CHAPTER 11. NATIONAL IMPACT ANALYSIS

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CHAPTER 11. NATIONAL IMPACT ANALYSIS

11.1 INTRODUCTION

This chapter describes the method for estimating the magnitude and net present value (NPV) of future national energy savings (NES) to customers from possible trial standards levels (TSLs) for commercial refrigeration equipment (CRE). Results of the national impact analysis (NIA) described here include national energy consumption and savings, monetary value of energy savings to the Nation as a result of standards, increased total installed costs to the Nation as a result of standards, and the NPV of energy savings (the difference between the present monetary values of energy savings and the increased total installed costs).

The U.S. Department of Energy (DOE) determined both the NPV and the NES for each candidate standard level it considered for each of the 15 equipment classes of commercial refrigeration equipment it examined. DOE considered five TSLs for each equipment class.

DOE performed all calculations using a Microsoft Excel spreadsheet, which is accessible on the Internet at http://www.eere.energy.gov/buildings/appliance_standards/commercial_products.html. Details and instructions for using the spreadsheet are discussed in Appendix H of the Technical Support Document (TSD). A more detailed set of results is available in Appendix I of the TSD. The important facets of national energy consumption for each equipment class of commercial refrigeration equipment include shipments, stock or inventory, national average electricity consumption, and the site-to-source conversion factor that is used to translate the amount of electricity consumed at the site where it is used into the amount of energy that must be consumed at the source where that electricity was produced. Chapter 10, Shipments Analysis, provides a detailed description of the shipments analysis that DOE used to forecast future purchases of commercial refrigeration equipment.

DOE was not able to obtain information that quantified how voluntary energy efficiency programs affect equipment efficiencies on a national basis, although voluntary programs may increase the share of energy efficient equipment prior to the implementation date of any new standards. Consequently, DOE did not explicitly incorporate the impact of market-based initiatives into the shipments forecasts detailed in Chapter 10 of this TSD.

11.2 NATIONAL ENERGY SAVINGS

11.2.1 National Energy Savings Definition

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

$$NES_t = AEC\ base - AEC\ standard \qquad \textbf{Eq. 11.1}$$

Cumulative energy savings are the sum over a defined time period from the implementation of a standard forward (from 2012 to 2042) of the annual national energy savings.

$$NES_{cum} = \sum_t NES_t \qquad \textbf{Eq. 11.2}$$

DOE calculated the AEC by multiplying the number or stock of commercial refrigeration equipment (by vintage) by the unit energy consumption (also by vintage) as shown by the following equation:

$$AEC = STOCK_v \text{ x } UEC_v \text{ x } src\_conv_t \qquad \textbf{Eq. 11.3}$$

For the above expressions, DOE defined the following quantities:

AEC = Annual national energy consumption each year in quadrillion British thermal units (quads), summed over vintages of commercial refrigeration equipment stock, $STOCK_v$,

NES = Annual national energy savings (quads),

$STOCK_v$ = Stock of commercial refrigeration equipment (millions of linear feet) of vintage *V* surviving in the year for which DOE calculated annual energy consumption.

Vintages range from seven years to approximately 20 years, a consequence of an assumed 10-year average lifetime of the equipment for equipment sold to large grocery chains, and an assumed 15-year average lifetime for equipment sold to small, independent grocery outlets,

UEC_v = Annual unit energy consumption in kilowatt hours (kWh),

src_conv_t = Time-dependent conversion factor to convert from site energy (kWh) to source energy (quads) (Btu/kWh),

V = Year in which the commercial refrigeration equipment was purchased as a new unit,

t = Year in the forecast (e.g., 2012 to 2042).

The stock of commercial refrigeration equipment is dependent on annual shipments and the lifetime of the equipment. DOE believes that the shipment projections under the standards cases could be lower than those in the base case projection because the higher installed costs would cause some customers to forego new equipment purchases. However, DOE has no information that would allow a calculation of this effect. For the Notice of Proposed Rulemaking (NOPR), the total shipments projections are the same in both the base case and standards cases.

11.2.2 National Energy Savings Inputs

Table 11.2.1 lists the inputs for the determination of NES.

Table 11.2.1 National Energy Saving Inputs

Input
Annual Unit Energy Consumption (*UEC*) (quads)
Shipments
Equipment Stock ($STOCK_v$)
Site-to-Source Conversion Factor (*src_conv*) (quads) (Btu/kWh)

11.2.2.1 Annual Unit Energy Consumption

The annual unit energy consumption (UEC) is the site energy consumed by a commercial refrigeration unit per year. UEC is directly tied to the efficiency of the unit. Thus, knowing the efficiency of a commercial refrigeration unit determines the corresponding UEC. Because the equipment classes analyzed represent equipment sold across a range of sizes, DOE's "unit" in the NES is actually expressed as a linear foot of equipment in an equipment class and not an individual unit of commercial refrigeration equipment of a specific size. As described below, DOE determined annual forecasted shipment-weighted average equipment efficiencies that, in turn, enabled a determination of shipment-weighted annual energy consumption values.

DOE did not have data on the market shares within each of the equipment classes by efficiency level. DOE used the 2005 commercial refrigeration equipment shipments by equipment class provided by the industry to develop future market shares by equipment class. DOE used these market shares and the estimates of future shipments for all commercial refrigeration equipment to develop projections of shipments by equipment class. It then adapted a cost-based method used in the National Energy Modeling System (NEMS) to estimate market shares within each equipment class by efficiency level. DOE then extrapolated future scenarios of the equipment efficiency both for a base case (i.e., without new standards) and for various standards-cases (i.e., with new standards) using the same cost-based method. The difference in equipment efficiency between the base case and standards case was the basis for determining the reduction in UEC resulting from new standards.

