CHAPTER 14. UTILITY IMPACT ANALYSIS

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CHAPTER 14. UTILITY IMPACT ANALYSIS

14.1 INTRODUCTION

The U.S. Department of Energy (DOE) analyzed the effects of amended energy conservation standards for commercial refrigeration equipment (CRE) on the electric utility industry. DOE conducted the utility impact analysis using Energy Information Administration's (EIA) National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectoral, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce a reference energy forecast for the United States, published in the *Annual Energy Outlook*.[1] The *Annual Energy Outlook* for 2008 (*AEO2008)* forecasts energy supply and demand through 2030.

DOE used a variant of this NEMS model, referred to as NEMS-BT,[b] to account for the impact of amended energy conservation standards on the reference energy forecast. The NEMS-BT reference case was modeled after the *AEO2008* reference case.[c] The utility impact analysis consists of a comparison between model results for the reference case and for the policy cases in which amended energy conservation standards are in place.[d]

NEMS-BT has several advantages that have led to its use in the analysis of national energy conservation standards. The model uses a set of assumptions that are well known and fairly transparent because of the exposure and scrutiny each *AEO* receives. In addition, the comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors, and the economy as a whole, producing a complete picture of the effects of energy conservation standards. Perhaps most importantly, NEMS-BT can be used to estimate marginal effects, which yield a more accurate estimate of the actual impacts of energy conservation standards compared to considering only average effects.

14.2 ASSUMPTIONS AND METHODOLOGY

DOE's utility impact analysis applies the same basic set of assumptions as the *AEO2008*. For example, the operating characteristics (energy conversion efficiency, emissions rates) of future electricity generating plants are as specified in the *AEO2008* Reference Case. The utility impact analysis reports the changes in installed capacity and generation, by fuel type, that results

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March 2003. More detailed and more current documentation of various sub-models within NEMS can be obtained from EIA's website: http://www.eia.doe.gov/oiaf/forecasting.html.
[b] DOE/EIA approves the use of NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations of DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Buildings Technologies Program, under whose aegis this work has been performed).
[c] The NEMS-BT reference case shows very slight differences from the AEO reference case. In 2030, total commercial electricity consumption in the NEMS-BT reference case was 0.10 percent lower than the 2008 AEO reference case. For total electricity generation and total installed generating capacity, NEMS-BT produced estimates that were 0.08 percent and 0.34 percent lower than the AEO reference case, respectively.
[d] In the discussion below, the abbreviated term "the reference case" should be understood to refer to the NEMS-BT *r*eference case.

from each trial standard level (TSL) as well as changes in electricity sales to the commercial sector.

The utility analysis uses the *AEO2008 Reference Case* as the base case and treats the energy conservation standards on commercial refrigeration equipment as variations in policy. The effect of the policy is calculated as the difference in the reference case and the proposed energy conservation standards case. Because the implementation of energy conservation standards for commercial refrigeration equipment reduces the electricity demand by less than one-tenth of 1 percent (in the range of 0.01 to 0.06 percent in 2025, depending on the TSL) in any given year, its effect is difficult to adequately measure in the NEMS simulations. Therefore, larger reductions in demand are modeled, and results for the TSLs are interpolated. The effects are assumed to be linear within the range of interpolation.

In its analysis of energy conservation standards for commercial refrigeration equipment, DOE adjusted the annual end-use energy consumption for refrigeration that was predicted within the commercial sector module of NEMS-BT. These decrements in the annual consumption were made for each census division using the method for computing energy savings developed in the national impact analysis (see Chapter 11). The changes in annual consumption were translated into changes in hourly system load as part of the normal NEMS modeling process using the NEMS' standard commercial building refrigeration shapes.

As mentioned above, the magnitude of the energy decrement that would be required for NEMS-BT to produce stable results, outside the range of numerical noise, is larger than the highest energy conservation standard under consideration.[e] Therefore, DOE estimated results corresponding to the TSL using interpolation. It implemented reductions to both the commercial refrigeration end use at multiples of the proposed standards, and linearly interpolated actual changes in generation and capacity due to the standard from these outputs. Compared to the total savings for all commercial refrigeration equipment under Trial Standard Level 4, the multipliers used in this analysis were 2.8, 5.7, and 8.5. Appendix K provides details of the interpolation method and how the multiples were selected.

