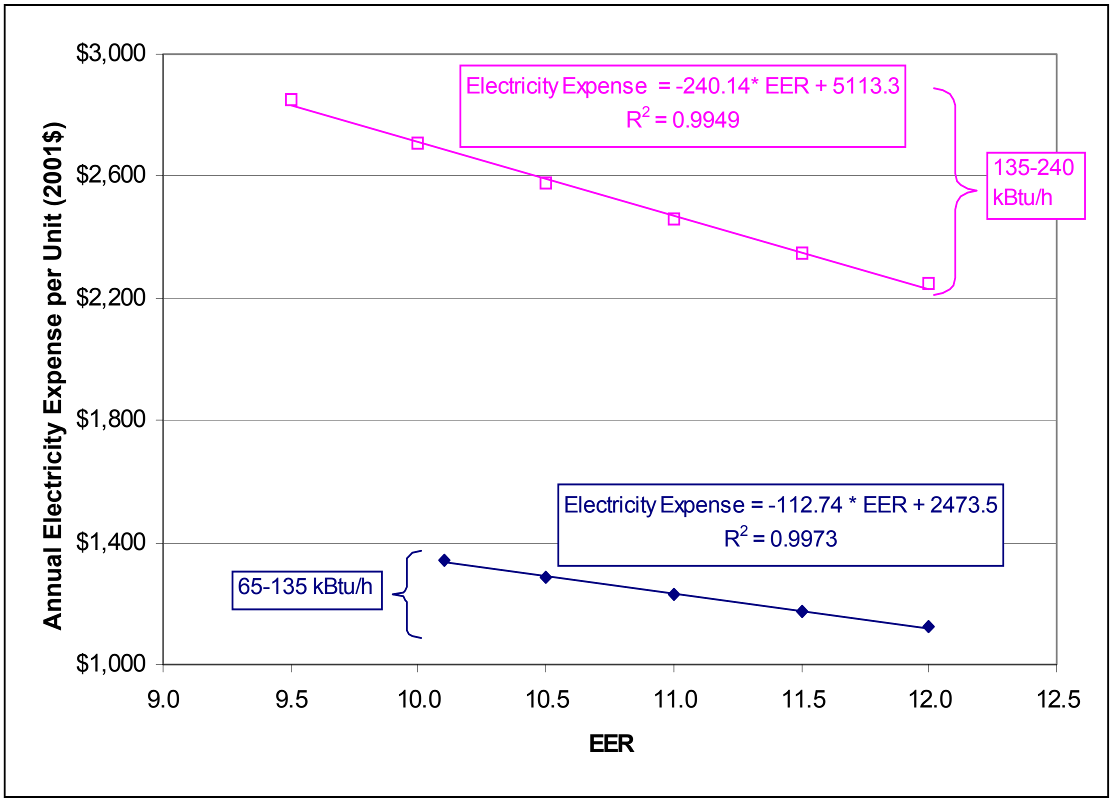

Figure 10.3.2 Average Annual Electricity Expense per Unit

Annual Repair Costs. The Department based average annual repair costs on the physical weight of the commercial unitary air-conditioning equipment (see Chapter 8, section 8.2.3.3). Table 10.3.4 shows the average per-unit repair costs for the two equipment classes of commercial unitary air conditioners. The Department presents the repair costs in Table 10.3.4 not only in absolute terms, but also on a per-ton and per-square-foot basis.

Table 10.3.4 Average Annual Repair Cost per Unit

	≥65,000 Btu/h to <135,000 Btu/h			≥135,000 Btu/h to <240,000 Btu/h		
	Per Unit	**Per Unit per Ton**	**Per Unit per sq.ft.**	**Per Unit**	**Per Unit per Ton**	**Per Unit per sq.ft.**
EER	*2001$*	*2001$/ton*	*2001$/sq.ft.*	*kWh/year*	*2001$/ton*	*2001$/sq.ft.*
9.5	-	-	-	$297	$19.82	$0.054
10.0	-	-	-	$302	$20.13	$0.055
10.1	$158	$21.02	$0.058	-	-	-
10.5	$161	$21.49	$0.587	$310	$20.64	$0.056
11.0	$168	$22.41	$0.061	$322	$21.49	$0.059
11.5	$180	$23.94	$0.065	$343	$22.89	$0.063
12.0	$198	$26.45	$0.072	$378	$25.19	$0.069

As with the installed cost and electricity expense data in Tables 10.3.2 and 10.3.3, respectively, the Department developed historical and forecasted annual repair costs based on the annual shipment-weighted efficiency levels specified in the base case and standards case efficiency trends. For the base case efficiency trends and each of the standards case efficiency trends, the Department provides annual shipment-weighted average energy efficiencies. Associated with each annual shipment-weighted average energy efficiency value, the Department assigned an annual repair cost, based on the relationship between efficiency and repair cost. It based the relationship between efficiency and annual repair cost on the data in Table 10.3.4. As shown in Figure 10.3.3, DOE plotted the annual repair cost and efficiency data and determined regression fits to establish the relationship between repair cost and energy efficiency. With that relationship defined, the Department determined historical and forecasted repair costs for the base case and standards case energy efficiency trends. Because the Department characterized each possible new standard with three efficiency scenarios and three efficiency growth trends, it developed annual repair cost trends for nine cases for each possible new standard.

