

# Commercial Demand Module

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The NEMS Commercial Sector Demand Module generates forecasts of commercial sector energy demand through 2030. The definition of the commercial sector is consistent with EIA's State Energy Data System (SEDS). That is, the commercial sector includes business establishments that are not engaged in transportation or in manufacturing or other types of industrial activity (e.g., agriculture, mining or construction). The bulk of commercial sector energy is consumed within buildings; however, street lights, pumps, bridges, and public services are also included if the establishment operating them is considered commercial. Since most of commercial energy consumption occurs in buildings, the commercial module relies on the data from the EIA Commercial Buildings Energy Consumption Survey (CBECS) for characterizing the commercial sector activity mix as well as the equipment stock and fuels consumed to provide end use services.<sup>12</sup>

The commercial module forecasts consumption by fuel<sup>13</sup> at the Census division level using prices from the NEMS energy supply modules, and macroeconomic variables from the NEMS Macroeconomic Activity Module (MAM), as well as external data sources (technology characterizations, for example). Energy demands are forecast for ten end-use services<sup>14</sup> for eleven building categories<sup>15</sup> in each of the nine Census divisions (see Figure 5). The model begins by developing forecasts of floorspace for the 99 building category and Census division combinations. Next, the ten end-use service demands required for the projected floorspace are developed. The electricity generation and water and space heating supplied by distributed generation and combined heat and power technologies are projected. Technologies are then chosen to meet the projected service demands for the seven major end uses.<sup>16</sup> Once technologies are chosen, the energy consumed by the equipment stock (both existing and purchased equipment) is developed to meet the projected end-use service demands.<sup>17</sup>

## Key Assumptions

The key assumptions made by the commercial module are presented in terms of the flow of the calculations described above. The sections below summarize the assumptions in each of the commercial module submodules: floorspace, service demand, distributed generation, technology choice, and end-use consumption. The submodules are executed sequentially in the order presented, and the outputs of each submodule become the inputs to subsequently executed submodules. As a result, key forecast drivers for the floorspace submodule are also key drivers for the service demand submodule, and so on.

### Floorspace Submodule

Floorspace is forecast by starting with the previous year's stock of floorspace and eliminating a portion to represent the age-related removal of buildings. Total floorspace is the sum of the surviving floorspace plus new additions to the stock derived from the MAM floorspace growth projection.<sup>18</sup>

#### *Existing Floorspace and Attrition*

Existing floorspace is based on the estimated floorspace reported in the 2003 *Commercial Buildings Energy Consumption Survey* (Table 11). Over time, the 2003 stock is projected to decline as buildings are removed from service (floorspace attrition). Floorspace attrition is estimated by a logistic decay function, the shape of which is dependent upon the values of two parameters: average building lifetime and *gamma*. The average building lifetime refers to the median expected lifetime of a particular building type. The *gamma* parameter corresponds to the rate at which buildings retire near their median expected lifetime. The current values for the average building lifetime and *gamma* vary by building type as presented in Table 12.<sup>19</sup>

**Table 11. 2003 Total Floorspace by Census Division and Principal Building Activity**  
(Millions of Square Feet)

|                       | Assem-<br>bly | Educa-<br>tion | Food<br>Sales | Food<br>Service | Health<br>Care | Lodging | Large<br>Office | Small<br>Office | Merc/<br>Service | Ware-<br>house | Other | Total  |
|-----------------------|---------------|----------------|---------------|-----------------|----------------|---------|-----------------|-----------------|------------------|----------------|-------|--------|
| New England           | 431           | 299            | 75            | 45              | 48             | 374     | 282             | 320             | 819              | 411            | 351   | 3,452  |
| Middle<br>Atlantic    | 1,243         | 1,384          | 163           | 127             | 310            | 797     | 1,523           | 1,065           | 1,641            | 1,112          | 1,177 | 10,543 |
| East North<br>Central | 1,355         | 1,990          | 218           | 248             | 316            | 549     | 1,297           | 1,129           | 2,148            | 2,023          | 1,152 | 12,424 |
| West North<br>Central | 772           | 552            | 102           | 206             | 123            | 595     | 219             | 704             | 1,045            | 994            | 369   | 5,680  |
| South<br>Atlantic     | 1,161         | 2,445          | 223           | 433             | 469            | 939     | 1,173           | 1,065           | 3,391            | 1,836          | 865   | 13,999 |
| East South<br>Central | 546           | 341            | 67            | 99              | 134            | 368     | 195             | 371             | 985              | 390            | 223   | 3,719  |
| West South<br>Central | 965           | 1,198          | 197           | 232             | 235            | 387     | 916             | 501             | 2,076            | 1,740          | 575   | 9,022  |
| Mountain              | 411           | 640            | 64            | 32              | 94             | 438     | 230             | 535             | 1,087            | 506            | 168   | 4,207  |
| Pacific               | 809           | 1,027          | 146           | 232             | 176            | 649     | 1,028           | 915             | 2,051            | 1,066          | 515   | 8,613  |
| United<br>States      | 7,693         | 9,874          | 1,255         | 1,654           | 1,905          | 5,096   | 6,861           | 6,605           | 15,242           | 10,078         | 5,395 | 71,658 |