The market share for each equipment class by efficiency level is defined as *EFF_Level_Share(i,y),* for each equipment class, *y,* at each efficiency level, *i*. Because the lifetime of each equipment class is presumed to be the same, and because DOE had no information regarding future changes in market shares between equipment classes, DOE assumed the market share for a particular equipment class to be constant over time. DOE calculated the *EFF_Level_Share(i,y)* for each efficiency level *i* using the formula below, based on the relative annualized cost of each efficiency level.

$$EFF\_Level\_Share(i,y) = \sum_{j=1}^{m} b_j \times \frac{\left(IC_{(i,y)} \times \frac{r_j}{1-(1+r_j)^{-n}} + OC_{(i.y)} \right)^{-v}}{\sum_{i=1}^{k} \left(IC_{(i,y)} \times \frac{r_j}{1-(1+r_j)^{-n}} + OC_{(i.y)} \right)^{-v}} \qquad \textbf{Eq. 11.4}$$

where

EFF_Level_Share(i,y) = the market share of equipment class *y* at TSL *i*,

IC(i, y) = installed costs of equipment class y at TSL *i*, *i*=1 to *k* ($),

OC(i,y) = annual operating cost (maintenance, repair, and energy cost) of equipment class *y* at TSL *i* ($),

r_j = private, risk-adjusted discount rate for risk class *j*. Derived by adding a "time preference premium" to the risk-free real rate of return in the marketplace (4.39 percent

long-term Treasury bond rate, minus the estimated long-term inflation rate of 2.2 0 percent = 2.39 percent)

b_j = market share of equipment users with risk class j, j =1 to m,

v = risk penalty factor (also known as a measure of market heterogeneity),

n = equipment lifetime (years).

The components for *IC* and *OC* came from the same inputs as the life-cycle cost analysis (see chapter 8, Life-Cycle Cost and Payback Period Analysis). The annualization factor $(r_j/(1-(1+r_j)^{-n})$ converts installed cost into its annual equivalent, so that market shares are based on the relative annual costs of each energy consumption level, with (generally) higher annualized costs of higher energy consumption levels leading to lower relative market shares. This is consistent with the approaches used in the Energy Information Administration's (EIA) National Energy Modeling System[1] (NEMS) and in the Canadian Integrated Modeling System (CIMS)[2a]. The calibration constants are the private risk-based discount rates by risk class r_j, taken from the NEMS commercial model as shown in Table 11.2.2, the default value of v = 10, taken from the CIMS, and the equipment lifetime of 7–20 years.

Table 11.2.2 Risk Premiums by Risk Class (j) in the NEMS Commercial Model

Percentage of Users in Class	Time Preference Premium	Implied Real Discount Rate
1%	0.0%	2.14%
2%	13.6%	15.79%
10%	19.9%	22.09%
15%	30.9%	33.09%
20%	55.4%	57.59%
25%	152.9%	155.09%
27%	1000.0%	1002.19%
100%		

Source: NEMS Commercial Model

Table 11.2.3 provides estimated base-case market shipment-weighted shares for each of the 15 equipment classes analyzed in this rulemaking.

To project changes in weighted-average efficiency as standards above the base-case efficiency are introduced, DOE assumed that market shares below the minimum permitted efficiency level would be reassigned to the new TSL level. For example, if a TSL 2 standard (equivalent to efficiency Level 4 for this piece of equipment) were imposed in 2012 on the VOP.RC.M equipment class, then the market shares for Levels 1, 2, and 3 would be assigned to Level 4, which would result in a market share of 70.8% = (17.4% +18.1% +18.4% +16.9%) from the first four columns of the first row in Table 11.2.3) for Level 4, beginning in 2012.

The market shares for Levels 5–8 would not be affected, since the market already has made a choice of that equipment with Level 4 equipment also available. It was assumed that the standard (efficiency Level 4) would not affect the relative attractiveness of equipment with efficiencies higher than the standard level.

[a] The CIMS Model was originally known as the Canadian Integrated Modeling System, but because the model is now being applied to other countries, the acronym is now used as its proper name.

Table 11.2.3 Shipment-Weighted Market Shares by Efficiency Level, Base Case

Equipment Class*	Shipment-Weighted Market Shares by Efficiency Level**,§							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	17.4%	18.1%	18.4%	16.9%	14.6%	14.0%	0.6%	0.0%
VOP.RC.L	15.2%	16.1%	16.4%	15.0%	14.7%	14.4%	8.2%	0.0%
VOP.SC.M	16.1%	17.2%	16.7%	15.4%	13.9%	10.0%	9.2%	1.4%
VCT.RC.M	19.9%	20.0%	19.7%	14.8%	8.8%	8.6%	8.2%	0.0%
VCT.RC.L	19.2%	19.3%	19.0%	12.0%	10.5%	10.3%	9.8%	0.0%
VCT.SC.I	14.3%	15.3%	15.4%	13.7%	11.3%	10.3%	10.3%	9.5%
VCS.SC.I	11.7%	12.3%	12.9%	13.5%	13.6%	12.8%	11.8%	11.3%
SVO.RC.M	17.1%	17.7%	18.0%	16.9%	15.1%	14.3%	0.9%	0.0%
SVO.SC.M	15.5%	16.6%	16.4%	15.3%	14.3%	10.6%	9.6%	1.8%
SOC.RC.M	17.6%	18.0%	18.2%	17.5%	17.0%	4.2%	4.1%	3.4%
HZO.RC.M	19.6%	20.5%	21.0%	20.0%	18.9%	0.0%	0.0%	0.0%
HZO.RC.L	20.1%	20.5%	20.5%	19.9%	19.1%	0.0%	0.0%	0.0%
HZO.SC.M	13.0%	13.8%	13.9%	13.8%	13.4%	11.3%	11.0%	9.7%
HZO.SC.L	12.8%	13.9%	14.0%	13.6%	13.6%	11.2%	10.9%	10.0%
HCT.SC.I	17.3%	17.9%	17.9%	16.8%	16.3%	13.8%	0.0%	0.0%

* Equipment class designations consist of a combination (in sequential order separated by periods) of a equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter), an operating mode code (RC=remote condensing or SC=self-contained), and a rating temperature code (M=medium temperature (38°F), L=low temperature (0°F), or I=ice-cream temperature (-15°F)). For example, "VOP.RC.M refers to the "vertical open, remote condensing, medium temperature" equipment class. See Chapter 3, Market and Technology Assessment, of the TSD for a more detailed explanation of the equipment class terminology

**A value of 0.0% means that no market share was calculated for this efficiency level. For example, the VOP.RC.M equipment class only had seven possible efficiency levels, so no market share was allotted to efficiency level 8.

