Commercial Demand Module

The National Energy Modeling System's (NEMS) Commercial Demand Module (CDM) projects commercial sector energy demand through 2050. The CDM defines the commercial sector the same way our State Energy Data System (SEDS) defines it; the commercial sector includes business establishments that are not engaged in transportation, manufacturing, or other types of industrial activity (for example, agriculture, mining, or construction). Buildings consume the bulk of commercial sector energy; however, we also include street lights, pumps, bridges, and public services if the establishment operating them is classified as commercial.

Because most commercial energy consumption occurs in buildings, the CDM relies on the data from our *Commercial Buildings Energy Consumption Survey* (CBECS) to define the commercial sector activity mix, the equipment stock, and the fuels consumed to provide end-use services.[1] We conduct the CBECS about once every four to six years. The AEO2022 uses data from the 2012 CBECS to develop base year projections.

The CDM projects consumption by fuel[2] at the census division level using prices from the NEMS energy supply modules, macroeconomic variables from the NEMS Macroeconomic Activity Module (MAM), and external data sources for technology characterizations and other inputs. We project energy demand for 10 end-use services[3] for 11 building categories[4] in each of the nine census divisions. The module begins by developing projections of floorspace for the 99 building category and census division combinations. Next, we develop the 10 end-use service demands required for the projected floorspace. The CDM projects the electricity generation and water and space heating supplied by distributed generation (DG) and combined-heat-and-power (CHP) technologies. The module chooses the technologies to meet the projected service demands for the seven major end uses and then calculates the energy consumed by the equipment stock (both existing and purchased equipment) to meet the projected end-use service demands. We model minor end uses in less detail. We derive annual energy consumption of select miscellaneous electric loads (MELs) by combining existing and projected equipment stock, energy consumption per device, and hours of use where applicable.

In the Reference case projections, we assume that no radical changes in commercial-sector technology or consumer behavior will occur through 2050. We assume no new regulations of efficiency beyond current law. We assume no new government programs fostering efficiency improvements beyond those that are currently available to commercial consumers. Technologies that have not gained widespread acceptance today will generally not achieve significant penetration into commercial buildings by the end of the projection period. Currently available technologies will increase in efficiency and decrease in cost. In general, future technologies at the same efficiency level will be less expensive, in real dollar terms, than those available today. When choosing new or replacement technologies, consumers will behave similarly to the way they now behave, and the intensity of end uses will change moderately in response to price changes.[5]

Key Assumptions

We present the CDM key assumptions in terms of the flow of the calculations described in the previous section. The following sections summarize the assumptions in each of the CDM submodules: floorspace, service demand, distributed generation, technology choice, and end-use consumption. The submodules follow the order of sections as presented, and the outputs of each submodule become the inputs to execute the next submodule. As a result, key projection drivers for the Floorspace Submodule are also key drivers for the Service Demand Submodule, and so on.

Floorspace Submodule

We project floorspace 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 and new additions to the stock derived from the MAM floorspace growth projection.[6]

Existing floorspace and attrition

We base existing floorspace on the estimated floorspace reported in the 2012 CBECS (Table 1). We project that, over time, the 2012 stock will decline as buildings are removed from service (floorspace attrition). We estimate floorspace attrition by a logistic decay function, the shape of which depends on 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 (Table 2).[7]

Table 1. Total floorspace by census division and principal building activity, 2012
million square feet

	Assembly	Education	Food sales	Food service	Health care	Lodging	Large office	Small office	Mercantile/ service	Warehouse	Other	Total
New England	633	642	110	130	169	207	399	445	717	521	333	4,305
Middle Atlantic	1,212	1,415	207	162	367	794	2,675	762	1,719	1,255	674	11,242
East North Central	1,762	2,208	99	217	350	663	1,333	1,273	2,343	1,584	920	12,751
West North Central	761	969	75	153	134	385	464	613	1,269	959	384	6,165
South Atlantic	1,728	2,839	188	396	391	1,220	1,549	1,882	3,498	2,842	1,424	17,957
East South Central	945	469	74	150	185	462	302	477	1,055	521	256	4,896
West South Central	1,314	1,849	137	225	302	600	795	1,037	1,842	1,916	1,390	11,409
Mountain	526	782	59	104	137	449	409	593	842	592	407	4,900
Pacific	1,209	1,066	304	283	317	942	1,280	1,498	2,694	2,941	918	13,451
Total United States	10,090	12,239	1,252	1,819	2,352	5,722	9,207	8,581	15,978	13,130	6,707	87,076

Source: U.S. Energy Information Administration, *2012 Commercial Buildings Energy Consumption Survey* public-use data
Note: Totals may not equal sum of components because of independent rounding.