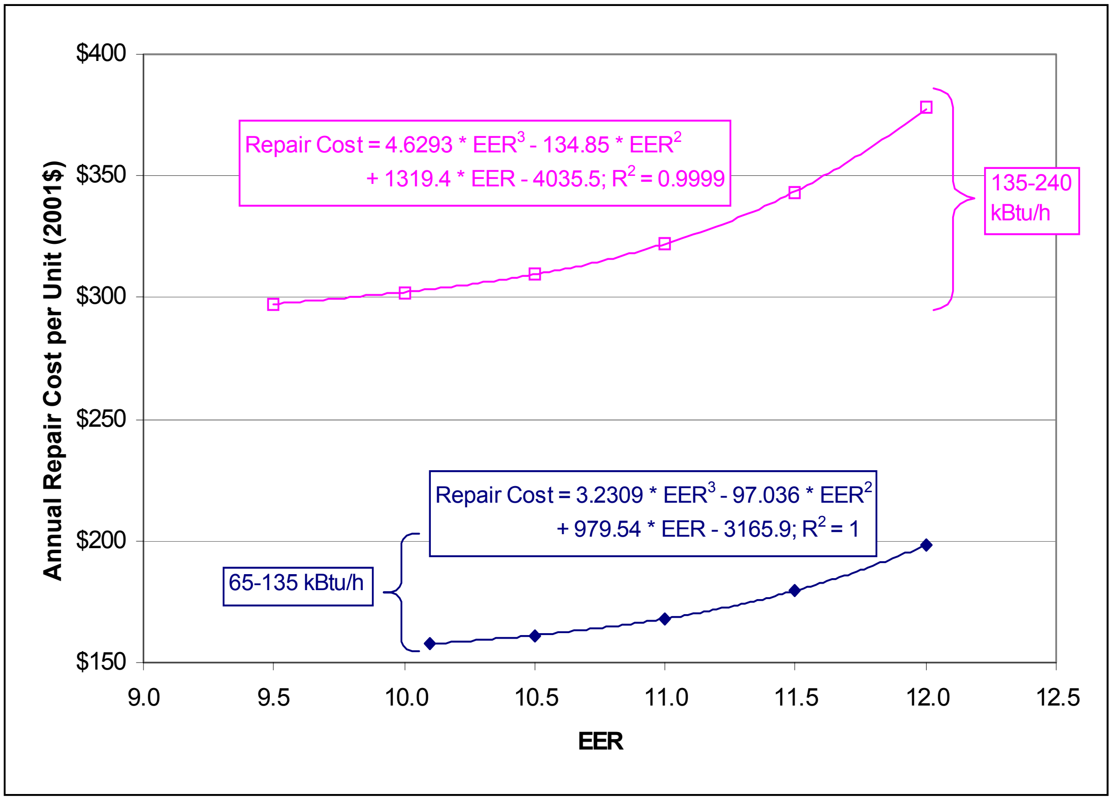

Figure 10.3.3 Average Annual Repair Cost per Unit

Annual Maintenance Costs. The Department determined average annual maintenance costs to be $200, regardless of cooling capacity or efficiency level (see Chapter 8, section 8.2.3.4). Thus, annual maintenance costs do not factor into the determination of the total operating cost savings.

10.3.2.3 Discount Factor

The Department multiplies monetary values in future years by the discount factor in order to determine the present value. The discount factor (*DF*) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-y_P)}}$$

where:

r	=	discount rate,
y	=	year of the monetary value, and
y_P	=	year in which the present value is being determined.

The Department estimated national impacts with both a three-percent and a seven-percent real discount rate as the average real rate of return on private investment in the U.S. economy. These discount rates are used in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003), and section E., "Identifying and Measuring Benefits and Costs," therein. The Department defines the present year as 2001 for consistency with the year in which the Department collected manufacturer cost data.

10.3.2.4 Present Value of Costs (*PVC*)

The present value of increased installed costs is the annual installed cost increase in each year (i.e., the difference between the standards case and base case), discounted to the present, and summed for the time period over which DOE is considering the installation of commercial unitary air conditioners (i.e., from the effective date of standards, 2008, to the year 2035).

The increase in total installed cost refers to both equipment cost and installation cost associated with the higher energy efficiency of commercial unitary air conditioners purchased in the standards case compared to the base case. The Department calculated annual installed costs as the difference in total installed cost for new equipment purchased each year, multiplied by the shipments in the standards case.

10.3.2.5 Present Value of Savings (*PVS*)

The present value of operating cost savings is the annual operating cost savings (i.e., the difference between the base case and standards case) discounted to the present, and summed over the period from the effective date, 2008, to the time when the last unit installed in 2035 is retired from service.

Savings are decreases in operating costs (including electricity, repair, and maintenance) associated with the higher energy efficiency of commercial unitary air conditioners purchased in the standards case compared to the base case. Total annual operating cost savings is the savings per unit multiplied by the number of units of each vintage surviving in a particular year. Equipment consumes energy over its entire lifetime, and for units purchased in 2035, the consumption includes energy consumed until the unit is retired from service.

10.4 NES AND NPV RESULTS

The NES spreadsheet model provides estimates of the NES and NPV due to various candidate standards levels. The inputs to the NES spreadsheet have been discussed earlier in sections 10.2.2 (NES Inputs) and 10.3.2 (NPV Inputs). The Department generated the NES and NPV results using a Microsoft Excel® spreadsheet, which is accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html). Details and instructions for using the spreadsheet are discussed in Appendix R.

10.4.1 NES and NPV Input Summary

Table 10.4.1 summarizes the inputs to the NES spreadsheet model. For each input a brief description of the data source is given.

Table 10.4.1 NES and NPV Inputs

Input	Data Description
Shipments	Annual shipments from shipments model (see Chapter 9).
Effective Date of Standard	2008 (2004 for the ASHRAE/IESNA 90.1-1999 standards case).
Base Case Efficiencies	Annual shipment-weighted efficiencies based on historical residential central air conditioner shipment-weighted efficiency trends and limited commercial unitary air conditioner shipment-weighted efficiencies. **Prior to 1993:** Efficiency trend equivalent to 1982-1991 residential equipment efficiency trend. **1993-1994:** Efficiency jump equivalent to 1991 to 1992 residential equipment efficiency jump. **1994-1998:** Efficiency trend equivalent to 1992-1999 residential equipment efficiency trend. **1999-2001:** Actual shipment weighted efficiencies from ARI. **2002-2030:** Efficiency trend growth rate equivalent to ½ of 1992-1999 residential equipment efficiency trend.
Standards Case Efficiencies	Annual shipment-weighted efficiencies based on the use of one of a Roll-up efficiency scenario and a Parallel growth trend.
Annual Energy Consumption per Unit	Annual weighted-average values are a function of efficiency level (established from the building simulation analysis, Chapter 6).
Total Installed Cost per Unit	Annual weighted-average values are a function of efficiency level (established from the life-cycle cost analysis, Chapter 8).
Electricity Expense per Unit	Annual weighted-average values are a function of the annual energy consumption and electricity prices (established form the life-cycle cost analysis, Chapter 8). Only expenses based on tariff-based electricity prices are used in the NES spreadsheet model.
Repair Cost per Unit	Annual weighted-average values are a function of efficiency level (established from the life-cycle cost analysis, Chapter 8).
Maintenance Cost per Unit	Annual weighted-average value equals $200 (established from the life-cycle cost analysis, Chapter 8).
Escalation of Electricity Prices	2003 EIA *Annual Energy Outlook* forecasts (to 2025) and extrapolation for 2025 and beyond (see the life-cycle cost analysis , Chapter 8).
Electricity Site-to-Source Conversion	Conversion varies yearly and is generated by DOE/EIA's NEMS* program (a time series conversion factor; includes electric generation, transmission, and distribution losses).
Discount Rate	3 and 7 percent real.
Present Year	Future expenses are discounted to year 2001.

* Chapter 13 on the utility impact analysis and Chapter 14 on the environmental assessment provide more detail on NEMS.

10.4.2 National Energy Savings Results

The following section provides NES results for the efficiency levels considered for the two equipment classes of commercial unitary air conditioners. Results are cumulative to 2035 and are shown as primary energy savings. Inputs to the NES spreadsheet model are based on weighted-average values yielding results which are discrete point values, rather than a distribution of values as in the LCC analysis.