§Shares may not add to 100% exactly due to rounding.

As stated earlier, annual energy consumption values are tied directly to the efficiency of the equipment. Table 11.2.4 presents the UEC values according to annual electricity use per linear foot per year (kWh/linear foot/year). Electricity use per linear foot is how DOE expressed the annual energy per unit in the NES spreadsheet model. Because projections of grocery refrigeration and freezer space (expressed in linear feet) are the primary drivers used to estimate future CRE shipments, DOE calculated the national refrigeration equipment energy expense by expressing the per-unit annual energy use on a linear-footage basis.

For the annual shipment-weighted efficiency levels specified in the base case and standards case efficiency scenarios, DOE calculated the shipment weighted UEC values shown in Table 11.2.5. For each equipment class, the value shown for a given efficiency level is the shipment-weighted average UEC for each standard level from chapter 10 (Shipments Analysis), after taking into account the non-availability of equipment at efficiency levels below the minimum standard efficiency level shown.

Table 11.2.4 Unit Energy Consumption by Efficiency Level

Equipment Class	Annual Energy Consumption per Linear Foot (kWh/linear foot/year)							
	Level 1 (Base Case)	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	1,761	1,681	1,581	1,542	1,450	1,444	1,331	NA
VOP.RC.L	4,064	3,860	3,603	3,445	3,428	3,407	3,297	NA
VOP.SC.M	3,614	3,401	3,280	3,138	3,046	2,802	2,793	2,676
VCT.RC.M	952	911	861	690	476	469	464	NA
VCT.RC.L	1,986	1,940	1,883	1,344	1,150	1,135	1,123	NA
VCT.SC.I	3,873	3,547	3,206	2,831	1,985	1,806	1,797	1,766
VCS.SC.I	2,303	2,181	2,063	1,921	1,837	1,672	1,638	1,619
SVO.RC.M	1,325	1,271	1,204	1,174	1,105	1,101	1,022.16	NA
SVO.SC.M	3,021	2,853	2,798	2,685	2,634	2,440	2,433	2,349
SOC.RC.M	964	913	849	818	798	647	644	627
HZO.RC.M	597	544	478	447	442	NA	NA	NA
HZO.RC.L	1,167	1,126	1,074	1,016	1,003	NA	NA	NA
HZO.SC.M	1,755	1,660	1,628	1,576	1,507	1,375	1,362	1,351
HZO.SC.L	3,530	3,321	3,287	3,071	3,059	2,778	2,766	2,750
HCT.SC.I	774	704	680	395	377	355	NA	NA

*A value of NA means that no energy use was calculated for this efficiency level. For example, the VOP.RC.M only had seven possible efficiency levels.

Table 11.2.5 Shipment-Weighted Average Annual Energy Consumption per Linear Foot by Trial Standard Level

Equipment Class	Shipment-Weighted UEC per Linear Foot (kWh/linear foot/year)					
	Level 1 (Base Case)	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	1,584	1,535	1,513	1,449	1,449	1,331
VOP.RC.L	3,612	3,500	3,425	3,398	3,297	3,297
VOP.SC.M	3,199	3,125	2,993	2,799	2,799	2,676
VCT.RC.M	764	756	735	469	464	464
VCT.RC.L	1,621	1,590	1,280	1,133	1,123	1,123
VCT.SC.I	2,739	2,423	1,927	1,794	1,766	1,766
VCS.SC.I	1,905	1,862	1,768	1,619	1,619	1,619
SVO.RC.M	1,200	1,168	1,152	1,104	1,104	1,022
SVO.SC.M	2,720	2,676	2,589	2,437	2,437	2,349
SOC.RC.M	842	833	811	780	780	627
HZO.RC.M	502	492	465	446	442	442
HZO.RC.L	1,078	1,049	1,014	1,003	1,003	1,003
HZO.SC.M	1,541	1,520	1,461	1,361	1,351	1,351
HZO.SC.L	3,095	3,059	2,965	2,764	2,750	2,750
HCT.SC.I	558	538	386	374	355	355

11.2.2.2 Shipments

DOE forecasted shipments for the base case and all standards cases (see chapter 10, Shipments Analysis).

11.2.2.3 Equipment Stock

The CRE stock in a given year is the total linear footage of commercial refrigeration equipment shipped from earlier years that survive in the given year. The NES spreadsheet model keeps track of the total linear footage of commercial refrigeration units shipped each year. For

purposes of the NES and NPV analyses, DOE assumed that existing CRE units in large grocery chains and multi-line retailers are retired by following a Weibull distribution with an average lifetime of 10 years; CRE units in small convenience stores and similar outlets are retired following a Weibull distribution with an average lifetime of 15 years. The Weibull distribution shows that approximately 1 percent of the existing units are retired from 2012 to 2019 (i.e., by year 7), retire rapidly through year 18, and then tail off gradually to less than 10 percent per year by year 20. Retired units are replaced until 2042. For units shipped in 2042, any units still remaining at the end of 2062 are replaced.

11.2.2.4 National Annual Energy Consumption

The national AEC is the product of the annual UEC and the stocks of CRE units of each vintage. This approach accounts for differences in unit energy consumption from year to year. Equation 11.3 above was used for determining the national annual energy consumption of CRE equipment.

DOE initially calculated the AEC at the site (i.e., electricity in kWh consumed by the CRE units). DOE 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.

11.2.2.5 Site-to-Source Conversion Factor

The site-to-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 site-to-source conversion factor accounts for losses in electricity generation, transmission, and distribution. DOE used annual site-to-source marginal conversion factors based on a detailed analysis contained in appendix H of the TSD. Theses factors take into account the fact that energy savings that would occur as a result of adopting more efficient equipment standard for commercial refrigeration equipment would be most likely to reduce demand for energy from power plants used for peaking power and load following, and that have heat rates lower than the U.S. average values. As shown in Table 11.2.6, the conversion factors vary over time because of projected changes in electricity generation sources (i.e., the power plant types projected to provide electricity to the country). Detailed discussion on calculations of marginal site-to-source conversion factors can be found in Appendix H.