Table 2. Floorspace attrition parameters, 2012

	Assembly	Education	Food sales	Food service	Health care	Lodging	Large office	Small office	Mercantile/ service	Ware- house	Other
Median expected lifetime (years)	55	62	55	50	55	53	65	58	50	58	60
Gamma	1.21	1.38	1.02	1.43	1.39	1.40	1.98	1.45	1.26	1.31	1.29

Source: U.S. Energy Information Administration, *2012 Commercial Buildings Energy Consumption Survey* public-use data

New construction additions to floorspace

The CDM estimates projected commercial floorspace additions by combining the surviving floorspace estimates with the total floorspace growth projection from MAM. We calculate total NEMS floorspace by applying the MAM-assumed floorspace growth rate within each census division and MAM building type to the corresponding NEMS CDM building types, based on the CBECS building type shares. We then subtract the previous year's NEMS surviving floorspace from the current year's total NEMS floorspace projection to yield new floorspace additions.[8]

Service Demand Submodule

After we project the building stock, the CDM projects 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
- Computing
- Office equipment

Distinct from personal computers (PCs), office equipment consists of copiers, fax machines, scanners, multi-function devices, video displays, and other miscellaneous office equipment.

A final *Other uses* category consists of miscellaneous electric loads (MELs) such as elevators, escalators, medical and other laboratory equipment, communications equipment, security equipment, transformers, warehouse robots, point-of-sale systems, televisions, and other miscellaneous electrical appliances. Commercial energy consumed outside of buildings—for combined heat and power and for minor uses of natural gas and distillate fuel oil—is also included in the *Other uses* category as well as commercial consumption of residual fuel oil, propane, coal, motor gasoline, and kerosene.

We measure the service demand intensity (SDI) in thousand British thermal units (Btu) of end-use service demand per square foot of commercial floorspace, and it differs across service, census division, and building type. We base SDIs on CBECS consumption data,[9] using a hybrid engineering and statistical approach. Projected service demand is the product of square feet and SDI for all end uses across the 11 building categories. It reflects adjustments for changes in shell efficiency for space heating and cooling and reflects the increasing adoption of sensor and control technologies for energy management.

Shell efficiency

The shell integrity of the building envelope is an important factor for the heating and cooling loads for each type of building. The NEMS CDM represents the shell efficiency by separate heating and cooling factors that change over time to reflect improvements in the building shell. The factors, dimensioned by building type and census division, affect the space heating and cooling service demand intensities and change the fuel consumed for these services as the shell integrity improves. We base AEO2022 building shell efficiencies on a 2018 report by ICF International we commissioned.[10] Averaged across census divisions and building types, building shells for new construction in 2012 are 8% more efficient for heating and 6% more efficient for cooling than the average existing building shell. By 2050, building shell efficiency for newly constructed buildings improves by an average of 56% for space heating and 20% for cooling relative to the existing 2012 building stock. As older buildings retire, we assume that by 2050, the average shell efficiency for buildings constructed before 2012 increases by 6% for heating and 4% for cooling relative to the 2012 average.

Sensors and controls

Sensor and control innovations for building energy management can lower the demand for end-use energy services such as space heating, space cooling, ventilation, and lighting in buildings. AEO2022 models the effect of increased adoption of these technologies over the projection period. Specific technologies modeled include lighting and HVAC (heating, ventilation, and air-conditioning) controls, building energy management software (BEMS), automatic fault detection and diagnosis (AFDD), and submeters. We use the 2012 CBECS to estimate technology penetration for these technologies by building type in 2012, and we project penetration and savings estimates based on a report by Leidos, Inc. that we commissioned.[11] Service demand is reduced by the product of the estimated savings from the various control technologies that apply to a given service, adjusted by the projected penetration of the control technologies relative to how widespread the technologies are during the base CBECS year.

Distributed generation and combined heat and power

We base historical data for installations of solar photovoltaic (PV) systems primarily on information from the Greentech Media (GTM) Research and the Solar Energy Industries Association's (SEIA) quarterly report on U.S. solar market trends. We use historical data from the Form EIA-860, *Annual Electric Generator Report*, to derive electricity generation by census division, building type, and fuel. Our projection of DG and CHP technologies used in electricity generation is based on the economic returns projected for those technologies. The module uses a detailed cash-flow approach to estimate the internal rate of return for an investment. Penetration assumptions for DG and CHP technologies are a function of the estimated internal rate of return relative to purchased electricity and of Bass diffusion parameter estimates based on historical capacity data. Table 3 provides the cost and performance parameters for representative DG and CHP technologies. Cost parameters account for tax incentives for DG technologies and for Section 201 tariffs placed on imported solar cells and modules in January 2018.