Table 10.4.2 and Figure 10.4.1 show the NES results for the candidate standard levels analyzed for both equipment classes of commercial unitary air conditioners. The Department based all the results on electricity price forecasts from the *AEO2003* Reference Case. Note that DOE projects the base case energy consumption (i.e., the national cumulative energy consumption without standards) to be 13.2 quads for the ≥65,000 Btu/h to <135,000 Btu/h equipment class and 10.8 quads for the ≥135,000 Btu/h to <240,000 Btu/h equipment class.

Table 10.4.2 Cumulative National Energy Savings for Commercial Unitary Air Conditioners

Candidate Standard Level	Effective Date	≥65 kBtu/h to <135 kBtu/h NES (Quads)	≥135 kBtu/h to <240 kBtu/h NES (Quads)
ASHRAE/IESNA 90.1-1999	2004	0.31	0.20
10.0 EER	2008	-	0.31
10.5 EER	2008	0.39	0.53
11.0 EER	2008	0.70	0.79
11.5 EER	2008	0.98	1.02
12.0 EER	2008	1.08	1.09

Note: Cumulative national energy consumption for the base case: 13.2 Quads for ≥65 kBtu/h to <135 kBtu/h; 10.8 Quads for ≥135 kBtu/h to <240 kBtu/h.

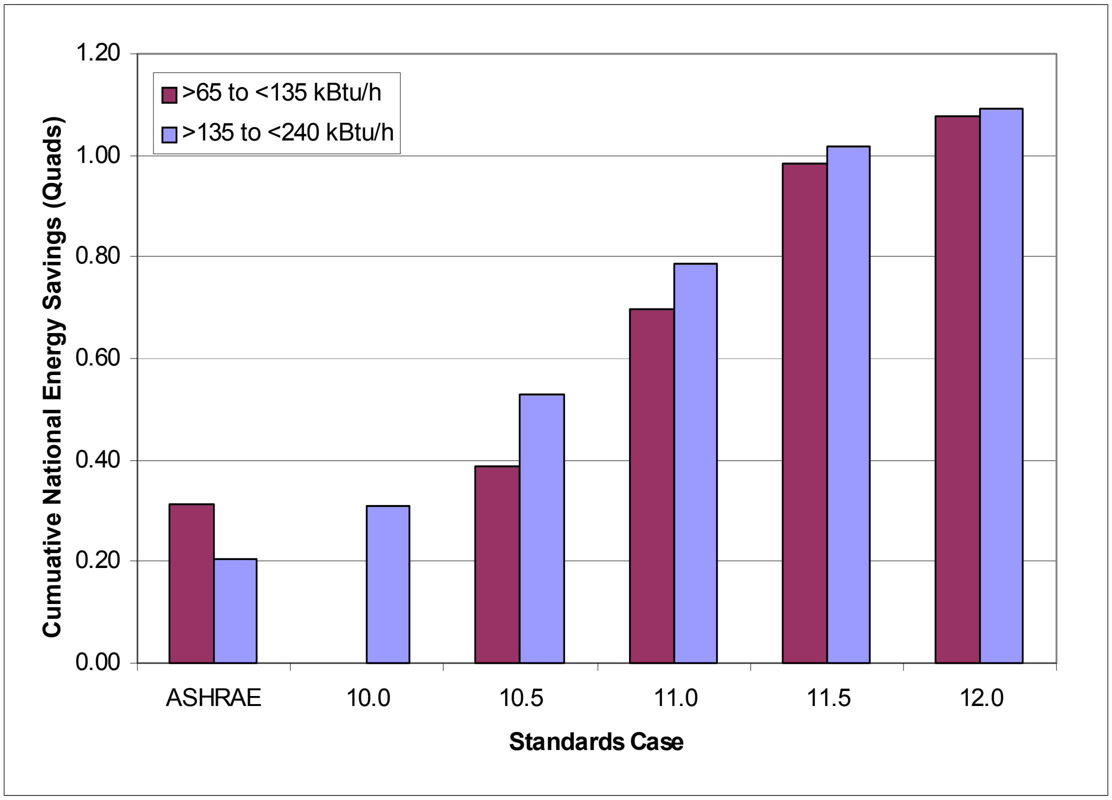

Figure 10.4.1 Cumulative National Energy Savings for Commercial Unitary Air Conditioners

10.4.3 Annual Costs and Savings

As a prelude to providing the NPVs for each candidate standard level in each equipment class, this section presents the annual equipment cost (or total installed cost) increases and annual operating cost savings at the national level.

For the ≥65,000 Btu/h to <135,000 Btu/h equipment class, Figures 10.4.2–10.4.6 show the changes over time of the non-discounted annual equipment price increases and the non-discounted operating cost savings at each of the five candidate standard levels: ASHRAE/IESNA 90.1-1999, and 10.5, 11.0, 11.5, and 12.0 EER. Each figure also shows the net annual impact, which is the difference between the savings and costs for each year. The annual equipment price change is the increase in equipment price for equipment purchased each year over the period 2008–2035 (the start year for the ASHRAE standards case is 2004). The annual operating savings is the savings in operating costs for equipment purchased, and which have not been retired, for each year over the time period. The Department determined the annual costs and savings presented in each figure based on the *AEO2003* Reference Case. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs.

Figures 10.4.3 through 10.4.6 initially show smaller annual operating cost savings compared to the increased equipment price costs. For candidate standard levels up through 11.0 EER, operating cost savings increase with time, as more and more equipment meeting the efficiency standard comprises the commercial unitary air conditioner stock. But for the 11.5 EER and 12.0 EER standards cases, operating cost savings begin to decrease after the early 2020s. There are two reasons for this decrease: 1) the equipment stock becomes saturated with air-conditioning units meeting the energy efficiency standard, and 2) the rate of increase in the efficiency of equipment under the standards case is slower than in the base case. Refer back to Figure 10.2.2 for details on the efficiency trends for the base case and standards cases. The disparity in the rate of the equipment energy efficiency increase between the standards case and base case also explains the smaller equipment price change in later years.