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey Public Use Data

**Table 12. Floorspace Attrition Parameters**

|                                     | Assem-<br>bly | Educa-<br>tion | Food<br>Sales | Food<br>Service | Health<br>Care | Lodging | Large<br>Office | Small<br>Office | Merc/<br>Service | Ware-<br>house | Other |
|-------------------------------------|---------------|----------------|---------------|-----------------|----------------|---------|-----------------|-----------------|------------------|----------------|-------|
| Median Expected<br>Lifetime (years) | 80            | 80             | 65            | 65              | 65             | 69      | 73              | 73              | 65               | 80             | 75    |
| gamma                               | 1.8           | 2.6            | 2.5           | 2.5             | 2.3            | 2.0     | 2.0             | 2.0             | 1.8              | 1.6            | 2.5   |

Sources: Energy Information Administration, Commercial Buildings Energy Consumption Survey 1999, 1995, 1992, and 1989 Public Use Data, 1986 Nonresidential Buildings Energy Consumption Survey, McGraw-Hill Construction Dodge Annual Starts - non residential building starts, and Journal of Business and Economic Statistics, April 1986, Vol. 4, No. 2.

## ***New Construction Additions to Floorspace***

The commercial module develops estimates of projected commercial floorspace additions by combining the surviving floorspace estimates with the total floorspace forecast from MAM. A total NEMS floorspace projection is calculated by applying the MAM assumed floorspace growth rate within each Census division and MAM building type to the corresponding NEMS Commercial Demand Module's building types based on the CBECS building type shares. The NEMS surviving floorspace from the previous year is then subtracted from the total NEMS floorspace projection for the current year to yield new floorspace additions.<sup>20</sup>

## **Service Demand Submodule**

Once the building stock is projected, the Commercial Demand module develops a forecast of demand for energy-consuming services required for the projected floorspace. The module projects service demands for the following explicit end-use services: space heating, space cooling, ventilation, water heating, lighting, cooking, refrigeration, personal computer office equipment, and other office equipment.<sup>21</sup> The service demand intensity (SDI) is measured in thousand Btu of end-use service demand per square foot and differs across service, Census division and building type. The SDIs are based on a hybrid engineering and statistical approach of CBECS consumption data.<sup>22</sup> Projected service demand is the product of square feet and SDI for all end uses across the eleven building categories with adjustments for changes in shell efficiency for space heating and cooling.

## **Shell Efficiency**

The shell integrity of the building envelope is an important determinant of the heating and cooling loads for each type of building. In the NEMS Commercial Demand Module, the shell efficiency is represented by an index, which changes over time to reflect improvements in the building shell. This index is dimensioned by building type and Census division and applies directly to heating. For cooling, the effects are computed from the index, but differ from heating effects, because of different marginal effects of shell integrity and because of internal building loads. In the *AEO2007* reference case, shell improvements for new buildings are up to 22 percent more efficient than the 2003 stock of similar buildings. Over the forecast horizon, new building shells improve in efficiency by 7 percent relative to their efficiency in 2003. For existing buildings, efficiency is assumed to increase by 5 percent over the 2003 stock average. The shell efficiency index affects the space heating and cooling service demand intensities causing changes in fuel consumed for these services as the shell integrity improves.

## **Distributed Generation and Combined Heat and Power**

Nonutility power production applications within the commercial sector are currently concentrated in education, health care, office and warehouse buildings. Program driven installations of solar photovoltaic systems are based on information from DOE's Photovoltaic and Million Solar Roofs programs as well as DOE and industry news releases and the National Renewable Energy Laboratory's Renewable Electric Plant Information System. Historical data from Form EIA-860, *Annual Electric Generator Report*, are used to derive electricity generation for 2004 through 2005 by Census division, building type and fuel. A forecast of distributed generation and combined heat and power (CHP) of electricity is developed based on the economic returns projected for distributed generation and CHP technologies. The model uses a detailed cash-flow approach to estimate the number of years required to achieve a cumulative positive cash flow (some technologies may never achieve a cumulative positive cash flow). Penetration assumptions for distributed generation and CHP technologies are a function of the estimated number of years required to achieve a positive cash flow. Table 13 provides the cost and performance parameters for representative distributed generation and CHP technologies.

The model also incorporates endogenous "learning" for new distributed generation and CHP technologies, allowing for declining technology costs as shipments increase. For fuel cell and photovoltaic systems, parameter assumptions for the *AEO2005* reference case result in a 13 percent reduction in capital costs each time the number of units shipped to the buildings sectors (residential and commercial) doubles. Doubling the number of microturbines shipped results in a 10 percent reduction in capital costs.