The module also incorporates learning for new DG and CHP technologies, allowing for declining technology costs as shipments increase. For fuel-cell and PV systems, parameter assumptions for the AEO2022 Reference case result in a 13% reduction in capital costs each time the installed capacity in the residential and commercial building sectors doubles (in the case of PVs, utility-scale capacity is also included for learning). Doubling the installed capacity of microturbines results in a 10% reduction in capital costs, and doubling the installed capacity of distributed wind systems results in a 3% reduction.

Technology Choice Submodule

The Technology Choice Submodule develops projections of major end-use equipment to meet projected service demands using the three major fuels: electricity, natural gas, and distillate fuel oil. Capital purchase decisions are driven by assumptions about behavioral rule proportions and time preferences (described in the next three sections) as well as:

- Projected fuel prices
- Average annual use of equipment (capacity factors)
- Relative technology capital costs
- Operating and maintenance (O&M) costs

Decision types

In each projection year, equipment is potentially purchased for three decision types. Equipment must be purchased for newly added floorspace and to replace the equipment in existing floorspace that is projected to wear out.[12] Equipment is also potentially purchased for retrofitting equipment that has become economically obsolete. Retrofit equipment is only purchased if the annual operating costs of a current technology exceed the annualized capital and operating costs of a technology available as a retrofit candidate.

Table 3. Capital cost and performance of selected commercial distributed generation technologies

Technology type	Year introduced	Average generating capacity (kW_{DC})[a]	Electrical efficiency[b]	Combined efficiency (electricity plus thermal)[c]	Installed capital cost (2018$ per kW_{DC})[d]	Service life (years)
Solar photovoltaic	2015	28	0.16	N/A	$3,921	25
	2020	42	0.19	N/A	$2,836	25
	2030	50	0.21	N/A	$2,072	30
	2040	55	0.21	N/A	$1,625	30
	2050	60	0.22	N/A	$1,317	30
Fuel cell	2015	250	0.56	0.59	$6,698	10
	2020	250	0.56	0.61	$6,238	10
	2030	250	0.57	0.62	$6,137	10
	2040	250	0.59	0.64	$6,009	10
	2050	250	0.60	0.65	$5,908	10
Natural gas engine	2015	373	0.29	0.83	$3,120	30
	2020	373	0.29	0.82	$3,110	30
	2030	373	0.29	0.82	$3,104	30
	2040	373	0.30	0.82	$3,091	30
	2050	373	0.30	0.85	$3,085	30
Oil-fired engine	2015	350	0.34	0.93	$3,260	30
	2020	350	0.34	0.93	$3,246	30
	2030	350	0.34	0.94	$3,228	30

Technology type	Year introduced	Average generating capacity (kW_{DC})[a]	Electrical efficiency[b]	Combined efficiency (electricity plus thermal)[c]	Installed capital cost (2018$ per kW_{DC})[d]	Service life (years)
	2040	350	0.35	0.96	$3,209	30
	2050	350	0.35	0.96	$3,200	30
Natural gas turbine	2015	1,210	0.30	0.77	$2,292	30
	2020	1,210	0.30	0.75	$2,279	30
	2030	1,210	0.30	0.78	$2,252	30
	2040	1,210	0.31	0.79	$2,227	30
	2050	1,210	0.31	0.78	$2,214	30
Natural gas	2015	200	0.30	0.63	$4,224	10
microturbine	2020	200	0.30	0.62	$4,199	10
	2030	200	0.31	0.64	$4,148	10
	2040	200	0.31	0.62	$4,099	10
	2050	200	0.32	0.65	$4,075	10
Wind	2015	2,000	0.40	N/A	$2,803	20
	2020	2,000	0.40	N/A	$2,738	25
	2030	2,000	0.40	N/A	$2,726	25
	2040	2,000	0.40	N/A	$2,714	25
	2050	2,000	0.41	N/A	$2,703	25

Source: U.S. Energy Information Administration, *Distributed Generation, Battery Storage, and Combined Heat and Power System Characteristics and Costs in the Buildings and Industrial Sectors*

[a] kW_{DC} = kilowatts (direct current).

[b] For wind, this value represents system capacity factor.

[c] Combined electric and thermal efficiency

[d] Costs for solar photovoltaic, fuel cell, microturbine, and wind technologies include learning effects.

Behavior rules

The CDM uses three alternative 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:

- **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 consumes 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 these three behavior rules, equipment that meets the service at the lowest annualized lifecycle cost is chosen. Table 4 illustrates the proportions of floorspace subject to the different behavior rules for space heating technology choices in large office buildings.

