The commercial demand module (CDM) forecasts energy consumption by Census division for eight marketed energy sources plus solar and geothermal energy. For the three major commercial sector fuels, electricity, natural gas and distillate oil, CDM is a structural model and its forecasts are built up from projections of the stock of commercial floorspace and energy–consuming equipment. For the remaining five marketed minor fuels, simple econometric projections are made.

The commercial sector encompasses business establishments that are not engaged in industrial or transportation activities. Commercial sector energy is consumed mainly in buildings, except for a relatively small amount for services such as street lights and water supply. CDM incorporates the effects of four broadly–defined determinants of energy consumption: economic and demographics, structural, technology turnover and change, and energy markets. Demographic effects include total floorspace, building type and location. Structural effects include changes in the mix of desired end–use services provided by energy (such as the penetration of telecommunications equipment, personal computers and other office equipment). Technology effects include changes in the stock of installed equipment caused by the normal turnover of old, worn out equipment to newer versions which tend to be more energy efficient, the integrated effects of equipment and building shell (insulation level) in new construction, and the projected availability of equipment with even greater energy–efficiency. Energy market effects include the short–run effects of energy prices on energy demands, the longer–run effects of energy prices on the efficiency of purchased equipment, and limitations on minimum levels of efficiency imposed by legislated efficiency standards. The model structure carries out a sequence of five basic steps, as shown in Figure 6. The first step is to forecast commercial sector floorspace. The second step is to forecast the energy services (space heating, lighting, etc.) required by the projected floorspace. The third step is to project the electricity generation and water and space heating supplied by distributed generation and combined heat and power (CHP) technologies. The fourth step is to select specific technologies (natural gas furnaces, fluorescent lights, etc.) to meet the demand for energy services. The last step is to determine how much energy will be consumed by the equipment chosen to meet the demand for energy services.

Floorspace Submodule

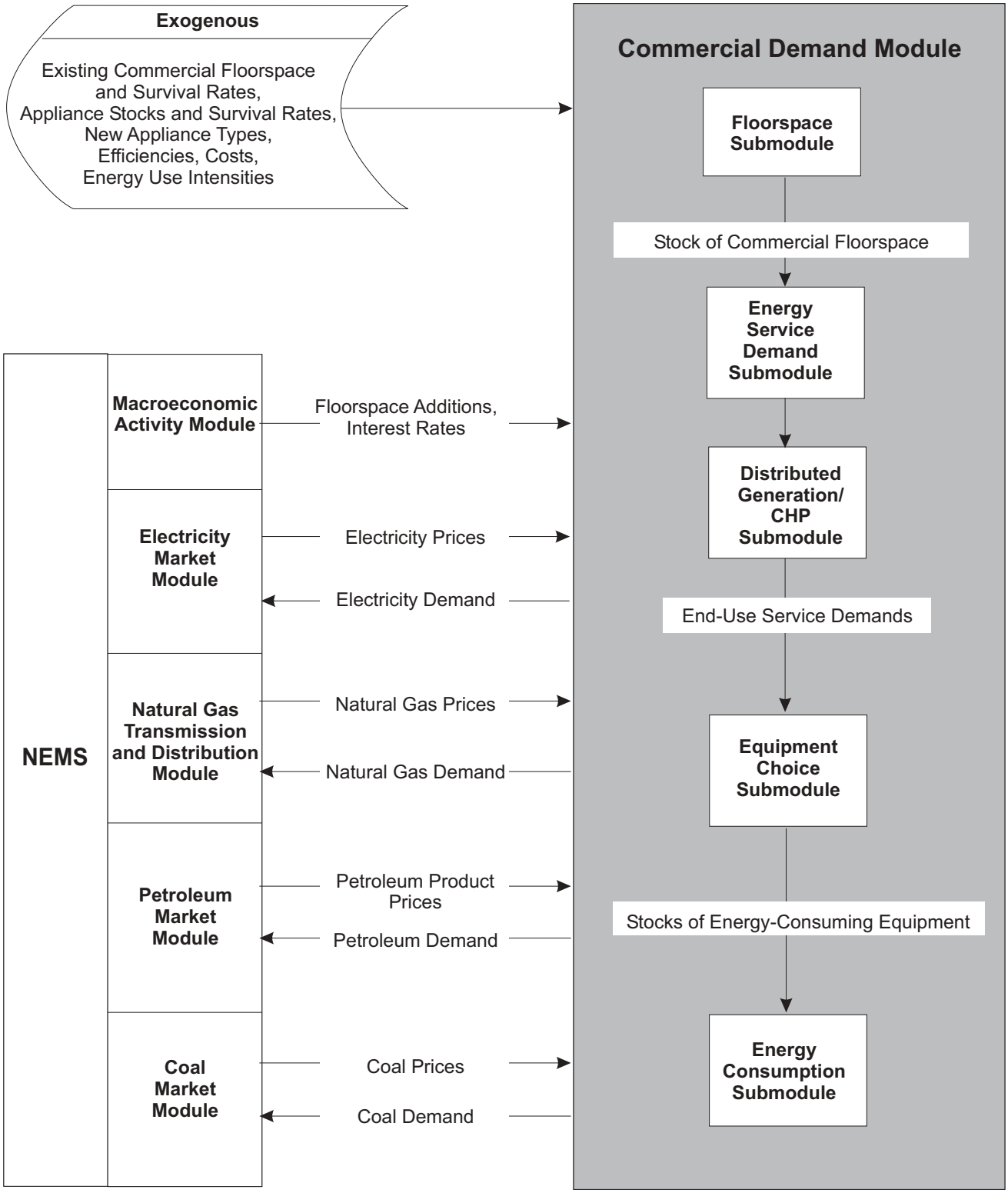
The base stock of commercial floorspace by Census division and building type is derived from EIA's 1999 Commercial Buildings Energy Consumption Survey (CBECS). CDM receives forecasts of total floorspace by building type and Census division from the macroeconomic activity module (MAM) based on Global Insight, Inc. (formerly DRI–WEFA) definitions of the commercial sector. These forecasts embody both economic and demographic effects on commercial floorspace. Since the definition of commercial floorspace from Global Insight, Inc. is not calibrated to CBECS, CDM estimates the surviving floorspace from the previous year and then calibrates its new construction so that growth in total floorspace matches that from MAM by building type and Census division.