The terminal year of the NEMS-BT model is 2030. Impacts beyond 2030 were extrapolated based on the pattern of electricity savings (in kWh) expected for a particular standard. The extrapolation was based on a comparison of the change in the NEMS-BT variable (e.g., coal-fired generation) to the change in electricity savings over the period 2025 to 2030. As a first step to implement the method, the changes in electricity savings over three periods—2030 to 2035, 2035 to 2040, and 2040 to 2042—were expressed as ratios to the change in electricity savings over the period 2025 to 2030. The changes in a utility-sector variable were then multiplied by these ratios to estimate the changes in the periods after 2030.

To illustrate the approach, the NEMS-BT results for TSL 3 indicate a reduction in installed generating capacity for coal plants (relative to the NEMS-BT reference case) of 0.204 gigawatts (GW) in 2025 and 0.300 GW in 2030. The reduction of coal-fired generation between these two years is 0.097 GW (rounded from the exact difference). From the National Energy

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[e] The numerical noise stems, in part, from the fact that a precise balancing between the demand and supply sides of NEMS is not always achieved, given the iterative nature of the solution process.

Savings Model (NES) (described in Chapter 11 of the TSD), the change in electricity savings from the CRE conservation standards from 2030 to 2035 is about 89 percent of that for 2025 to 2030. Thus, the change in coal generation between 2030 and 2035 is calculated to be (0.89) x (0.097) GW or 0.086 GW. Accordingly, the extrapolated value of the reduction in coal generating capacity compared to the reference case for 2035 is (0.300 + 0.086), or 0.386 GW.

14.3 RESULTS

The results from the reference case are shown in Table 14.3.1. Results for the various TSLs are presented in Table 14.3.2 through Table 14.3.6. Each table shows forecasts using interpolated results, as described in section 14.2, for commercial sector energy sales, total U.S. electricity generation, and installed capacity.

Table 14.3.1 Reference Case Forecast: Commercial Electricity Consumption, Electricity Generation, and Electricity Capacity

NEMS-BT Results:						
	2005*	**2010**	**2015**	**2020**	**2025**	**2030**
*Commercial Sector Electricity Consumption***						
Electricity Sales (TWh)	1,275	1,386	1,521	1,661	1,802	1,939
Total U.S. Electricity Generation†						
Coal (TWh)	2,014	2,056	2,180	2,359	2,573	2,808
Petroleum (TWh)	122	56	56	60	65	66
Gas (TWh)	761	912	911	835	773	755
Nuclear (TWh)	782	797	807	868	910	928
Renewables (TWh)	372	474	530	601	651	674
Total (TWh)	4,050	4,294	4,483	4,723	4,972	5,231
Installed Generating Capacity‡						
Fossil Steam (GW)	430.9	434.4	416.9	434.8	464.6	494.2
Combined Cycle (GW)	169.3	190.0	192.2	196.8	205.8	210.6
Combustion Turbines (GW)	130.3	137.4	129.4	131.4	143.0	164.4
Nuclear (GW)	100.2	100.9	102.1	110.9	115.6	116.1
Renewables (GW)	114.9	133.4	139.8	148.1	155.2	163.3
Total (GW)	945.6	996.0	980.4	1,022.0	1,084.2	1,148.4

* Values for 2005 are reported by NEMS-BT, but are very close to the historical values shown in various tables in EIA's *Annual Energy Review 2006*

** Comparable to panel in Table A8 of AEO 2008, Electricity Supply, Disposition, Prices, and Emissions, that displays electricity sales by sector

† Comparable to Table A8 of AEO2008 Electricity Supply, Disposition, Prices, and Emissions. Includes generation from electricity-only, combined heat and power, and end-use generators

‡ Comparable to Table A9 of AEO2008: Electricity Generating Capacity. Fossil Steam includes coal steam and other fossil fuel steam plants