Table 4. Assumed behavior rules for choosing space heating equipment in large office buildings
percentage

	Unrestricted	Same fuel	Same technology	Total
New equipment decision	16%	31%	53%	100%
Replacement decision	5%	25%	70%	100%
Retrofit decision	1%	4%	95%	100%

Source: U.S. Energy Information Administration, *Commercial Demand Module of the National Energy Modeling System: Model Documentation*, DOE/EIA-M066

Time preferences

We assume commercial building owners' preferences about current versus future expenditures are distributed among seven alternative time-preference premiums. By adding the risk-adjusted time-preference premiums to the 10-year Treasury note rate from the MAM, the module calculates implicit discount rates, also known as hurdle rates, which apply to the assumed proportions of commercial floorspace. This distribution of discount rates prevents a single technology from dominating purchase decisions in lifecycle cost comparisons. The distribution used for AEO2022 assigns some floorspace a very high discount (or hurdle) rate to simulate floorspace that will never retrofit existing equipment and that will only use purchased 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 purchased equipment.

The share of floorspace assigned to each rate in the distribution varies by end-use service. Table 5 illustrates the distribution of time-preference premiums for space heating and lighting in 2021. 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. We expect the federal sector to purchase energy-efficient equipment to meet the federal buildings performance standards of the Energy Policy Act of 2005 (EPACT2005) and the Energy Independence and Security Act of 2007 (EISA2007) when it is cost-effective. For federal purchase decisions relating to energy conservation, cost-effectiveness is determined using a discount rate based on long-term Treasury bond rates, estimated in the CDM by the 10-year Treasury note rate.

For lighting, the proportion of floorspace assumed for the 0.0 time preference premium is increased to include all federal floorspace. Federal floorspace is included to represent the EISA2007 provision that all federal buildings must have energy-efficient lighting fixtures and bulbs to the maximum extent feasible, including when replacing bulbs in existing fixtures.

Table 5. Assumed distribution of risk-adjusted time preference premiums for space heating and lighting equipment in 2021
percentage

Time preference premium	Proportion of floorspace—space heating	Proportion of floorspace—lighting
1,000.0	26.6%	25.6%
100.0	23.5%	24.0%
45.0	19.6%	20.0%
25.0	18.7%	18.9%
15.0	9.8%	7.5%
6.5	1.6%	1.9%
0.0	0.2%	2.1%
Proportion of floorspace	100.0%	100.0%

Source: Institute of Real Estate Management (IREM), *Building Performance That Pays: Insights from the First IREM Energy Efficiency Survey*, 2017; Navigant, *The Leading Edge of New Energy Efficiency and Renewable Energy Technologies Coming to the Market*, September 2014; and the U.S. Energy Information Administration, *Commercial Demand Module of the National Energy Modeling System: Model Documentation*, DOE/EIA-M066

Changes in fuel prices also affect the distribution of hurdle rates used in the CDM. If a fuel's price rises relative to its price in the base year (2012), 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. If the module input for the risk-adjusted time preference premium results in a hurdle rate that is lower than the assumed financial discount rate—15% for the commercial sector—with base-year fuel prices, such as the 0.0 rate (Table 5), we assume no response to increasing fuel prices.

Technology characterization menu

The technology characterization menu organizes all relevant major end-use equipment data. We index equipment by:

- Technology
- Vintage
- Fuel
- End-use service provided
- Census division (or building type for ventilation, lighting, and refrigeration end uses)
- Initial market share
- Efficiency (either 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
- Last year available for purchase

Equipment may be selected to satisfy service demand only if the year in which the decision is made falls within the window of availability. Equipment acquired before the lapse of its availability continues to be treated as part of the existing stock and is subject to replacement or retrofitting. Because of this flexibility in limiting equipment availability, we can directly model equipment efficiency standards. Table 6 provides a sample of the technology data for space heating in the New England Census Division.

Table 6. Capital cost and efficiency ratings of selected commercial space heating equipment[a]