Table 11.2.6 Site-to-Source Conversion Factors

Year	Site-to-Source Conversion Factor Btu/kWh
2012	9,587
2013	9,587
2014	9,587
2015	9,331
2016	9,115
2017	9,207
2018	9,529
2019	10,128
2020	10,347
2021	10,200
2022	9,834
2023	9,854
2024	10,060
2025	10,093
2026	10,020
2027	9,932
2028	9,920
2029	9,990
2030	9,990
2031	9,990
2032–2062	9,990

For details, see Appendix H of the TSD.

11.3 NET PRESENT VALUE

11.3.1 Net Present Value Definition

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

$$NPV = PVS - PVC \qquad \textbf{Eq. 11.5}$$

where

PVS = present value of operating cost savings (including electricity, repair, and maintenance costs) ($),
PVC = present value of increased total installed costs (including equipment and installation) ($).

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

$$PVS = \sum OCS_t \times DF_t \qquad \textbf{Eq. 11.6}$$

$$PVC = \sum TIC_t \times DF_t \qquad \textbf{Eq. 11.7}$$

where

OCS = total annual operating cost savings ($),
TIC = total annual installed cost increases ($),
DF = discount factor,
t = year (*PVS* is summed over 2012-2062, and *PVC* is summed over 2012-2042).

DOE determined the contribution to *PVC* for each year, from the effective date of the standard (2012) to the year 2042, discounted for the ANOPR analysis, to the year 2008. The contribution to *PVS* was determined for each year, from the effective date of the standard (2012) to the year when units purchased in 2042 retire (assumed to be 2062). DOE calculated costs and savings as the difference between a standards case and a base case (i.e., without new standards). DOE 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. DOE calculated the NPV as the sum over time of the discounted net savings (which is equivalent to the approach shown in Equations 11.5–11.7).

11.3.2 Net Present Value Inputs

Table 11.3.1 summarizes the inputs to the NPV calculation.

Table 11.3.1 Net Present Value Inputs

Input
Total Annual Installed Cost (TIC_t) ($)
Total Annual Operating Cost Savings (OCS_t) ($)
Discount Factor
Present Value of Costs (*PVC*) ($)
Present Value of Savings (*PVS*) ($)

11.3.2.1 Total Annual Installed Cost

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. The total installed cost includes both the equipment cost and the installation price. DOE based average equipment costs on average manufacturer prices (see chapter 8, Life-Cycle Cost and Payback Period Analysis) multiplied by average overall markup values also shown in chapter 8). DOE based average installation prices on nationally representative values for each equipment class (see chapter 8). Table 11.3.2 shows the resulting average total installed costs per linear foot for each of the equipment classes of commercial refrigeration units by efficiency level.

DOE developed base case and standards case energy efficiency scenarios as discussed in section 11.2.2.1. For both the base case and standards case energy efficiency scenarios, DOE calculated annual shipment-weighted average efficiencies. Associated with each annual shipment-weighted average efficiency value, DOE assigned a total installed cost, based on shipment-weighted total installed cost for all efficiency levels. DOE based the relationship between efficiency and total installed cost for each CRE class on the data in Table 11.3.2. As shown in Table 11.3.3, DOE estimated the shipments-weighted installed cost. DOE determined

forecasted average shipments-weighted total installed costs based on the annual shipments by efficiency level.

Table 11.3.2 Average Total Installed Cost per Linear Foot by Efficiency Level (2007$)

Equipment Class	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$672	$676	$684	$692	$717	$722	$1,093	NA
VOP.RC.L	$936	$943	$962	$992	$995	$1,001	$1,098	NA
VOP.SC.M	$1,096	$1,103	$1,117	$1,144	$1,167	$1,254	$1,271	$1,662
VCT.RC.M	$916	$919	$925	$978	$1,073	$1,078	$1,084	NA
VCT.RC.L	$988	$991	$997	$1,117	$1,170	$1,175	$1,186	NA
VCT.SC.I	$1,536	$1,545	$1,568	$1,629	$1,781	$1,831	$1,834	$1,858
VCS.SC.I	$983	$987	$991	$999	$1,007	$1,035	$1,051	$1,059
SVO.RC.M	$623	$625	$630	$636	$654	$659	$929	NA
SVO.SC.M	$930	$936	$942	$962	$973	$1,040	$1,057	$1,342
SOC.RC.M	$1,062	$1,064	$1,070	$1,076	$1,082	$1,280	$1,285	$1,316
HZO.RC.M	$678	$680	$686	$693	$699	NA	NA	NA
HZO.RC.L	$683	$685	$691	$700	$706	NA	NA	NA
HZO.SC.M	$850	$852	$854	$860	$871	$907	$911	$928
HZO.SC.L	$959	$965	$966	$990	$991	$1,053	$1,058	$1,074
HCT.SC.I	$725	$728	$730	$770	$775	$795	NA	NA

*A value of NA means that no installed cost was calculated for this efficiency level. For example, the VOP.RC.L only had seven possible efficiency levels.

Table 11.3.3 Shipment-Weighted Average Total Installed Cost per Linear Foot by Trial Standard Level (2007$)

Equipment Class	Level 1 (Base Case)	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	$694	$698	$702	$720	$720	$1,093
VOP.RC.L	$981	$988	$1,002	$1,008	$1,098	$1,098
VOP.SC.M	$1,158	$1,164	$1,192	$1,261	$1,261	$1,662
VCT.RC.M	$969	$970	$972	$1,078	$1,084	$1,084
VCT.RC.L	$1,063	$1,066	$1,135	$1,176	$1,186	$1,186
VCT.SC.I	$1,674	$1,710	$1,799	$1,837	$1,858	$1,858
VCS.SC.I	$1,013	$1,015	$1,022	$1,059	$1,059	$1,059
SVO.RC.M	$640	$642	$645	$657	$657	$929
SVO.SC.M	$975	$978	$995	$1,047	$1,047	$1,342
SOC.RC.M	$1,097	$1,097	$1,099	$1,107	$1,107	$1,316
HZO.RC.M	$687	$688	$690	$694	$699	$699
HZO.RC.L	$693	$696	$701	$706	$706	$706
HZO.SC.M	$876	$877	$885	$913	$928	$928
HZO.SC.L	$1,002	$1,003	$1,014	$1,059	$1,074	$1,074
HCT.SC.I	$752	$753	$774	$778	$795	$795

11.3.2.2 Total Annual Operating Cost Savings

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 annual operating cost includes electricity, repair, and maintenance costs.