CDM models commercial floorspace for the following 11 building types:

- Assembly
- Education
- Food sales
- Food service
- Health care
- Lodging
- Office–large
- Office–small
- Mercantile and service
- Warehouse
- Other

CDM Outputs	Inputs from NEMS	Exogenous Inputs
Energy demand by service and fuel type Changes in floorspace and appliance stocks	Energy product prices Interest rates Floorspace growth	Existing commercial floorspace Floorspace survival rates Appliance stocks and survival rates New appliance types, efficiencies, costs Energy use intensities

Figure 6. Commercial Demand Module Structure



Energy Service Demand Submodule

Energy consumption is derived from the demand for energy services. So the next step is to forecast energy service demands for the projected floorspace. CDM models service demands for the following ten end–use services:

- Heating
- Cooling
- Ventilation
- Water heating
- Lighting
- Cooking
- Refrigeration
- Office equipment personal computer (PC)
- Office equipment other
- Other end uses.

Different building types require unique combinations of energy services. A hospital must have more light than a warehouse. An office building in the Northeast requires more heating than one in the South. Total service demand for any service depends on the floorspace, type, and location of buildings. Base service demand by end use by building type and Census division is derived from estimates developed from CBECS energy consumption. Projected service demands are adjusted for trends in new construction based on CBECS data concerning recent construction.

Distributed Generation and CHP Submodule

Commercial consumers may decide to purchase equipment to generate electricity (and perhaps provide heat as well) rather than depend on purchased electricity to fulfill all of their electric power requirements. The third basic step of the commercial module structure projects electricity generation, fuel consumption, water heating, and space heating supplied by ten distributed generation and CHP technologies. The characterized technologies include: photovoltaic solar systems; natural gas fuel cells, reciprocating engines, turbines and microturbines; diesel engines; coal–fired CHP; and municipal solid waste, wood, and hydroelectric generators.

Existing electricity generation by CHP technologies is derived from historical data contained in the most recent year's version of Form EIA–860B, Annual Electric Generator Report–Nonutility. The estimated units form the installed base of CHP equipment that is carried forward into future years and supplemented with any projected additions. Program driven installations of solar photovoltaic systems and fuel cells are also included based on information from the Departments of Energy and Defense. For years following the base year, an endogenous forecast of distributed generation and CHP is developed based on the economic returns projected for distributed generation technologies. A detailed cash–flow approach is used to estimate the number of years required to achieve a positive cumulative cash flow. The calculations include the annual costs (down payments, loan payments, maintenance costs, and fuel costs) and returns (tax deductions, tax credits, and energy cost savings) from the investment covering a 30–year period from the time of the investment decision. Penetration of these technologies is a function of how quickly an investment in a technology is estimated to recoup its flow of costs. In terms of NEMS projections, investments in distributed generation reduce purchases of electricity. Fuel consuming technologies also generate waste heat which is assumed to be partially captured and used to offset commercial water heating and space heating energy use.