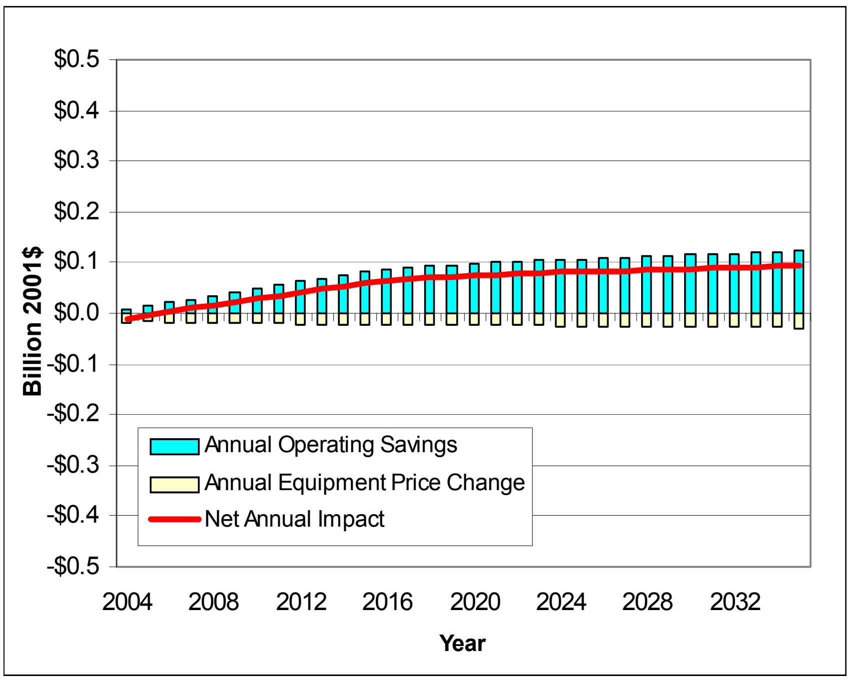

Figure 10.4.2 ≥65,000 Btu/h to <135,000 Btu/h: National Annual Costs and Savings for ASHRAE/IESNA 90.1-1999 Candidate Standard Level

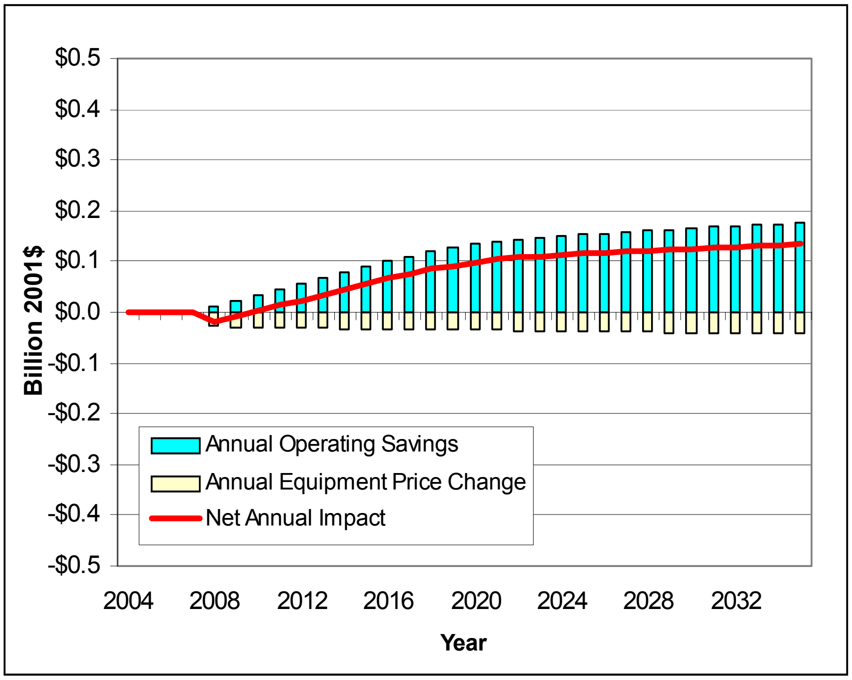

Figure 10.4.3 ≥65,000 Btu/h to <135,000 Btu/h: National Annual Costs and Savings for 10.5 EER Candidate Standard Level

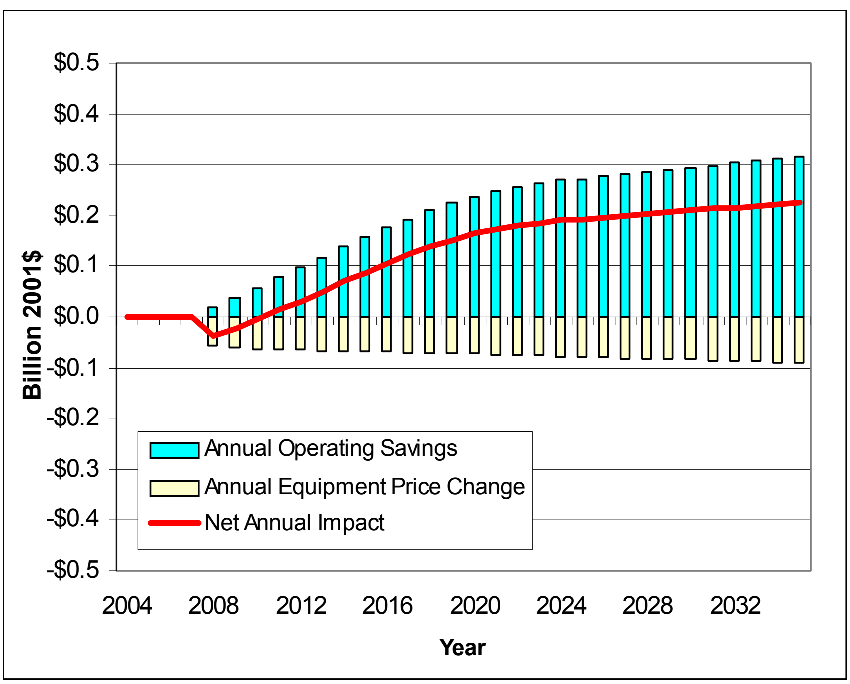

Figure 10.4.4 ≥65,000 Btu/h to <135,000 Btu/h: National Annual Costs and Savings for 11.0 EER Candidate Standard Level

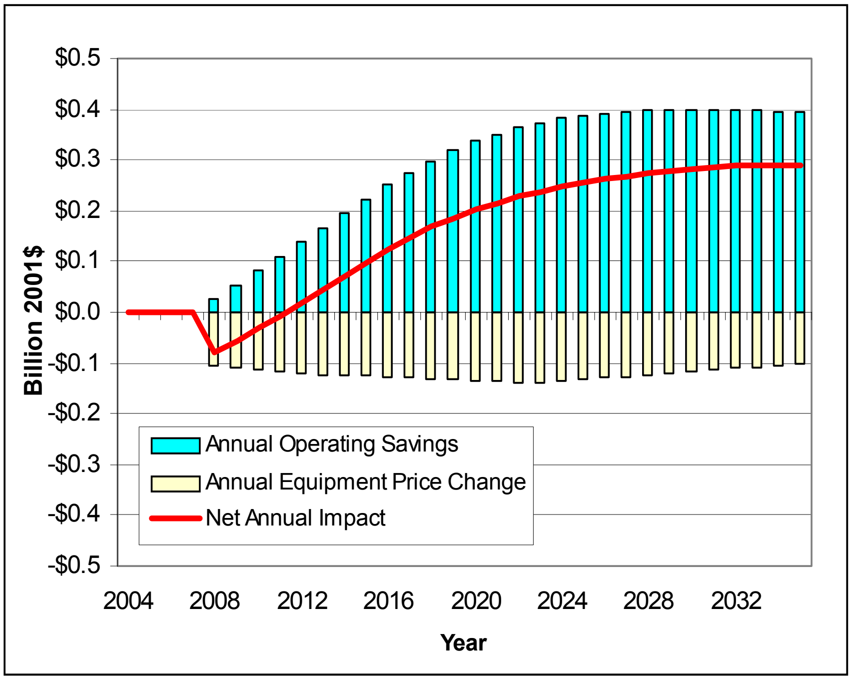

Figure 10.4.5 ≥65,000 Btu/h to <135,000 Btu/h: National Annual Costs and Savings for 11.5 EER Candidate Standard Level