Annual Electricity Cost Savings. As described in chapter 8, DOE calculated annual electricity costs based on average State-level commercial electricity prices. To calculate annual energy cost savings for a particular equipment class in a given year, DOE first calculated the annual energy costs in each forecast year at each standard level by multiplying the weighted-average energy consumption at each efficiency level from Table 11.2.6 times the linear feet of equipment stock in the equipment class in each year, and then times the sales-weighted national average electricity prices for the four building types in Chapter 8. To determine energy savings, the national energy costs at each efficiency level (Levels 2–8) were then subtracted from the national energy costs at the baseline level (Level 1). Because projections of the stock of commercial refrigeration equipment (expressed in linear feet) are the primary drivers used to estimate future CRE shipments, DOE calculated the national energy cost more readily by expressing the AEC on a linear-footage basis.

Annual Repair Costs. DOE based average annual repair costs on the value of the commercial refrigeration equipment (see chapter 8). Table 11.3.4 shows the average repair costs per linear foot for the equipment classes of commercial refrigeration units. The NES spreadsheet provides the capability to allow repair costs to differ by the price of the commercial refrigeration equipment, and, therefore, by TSL. For the purposes of this NOPR analysis, DOE assumed the repair costs to increase in each equipment class as the manufacturer selling price increases, as shown in Table 11.3.4. Table 11.3.5 provides repair costs per linear foot by TSL.

Table 11.3.4 Average Annual Repair Cost per Linear Foot (2007$)

Equipment Class	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$26.60	$26.87	$27.52	$27.52	$27.72	$27.72	$27.72	NA
VOP.RC.L	$40.91	$41.54	$43.05	$43.29	$43.29	$43.29	$43.29	NA
VOP.SC.M	$50.54	$50.96	$51.81	$52.01	$52.49	$53.14	$53.14	$53.14
VCT.RC.M	$40.41	$40.62	$41.13	$41.13	$41.88	$41.88	$41.93	NA
VCT.RC.L	$44.50	$44.71	$45.22	$46.17	$46.17	$46.17	$46.25	NA
VCT.SC.I	$76.11	$76.56	$77.27	$77.27	$78.41	$78.78	$78.91	$79.21
VCS.SC.I	$44.92	$45.17	$45.32	$45.93	$45.99	$46.30	$46.30	$46.60
SVO.RC.M	$23.71	$23.89	$24.32	$24.32	$24.46	$24.46	$24.46	NA
SVO.SC.M	$41.12	$41.39	$41.78	$41.93	$42.09	$42.59	$42.59	$42.59
SOC.RC.M	$46.01	$46.19	$46.62	$46.62	$46.67	$46.67	$46.67	$46.91
HZO.RC.M	$26.28	$26.46	$26.89	$26.95	$26.95	NA	NA	NA
HZO.RC.L	$26.54	$26.72	$27.15	$27.22	$27.22	NA	NA	NA
HZO.SC.M	$35.97	$36.07	$36.21	$36.60	$36.68	$36.95	$37.11	$37.11
HZO.SC.L	$43.56	$43.75	$43.88	$44.35	$44.41	$44.88	$45.04	$45.04
HCT.SC.I	$28.41	$28.52	$28.60	$28.90	$29.09	$29.09	NA	NA

*A value of NA means that no installed cost was calculated for this efficiency level. For example, the VOP.RC.L only had seven possible efficiency levels.

Annual Maintenance Costs. DOE determined average annual maintenance costs in two parts: a preventative maintenance cost of $160/year per unit, regardless of cooling capacity or efficiency level; and a lighting maintenance cost that varied with efficiency level or when decreased energy consumption level was due to particular types of lighting measures (see Chapter 8). Table 11.3.6 shows the resulting annual maintenance costs per linear foot by efficiency level. Table 11.3.7 shows the corresponding shipments-weighted annual maintenance cost per linear foot by TSL.

Table 11.3.5 Shipment-Weighted Average Annual Repair Cost per Linear Foot by Trial Standard Level (2007$)

Equipment Class	Standard Level					
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	$27.30	$27.58	$27.58	$27.72	$27.72	$27.72
VOP.RC.L	$42.60	$43.17	$43.29	$43.29	$43.29	$43.29
VOP.SC.M	$51.86	$52.21	$52.63	$53.14	$53.14	$53.14
VCT.RC.M	$41.08	$41.12	$41.33	$41.89	$41.93	$41.93
VCT.RC.L	$45.39	$45.63	$46.18	$46.18	$46.25	$46.25
VCT.SC.I	$77.63	$77.91	$78.57	$78.94	$79.21	$79.21
VCS.SC.I	$45.81	$45.88	$46.13	$46.60	$46.60	$46.60
SVO.RC.M	$24.18	$24.36	$24.36	$24.46	$24.46	$24.46
SVO.SC.M	$41.86	$42.03	$42.20	$42.59	$42.59	$42.59
SOC.RC.M	$46.46	$46.49	$46.64	$46.68	$46.68	$46.91
HZO.RC.M	$26.70	$26.74	$26.91	$26.95	$26.95	$26.95
HZO.RC.L	$26.97	$27.18	$27.22	$27.22	$27.22	$27.22
HZO.SC.M	$36.54	$36.59	$36.80	$37.11	$37.11	$37.11
HZO.SC.L	$44.31	$44.37	$44.60	$45.04	$45.04	$45.04
HCT.SC.I	$28.75	$28.80	$28.96	$29.09	$29.09	$29.09

Table 11.3.6 Average Annual Maintenance Cost per Linear Foot by Efficiency Level (2007$)