Equipment type	Vintage	efficiency[b]	Capital cost (2017$ per MMBtu[c]/hour)	Maintenance cost (2017$ per MMBtu/hour)	Service life (years)
Rooftop air-source heat pump	2012 installed base	3.30	$83.89	$3.44	21
	2017 typical	3.30	$83.89	$3.44	21
	2017 ENERGY STAR®	3.40	$86.11	$3.44	21
	2017 high	3.70	$178.33	$3.44	21
Ground-source heat pump	2012 installed base	3.10	$571.88	$3.13	14
	2017 typical	3.70	$396.88	$3.13	14
	2017 mid-range	3.80	$408.33	$3.13	14
	2017 high	4.00	$420.83	$3.13	14
Electric boiler	2017 typical	0.94	$22.27	$0.21	15
Electric resistance heater	2012 installed base	1.00	$37.35	$0.01	18
Natural gas heat pump	2012 Installed base	1.40	$312.50	$5.17	15
	2012 residential-type installed base	1.30	$226.67	$2.83	15
	2017 typical	1.40	$275.00	$5.17	15
Natural gas furnace	2012 installed base	0.78	$6.93	$0.55	23
	2017 typical	0.78	$6.93	$0.55	23
	2017 high	0.93	$10.67	$0.49	23
	2020 typical/2023 standard	0.79	$7.00	$0.54	23
Natural gas boiler	2012 installed base	0.77	$33.81	$2.35	30
	2017 current standard	0.80	$40.31	$2.81	25
	2017 typical	0.85	$47.72	$2.65	25
	2017 mid-range	0.93	$57.33	$2.42	25
	2017 high	0.99	$59.03	$2.27	25
Distillate oil furnace	2012 installed base	0.79	$20.85	$0.96	23
	2017 typical/2023 standard	0.80	$20.75	$0.94	23
	2020 standard	0.83	$20.45	$0.91	23
Distillate oil boiler	2012 installed base	0.81	$19.16	$1.49	30
	2017 current standard	0.82	$42.68	$3.51	25
	2017 typical	0.85	$46.32	$3.38	25
	2017 high	0.97	$68.62	$2.96	25

Source: U.S. Energy Information Administration, *Updated Buildings Sector Appliance and Equipment Costs and Efficiency*, June 2018

[a] Equipment listed is for the New England Census Division, but it also represents the technology data for the rest of the United States. The source reference provides a link to the complete set of technology data.

[b] Efficiency metrics vary by equipment type. Electric rooftop air-source heat pumps, ground-source heat pumps, and natural gas heat pumps are rated for heating performance using the coefficient of performance (COP); natural gas and distillate furnaces and boilers reflect thermal efficiency.

[c] million British thermal units

One option allows for endogenous price-induced technological change in determining equipment costs and its availability for the menu of equipment. This concept allows future technologies faster diffusion into the marketplace if fuel prices significantly increase for a sustained period. This option was not used for the AEO2022 model runs.

End-Use Consumption Submodule

The End-Use Consumption Submodule calculates the consumption of each of the three major fuels (electricity, natural gas, and distillate fuel oil) for the 10 end-use services plus fuel consumption for CHP and district services.[13] For major end-use services, we divide the end-use service demand met by the equipment by its efficiency to find the energy consumption for each type of equipment. The energy used for each end-use service is equal to the sum of energy used by all existing equipment types for that service. This calculation includes dimensions for census division, building type, and fuel. We project consumption of the five minor fuels (residual fuel oil, propane, motor gasoline, kerosene, and coal) based on historical trends.

Equipment efficiency

We initially base the average energy consumption of an appliance on estimates taken from the 2012 CBECS. As the stock efficiency changes during the model simulation, energy consumption decreases nearly as much as, but not quite proportionally to, the increase in efficiency. The difference is a result the efficiency (calculated using the harmonic average)[14] and also the efficiency rebound effect. For example, if electric heat pumps are now 10% more efficient, on average, than in 2012 and all else remains constant (weather, real energy prices, shell efficiency, etc.), energy consumption per heat pump would now average about 9% less. The Service Demand Submodule and Technology Choice Submodule together determine the average efficiency of the stocks used in adjusting the initial average energy consumption.

Adjusting for weather and climate

Recognizing the effect of weather on space heating and air-conditioning is necessary to avoid projecting abnormal demand based on weather conditions in the base year. In the CDM, we make proportionate adjustments to space heating and air-conditioning demand by census division. We base these adjustments on National Oceanic and Atmospheric Administration (NOAA) heating degree day (HDD) and cooling degree day (CDD) data. We develop short-term projections with NOAA's 15-month outlook from its Climate Prediction Center,[15] which encompasses the first forecast year. State-level projections of degree days beyond that are informed by a linear trend using the most recent 30 years of complete annual historical degree-day data, which are then population-weighted to the census division level. In this way, the CDM accounts for projected population migrations across the nation and continues any realized historical changes in degree days at the state level. A 10% increase in HDD would increase space heating consumption by 10%, and a 10% increase in CDD would increase cooling consumption by about 11%.

Short-term price effect and efficiency rebound

We assume 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 -0.10 is currently used for commercial refrigeration. A value of -0.05 is currently used for computing, office equipment, and other minor uses of electricity. For example, for lighting, this value implies that for a 1.0% increase in the price of a fuel, energy consumption will decrease by 0.25%. 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% increase in efficiency will reduce the cost of providing the service by 10%. 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% (-10% multiplied by -0.15). Currently, all services are affected by the short-term price effect. Services affected by efficiency rebound are space heating and cooling, water heating, ventilation, and lighting.