## **Technology Choice Submodule**

The technology choice submodule develops projections of the results of the capital purchase decisions for equipment fueled by the three major fuels (electricity, natural gas, and distillate fuel). Capital purchase decisions are driven by assumptions concerning behavioral rule proportions and time preferences, described below, as well as projected fuel prices, average utilization of equipment (the capacity factors), relative technology capital costs, and operating and maintenance (O&M) costs.

### **Decision Types**

In each forecast year, equipment is potentially purchased for three "decision types". Equipment must be purchased for newly added floorspace and to replace the portion of equipment in existing floorspace that is projected to wear out.<sup>23</sup> Equipment is also potentially purchased for retrofitting equipment that has become economically obsolete. The purchase of retrofit equipment occurs only if the annual operating costs of a current technology exceed the annualized capital and operating costs of a technology available as a retrofit candidate.

### **Behavioral Rules**

The commercial module allows the use of three alternate assumptions about equipment choice behavior. These assumptions constrain the equipment selections to three choice sets, which are progressively more restrictive. The choice sets vary by decision type and building type:

**Table 13. Capital Cost and Performance Parameters of Selected Commercial Distributed Generation Technologies**

| Technology Type           | Year | Average Generating Capacity (kW) | Electrical Efficiency | Combined Efficiency (Elec.+Thermal) | Installed Capital Cost (\$2005 per kW of Capacity)* | Service Life (Years) |
|---------------------------|------|----------------------------------|-----------------------|-------------------------------------|---|----------------------|
| Solar Photovoltaic        | 2005 | 30                               | 0.16                  | N/A                                 | \$5,350   | 30                   |
|                           | 2010 | 32                               | 0.18                  | N/A                                 | \$4,045   | 30                   |
|                           | 2015 | 35                               | 0.20                  | N/A                                 | \$3,800   | 30                   |
|                           | 2020 | 40                               | 0.22                  | N/A                                 | \$3,714   | 30                   |
|                           | 2025 | 40                               | 0.22                  | N/A                                 | \$3,451   | 30                   |
|                           | 2030 | 45                               | 0.25                  | N/A                                 | \$3,015   | 30                   |
| Fuel Cell                 | 2005 | 200                              | 0.36                  | 0.72                                | \$5,946   | 20                   |
|                           | 2010 | 200                              | 0.44                  | 0.66                                | \$5,466   | 20                   |
|                           | 2015 | 200                              | 0.45                  | 0.67                                | \$5,203   | 20                   |
|                           | 2020 | 200                              | 0.47                  | 0.69                                | \$4,187   | 20                   |
|                           | 2025 | 200                              | 0.48                  | 0.70                                | \$3,674   | 20                   |
|                           | 2030 | 200                              | 0.49                  | 0.72                                | \$3,108   | 20                   |
| Natural Gas Engine        | 2005 | 300                              | 0.31                  | 0.77                                | \$2,132   | 20                   |
|                           | 2010 | 300                              | 0.32                  | 0.78                                | \$1,878   | 20                   |
|                           | 2015 | 300                              | 0.32                  | 0.78                                | \$1,714   | 20                   |
|                           | 2020 | 300                              | 0.33                  | 0.78                                | \$1,551   | 20                   |
|                           | 2025 | 300                              | 0.33                  | 0.78                                | \$1,343   | 20                   |
|                           | 2030 | 300                              | 0.34                  | 0.79                                | \$1,134   | 20                   |
| Oil-Fired Engine          | 2005 | 200                              | 0.31                  | 0.72                                | \$1,320   | 20                   |
|                           | 2010 | 200                              | 0.31                  | 0.72                                | \$1,150   | 20                   |
|                           | 2015 | 200                              | 0.31                  | 0.71                                | \$1,040   | 20                   |
|                           | 2020 | 200                              | 0.31                  | 0.71                                | \$ 990  | 20                   |
|                           | 2025 | 200                              | 0.31                  | 0.71                                | \$ 990  | 20                   |
|                           | 2030 | 200                              | 0.31                  | 0.71                                | \$ 990  | 20                   |
| Natural Gas Turbine       | 2005 | 1000                             | 0.22                  | 0.68                                | \$2,000   | 20                   |
|                           | 2010 | 1000                             | 0.23                  | 0.68                                | \$1,775   | 20                   |
|                           | 2015 | 1000                             | 0.24                  | 0.68                                | \$1,684   | 20                   |
|                           | 2020 | 1000                             | 0.24                  | 0.69                                | \$1,593   | 20                   |
|                           | 2025 | 1000                             | 0.25                  | 0.69                                | \$1,511   | 20                   |
|                           | 2030 | 1000                             | 0.26                  | 0.70                                | \$1,429   | 20                   |
| Natural Gas Micro Turbine | 2005 | 200                              | 0.29                  | 0.60                                | \$1,706   | 20                   |
|                           | 2010 | 200                              | 0.29                  | 0.60                                | \$1,648   | 20                   |
|                           | 2015 | 200                              | 0.31                  | 0.61                                | \$1,633   | 20                   |
|                           | 2020 | 200                              | 0.33                  | 0.61                                | \$1,573   | 20                   |
|                           | 2025 | 200                              | 0.34                  | 0.62                                | \$1,343   | 20                   |
|                           | 2030 | 200                              | 0.36                  | 0.63                                | \$1,052   | 20                   |

\*Installed costs are given in 2005 dollars in the original source document. Costs for solar photovoltaic, fuel cell, and microturbine technologies include learning effects.