Equipment Class	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$21.73	$21.73	$21.73	$24.71	$24.71	$24.71	$48.77	NA
VOP.RC.L	$16.76	$16.76	$16.76	$16.76	$18.04	$18.04	$22.88	NA
VOP.SC.M	$48.76	$48.76	$48.76	$48.76	$51.82	$51.82	$51.82	$74.84
VCT.RC.M	$20.02	$20.02	$20.02	$18.87	$18.87	$18.87	$18.87	NA
VCT.RC.L	$19.99	$19.99	$19.99	$19.99	$18.85	$18.85	$18.85	NA
VCT.SC.I	$47.80	$47.80	$47.80	$44.21	$44.21	$44.21	$44.21	$44.21
VCS.SC.I	$36.38	$36.38	$36.38	$36.38	$36.38	$36.38	$36.38	$36.38
SVO.RC.M	$19.25	$19.25	$19.25	$21.38	$21.38	$21.38	$39.02	NA
SVO.SC.M	$45.80	$45.80	$45.80	$45.80	$47.96	$47.96	$47.96	$65.09
SOC.RC.M	$19.25	$19.25	$19.25	$21.38	$21.38	$32.63	$32.63	$32.63
HZO.RC.M	$13.04	$13.04	$13.04	$13.04	$13.04	NA	NA	NA
HZO.RC.L	$13.04	$13.04	$13.04	$13.04	$13.04	NA	NA	NA
HZO.SC.M	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11
HZO.SC.L	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11
HCT.SC.I	$45.74	$45.74	$45.74	$45.74	$45.74	$45.74	NA	NA

*A value of NA means that no maintenance cost was calculated for this efficiency level. For example, the VOP.RC.M only had seven possible efficiency levels.

Table 11.3.7 Shipment-Weighted Average Annual Maintenance Cost per Linear Foot by Trial Standard Level (2007$)

Equipment Class	Standard Level					
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	$23.25	$23.25	$24.85	$24.85	$24.85	$48.77
VOP.RC.L	$17.63	$17.63	$17.63	$18.43	$22.88	$22.88
VOP.SC.M	$50.14	$50.14	$52.14	$52.14	$52.14	$74.84
VCT.RC.M	$19.55	$19.55	$19.55	$18.87	$18.87	$18.87
VCT.RC.L	$19.64	$19.64	$19.64	$18.85	$18.85	$18.85
VCT.SC.I	$45.83	$44.21	$44.21	$44.21	$44.21	$44.21
VCS.SC.I	$36.38	$36.38	$36.38	$36.38	$36.38	$36.38
SVO.RC.M	$20.42	$20.42	$21.54	$21.54	$21.54	$39.02
SVO.SC.M	$46.88	$46.88	$48.26	$48.26	$48.26	$65.09
SOC.RC.M	$21.54	$21.54	$21.54	$22.69	$22.69	$32.63
HZO.RC.M	$13.03	$13.03	$13.03	$13.03	$13.03	$13.03
HZO.RC.L	$13.03	$13.03	$13.03	$13.03	$13.03	$13.03
HZO.SC.M	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11
HZO.SC.L	$39.11	$39.11	$39.11	$39.11	$39.11	$39.11
HCT.SC.I	$45.74	$45.74	$45.74	$45.74	$45.74	$45.74

11.3.2.3 Discount Factor

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

$$DF = \frac{1}{(1+r)^{t-tp}} \qquad \textbf{Eq. 11.8}$$

where

r = discount rate (percent),
t = year of the monetary value,
t_p = year in which the present value is being determined.

DOE estimated national impacts with both a 3 percent and a 7 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's (OMB) 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. DOE defined the present year as 2008 for the NOPR analysis.

11.3.2.4 Present Value of Costs

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 the base case), discounted to the present, and summed for the time period over which DOE is considering the installation of commercial refrigeration equipment (i.e., from the effective date of standards, 2012, to the year 2042).

The increase in total installed cost refers to both equipment cost and installation cost associated with the higher energy efficiency of commercial refrigeration units purchased in the

standards case compared to the base case. DOE 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.

11.3.2.5 Present Value of Savings

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 year 2008, and summed over the period from the effective date of the standard, 2012, to the time when the last unit installed in 2042 is retired from service (assumed to be 2062). Savings represent decreases in operating costs (including electricity, repair, and maintenance) associated with the higher energy efficiency of commercial refrigeration units purchased in the standards case compared to the base case. Total annual operating cost savings is the savings per linear foot multiplied by the number of linear feet of each vintage surviving in a particular year. Equipment consumes energy over its entire lifetime, and for units purchased in 2042, the PVS includes energy consumed until the last unit is retired from service at the end of 2062.

11.4 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NES spreadsheet model provides estimates of the NES and NPV due to various efficiency levels. The inputs to the NES spreadsheet have been discussed earlier in sections 11.2.2 (National Energy Savings Inputs) and 11.3.2 (Net Present Value Inputs). DOE generated the NES and NPV results using a Microsoft Excel spreadsheet, which is accessible on the Internet at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/refrigeration_equipment.html. Details and instructions for using the spreadsheet are discussed in Appendix H of the TSD.

11.4.1 National Energy Savings and Net Present Value Input Summary

Table 11.4.1 summarizes the inputs to the NES spreadsheet model. For each input, a brief description of the data source is given.

11.4.2 National Energy Savings Results

The following section provides NES results for each trial standard level considered for the 15 equipment classes of commercial refrigeration equipment analyzed. Results are cumulative to 2042 and are shown as primary energy savings in quads. Inputs to the NES spreadsheet model are based on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost (LCC) analysis.

Table 11.4.2 shows the NES results for the efficiency levels analyzed for each equipment class of commercial refrigeration equipment.