Energy efficiency rebates

Energy-efficient heating, cooling, lighting, water heating, and refrigeration end-use technologies are given rebates to more explicitly reflect energy efficiency program expenditures. Energy efficiency rebates are often provided at the utility and local scale, but the NEMS CDM does not represent this level of detail. AEO2022 assumes rebate levels at the census division level and by technology. Table 7 shows energy efficiency rebate levels by end use for energy efficiency technologies in 2020. Lighting rebates begin to phase out in 2020 as LED lights approach market saturation, and certain appliance rebates may change slightly over time as the incremental cost of the technology changes.

Table 7. Selected commercial energy efficiency rebates in 2020

percentage of installed cost

Equipment type	New England	Middle Atlantic	East N. Central	West N. Central	South Atlantic	East S. Central	West S. Central	Mountain	Pacific
Rooftop air-source heat pump (ENERGY STAR/high efficiency)	3%	6%	3%	5%	9%	15%	0%	11%	12%
Natural gas furnace	16%	13%	12%	10%	10%	5%	9%	12%	13%
Ground-source heat pump (mid to high efficiency)	20%	12%	5%	3%	2%	0%	27%	0%	0%
Rooftop AC[a]	4%	7%	3%	2%	8%	12%	0%	7%	8%
Wall/window/room AC	8%	7%	5%	5%	5%	3%	5%	7%	7%
Residential-type central AC	10%	5%	7%	7%	4%	6%	18%	7%	6%
Heat pump water heater	30%	30%	30%	30%	30%	26%	30%	30%	30%
Natural gas water heater	18%	9%	3%	3%	0%	0%	0%	4%	6%
Compact fluorescent bulbs	0%	0%	0%	0%	0%	0%	0%	0%	0%
LED PAR38, LED A Lamps[b]	8%	8%	8%	8%	8%	8%	8%	8%	8%
LED Integrated Luminaire[b]	21%	21%	21%	21%	21%	21%	21%	21%	21%

Source: U.S. Energy Information Administration (EIA), *Northeast Regional Energy Efficiency Database (REED) 2018 data update*; U.S. Energy Information Administration, *Northeast Regional Energy Efficiency Database (REED), Program and Measure Data: Report on Results of Investigations*, May 2020; U.S. Energy Information Administration, *Assessing Existing Energy Efficiency Program Activity*, June 2018; and ENERGY STAR Summaries of Programs; Consortium for Energy Efficiency (CEE) Program Resources

[a] Air-conditioning.

[b] Rebates for LEDs are drawn down for post-2019 vintages and eliminated for post-2029 vintages as technology achieves penetration.

Legislation and Regulations

Consolidated Appropriations Act, 2021 (P.L. 116-260)

Passed in December 2020, this act extended the phase out of investment tax credits (ITCs) for distributed generation equipment by an additional two years. Commercial ITCs drop to 10% after 2023. We do not apply any safe harbor provisions to distributed generation equipment ITCs in the buildings sector. We assume all systems are installed within the same calendar year as the relevant ITC rate.

Bipartisan Budget Act of 2018 (P.L. 115-123)

The Bipartisan Budget Act, passed in February 2018, extends ITC provisions for several technologies not covered by the 2016 Consolidated Appropriations Act, including geothermal heat pumps, qualified fuel cell and microturbine equipment, combined heat and power, and qualified small wind. For these technologies, the extension applies to equipment beginning construction before January 1, 2022.

Solar PV Tariffs under Section 201 of the Trade Act of 1974 (P.L. 93-618)

Effective February 2018, the United States imposed four-year tariffs on imported solar PV cells and modules. The tariff level is 30% in the first year, declining by 5% per year during the remaining three years. The tariff includes an exemption for 2.5 gigawatts (GW) of PV cells per year and also excludes some developing countries.

Tax Cuts and Jobs Act of 2017 (P.L. 115-97)

The Tax Cuts and Jobs Act, passed in December 2017, introduces 100% expensing for qualified property, including geothermal heat pumps, solar PV, and solar thermal water heating placed in service between September 27, 2017, and January 1, 2023. This provision allows the full cost of this equipment to be deducted from a firm's tax bill in the first year. Qualified property placed in service from 2023 to 2026 receives a 50% bonus depreciation.

Consolidated Appropriations Act of 2016 (P.L. 114-113)

The H.R. 2029 legislation, passed in December 2015, extends the ITC provisions of EPACT2005 for renewable energy technologies. The five-year ITC extension for solar energy systems allows for a 30% tax credit through 2019, decreasing to 26% in 2020 and 22% in 2021 and then remaining at 10% from 2022 through 2050. The credit is directly incorporated into the cash-flow approach for projecting distributed generation by commercial PV systems and is factored into the installed capital cost assumptions for solar water heaters.