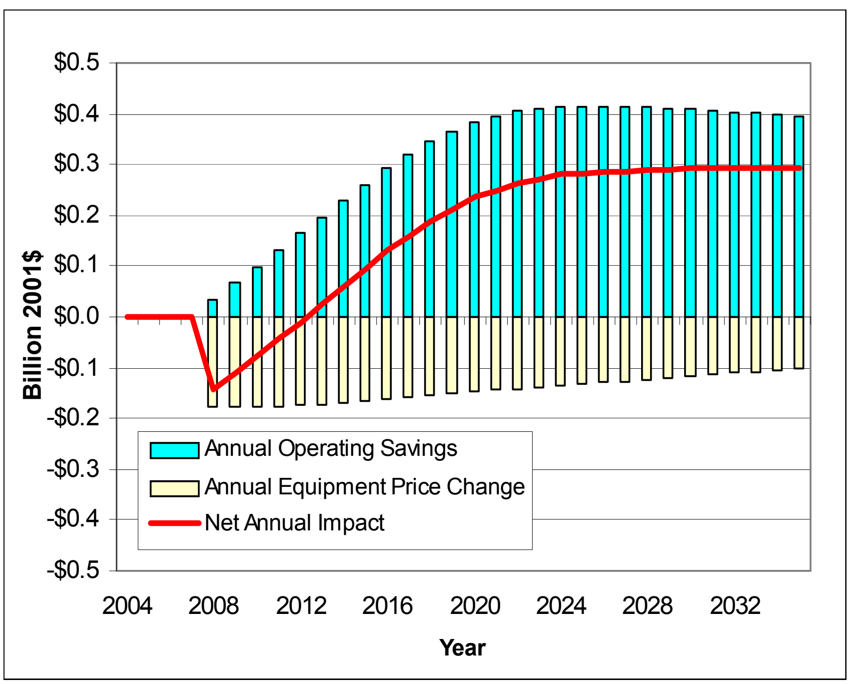

Figure 10.4.6 ≥65,000 Btu/h to <135,000 Btu/h: National Annual Costs and Savings for 12.0 EER Candidate Standard Level

For the ≥135,000 Btu/h to <240,000 Btu/h equipment class, Figures 10.4.7–10.4.12 show the changes over time of the non-discounted annual equipment price increases and the non-discounted operating cost savings at each of the six candidate standard levels: ASHRAE/IESNA 90.1-1999, and 10.0, 10.5, 11.0, 11.5, and 12.0 EER. Each figure also shows the net annual impact, which is the difference between the savings and costs for each year. The annual equipment price change is the increase in equipment price for equipment purchased each year over the period 2008 to 2035 (the start year for the ASHRAE standards case is 2004). The annual operating savings is the savings in operating costs for equipment purchased, and which have not been retired, for each year over the time period. The Department determined the annual costs and savings presented in each figure based on the *AEO2003* Reference Case. The NPV is the difference between the cumulative annual discounted savings and cumulative annual discounted costs. The operating cost savings and equipment price increases for each of the efficiency levels for the ≥135,000 Btu/h to <240,000 Btu/h equipment class behave in a manner similar to that presented earlier for the ≥65,000 Btu/h to <135,000 Btu/h equipment class (Figures 10.4.2–10.4.6).

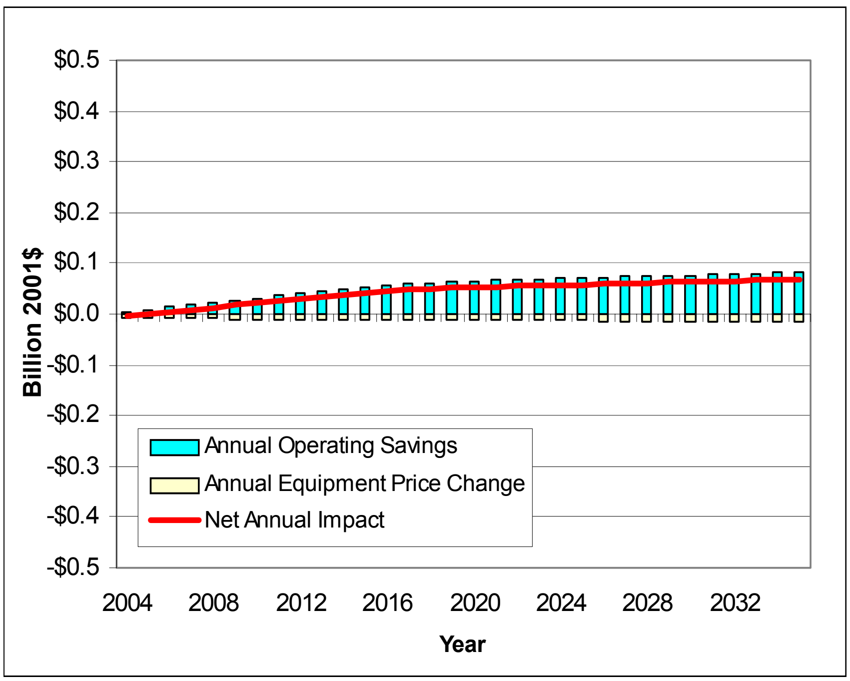

Figure 10.4.7 ≥135,000 Btu/h to <240,000 Btu/h: National Annual Costs and Savings for ASHRAE/IESNA 90.1-1999 Candidate Standard Level