Table 11.4.1 NES and NPV Inputs

Input Data	Description
Shipments	Annual shipments from shipments model (see chapter 10, Shipments Analysis).
Effective Date of Standard	2012
Base-Case Efficiencies	Distribution of base-case shipments by efficiency level.
Standards-Case Efficiencies	Distribution of shipments by efficiency level for each standards case. Standards-case annual market shares by efficiency level remain constant over time for base case and each standards case.
Annual Energy Consumption per Linear Foot	Annual weighted-average values are a function of efficiency level. (Established from the Engineering Analysis, chapter 5). Converted to a per linear foot basis.
Total Installed Cost per Linear Foot	Annual weighted-average values are a function of efficiency level (see chapter 8, Life-Cycle Cost and Payback Period Analysis). Converted to a per linear foot basis.
Repair Cost per Linear Foot	Annual weighted-average values are constant with efficiency level (see chapter 8). Converted to a per linear foot basis.
Maintenance Cost per Linear Foot	Annual weighted-average value equals $160 (see chapter 8), plus lighting maintenance cost. Converted to a per linear foot basis.
Escalation of Electricity Prices	2008 EIA *Annual Energy Outlook* forecasts (to 2030) and extrapolation for beyond 2030 (see 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 costs are discounted to year 2008.

* Chapter 14 on the utility impact analysis and Chapter 15 on the environmental assessment provide more detail on NEMS.

Table 11.4.2 Cumulative National Energy Savings for Commercial Refrigeration Equipment (2012-2042)

	National Energy Savings (quads*) by Trial Standard Level				
Equipment Class	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
VOP.RC.M	0.057	0.082	0.157	0.157	0.294
VOP.RC.L	0.006	0.011	0.012	0.018	0.018
VOP.SC.M	0.006	0.016	0.031	0.031	0.041
VCT.RC.M	0.001	0.002	0.024	0.025	0.025
VCT.RC.L	0.035	0.392	0.561	0.574	0.574
VCT.SC.I	0.009	0.023	0.027	0.028	0.028
VCS.SC.I	0.000	0.001	0.002	0.002	0.002
SVO.RC.M	0.029	0.043	0.085	0.085	0.157
SVO.SC.M	0.005	0.015	0.033	0.033	0.043
SOC.RC.M	0.002	0.007	0.014	0.014	0.048
HZO.RC.M	0.001	0.005	0.008	0.008	0.008
HZO.RC.L	0.013	0.028	0.032	0.032	0.032
HZO.SC.M	0.000	0.001	0.002	0.002	0.002
HZO.SC.L	0.001	0.003	0.007	0.007	0.007
HCT.SC.I	0.002	0.016	0.017	0.019	0.019
Total	**0.168**	**0.645**	**1.013**	**1.035**	**1.298**

* 0.000 indicates savings are less than 0.0005 quadrillion Btu.

11.4.3 Annual Costs and Savings

As a prelude to providing the NPVs for each 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.

Figure 11.4.1 shows the changes over time of the non-discounted annual equipment price increases and the non-discounted operating cost savings for TSL 3 (and TSL 4) for the VOP.RC.M equipment class, which corresponds to efficiency Level 5. The total net annual impact is the discounted value of the difference between annual equipment purchases and annual operating costs at a 7 percent discount rate. Appendix I of the TSD shows comparable figures for other efficiency levels and other equipment classes. 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 2012–2042. 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 2012–2062. DOE determined the annual costs and savings presented in each figure based on the *AEO 2008* Reference Case.[3] The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs.

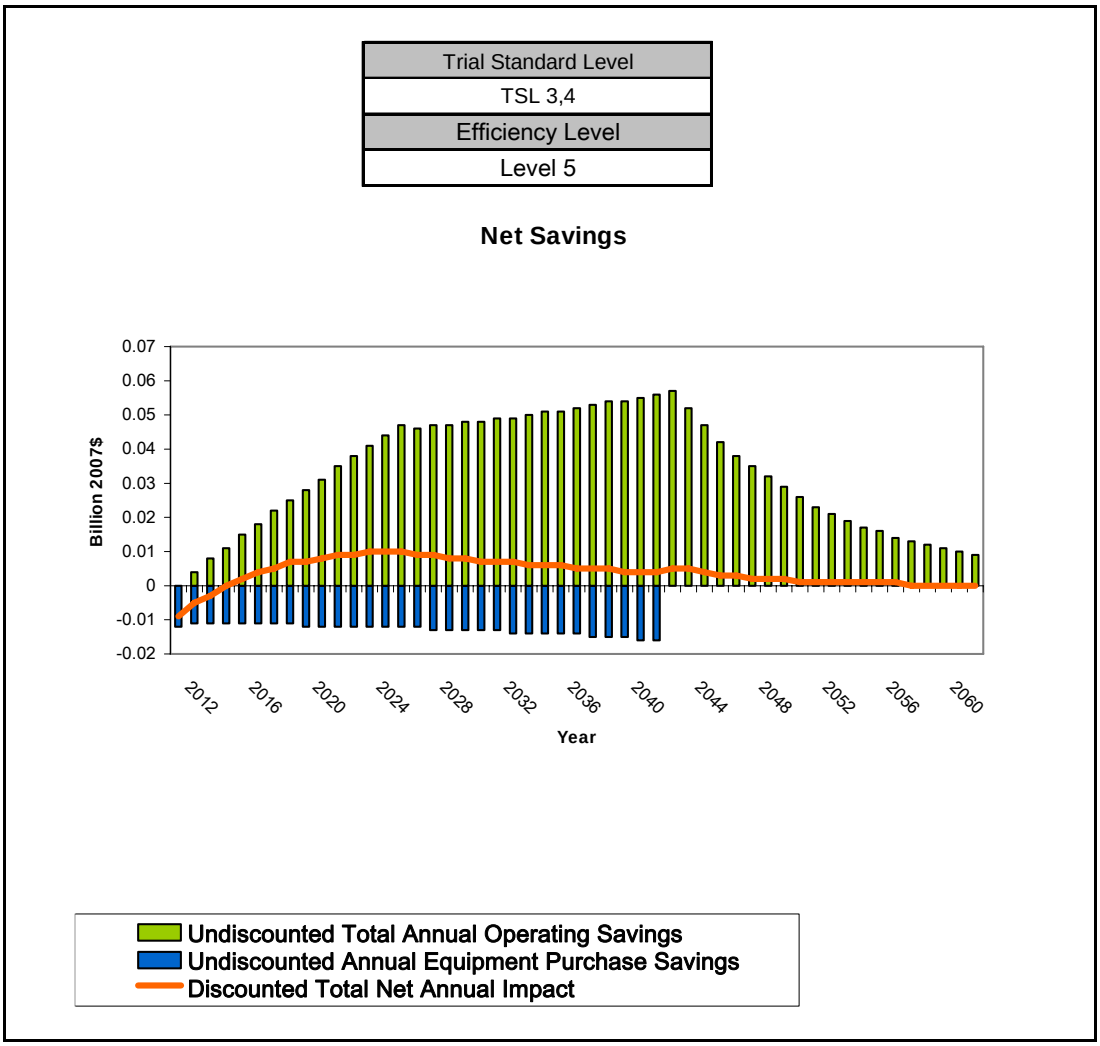

Figure 11.4.1 National Annual Costs and Savings for Trial Standard Level 3 (Efficiency Level 5)