Table 14.3.2 TSL 1 Utility Impacts for Commercial Refrigeration Equipment

NEMS-BT Results:	Difference from Reference Case						
					Extrapolation		
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2042**
Commercial Sector Electricity Consumption							
Electricity Sales (TWh)	-0.198	-0.414	-0.595	-0.741	-0.871	-1.038	-1.117
Total U.S. Electricity Generation							
Coal (TWh)	-0.129	-0.283	-0.349	-0.294	-0.245	-0.183	-0.153
Petroleum (TWh)	-0.002	-0.005	-0.004	-0.001	0.003	0.007	0.008
Gas (TWh)	-0.060	-0.132	-0.162	-0.137	-0.114	-0.085	-0.071
Nuclear (TWh)	0.000	0.000	-0.012	-0.091	-0.161	-0.252	-0.294
Renewables (TWh)	0.005	-0.017	-0.083	-0.186	-0.278	-0.396	-0.451
Total (TWh)	-0.186	-0.436	-0.611	-0.709	-0.796	-0.909	-0.962
Installed Generating Capacity							
Fossil Steam (GW)	-0.007	-0.020	-0.034	-0.050	-0.065	-0.083	-0.092
Combined Cycle (GW)	-0.002	-0.005	-0.008	-0.011	-0.013	-0.016	-0.018
Combustion Turbines (GW)	0.005	0.012	0.018	0.023	0.027	0.033	0.035
Nuclear (GW)	0.001	0.001	-0.003	-0.010	-0.016	-0.023	-0.027
Renewables (GW)	0.000	-0.001	-0.004	-0.008	-0.012	-0.017	-0.019
Total (GW)	-0.003	-0.014	-0.031	-0.057	-0.079	-0.107	-0.121

Table 14.3.3 TSL 2 Utility Impacts for Commercial Refrigeration Equipment

NEMS-BT Results:	Difference from Reference Case						
					Extrapolation		
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2042**
Commercial Sector Electricity Consumption							
Electricity Sales (TWh)	-0.760	-1.590	-2.287	-2.849	-3.348	-3.991	-4.294
Total U.S. Electricity Generation							
Coal (TWh)	-0.497	-1.088	-1.341	-1.131	-0.944	-0.703	-0.590
Petroleum (TWh)	-0.009	-0.018	-0.016	-0.002	0.010	0.025	0.032
Gas (TWh)	-0.231	-0.506	-0.624	-0.526	-0.439	-0.327	-0.274
Nuclear (TWh)	0.000	0.000	-0.047	-0.351	-0.621	-0.968	-1.132
Renewables (TWh)	0.020	-0.066	-0.320	-0.716	-1.068	-1.521	-1.735
Total (TWh)	-0.717	-1.678	-2.348	-2.726	-3.061	-3.494	-3.697
Installed Generating Capacity							
Fossil Steam (GW)	-0.026	-0.075	-0.132	-0.194	-0.250	-0.321	-0.355
Combined Cycle (GW)	-0.008	-0.021	-0.032	-0.042	-0.051	-0.063	-0.068
Combustion Turbines (GW)	0.018	0.046	0.069	0.088	0.104	0.126	0.136
Nuclear (GW)	0.004	0.003	-0.011	-0.037	-0.060	-0.089	-0.103
Renewables (GW)	0.000	-0.005	-0.015	-0.032	-0.047	-0.065	-0.074
Total (GW)	-0.011	-0.052	-0.121	-0.217	-0.303	-0.413	-0.465

Table 14.3.4 TSL 3 Utility Impacts for Commercial Refrigeration Equipment

NEMS-BT Results:	Difference from Reference Case						
					Extrapolation		
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2042**
Commercial Sector Electricity Consumption							
Electricity Sales (TWh)	-1.177	-2.462	-3.540	-4.410	-5.184	-6.179	-6.648
Total U.S. Electricity Generation							
Coal (TWh)	-0.769	-1.685	-2.076	-1.750	-1.461	-1.089	-0.913
Petroleum (TWh)	-0.014	-0.027	-0.024	-0.003	0.015	0.039	0.050
Gas (TWh)	-0.358	-0.784	-0.966	-0.814	-0.679	-0.505	-0.424
Nuclear (TWh)	0.000	0.000	-0.073	-0.543	-0.961	-1.498	-1.752
Renewables (TWh)	0.031	-0.102	-0.495	-1.109	-1.654	-2.355	-2.686
Total (TWh)	-1.110	-2.598	-3.635	-4.220	-4.740	-5.409	-5.724
Installed Generating Capacity							
Fossil Steam (GW)	-0.040	-0.117	-0.204	-0.300	-0.386	-0.497	-0.549
Combined Cycle (GW)	-0.012	-0.032	-0.050	-0.066	-0.080	-0.098	-0.106
Combustion Turbines (GW)	0.028	0.071	0.107	0.136	0.162	0.195	0.210
Nuclear (GW)	0.007	0.004	-0.017	-0.057	-0.093	-0.138	-0.160
Renewables (GW)	0.000	-0.008	-0.024	-0.049	-0.072	-0.101	-0.115
Total (GW)	-0.018	-0.081	-0.187	-0.337	-0.469	-0.640	-0.720