Sources: Energy Information Administration, *Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA's NEMS*, Decision Analysis Corporation and Discovery Insights LLC., February 2006, National Renewable Energy Laboratory, *Gas-Fired Distributed Energy Resource Technology Characterizations: Reference Number NREL/TP-620-34783*, November 2003, Discovery Insights, LLC, *"Installed Costs for Small CHP Systems - Estimates and Projections"* (April 2005), and Solar Energy Industries Association, *Our Solar Power Future - The U.S. Photovoltaic Industry Roadmap through 2030 and Beyond*, (SEIA, September 2004).

- **Unrestricted Choice Behavior** - This rule assumes that commercial consumers consider *all* types of equipment that meet a given service, across all fuels, when faced with a capital purchase decision.
- **Same Fuel Behavior** - This rule restricts the capital purchase decision to the set of technologies that consume the *same fuel* that currently meets the decision maker's service demand.
- **Same Technology Behavior** - Under this rule, commercial consumers consider only the available models of the *same technology and fuel* that currently meet service demand, when facing a capital stock decision.

Under any of the above three behavior rules, equipment that meets the service at the lowest annualized lifecycle cost is chosen. Table 14 illustrates the proportions of floorspace subject to the different behavior rules for space heating technology choices in large office buildings.

**Table 14. Assumed Behavior Rules for Choosing Space Heating Equipment in Large Office Buildings**  
(Percent)

|                        | Unrestricted | Same Fuel | Same Technology | Total |
|------------------------|--------------|-----------|-----------------|-------|
| New Equipment Decision | 21           | 30        | 49              | 100   |
| Replacement Decision   | 8            | 35        | 57              | 100   |
| Retrofit Decision      | 0            | 5         | 95              | 100   |

Source: Energy Information Administration, *Model Documentation Report: Commercial Sector Demand Module of the National Energy Modeling System*, DOE/EIA-M066(2007) (February 2007).

## Time Preferences

Commercial building owners' time preferences regarding current versus future expenditures are assumed to be distributed among seven alternate time preference premiums (Table 15). Adding the risk-adjusted time preference premiums to the 10-year Treasury Bill rate from MAM results in implicit discount rates, also known as hurdle rates, applicable to the assumed proportions of commercial floorspace. The effect of the use of this distribution of discount rates is to prevent a single technology from dominating purchase decisions in the lifecycle cost comparisons. The distribution used for *AEO2007* assigns some floorspace a very high discount or hurdle rate to simulate floorspace which will never retrofit existing equipment and which will only purchase equipment with the lowest capital cost. Discount rates for the remaining six segments of the distribution get progressively lower, simulating increased sensitivity to the fuel costs of the equipment that is purchased. The proportion of floorspace assumed for the 0.0 time preference premium represents an estimate of the Federally owned commercial floorspace that is subject to purchase decisions in a given year. In accordance with Executive Order 13123 signed in June 1999, the Federal sector uses a rate comparable to the 10-year Treasury Bill rate when making purchase decisions.

The distribution of hurdle rates used in the commercial module is also affected by changes in fuel prices. If a fuel's price rises relative to its price in the base year (2003), the nonfinancial portion of each hurdle rate in the distribution decreases to reflect an increase in the relative importance of fuel costs, expected in an environment of rising prices. Parameter assumptions for *AEO2007* result in a 30 percent reduction in the nonfinancial portion of a hurdle rate if the fuel price doubles. If the risk-adjusted time preference premium input by the model user results in a hurdle rate below the assumed financial discount rate for the commercial sector, 15 percent, with base year fuel prices (such as the rate given in Table 15 for the Federal sector), no response to increasing fuel prices is assumed.

**Table 15. Assumed Distribution of Risk-adjusted Time Preference Premiums**  
(Percent)

| Proportion of Floorspace-All Services Except Lighting | Proportion of Floorspace-Lighting | Time Preference Premium |
|---|-----------------------------------|-------------------------|
| 27.0  | 27.0                              | 1000.0                  |
| 25.4  | 25.4                              | 152.9                   |
| 20.4  | 20.4                              | 55.4                    |
| 16.2  | 16.2                              | 30.9                    |
| 10.0  | 8.5                               | 19.9                    |
| 0.8   | 2.3                               | 13.6                    |
| 0.2   | 0.2                               | 0.0                     |
| 100.0   | 100.0                             | --                      |

Source: Energy Information Administration, *Model Documentation Report: Commercial Sector Demand Module of the National Energy Modeling System*, DOE/EIA-M066(2007) (February 2007).