American Recovery and Reinvestment Act of 2009 (ARRA2009)

The ARRA2009 legislation, passed in February 2009, provides energy-efficiency funding for federal agencies, State Energy Programs (SEP), and block grants. To account for the impact of this funding, we assume states adopt and enforce the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-2007 standard by 2018 for building shell measures. We assume all public buildings (federal, state, and local) use the 10-year Treasury note rate for purchase decisions related to both new construction and replacement equipment while ARRA stimulus package funding is available. We assume a percentage of the SEP and Conservation Block Grant funding is used for solar PV and small wind turbine installations. Additional stimulus funding is applied to fuel cell installations.

The ARRA2009 provisions remove the cap on the 30% business ITC for wind turbines. The ITC was available for systems installed through 2016. These credits are directly incorporated into the cash-flow approach for DG systems.

Energy Improvement and Extension Act of 2008 (EIEA2008)

The EIEA2008 legislation, passed in October 2008, extended the ITC provisions of EPACT2005 and expanded the credit to include additional technologies. The ITCs of 30% for solar energy systems and fuel cells and 10% for microturbines were extended through 2016. The cap on the fuel cell credit was increased from $500 to $1,500 per half kilowatt of capacity. The EIEA2008 provisions expanded the ITC to include a 10% credit for CHP systems and ground-source heat pumps and a 30% credit for wind turbines with the wind credit capped at $4,000. The expanded credits were available for systems installed through 2016. These credits are directly incorporated into the cash-flow approach for DG systems, including CHP, and they are factored into the installed capital cost assumptions for solar water heaters and ground-source heat pumps.

Energy Independence and Security Act of 2007 (EISA2007)

The EISA2007 legislation, passed in December 2007, provides standards for specific explicitly modeled commercial equipment. EISA2007 requires specific energy-efficiency measures in commercial walk-in coolers and walk-in freezers effective January 1, 2009, and an additional update became effective in 2017. Incandescent and halogen lamps must meet standards for maximum allowable wattage based on lumen output starting in 2012. Metal halide lamp fixtures using lamps between 150 watts and 500 watts must have a minimum ballast efficiency ranging from 88% to 94%, depending on ballast type, effective January 1, 2009. Additional requirements became effective in 2017.

For general service lighting (GSL)—including A-type and PAR38 bulbs used in commercial applications—a backstop standard in EISA2007 had required bulbs to achieve efficiencies of 48 lumens per watt in 2020. In December 2019, however, the U.S. Department of Energy issued a final rule to eliminate this backstop standard. We first incorporated this final rule in the AEO2021, and it remains in AEO2022.

The EISA2007 requirement for federal buildings to use energy-efficient lighting fixtures and bulbs to the maximum extent possible is represented by adjusting the proportion of the commercial sector assumed to use the 10-year Treasury note rate as an implicit discount (or hurdle) rate for lighting.

Energy Policy Act of 2005 (EPACT2005)

The passage of EPACT2005 in August 2005 provided additional minimum efficiency standards for commercial equipment. Some of the standards for explicitly modeled equipment, effective January 1, 2010, include an increased Energy Efficiency Rating (EER) 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. EPACT2005 adds standards for medium-base compact fluorescent lamps effective January 1, 2006, and for ballasts for Energy Saver fluorescent lamps effective in 2009 and 2010. It also bans the manufacture or import of mercury vapor lamp ballasts effective January 1, 2008.

Several efficiency standards in EPACT2005 pertain to equipment not explicitly represented in the NEMS CDM. For low-voltage dry-type transformers, share estimates of projected miscellaneous electricity use caused by transformer losses account for the efficiency standard in this law. For illuminated exit signs, traffic signals, and commercial premise 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 EPACT2005 standards, illuminated exit signs and traffic signal modules must have met 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 from 8 watts 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 97.0% to 98.9% based on output. Commercial pre-rinse spray valves[16] must have a maximum flow rate between 1.00 gallon and 1.28 gallons per minute, effective January 1, 2019, which results in energy reductions caused by reduced hot water use.

EPACT2005 expanded the business ITC to 30% for solar property installed in 2006 and 2007. ITCs of 30% for fuel cells and 10% for microturbine power plants were also available for property installed in 2006 and 2007. The EPACT2005 tax credit provisions were extended in December 2006 to cover equipment installed in 2008. These credits are directly incorporated into the cash-flow approach for distributed generation systems and are factored into the installed capital cost assumptions for solar hot water heaters.