Table 14.3.5 TSL 4 Utility Impacts for Commercial Refrigeration Equipment

NEMS-BT Results:	Difference from Reference Case						
					Extrapolation		
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2042**
Commercial Sector Electricity Consumption							
Electricity Sales (TWh)	-1.221	-2.553	-3.671	-4.573	-5.375	-6.407	-6.893
Total U.S. Electricity Generation							
Coal (TWh)	-0.797	-1.747	-2.153	-1.815	-1.515	-1.129	-0.947
Petroleum (TWh)	-0.015	-0.028	-0.025	-0.004	0.016	0.040	0.052
Gas (TWh)	-0.371	-0.813	-1.001	-0.844	-0.704	-0.524	-0.439
Nuclear (TWh)	0.000	0.000	-0.076	-0.563	-0.997	-1.554	-1.816
Renewables (TWh)	0.032	-0.106	-0.513	-1.150	-1.715	-2.442	-2.785
Total (TWh)	-1.151	-2.694	-3.769	-4.376	-4.915	-5.609	-5.936
Installed Generating Capacity							
Fossil Steam (GW)	-0.041	-0.121	-0.211	-0.312	-0.401	-0.515	-0.569
Combined Cycle (GW)	-0.013	-0.033	-0.052	-0.068	-0.083	-0.101	-0.110
Combustion Turbines (GW)	0.029	0.074	0.111	0.141	0.168	0.202	0.218
Nuclear (GW)	0.007	0.005	-0.017	-0.059	-0.096	-0.144	-0.166
Renewables (GW)	0.000	-0.008	-0.025	-0.051	-0.075	-0.105	-0.119
Total (GW)	-0.018	-0.084	-0.194	-0.349	-0.486	-0.663	-0.747

Table 14.3.6 TSL 5 Utility Impacts for Commercial Refrigeration Equipment

NEMS-BT Results:	Difference from Reference Case						
					Extrapolation		
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2042**
Commercial Sector Electricity Consumption							
Electricity Sales (TWh)	-1.531	-3.202	-4.604	-5.735	-6.741	-8.035	-8.645
Total U.S. Electricity Generation							
Coal (TWh)	-1.000	-2.191	-2.700	-2.276	-1.900	-1.416	-1.187
Petroleum (TWh)	-0.019	-0.035	-0.032	-0.004	0.020	0.051	0.065
Gas (TWh)	-0.465	-1.019	-1.256	-1.058	-0.883	-0.657	-0.551
Nuclear (TWh)	0.000	0.000	-0.095	-0.707	-1.250	-1.949	-2.278
Renewables (TWh)	0.041	-0.133	-0.644	-1.442	-2.151	-3.063	-3.493
Total (TWh)	-1.443	-3.378	-4.727	-5.488	-6.164	-7.034	-7.444
Installed Generating Capacity							
Fossil Steam (GW)	-0.052	-0.152	-0.265	-0.391	-0.502	-0.646	-0.714
Combined Cycle (GW)	-0.016	-0.042	-0.065	-0.085	-0.104	-0.127	-0.138
Combustion Turbines (GW)	0.037	0.092	0.139	0.177	0.210	0.253	0.273
Nuclear (GW)	0.009	0.006	-0.022	-0.074	-0.120	-0.180	-0.208
Renewables (GW)	0.000	-0.010	-0.031	-0.064	-0.094	-0.132	-0.150
Total (GW)	-0.023	-0.105	-0.244	-0.438	-0.610	-0.832	-0.936

14.3.1 Impacts Related to Commercial Refrigeration Equipment – TSL 1

Table 14.3.2 shows the impacts for all commercial refrigeration equipment under TSL 1. The top line of Table 14.3.2 shows that under TSL 1, total commercial electricity use in terawatt hours (TWh) declines by 0.20 TWh in 2015 and by 0.74 TWh in 2030.

The reductions in total commercial electricity generation (shown as the last line in the second panel of the table) are slightly different than the reductions in commercial electricity use (shown in the first line of the table). These differences are to due to the net impact of various factors at the energy system level. The NEMS model suggests that electricity prices generally decline slightly following the implementation of the standard. These price changes lead to very small increases in demand for all major end-use sectors (residential, industrial, and commercial[f]). An offsetting factor at the system level, however, is that some changes in generation also reflect transmission and distribution losses that respond to higher or lower sales to end users.