## ***Technology Characterization Database***

The technology characterization database organizes all relevant technology data by end use, fuel, and Census division. Equipment is identified in the database by a technology index as well as a vintage index, the index of the fuel it consumes, the index of the service it provides, its initial market share, the Census division index for which the entry under consideration applies, its efficiency (or coefficient of performance or efficacy in the case of lighting equipment), installed capital cost per unit of service demand satisfied, operating and maintenance cost per unit of service demand satisfied, average service life, year of initial availability, and last year available for purchase. Equipment may only be selected to satisfy service demand if the year in which the decision is made falls within the window of availability. Equipment acquired prior to the lapse of its availability continues to be treated as part of the existing stock and is subject to replacement or retrofitting. This flexibility in limiting equipment availability allows the direct modeling of equipment efficiency standards. Table 16 provides a sample of the technology data for space heating in the New England Census division.

An option to allow endogenous price-induced technological change has been included in the determination of equipment costs and availability for the menu of equipment. This concept allows future technologies faster diffusion into the market place if fuel prices increase markedly for a sustained period of time. Although no price-induced change would have been expected using *AEO2007* reference case fuel prices, the option was not exercised for the *AEO2007* model runs.

## **End-Use Consumption Submodule**

The end-use consumption submodule calculates the consumption of each of the three major fuels for the ten end-use services plus fuel consumption for combined heat and power and district services. For the ten end-use services, energy consumption is calculated as the end-use service demand met by a particular type of equipment divided by its efficiency and summed over all existing equipment types. This calculation includes dimensions for Census division, building type, and fuel. Consumption of the five minor fuels is forecast based on historical trends.

## ***Equipment Efficiency***

The average energy consumption of a particular appliance is based initially on estimates derived from the 2003 CBECS. As the stock efficiency changes over the model simulation, energy consumption decreases nearly, but not quite proportionally to the efficiency increase. The difference is due to the calculation of efficiency using the harmonic average and also the efficiency rebound effect discussed below. For example, if on average, electric heat pumps are now 10 percent more efficient than in 2003, then all else constant (weather, real energy prices, shell efficiency, etc.), energy consumption per heat pump would now average about 9 percent less. The Service Demand and Technology Choice Submodules together determine the average efficiency of the stocks used in adjusting the initial average energy consumption.

## ***Adjusting for Weather and Climate***

Weather in any given year always includes short-term deviations from the expected longer-term average (or climate). Recognition of the effect of weather on space heating and air conditioning is necessary to avoid projecting abnormal weather conditions into the future. In the commercial module, proportionate adjustments are made to space heating and air conditioning demand by Census division. These adjustments are based on National Oceanic and Atmospheric Administration (NOAA) data for Heating Degree Days (HDD) and Cooling Degree Days (CDD). A 10 percent increase in HDD would increase space heating consumption by 10 percent over what it would have been otherwise. The commercial module uses a 30-year average for HDD and CDD by Census division, adjusted over the projection period by projections for state population shifts.