Equipment Choice Submodule

Once service demands are projected, the next step is to project the type and efficiency of equipment that will be used to satisfy the demands. The bulk of equipment required to meet service demand will carry over from the equipment stock of the previous model year. However, equipment must always be purchased to satisfy service demand for new construction. It must also be purchased for equipment which has either worn out (replacement equipment) or reached the end of its economically useful life (retrofit equipment). For required equipment replacements, CDM uses a constant decay rate based on equipment life. A technology will be retrofitted only if the combined annual operating and maintenance costs plus annualized capital costs of a potential technology are lower than the annual operating and maintenance costs of an existing technology.

Equipment choices are made based on a comparison of annualized capital and operating and maintenance costs across all allowable equipment for a particular end–use service. In order to add inertia to the equipment choices, only subsets of the total menu of potentially available equipment may be allowed for defined market segments. For example,only 8 percent of floorspace in large office buildings may consider all available equipment using any fuel or technology when making space heating equipment replacement decisions. A second segment equal to 35 percent of floorspace, must select from technologies

using the same fuel as already installed. A third segment, the remaining 57 percent of floorspace, is constrained to consider only different efficiency levels of the same fuel and technology already installed. For lighting, all replacement choices are limited to the same technology, where technologies are broadly defined to encompass principal competing technologies (outdoor lighting types do not compete for indoor lighting service demand).

When computing annualized costs for determining equipment choices, commercial floorspace is segmented by what are referred to as hurdle rates or implicit discount rates (to distinguish them from the generally lower and more common notion of financial discount rates). Seven segments are used to simulate consumer behavior when purchasing commercial equipment. The segments range from rates as low as the 10–year Treasury bond rate, to rates high enough to guarantee that only equipment with the lowest capital cost (and least efficiency) is chosen. As real energy prices increase (decrease) there is an incentive for all but the highest implicit discount rate segments to purchase increased (decreased) levels of efficiency.

The equipment choice submodule is designed to choose among a discrete set of technologies that are characterized by a menu which defines availability, capital costs, maintenance costs, efficiencies, and equipment life. Technology characteristics for selected space heating equipment are shown in the table on page 31, derived from the report *Assumptions to the Annual Energy Outlook 2003*.[22] This menu of projected equipment models projects technological innovation, market developments, and policy interventions. For the *Annual Energy Outlook 2003*, the technology types that are included for seven of the ten service demand categories are listed in the table on page 32.

The remaining three end–use services (PC–related office equipment, other office equipment, and other end uses) are considered minor services and are forecast using exogenous equipment efficiency and market penetration trends.

Energy Consumption Submodule

Once the required equipment choices have been made, the total stock and efficiency of equipment for a particular end use are determined. Energy consumption by fuel can be calculated from the amount of service demand satisfied by each technology and the corresponding efficiency of the technology. At this stage, adjustments to energy consumption are also made.

These include adjustments for changes in real energy prices (short–run price elasticity effects), adjustments in utilization rates caused by efficiency increases (efficiency rebound effects), and changes for weather relative to the CBECS survey year. Once these modifications are made, total energy use is computed across end uses and building types for the three major fuels, for each Census division. Combining these projections with the econometric/trend projections for the five minor fuels yields total projected commercial energy consumption.

[22] Energy Information Administration, *Assumptions to the Annual Energy Outlook 2003,* http://www.eia.doe.gov/loiaf/aeo/assumption/pdf/0554(2003).pdf (Washington, DC, January 2003).