Energy Policy Act of 1992 (EPACT1992)

A key assumption incorporated in the technology selection process is that the equipment efficiency standards described in EPACT1992 constrain minimum equipment efficiencies. We model the effects of these standards by modifying the technology database to eliminate equipment that no longer meets the minimum efficiency requirements. Some of the EPACT1992 standards implemented in the module include the following:

- Natural gas- and oil-fired boilers—minimum combustion efficiency of 0.80 and 0.83, respectively, amended to minimum thermal efficiency of 0.80 and 0.81, respectively, in 2012
- Natural gas- and oil-fired furnaces—minimum thermal efficiency of 0.80 and 0.81, respectively
- Electric water heaters—minimum energy factor of 0.85
- Natural gas and oil water heaters—minimum thermal efficiency of 0.80

A fluorescent lamp ballast standard, effective in 2005, requires electronic ballasts with a minimum ballast efficacy factor of 1.17 for 4-foot, two-lamp ballasts and an efficacy factor of 0.63 for 8-foot, two-lamp ballasts. Fluorescent lamps and incandescent reflector lamp bulbs must meet amended standard levels for minimum average lamp efficacy in 2012. Other updates for commercial refrigeration equipment include maximum energy consumption standards for refrigerated vending machines and display cases based on volume.

The 10% business ITC for solar energy property included in EPACT1992 was extended by the *Consolidated Appropriations Act, 2021* and is directly incorporated into the cash-flow approach for projecting distributed generation by commercial PV systems after 2023. For solar water heaters, we factor the tax credit into the installed capital cost assumptions used in the Technology Choice Submodule.

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 CDM includes several features that allow projected efficiency to increase in response to voluntary programs (for example, 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 shown in Table 5. In addition, we assume the shell efficiencies of new and existing buildings increase from 2012 through 2050 (as discussed in the section on shell efficiency). Finally, we model utility energy efficiency programs explicitly, as shown in Table 7.

Notes and Sources

[1] U.S. Energy Information Administration, *2012 Commercial Buildings Energy Consumption Survey* (CBECS) public use data.
[2] The CDM accounts for electricity, natural gas, distillate fuel oil, residual fuel oil, propane, coal, motor gasoline, and kerosene. Current commercial use of biomass (wood and municipal solid waste) is also included. In addition to these fuels, the use of solar energy is projected based on an exogenous estimate of existing solar PV system installations, projected installations as a result of state and local incentive programs, and the potential endogenous penetration of solar PV systems and solar thermal water heaters. The use of wind energy is projected based on an estimate of existing distributed wind turbines and the potential endogenous penetration of wind turbines in the commercial sector.
[3] The end-use services in the CDM are heating, cooling, water heating, ventilation, cooking, lighting, refrigeration, computing, office equipment, and other uses (a category that accounts for all other minor end uses).
[4] The 11 building categories are assembly, education, food sales, food services, health care, lodging, large offices, small offices, mercantile/services, warehouse, and other.
[5] The *Model Documentation Report* contains additional details concerning model structure and operation. Refer to U.S. Energy Information Administration, *Commercial Demand Module–NEMS Documentation*, DOE/EIA-M066.
[6] The Macroeconomic Activity Module estimates commercial floorspace growth rates using data from Dodge Data and Analytics.
[7] The CDM performs attrition for 10 vintages of floorspace developed using stock estimates from the 2012 CBECS.
[8] If the computation of additions produces a negative value for a specific building type, the value is assumed to be zero.
[9] Based on 2012 CBECS end-use-level consumption data developed using the methodology described in *Estimation of Energy End-Use Consumption.*
[10] ICF International, *Development of Commercial Building Shell Heating and Cooling Load Factors,* prepared for U.S. Energy Information Administration, February 2018.
[11] Leidos, Inc., *Trends in Commercial Whole-Building Sensors and Controls,* prepared for U.S. Energy Information Administration, December 2020.
[12] The proportion of equipment retiring is inversely related to the equipment life.
[13] District services involve the production of steam, hot water, or chilled water at a central physical plant, which are then distributed over a wide area, such as a campus environment or urban center, to provide space heating, water heating, cooling, or a combination of these. In the CDM, projected district services demand by end-use service is converted to consumption of the source fuels used by the central plant and added to energy consumption for the appropriate end-use service.
[14] The harmonic average refers to the reciprocal of the arithmetic mean of the reciprocals of a number set. This technique is often better suited to averaging rates (such as efficiencies) than the arithmetic mean.
[15] National Oceanic and Atmospheric Administration, National Weather Service, Experimental Monthly Degree Day Forecast. An explanation of the forecast is also available.
[16] Commercial pre-rinse spray valves are handheld devices used to remove food residue from dishes and flatware before cleaning.