Commercial Sector and Energy Use

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Glossary

annual total energy The sum of all energy used from all sources in a year.

British thermal unit (Btu) Generically, the amount of energy or heat required to raise the temperature of 1 lb of water (about 0.5 quart or 0.5 liter) 1 degree Fahrenheit (equals about 1055 Joule).

commercial sector The portion of buildings in a nation or the world including all buildings that are not residential, industrial, or agricultural.

electricity losses Energy lost in generation, transmission, and distribution of electricity.

empirical Obtained through physical measurement or observation.

energy intensity Annual total energy divided by some normalizing factor, usually gross floor area of a building.

energy performance An empirical value indicating the energy efficiency of one commercial building compared to other, usually similar, commercial buildings.

Energy Star rating system Energy performance rating systems developed by the United States Environmental Protection Agency for specific U.S. commercial building types, which as of June 2003 included offices, hospitals, primary and secondary schools, grocery stores, and hotels and motels, with adjustment capabilities for special spaces such as computer centers and parking garages.

exaJoule (EJ) 10^{18} Joule.

Joule Watt-second, the energy to maintain 1W for 1 sec.

kBtu 1000 British thermal units.

microdata Detailed survey data arranged in an electronic file for computer analysis.

normalization A method to adjust a quantity, in this case energy use, to account for allowable differences in operational or other factors, such as worker density, hours of operation, and personal computer density.

quads A quadrillion British thermal units; 1 quadrillion is 10 raised to the fifteenth power.

rating scale A numerical scale matched to a range of values of interest, such as normalized annual energy use.

regression An analysis method for statistically determining functional relationships between quantities that are correlated, often using empirical data.

standards Authoritative or legally fixed bases for comparison, valuation, or compliance.

subsectors Subsets of a sector; office buildings, for example, represent a subsector of the commercial sector.

Energy use in commercial buildings is complicated to understand, due to the wide range of building uses and ownership, variations in the size and complexity of energy systems, differences in energy system operation, and other factors. Due to this complexity, as national economies grow toward more specialized services and enterprise management, the share of national energy use held by the commercial sector also tends to grow relative to other sectors. Increased understanding of commercial building energy performance, probably through performance ratings and certifications, is needed to help reduce commercial sector energy growth relative to other sectors in advancing economies.

1. DEFINITION AND EXTENT OF COMMERCIAL SECTOR

The commercial sector is defined typically in terms of including everything else that other sectors do not include. The energy use breakout of national economies related to buildings typically covers residential and commercial buildings; where commercial buildings are typically all buildings that are not residential, industrial, or agricultural. Sometimes this broader grouping of commercial buildings is separated further into institutional and commercial, or governmental and commercial. Thus the commercial sector consists of buildings used by businesses or other organizations to provide workspace or gathering space or offer services. The sector includes service businesses, such as shops and stores, hotels and motels, restaurants, and hospitals, as well as a wide range of facilities that would not be considered commercial in a traditional economic sense, such as public schools, specialized governmental facilities, and religious organizations. Many other types of buildings are also included.

The wide range of building uses is one factor contributing to the complexity of the commercial sector. In the United States, a major national survey of commercial buildings, examining an extensive set of their characteristics and their energy use, is conducted every 4 years. The latest available survey, for 1999, includes in the detailed microdata over 40 different types of building uses that can categorize commercial buildings (Table I). Commercial buildings in the United States, where perhaps the most specialized services and enterprise management exist, are estimated to number 4–5 million, with a total gross floor area of over 6 billion m^2 (over 65 billion ft^2). The approximate breakout of commercial buildings (Table I), showing the range of building uses, the number of buildings, and total floor area estimates, provides an informative starting point for understanding the commercial sector in the United States and elsewhere. Although comparison of these estimates with other, more detailed estimates for subsectors, such as schools, would show some discrepancy in estimates, the scope and size of the commercial sector are well illustrated. For even the least developed countries, the same general range of facilities that comprise the commercial sector will exist, although the aggregate size relative to other sectors typically is smaller.

2. *MAGNITUDE AND SIGNIFICANCE OF COMMERCIAL ENERGY USE*

The amount of energy consumed in the commercial sector often must be estimated as a fraction of energy use in the combined residential and commercial sectors; national energy use in buildings is often tracked within the major sectors, categorized as industrial, transportation, and "other," with residential and commercial buildings aggregated and accounting for most of the energy use in this "other" sector. Thus some quick checks on world total energy consumption are useful. The units used to sum world energy use are not easily comprehended by most people, so the important knowledge to retain is the relative values. Total world energy consumption in the year 2000 was about 395 quads (quad = 10^{15} Btu), or about 420 EJ (exaJoule). Fuel processing, nonenergy use of fuels, and other losses reduce the total final energy consumption in the major energy-using sectors to about 270 quads (280 EJ).