As expected, total generation falls in a nearly continuous fashion with respect to the lower electricity demand prompted by the energy conservation standard. However, for the individual generation technologies by fuel type, the responses are much more varied. In the *long term* (e.g., by 2030), the NEMS-BT model suggests that there may be significant changes, *compared to the reference case*, between plants serving primarily base load uses (principally coal and nuclear) and plants using other fuels. The CRE energy conservation standards generally

[f] Specifically, in the NEMS-BT commercial sector model, the response to higher electricity prices is modeled in two ways. First, the selection of more efficient equipment is prompted when new buildings are constructed or when equipment is replaced in existing buildings. Second, a general behavioral response to higher prices is modeled via a price elasticity in which a percentage increase in prices (x) is reflected by a different percentage reduction in consumption (y). For most commercial end uses, this price elasticity (y/x) is approximately -0.15.

reduce base load (and thus off-peak) electricity demand. This change in the load profile reduces the attractiveness of coal and, to a lesser extent, nuclear plants.

In the near term (through 2020), the NEMS-BT model suggests slightly different behavior. Electricity generation from natural gas plants is somewhat lower than that in the reference case. Nuclear generation is relatively unchanged, reflecting the inability of that segment of the industry to adjust quickly to changes in demand. In general, because there is less opportunity over the next decade (through 2020) to build new plants and optimize the electricity supply system to meet the altered character of the load, other institutional and economic factors may be more relevant in how various generating facilities are dispatched.

The bottom panel of results in Table 14.3.2 shows the impacts on generating capacity by type of generation technology. Total generation capacity is lower by about 0.06 gigawatts (GW) in 2030, roughly a 0.005 percent decline from the reference case.

The components of total capacity are distinguished by type of generation technology rather than strictly by fuel type. Fossil fuel steam plants are primarily coal fired, but also include some petroleum use. High efficiency, combined-cycle plants and combustion turbines both use natural gas.

Because coal plants are primarily used to meet base loads, the capacity of this type of plant shows a relatively large decline over the next two decades. Compared to the reference case, the total generation capacity of coal plants declines (relative to the reference case) throughout the forecast period and is lower by about 0.05 GW by 2030. Nuclear plants, which are also used to meet base loads, are projected to see a capacity decline of 0.01 GW by the same date.

As opposed to combined cycle power plant capacity, combustion turbine capacity is higher than the reference case. Because the overall load profile shows a higher proportion of weather-related electricity consumption, combustion turbine capacity in 2030 is about 0.02 GW higher than the reference case. Combined cycle plants witness a decline in capacity of 0.01 GW as they tend to be slightly less weather-related than combustion turbines. Generation capacity from renewables slightly declines by 0.008 GW.[g]

14.3.2 Results for TSL 2 through TSL 5

Table 14.3.3 through Table 14.3.6 show the estimated impacts for TSLs 2 through 5. Table 14.3.4, corresponding to TSL 3, shows the impacts associated with energy conservation standards selected to match minimum life-cycle cost levels for each type of refrigeration equipment. As shown in this table, compared to the reference case, total generation in 2030 would decline by about 4 TWh. The major reductions in generation occur at coal, nuclear, gas,

[g] Any comparison between the generation and capacity impacts shown in the table is complicated by the fact that various types of generating plants operate for different numbers of hours during the year. Base load plants, such as fossil fuel steam and nuclear, are relatively comparable as they operate for roughly the same number of hours during the year. Because renewables comprise a number of technologies with various operating hours, it is not surprising to see a divergence between the behavior of generation and capacity at this aggregate level.

and renewable energy facilities. Total generation capacity falls by 0.34 GW relative to the reference case or about 0.03 percent.

Table 14.3.5 shows impacts under TSL 4 for all CRE products considered in this rulemaking. TSL 4 corresponds to a case in which for the majority of products the standards are set at the maximum (technologically feasible) level. For five products (as cited in Chapter 9), the levels are set at the minimum life-cycle cost level identical to those in TSL 3. In this mixed case, the 2030 impact on total generation is nearly 4 percent greater than that for TSL 3. Total capacity is lower about 0.35 GW compared to the reference case.

In TSL 5, the standards for *all* products are set to the maximum (technologically feasible) level. The impacts from this case are shown in Table 14.3.6. In this case, the 2030 impact on total generation is 30 percent greater than that of TSL 3, or 5.4 TWh. Total capacity is lower by about 0.44 GW, compared to the reference case.

REFERENCES

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