**Table 16. Capital Cost and Efficiency Ratings of Selected Commercial Space Heating Equipment<sup>1</sup>**

| Equipment Type          | Vintage                | Efficiency <sup>2</sup> | Capital Cost (\$2004 per Mbtu/hour) <sup>3</sup> | Maintenance Cost (\$2004 per Mbtu/hour) <sup>3</sup> | Service Life (Years) |
|-------------------------|------------------------|-------------------------|--|--|----------------------|
| Electric Heat Pump      | Current Standard       | 6.8                     | \$105.56   | \$3.33   | 14                   |
|                         | 2004- high efficiency  | 10.6                    | \$194.44   | \$3.33   | 14                   |
|                         | 2006-Standard          | 7.7                     | \$115.28   | \$3.33   | 14                   |
|                         | 2010 - typical         | 7.7                     | \$115.28   | \$3.33   | 14                   |
|                         | 2010 - high efficiency | 10.6                    | \$194.44   | \$3.33   | 14                   |
|                         | 2020 - typical         | 7.8                     | \$115.28   | \$3.33   | 14                   |
| Ground-Source Heat Pump | 2020 - high efficiency | 10.8                    | \$194.44   | \$3.33   | 14                   |
|                         | 2004- typical          | 3.5                     | \$195.83   | \$1.46   | 20                   |
|                         | 2004- high efficiency  | 4.9                     | \$300.00   | \$1.46   | 20                   |
|                         | 2010- typical          | 3.5                     | \$195.83   | \$1.46   | 20                   |
| Natural Gas Heat Pump   | 2010 - high efficiency | 4.9                     | \$300.00   | \$1.46   | 20                   |
|                         | 2020 - typical         | 3.8                     | \$195.83   | \$1.46   | 20                   |
|                         | 2020 - high efficiency | 5.1                     | \$300.00   | \$1.46   | 20                   |
|                         | Electric Boiler        | Current Standard        | 0.98   | \$21.85  | \$0.14               |
| Packaged Electric       | Typical                | 0.96                    | \$15.54  | \$3.64   | 18                   |
| Natural Gas Furnace     | Current Standard       | 0.80                    | \$9.75   | \$0.97   | 18                   |
|                         | 2004 - high efficiency | 0.92                    | \$14.16  | \$0.84   | 18                   |
|                         | 2020 - typical         | 0.81                    | \$8.58   | \$0.96   | 18                   |
| Natural Gas Boiler      | Current Standard       | 0.80                    | \$23.09  | \$0.55   | 25                   |
|                         | 2004 - high efficiency | 0.90                    | \$36.81  | \$0.67   | 25                   |
|                         | 2010 - typical         | 0.81                    | \$22.79  | \$0.55   | 25                   |
| Natural Gas Heat Pump   | 2004 - absorption      | 1.3                     | \$180.56   | \$4.17   | 15                   |
|                         | 2010 - absorption      | 1.4                     | \$180.56   | \$4.17   | 15                   |
|                         | 2020 - absorption      | 1.5                     | \$180.56   | \$4.17   | 15                   |
| Distillate Oil Furnace  | Current Standard       | 0.81                    | \$10.19  | \$0.96   | 18                   |
|                         | 2020 - typical         | 0.82                    | \$10.06  | \$0.94   | 18                   |
| Distillate Oil Boiler   | Current Standard       | 0.83                    | \$17.09  | \$0.13   | 20                   |
|                         | 2004 - high efficiency | 0.89                    | \$19.35  | \$0.12   | 20                   |
|                         | 2010 - typical         | 0.83                    | \$16.56  | \$0.13   | 20                   |

<sup>1</sup>Equipment listed is for the New England Census division, but is also representative of the technology data for the rest of the U.S. See the source referenced below for the complete set of technology data.

<sup>2</sup>Efficiency measurements vary by equipment type. Electric air-source heat pumps are rated for heating performance using the Heating Seasonal Performance Factor (HSPF); natural gas and distillate furnaces are based on Thermal Efficiency; ground source and natural gas heat pumps are rated on coefficient of performance; and boilers are based on combustion efficiency.

<sup>3</sup>Capital and maintenance costs are given in 2004 dollars.

Source: Energy Information Administration, "EIA - Technology Forecast Updates - Residential and Commercial Building Technologies - Reference Case", Navigant Consulting, Inc., Reference Number 117943, September 2004.

### **Short-Term Price Effect and Efficiency Rebound**

It is assumed that energy consumption for a given end-use service is affected by the marginal cost of providing that service. That is, all else equal, a change in the price of a fuel will have an inverse, but less than proportional, effect on fuel consumption. The current value for the short-term price elasticity parameter is -0.25 for all major end uses except refrigeration. A value of -0.1 is currently used for commercial refrigeration. A value of -0.05 is currently used for PC and non-PC office equipment and other minor uses of electricity. For example, for lighting this value implies that for a 1 percent increase in the price of a fuel, there will be a corresponding decrease in energy consumption of 0.25 percent. Another way of affecting the marginal cost of providing a service is through equipment efficiency. As equipment efficiency changes over

time, so will the marginal cost of providing the end-use service. For example, a 10 percent increase in efficiency will reduce the cost of providing the service by 10 percent. The short-term elasticity parameter for efficiency rebound effects is -0.15 for affected end uses; therefore, the demand for the service will rise by 1.5 percent (-10 percent x -0.15). Currently, all services are affected by the short-term price effect and services affected by efficiency rebound are space heating and cooling, water heating, ventilation and lighting.

## **Legislation and Other Federal Programs**

### ***Energy Policy Act of 1992 (EPACT92)***

A key assumption incorporated in the technology selection process is that the equipment efficiency standards described in the EPACT92 constrain minimum equipment efficiencies. The effects of standards are modeled by modifying the technology database to eliminate equipment that no longer meets minimum efficiency requirements. For standards effective January 1, 1994, affected equipment includes electric heat pumps—minimum heating system performance factor of 6.8, gas and oil-fired boilers—minimum combustion efficiency of 0.8 and 0.83, respectively, gas and oil-fired furnaces—minimum thermal efficiency of 0.8 and 0.81, respectively, fluorescent lighting—minimum efficacy of 75 lumens per watt, incandescent lighting—minimum efficacy of 16.9 lumens per watt, air-cooled air conditioners—minimum energy efficiency ratio of 8.9, electric water heaters—minimum energy factor of 0.85, and gas and oil water heaters—minimum thermal efficiency of 0.78. Updated standards are effective October 29, 2003 for gas water heaters—minimum thermal efficiency of 0.8. An additional standard affecting fluorescent lamp ballasts is effective April 1, 2005. The standard mandates electronic ballasts with a minimum ballast efficacy factor of 1.17 for 4-foot, 2-lamp ballasts and 0.63 for 8-foot, 2-lamp ballasts.