Because the importance of energy use in the industrial and building sectors can be misunderstood if losses associated with generation and distribution of electricity are not included, comparisons that show both totals are useful. The estimated sectoral breakouts (Table II), without accounting for electricity losses, are 87 quads for industry, 71 quads for transport, and 109 quads for "other," which is primarily residential and commercial buildings. Adding approximate electricity losses (Table II) brings the totals to 122 quads for industry, 73 quads for transport, and 156 quads for "other," for a total of about 350 quads, or 370 EJ. For the world overall in the year 2000, commercial sector energy use is approximately 30% of the "other" energy use, which amounts to a little over 30 quads (35 EJ) when electricity losses are not included. This energy use represents about 12% of the approximately 270 quads of total final energy consumption for the world. When electricity losses are included, commercial sector energy use is about 45 quads (50 EJ).

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Although commercial sector energy use is only 12% of the world total, as economies develop, energy use in this sector tends to rise relative to other sectors and is one of the most difficult to reduce, due to complexities of systems, building ownership, and building uses. The rise in energy use relative to other sectors appears to result from the need for increasingly sophisticated facilities to handle activities in this sector as national economies advance, as well as from a concurrent rise in income within the sector relative to the cost of facilities.

The history of the commercial sector relative to the residential sector in the United States provides an example of this pattern of change. Specialization in services and enterprise management grew significantly in the United States throughout the last half of the 20th century. Allowing some time to pass after World War II, so that wartime effects and rationing-induced behaviors can be discounted, energy use in the commercial sector was about 50% of residential energy use in the year 1960. This ratio grew to about two-thirds by 1980, and in the year 2000 was over 83% (Fig. 1). Residential sector energy use in the United States was 20% of total national energy use in both 1960 and

TABLE I

U.S. Commercial Buildings, 1999; Approximate Breakout

Building use	No. of buildings (thousands)	Floor area (billions) (m²)	(ft²)	Building use	No. of buildings (thousands)	Floor area (billions) (m²)	(ft²)
Administrative/professional office	503	0.83	8.92	Nursing home/assisted living	25	0.06	0.68
Auto dealership/showroom	56	0.04	0.41	Other education	40	0.04	0.40
Auto service/auto repair	210	0.13	1.42	Other food sales or service	129	0.04	0.39
Bank/financial	128	0.09	0.97	Other health care	22	0.03	0.31
Clinic/outpatient health	37	0.03	0.34	Other lodging	4	0.02	0.17
College/university	25	0.11	1.18	Other office	25	0.03	0.37
Courthouse/probation office	3	0.02	0.23	Other public assembly	21	0.06	0.63
Doctor/dentist office	111	0.10	1.03	Other public order and safety	11	0.02	0.20
Dormitory/fraternity/sorority	35	0.17	0.80	Other retail	88	0.04	0.42
Dry cleaner/laundromat	58	0.03	0.30	Other service	118	0.08	0.82
Elementary/middle/high school	230	0.61	6.52	Post office/postal center	25	0.03	0.33
Enclosed mall	3	0.15	1.64	Preschool/daycare	32	0.05	0.51
Entertainment (theater/sports arena/nightclub)	35	0.07	0.78	Recreation (gymnasium/bowling alley/health club)	88	0.11	1.22
Fire station/police station	52	0.04	0.48	Refrigerated warehouse	14	0.08	0.87
Government office	33	0.11	1.21	Religious worship	307	0.32	3.40
Grocery store/food market	49	0.06	0.62	Repair shop	68	0.05	0.51
Hospital/inpatient health	7	0.15	1.65	Restaurant (bar/fast food/cafeteria)	345	0.17	1.84
Hotel	28	0.17	1.81	Social meeting center/convention center	132	0.11	1.22
Jail/reformatory/penitentiary	6	0.02	0.26	Store	389	0.36	3.92
Laboratory	27	0.04	0.42	Strip shopping center	131	0.37	3.94
Library/museum	28	0.05	0.52	Vacant	253	0.18	1.90
Motel/inn/resort	61	0.10	1.04	Other	75	0.07	0.80
Nonrefrigerated warehouse	589	0.89	9.56	Total	4654	6.22	67.00

TABLE II

World Sectoral Energy Consumption in 2000[a]

Sector	Without electric losses Quads	Without electric losses EJ	With electric losses Quads	With electric losses EJ
Industry	87	92	122	129
Transport	71	75	73	77
Other	109	115	156	165
Total	267	282	351	370

[a]Values are approximate and can also vary depending on the detail in accounting for different types of losses or fuel processing. Sectors may not add to totals due to rounding.