Characteristics of Selected Space Heating Equipment in the Commercial Sector

Equipment Type[1]	Vintage	Efficiency[2]	Capital Cost (2001 dollars per thousand Btu per hour)[3]	Maintenance Cost (2001 dollars per thousand Btu per hour)[3]	Service Life (years)
Electric Heat Pump	Current Standard	6.8	$81.39	$3.33	14
	2000- typical	7.5	$97.92	$3.33	14
	2000- high efficiency	9.8	$155.56	$3.33	14
	2005- typical	7.5	$97.22	$3.33	14
	2005- high efficiency	9.8	$155.56	$3.33	14
	2010 - typical	7.5	$97.22	$3.33	14
	2010 - high efficiency	9.8	$155.56	$3.33	14
	2020 - typical	7.8	$97.22	$3.33	14
	2020 - high efficiency	10.0	$150.00	$3.33	14
Ground-Source Heat Pump	2000- typical	3.4	$167.50	$1.46	20
	2000- high efficiency	4.0	$229.17	$1.46	20
	2005- typical	3.4	$166.67	$1.46	20
	2005- high efficiency	4.3	$229.17	$1.46	20
	2010 - typical	3.4	$166.67	$1.46	20
	2010 - high efficiency	4.3	$208.33	$1.46	20
	2020- typical	3.8	$166.67	$1.46	20
	2020 -high efficiency	4.5	$197.92	$1.46	20
Electric Boiler	Current Standard	0.98	$21.83	$0.14	21
Packaged Electric	1995	0.93	$19.77	$3.49	18
Natural Gas Furnace	Current Standard	0.80	$9.11	$1.00	15
	2000- high efficiency	0.92	$14.82	$0.88	15
	2010 - typical	0.81	$8.70	$0.96	15
Natural Gas Boiler	Current Standard	0.80	$16.11	$0.55	25
	2000 - high efficiency	0.87	$33.82	$0.69	25
	2005- typical	0.81	$17.87	$0.55	25
	2005- high efficiency	0.90	$31.68	$0.67	25
Natural Gas Heat Pump	2005- absortion	1.4	$173.61	$4.17	15
Distillate Oil Furnace	Current Standard	0.81	$14.25	$1.00	15
	2000	0.86	$23.46	$1.00	15
	2010	0.89	$22.69	$1.00	15
Distillate Oil Boiler	Current Standard	0.83	$15.76	$0.13	20
	2000- high efficiency	0.88	$18.83	$0.12	20
	2005- typical	0.83	$15.76	$0.13	20
	2005- high efficiency	0.88	$18.83	$0.12	20

[1]Equipment listed is for the New England Census division but is also representative of the technology data for the rest of the United States.
[2]Efficiency measurements vary by equipment type. Electric air-source and natural gas heat pumps are rated for heating performance using the Heating Seasonal Performance Factor (HSPF); natural gas and distillate furnaces are based on Annual Fuel Utilization Efficiency; ground-source heat pumps are rated on coefficient of performance; and boilers are based on combustion efficiency.
[3]Capital and maintenance costs are given in 2001 dollars.
Source: Energy Information Administration, "Technology Forecast Updates - Residential and Commercial Building Technologies - Reference Case", Arthur D. Little, Inc., Reference Number 8675309, October 2001.

Commercial End-Use Technology Types

End-Use Service by Fuel	Technology Types
Electric Space Heating:	air-source heat pump, ground-source heat pump, boiler, packaged space heating
Natural Gas Space Heating:	boiler, furnace, engine-driven heat pump, absorption heat pump
Fuel Oil Space Heating:	boiler, furnace
Electric Space Cooling:	air-source heat pump, ground-source heat pump, reciprocating chiller, centrifugal chiller, rooftop air conditioner, residential style central air conditioner, window unit
Natural Gas Space Cooling:	absorption chiller, engine-driven chiller, rooftop air conditioner, engine-driven heat pump, absorption heat pump
Electric Water Heating:	electric resistance, heat pump water heater, tankless water heater
Natural Gas Water Heating:	natural gas water heater, tankless water heater
Fuel Oil Water Heating:	fuel oil water heater
Ventilation:	small Constant Air Volume (CAV) system, large CAV system, small Variable Air Volume (VAV) system, large VAV system, fan coil unit, multi-zone CAV system
Electric Cooking:	range, convection oven, deck oven, fryer, griddle, other electric
Natural Gas Cooking:	range, range w/power burner, deck oven, fryer, infrared fryer, griddle, infrared griddle, other
Incandescent Style Lighting:	incandescent, compact fluorescent, halogen, halogen-infrared, coated filament, hafnium carbide
Four-foot Fluorescent Lighting:	magnetic ballast, electronic ballast, electronic w/controls, electronic w/reflectors, scotopic, electrodeless
Eight-foot Fluorescent Lighting:	magnetic ballast, electronic ballast, magnetic-high output, electronic-high output, scotopic, electrodeless
High Intensity Discharge Lighting:	metal halide, mercury vapor, high pressure sodium, sulfur
Refrigeration:	centralized refrigeration system, walk-in cooler, walk-in freezer, reach-in refrigerator, reach-in freezer, ice machine, refrigerated vending machine