The 10 percent Business Investment Tax Credit for solar energy property included in EPACT92 is directly incorporated into the cash-flow approach for projecting distributed generation by commercial photovoltaic systems. For solar hot water heaters, the tax credit is factored into the installed capital cost assumptions used in the technology choice submodule.

### ***Energy Policy Act of 2005 (EPACT05)***

The passage of the EPACT05 in August 2005 provides additional minimum efficiency standards for commercial equipment. Some of the standards for explicitly modeled equipment, effective January 1, 2010, include: an Energy Efficiency Rating (EER) ranging from 10.8 to 11.2 for small package air conditioning and heating equipment; daily electricity consumption limits by volume for commercial refrigerators, freezers, and refrigerator-freezers; and electricity consumption limits per 100 pounds of ice produced based on equipment type and capacity for automatic ice makers. The EPACT05 adds standards for medium base compact fluorescent lamps effective January 1, 2006, for ballasts for Energy Saver fluorescent lamps effective in 2009 and 2010, and bans the manufacture or import of mercury vapor lamp ballasts effective January 1, 2008.

Several efficiency standards in the EPACT05 pertain to equipment not explicitly represented in the NEMS Commercial Demand Module. For low voltage dry-type transformers, effects of the standard are included in estimating the share of projected miscellaneous electricity use attributable to transformer losses. For illuminated exit signs, traffic signals, and commercial pre-rinse spray valves, assumed energy reductions are calculated based on per-unit savings relative to a baseline unit and the estimated share of installed units and sales that already meet the standard. Total projected reductions are phased in over time to account for stock turnover. Under the EPACT05 standards, illuminated exit signs and traffic signal modules must meet ENERGY STAR program requirements as of January 1, 2006. The requirements limit input power demand to 5 watts or less per face for exit signs. Nominal wattages for traffic signal modules are limited to 8 to 15 watts, based on module type. Effective January 1, 2007, low voltage dry-type distribution transformers are required to meet the National Electrical Manufacturers Association Class I Efficiency Levels with minimum efficiency levels ranging from 97 percent to 98.9 percent based on output. Commercial pre-rinse spray valves<sup>24</sup> must have a maximum flow rate of 1.6 gallons per minute, effective January 1, 2006 with energy reductions attributed to hot water use.

The EPACT05 expands the Business Investment Tax Credit to 30 percent for solar property installed in 2006 and 2007. Business Investment Tax Credits of 30 percent for fuel cells and 10 percent for microturbine power plants are also available for property installed in 2006 and 2007. These credits are directly incorporated into the cash-flow approach for distributed generation systems and factored into the installed capital cost assumptions for solar hot water heaters.

## Energy Efficiency Programs

Several energy efficiency programs affect the commercial sector. These programs are designed to stimulate investment in more efficient building shells and equipment for heating, cooling, lighting, and other end uses. The commercial module includes several features that allow projected efficiency to increase in response to voluntary programs (e.g., the distribution of risk-adjusted time preference premiums and shell efficiency parameters). Retrofits of equipment for space heating, air conditioning and lighting are incorporated in the distribution of premiums given in Table 14. Also the shell efficiency of new and existing buildings is assumed to increase from 2003 through 2030. Shells for new buildings increase in efficiency by 7 percent over this period, while shells for existing buildings increase in efficiency by 5 percent.

## Commercial Technology Cases and Alternative Renewables Cases

In addition to the *AEO2007* reference case, three side cases were developed to examine the effect of equipment and building standards on commercial energy use—a *2006 technology case*, a *high technology case*, and a *best available technology case*. These side cases were analyzed in stand-alone (not integrated with the NEMS demand and supply modules) buildings (residential and commercial) modules runs and thus do not include supply-responses to the altered commercial consumption patterns of the three cases. *AEO2007* also analyzed an *integrated high technology case*, which combines the *high technology cases* of the four end-use demand sectors, the *electricity high fossil technology case*, the *low nuclear cost case*, and the *high renewables case*, and an *integrated 2006 technology case*, which combines the *2006 technology cases* of the four end-use demand sectors, the *electricity low fossil technology case*, and the *low renewables case*.

The *2006 technology case* assumes that all future equipment purchases are made based only on equipment available in 2006. This case assumes building shell efficiency to be fixed at 2006 levels. In the reference case, existing building shells are allowed to increase in efficiency by 5 percent over 2003 levels, and new building shells improve by 7 percent by 2030 relative to new buildings in 2003.