2000, whereas commercial sector use increased from 10 to 17% of the total. Thus, commercial sector energy use was about 30% of sectoral energy use in the building or "other" category in the United States in 1960, but by 2000 had grown to 45% of the building sector total.

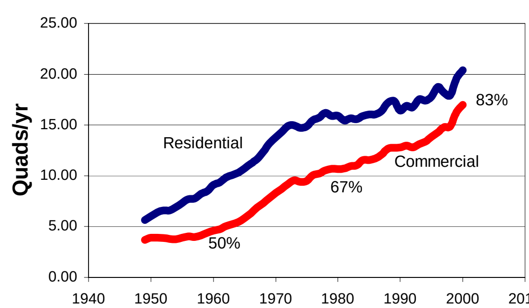

FIGURE 1 Comparison of commercial and residential energy use in the United States from 1960 to 2000; the ratio of commercial to residential energy use grew from 50% to 83%. Electricity losses are included.

Variations among countries and location are dramatic. Although the commercial sector in the United States accounts for about 17% of all energy use, in China it accounts for about 5%. Commercial buildings in rural areas typically are less complicated and use less energy, as compared to those in metropolitan areas; over 80% of commercial sector energy use is in metropolitan areas.

3. MEASURING ENERGY PERFORMANCE

Interest in rating the real-life energy performance of buildings has increased in recent years, and the real-life efficiency performance rating of buildings is important for any sustainable energy future. The ability to compare the energy performance of one commercial building with that of another is important for determination of national and international energy efficiency because comparison allows meaningful measurements of potential relative improvements. This ability also may allow different classes of buildings to be analyzed together (e.g., offices and hospitals).

The European Union has been examining requirements for improving the energy performance of residential and commercial buildings, because a large potential improvement in energy performance has been determined to exist. Among the requirements examined is the establishment of a general framework for a common methodology for calculating the integrated energy performance of buildings.

The United States Environmental Protection Agency (EPA) has established an empirical energy performance rating system for some commercial building types, the Energy Star rating system, whereby a normalized energy performance rating scale is developed. The energy use of a specific building is normalized based on the factors in the method, and the normalized energy is compared to the performance rating scale. Buildings scoring in the top 25% on the scale have an energy performance level that makes them eligible for consideration of award of an Energy Star label.

Commercial building energy performance, or energy efficiency, is often measured to a certain degree by building energy experts, and even many nonexperts, without using any real standards. To judge how well a specific building is doing, however, energy performance measurement should involve a comparison of building energy use to some type of standard, which in the past has typically been the energy use of other, similar buildings. The challenge over the years has been to determine a true standard for comparison and to determine what a "similar" building is. Because the historical methods of comparison had known limitations, building energy experts developed their own sense of what constitutes an energy-efficient building. This expert sense is based on experience with similar buildings, the types of activities within specific buildings, and any history of achieving reductions in energy use in comparable buildings. This expert knowledge has gaps and is not easily transferable, because it is usually based on several years of experience concerning expected patterns of energy use for different buildings and impacts of schedules, uses, geographic location, and system configurations. This expert knowledge is used to "adjust" the measure of the performance of a commercial building to provide a more informed measure of performance. However, this knowledge is ad hoc, with multiple practitioners probably arriving at differing assessments of the same building. In the end, the result is essentially a subjective expert opinion, albeit possibly a very good one, but also possibly not.

Five generic classes of building energy data analysis methods have been identified as useful in measuring the energy performance of commercial buildings:

1. Annual total energy and energy intensity comparisons.
2. Linear regression and end-use component models.
3. Multiple regression models.
4. Building simulation programs.
5. Dynamic thermal performance models.

All of these analytical approaches can be used to develop building energy performance measurement methods, but the most effective current approach in use today, based on results achieved, involves the third approach, multiple regression models. When calculating commercial building energy performance using multiple regression models, the effects of many factors can be modeled, potentially factoring out influences such as the number of people in a building or occupant density. The Energy Star rating system develops its performance rating scales using multiple regression models.