Figure 11.4.1 initially shows smaller annual operating cost savings compared to the increased equipment price costs (shown on Figure 11.4.1 as operating savings). For efficiency levels up through Level 7, operating cost savings increase with time, as more and more equipment meeting the efficiency level comprises the CRE stock.

11.4.4 Net Present Value Results

The following section provides NPV results for the trial standard levels considered for the equipment classes of commercial refrigeration units. 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 that 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 2008, and summed over the time period in which DOE evaluates the impact of standards (i.e., from the effective date of the standards, 2012, to the year 2062).

Savings are decreases in operating costs (including electricity, repair, and maintenance) associated with the higher energy efficiency of commercial refrigeration units 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 refrigeration equipment consumes energy and must be maintained over its entire lifetime. For units purchased in 2042, the operating cost includes energy consumed and maintenance and repair costs incurred until the last unit is retired from service in 2062.

Table 11.4.3 shows the NPV results for the standard levels considered for commercial refrigeration equipment based on a 7 percent discount rate. DOE based all results on electricity price forecasts from the *AEO 2008* Reference Case. Detailed results showing the breakdown of the NPV into national equipment costs and national operating costs are provided in Appendix I of the TSD.

Table 11.4.3 Cumulative NPV Results Based on a Seven-Percent Discount Rate

	Trial Standard Level (Billion 2007$)*				
Equipment Class	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
VOP.RC.M	$0.12	$0.10	$0.20	$0.20	($2.04)
VOP.RC.L	$0.01	$0.02	$0.02	$0.01	$0.01
VOP.SC.M	$0.01	$0.02	$0.04	$0.04	($0.12)
VCT.RC.M	$0.00	$0.00	$0.02	$0.02	$0.02
VCT.RC.L	$0.07	$0.60	$0.84	$0.83	$0.83
VCT.SC.I	$0.02	$0.04	$0.05	$0.05	$0.05
VCS.SC.I	$0.00	$0.00	$0.00	$0.00	$0.00
SVO.RC.M	$0.06	$0.05	$0.11	$0.11	($1.14)
SVO.SC.M	$0.01	$0.02	$0.04	$0.04	($0.14)
SOC.RC.M	$0.00	$0.01	$0.02	$0.02	($0.16)
HZO.RC.M	$0.00	$0.01	$0.01	$0.01	$0.01
HZO.RC.L	$0.02	$0.05	$0.05	$0.05	$0.05
HZO.SC.M	$0.00	$0.00	$0.00	$0.00	$0.00
HZO.SC.L	$0.00	$0.01	$0.01	$0.01	$0.01
HCT.SC.I	$0.00	$0.03	$0.03	$0.03	$0.03
Total	**$0.33**	**$0.98**	**$1.45**	**$1.41**	**($2.59)**

* 0.00 indicates savings are less than $0.005 billion.

Table 11.4.4 provides the NPV results based on the 3 percent discount rate and electricity price forecasts from the *AEO 2008* Reference Case. As with the NPV results based on a 7 percent discount rate, detailed results showing the breakdown of the NPV into national equipment costs and national operating costs based on a 3 percent discount rate are provided in Appendix I.

Table 11.4.4 Cumulative NPV Results based on a Three-Percent Discount Rate

Equipment Class	Trial Standard Level (Billion 2007$)*				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	$0.29	$0.27	$0.54	$0.54	($3.80)
VOP.RC.L	$0.03	$0.05	$0.06	$0.03	$0.03
VOP.SC.M	$0.03	$0.06	$0.10	$0.10	($0.19)
VCT.RC.M	$0.00	$0.01	$0.07	$0.07	$0.07
VCT.RC.L	$0.16	$1.62	$2.31	$2.29	$2.29
VCT.SC.I	$0.05	$0.11	$0.12	$0.12	$0.12
VCS.SC.I	$0.00	$0.01	$0.01	$0.01	$0.01
SVO.RC.M	$0.14	$0.14	$0.30	$0.30	($2.14)
SVO.SC.M	$0.03	$0.06	$0.11	$0.11	($0.21)
SOC.RC.M	$0.01	$0.03	$0.04	$0.04	($0.26)
HZO.RC.M	$0.01	$0.02	$0.04	$0.03	$0.03
HZO.RC.L	$0.06	$0.13	$0.14	$0.14	$0.14
HZO.SC.M	$0.00	$0.00	$0.01	$0.01	$0.01
HZO.SC.L	$0.00	$0.01	$0.03	$0.03	$0.03
HCT.SC.I	$0.01	$0.08	$0.08	$0.08	$0.08
Total	**$0.83**	**$2.60**	**$3.97**	**$3.93**	**($3.79)**

* 0.00 indicates savings are less than $0.005 billion.

REFERENCES

[1] Energy Information Administration (EIA). National Energy Modeling System Commercial Model (2004 Version).

[2] ERG/MKJ. Energy Research Group & M.K. Jaccard & Associates. 2000. Integration of GHG Emissions Reduction Options using CIMS. <<http://www.emrg.sfu.ca/reports/Rollup.pdf>> (05 June 2001).

[3] U.S. Department of Energy/Energy Information Administration (DOE/EIA), Annual Energy Outlook 2008, June 2008. Washington, D.C. DOE/EIA-0383(2008).