The *high technology case* assumes earlier availability, lower costs, and/or higher efficiencies for more advanced equipment than the reference case. Equipment assumptions were developed by engineering technology experts, considering the potential impact on technology given increased research and development into more advanced technologies. In the *high technology case*, building shell efficiencies are assumed to improve 25 percent more than in the reference case after 2006. Existing building shells, therefore, increase by 6.25 percent relative to 2003 levels and new building shells by 8.75 percent relative to their efficiency in 2003 by 2030.

The *best available technology case* assumes that all equipment purchases after 2006 are based on the highest available efficiency in the high technology case in a particular simulation year, disregarding the economic costs of such a case. It is designed to show how much the choice of the highest-efficiency equipment could affect energy consumption. Shell efficiencies in this case are assumed to improve 50 percent more than in the reference case after 2006, i.e., existing shells increase by 7.5 percent relative to 2003 levels and new building shells by 10.5 percent relative to their efficiency in 2003 by 2030.

Fuel shares, where appropriate for a given end use, are allowed to change in the technology cases as the available technologies from each technology type compete to serve certain segments of the commercial floorspace market. For example, in the *best available technology case*, the most efficient gas furnace technology competes with the most efficient electric heat pump technology. This contrasts with the reference case, in which, a greater number of technologies for each fuel with varying efficiencies all compete to serve the heating end use. In general, the fuel choice will be affected as the available choices are constrained or expanded, and will thus differ across the cases.

Two sensitivities that focus on electricity generation incorporate alternative assumptions for non-hydro renewable energy technologies in the power sector, the industrial sector, and the buildings sectors, including residential and commercial photovoltaic systems. In each of these cases, assumptions regarding non-renewable technologies are not changed from the reference case.

The *low renewables case* assumes that the cost and performance characteristics for residential and commercial photovoltaic systems remain fixed at 2006 levels through the forecast horizon.

The *high renewables case* assumes that costs for residential and commercial photovoltaic systems are 10 percent lower than reference case cost estimates by 2030.

## Notes and Sources

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[12] Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey (CBECS) Public Use Files, web site [www.eia.doe.gov/emeu/cbeecs/cbeecs2003/public\\_use\\_2003/cbeecs\\_pubdata2003.html](http://www.eia.doe.gov/emeu/cbeecs/cbeecs2003/public_use_2003/cbeecs_pubdata2003.html).

[13] The fuels accounted for by the commercial module are electricity, natural gas, distillate fuel oil, residual fuel oil, liquefied petroleum gas (LPG), coal, motor gasoline, and kerosene. Current commercial use of biomass (wood, Municipal solid waste) is also included. In addition to these fuels the use of solar energy is projected based on an exogenous forecast of projected solar photovoltaic system installations under the Million Solar Roofs program, State and local incentive programs, and the potential endogenous penetration of solar photovoltaic systems and solar thermal water heaters.

[14] The end-use services in the commercial module are heating, cooling, water heating, ventilation, cooking, lighting, refrigeration, PC and non-PC office equipment and a category denoted other to account for all other minor end uses.

[15] The 11 building categories are assembly, education, food sales, food services, health care, lodging, large offices, small offices, mercantile/services, warehouse and other.

[16] Minor end uses are modeled based on penetration rates and efficiency trends.

[17] The detailed documentation of the commercial module contains additional details concerning model structure and operation. Refer to Energy Information Administration, Model Documentation Report: Commercial Sector Demand Module of the National Energy Modeling System, DOE/EIA M066(2007), (February 2007).

[18] The commercial floorspace equations of the Macroeconomic Activity Model are estimated using the F.W. Dodge Statistics and Forecasts Group database of historical floorspace estimates. The F.W. Dodge estimate for commercial floorspace in the U.S. is approximately 16 percent lower than the estimate obtained from the CBECS used for the Commercial module. See F.W. Dodge, Building Stock Database Methodology and 1991 Results, Construction Statistics and Forecasts, F.W. Dodge, McGraw-Hill.

[19] The commercial module performs attrition for 9 vintages of floorspace developed using stock estimates from the previous 5 CBECS and historical floorspace additions data from F.W. Dodge data.

[20] In the event that the computation of additions produce a negative value for a specific building type, it is assumed to be zero.

[21] "Other office equipment" includes copiers, fax machines, typewriters, cash registers, mainframe computers, and other miscellaneous office equipment. A tenth category denoted other includes equipment such as elevators, medical, and other laboratory equipment, communications equipment, security equipment, transformers and miscellaneous electrical appliances. Commercial energy consumed outside of buildings and for combined heat and power is also included in the "other" category.

[22] Based on updated estimates using 2003 CBECS building-level consumption data and CBECS 1995 end-use-level consumption data and the methodology described in Estimation of Energy End-Use Intensities, web site [www.eia.doe.gov/emeu/cbeecs/tech\\_end\\_use.html](http://www.eia.doe.gov/emeu/cbeecs/tech_end_use.html).

[23] The proportion of equipment retiring is inversely related to the equipment life.

[24] Commercial pre-rinse spray valves are handheld devices used to remove food residue from dishes and flatware before cleaning.