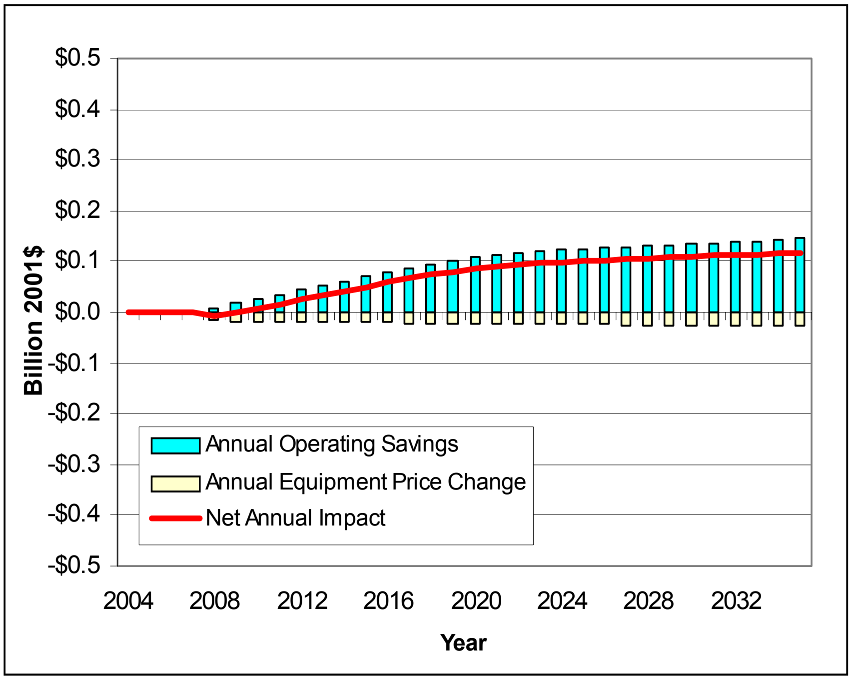

Figure 10.4.8 ≥135,000 Btu/h to <240,000 Btu/h: National Annual Costs and Savings for 10.0 EER Candidate Standard Level

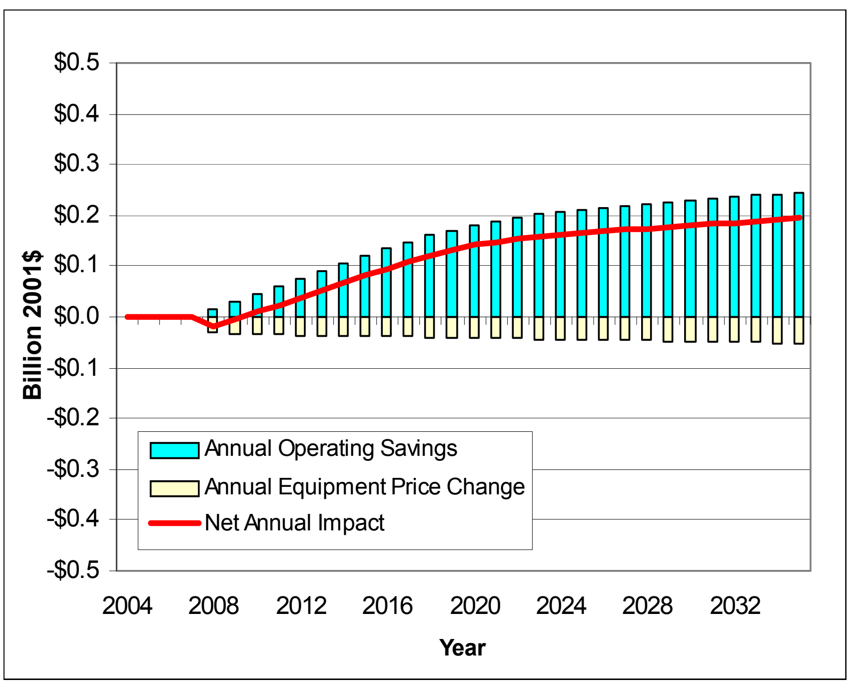

Figure 10.4.9 ≥135,000 Btu/h to <240,000 Btu/h: National Annual Costs and Savings for 10.5 EER Candidate Standard Level

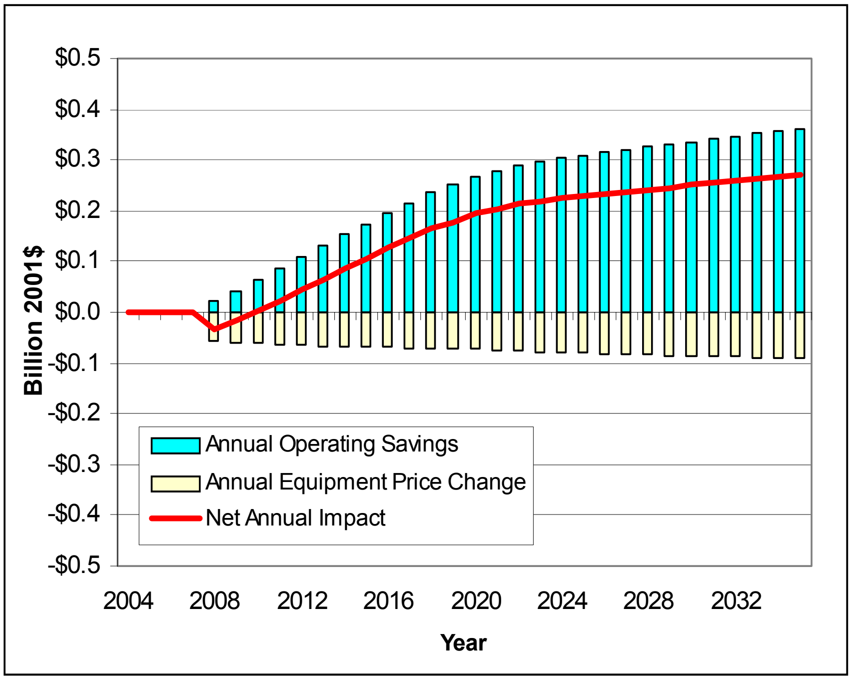

Figure 10.4.10 ≥135,000 Btu/h to <240,000 Btu/h: National Annual Costs and Savings for 11.0 EER Candidate Standard Level

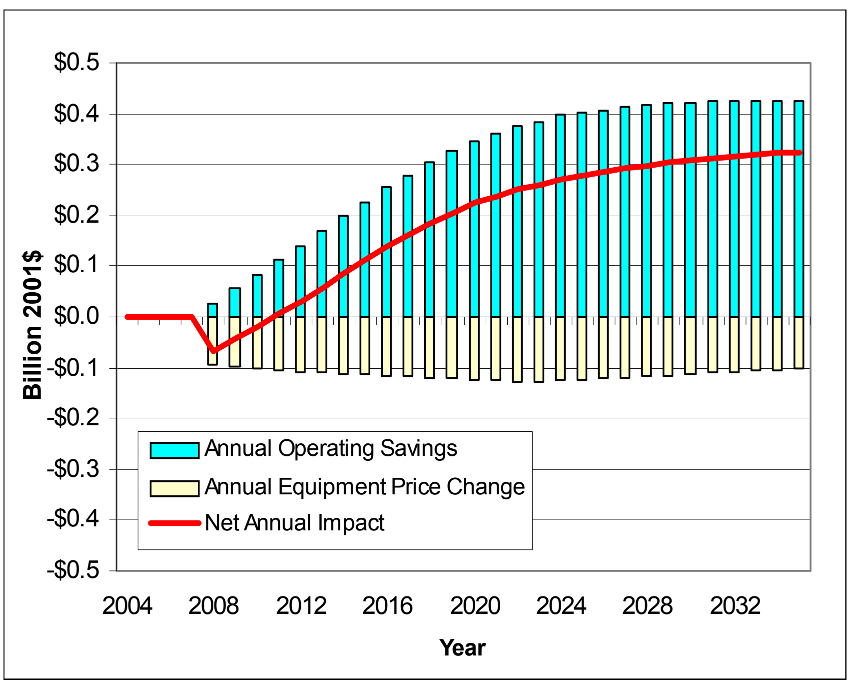

Figure 10.4.11 ≥135,000 Btu/h to <240,000 Btu/h: National Annual Costs and Savings for 11.5 EER Candidate Standard Level

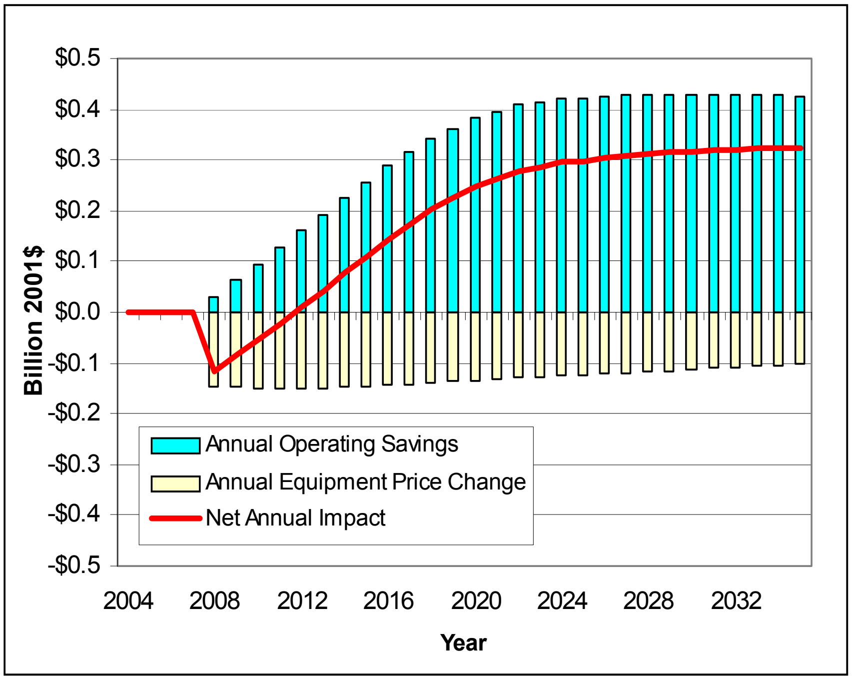

Figure 10.4.12 ≥135,000 Btu/h to <240,000 Btu/h: National Annual Costs and Savings for 12.0 EER Candidate Standard Level

10.4.4 Net Present Value Results

The following section provides NPV results for the candidate standards levels considered for the two equipment classes of commercial unitary air conditioners. Results are cumulative and are shown as the discounted value of these savings in dollar terms. The inputs to the NES spreadsheet model are based on weighted-average values yielding results which are discrete point values, rather than a distribution of values as in the LCC analysis.

The present value of increased total installed costs is the total installed cost increase (i.e., the difference between the standards case and base case), discounted to the present, and summed over the time period in which DOE evaluates the impact of standards (i.e., from the effective date of standards, 2008 (or 2004 for the ASHRAE/IESNA 90.1-1999 standards case), to the year 2035).

Savings are decreases in operating costs (including electricity, repair, and maintenance) associated with the higher energy efficiency of commercial unitary air conditioners purchased in the standards case compared to the base case. Total operating cost savings are the savings per unit multiplied by the number of units of each vintage (i.e., the year of manufacture) surviving in a particular year. Commercial unitary air-conditioning equipment consumes energy and must be maintained over its entire lifetime. For units purchased in 2035, the operating cost includes energy consumed and maintenance and repair costs incurred until the last unit is retired from service.

Table 10.4.3 and Figure 10.4.13 show the NPV results for the standard levels considered for commercial unitary air conditioners based upon a seven percent discount rate. The Department based all results on electricity price forecasts from the *AEO2003* Reference Case. Note that the cumulative national equipment and operating costs of unitary air conditioners under the base case (i.e., without standards) equals $58 billion for the ≥65,000 Btu/h to <135,000 Btu/h equipment class and $43 billion for the ≥135,000 Btu/h to <240,000 Btu/h equipment class. Detailed results showing the breakdown of the NPV into national equipment costs and national operating costs are provided in Appendix S.

Table 10.4.3 Cumulative NPV Results based on a Seven percent Discount Rate (billion 2001$)

Candidate Standard Level	Effective Date	**≥65 kBtu/h to <135 kBtu/h** **NPV** (billion 2001$)	**≥135 kBtu/h to <240 kBtu/h** **NPV** (billion 2001$)
ASHRAE/IESNA 90.1-1999	2004	0.52	0.38
10.0 EER	2008	-	0.51
10.5 EER	2008	0.57	0.83
11.0 EER	2008	0.93	1.12
11.5 EER	2008	1.08	1.24
12.0 EER	2008	1.02	1.20

Note: Cumulative national energy consumption for the base case: $58 billion for ≥65 kBtu/h to <135 kBtu/h; $43 billion for ≥135 kBtu/h to <240 kBtu/h.

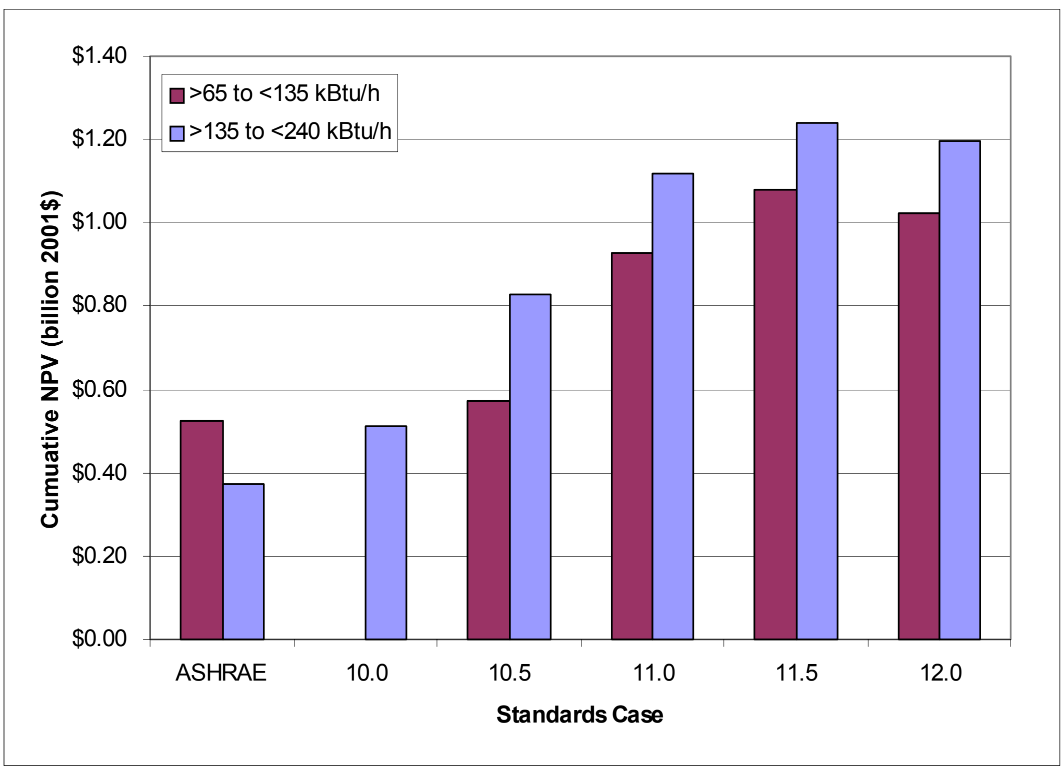

Figure 10.4.13 Cumulative NPV at a Seven percent Discount Rate for Commercial Unitary Air Conditioners

Table 10.4.4 and Figure 10.4.14 provide the NPV results based on the three percent discount rate and electricity price forecasts from the *AEO2003* Reference Case. There is an increase in the total national costs of operating commercial unitary air conditioners in the base case ($125 billion and $94 billion at a three percent discount rate as opposed to $58 billion and $43 billion at a seven percent discount rate for the ≥65,000 Btu/h to <135,000 Btu/h to ≥135,000 Btu/h to <240,000 Btu/h equipment classes, respectively). As with the NPV results based upon a seven percent discount rate, detailed results showing the breakdown of the NPV into national equipment costs and national operating costs based upon a three percent discount rate are provided in Appendix S.

Table 10.4.4 Cumulative NPV Results based on a Three percent Discount Rate (billion 2001$)

Candidate Standard Level	Effective Date	**≥65 kBtu/h to <135 kBtu/h** **NPV** (billion 2001$)	**≥135 kBtu/h to <240 kBtu/h** **NPV** (billion 2001$)
ASHRAE/IESNA 90.1-1999	2004	1.25	0.90
10.0 EER	2008	-	1.33
10.5 EER	2008	1.52	2.19
11.0 EER	2008	2.53	3.02
11.5 EER	2008	3.06	3.44
12.0 EER	2008	3.05	3.44

Note: Cumulative national energy consumption for the base case: $125 billion for ≥65 kBtu/h to <135 kBtu/h; $94 billion for ≥135 kBtu/h to <240 kBtu/h.

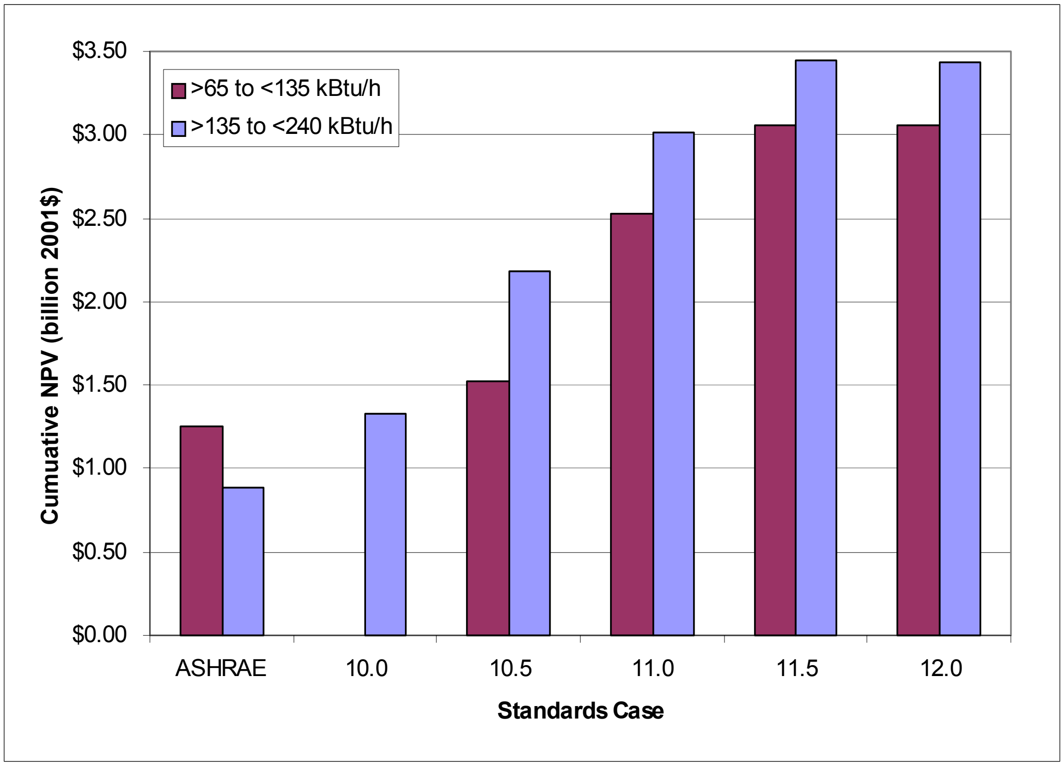

Figure 10.4.14 Cumulative NPV at a Three percent Discount Rate for Commercial Unitary Air Conditioners

10.4.5 "Max Tech" Sensitivity

As discussed earlier, the maximum technologically feasible design (i.e., "max tech") is 12.0 EER. In anticipation that a "max tech" level could be justified beyond 12.0 EER, the Department ran a sensitivity case to determine the impact on the NES and NPV from a "max tech" design that is greater than 12.0 EER. Under this sensitivity case, the "max tech" design is allowed to be two EER rating points higher than the standard. Under the ASHRAE/IESNA Standard 90.1-1999 and 10.0 EER candidate standard levels, the forecasted efficiency trend remains unchanged as the "max tech" design remains at 12.0 EER. But under all other candidate standard levels, the forecasted efficiency trends are impacted as the "max tech" design is greater than 12.0 EER (i.e., 12.5 EER for the 10.5 EER candidate standard level, 13.0 EER for the 11.0 EER candidate standard level, 13.5 EER for the 11.5 EER candidate standard level, and 14.0 EER for the 12.0 EER candidate standard level). Although the "max tech" design is allowed to be greater than 12.0 EER, it is gradually phased in over time resulting in efficiency trends that are not dramatically different than those developed with a 12.0 EER "max tech" design. As a result, only the NES and NPV results for the12.0 EER candidate standard levels are significantly different from those results based on a "max tech" design of 12.0 EER. Appendix U provides the details on the efficiency trends and the NES and NPV results for the "max tech" sensitivity.

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1. Air-Conditioning and Refrigeration Institute (ARI), *2000 Statistical Profile*, 2000. Arlington, VA.

2. U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2003*, January 2003. Washington, DC. Report No. DOE/EIA-0383(2003).