The limitations of the other methods include their inability to cover wide ranges of buildings without an inordinate amount of data. Some of the other methods require large volumes of data to develop empirical results. In the following discussion of performance rating systems, both simple annual total energy intensity comparisons (Method 1 above) and multiple regression method information will be addressed; the first is useful both as an example and as a well-understood quantity, whereas multiple regression analysis illustrates the state-of-the-art approach in current methodology.

4. PERFORMANCE RATING SYSTEMS

Many people confuse building simulation and energy audits or energy assessments with energy performance ratings. Energy performance ratings are less detailed and provide much less information regarding potential causes of specific energy performance. Instead, what is provided is a true indication of overall energy performance relative to similar buildings. Highly technical assessments, including calibrated simulations, are a tremendous tool for diagnosing root causes of specific building energy performance. But these approaches typically provide only very limited information about performance relative to other buildings or relative to any ranking scale based on performance of similar buildings, and their complexity makes them impractical for extensive use in rating performance.

Performance rating can be done many ways. The EPA Energy Star rating system for buildings uses a percentile rating scale of 1 to 100 for a particular building type, with a rating of 75 or greater required to qualify for an Energy Star label. The energy performance rating of 1 to 100 can be obtained simply by using the rating tool. The rating scale is developed from a regression analysis of energy use versus key characteristics of the class of buildings against which energy use is to be normalized. A simple and straightforward way of quantifying and comparing building energy performance is accomplished by using the annual total energy and energy intensity data. Annual total energy is the sum of the energy content of all fuel used by the building in one year. Energy intensity is the total energy used divided by the total floor area. It would also be possible to examine annual energy or energy intensities for individual fuels.

The strength of the total energy and energy intensity comparisons is their ease of use and widespread familiarity. However, knowledge is lacking regarding causes of variation that have been observed and the relative impacts of factors such as schedules, functional uses, and density of use on the energy performance. This general approach to rating commercial building energy performance is of interest for quick comparison of one building's energy use from one year to another or quick comparisons of many buildings, but information to adjust for at least some of the wide variation typically observed across a data set with many buildings is lacking.

In cases in which a performance rating system is desired for a specific type of building in a relatively homogeneous climate region, rating scales based on total energy or energy intensity by floor area have some practicality. In the Czech Republic, "labels" of actual, measured energy performance (energy intensity) have been studied, tested, and are now required for apartment buildings. The European Union is likely to require energy performance certificates for buildings by the year 2010. These certificates may have to be renewed every 5 years. With reasonably small ranges of climatic differences, certificates for specific types of buildings based on simple energy intensity values can be a moderately reasonable approach to an energy performance rating system. However, even with a common building type and common climate, there are other variations in key factors that should typically be considered. The basic annual energy intensity accounts for floor area, which has been found to be the most important factor to use in normalizing energy use. If multiple climates must be considered, adjustments for climatic variation, such as normalization for heating degree-days and cooling degree-days, should be included in an energy performance rating system.

Beyond floor area and climate, there will typically be variations in other important factors based on building use, e.g., hospitals and offices will have different normalization factors. Decisions on such factors can be, and at times are, arbitrary. Also, differing policy perspectives can strongly influence consideration of what parameters should be evaluated for normalization of energy performance. Rating systems of the more sophisticated, multifactor type typically consist of parameters for normalization of energy use, a normalization equation or calculation method, and a normalized distribution of energy use. The normalized distribution is typically matched to some scale, often a percentile scale of 1 to 100, to allow a simplified rating result to be obtained. After the energy use of a building is normalized for the factors in the method, the normalized result is compared to the rating scale to determine a rating.

A generic rating system developed for the entire commercial sector in the United States included normalization factors (Table III) that adjusted for floor area, climate, amount of building cooled and heated, worker density, personal computer density, extent of food service and education/training facilities, hours open, and average adjustments for specific types of building space uses. These factors were found to account for over 70% of the variation in energy use in the entire combined U.S. commercial sector, with its wide range of building types. The percentile scale for this particular rating system (Fig. 2) was based on the building energy use index that included electricity losses.

TABLE III

Normalization Factors in a Generic Energy Performance Rating System for All U.S. Commercial Buildings

Floor area (ft^2)
Annual cooling degree days (base 65°F)
Annual heating degree days (base 65°F)
Floor area cooled is less than 25% (yes or no)
Floor area cooled is 50 to 75% (yes or no)
Floor area cooled is 75 to 100% (yes or no)
Floor area heated is 75 to 100% (yes or no)
Personal computers per 1000 ft^2
Workers per 1000 ft^2
Food seats per 1000 ft^2
Educational seats per 1000 ft^2
Hours per week open
Fraction of area that is laboratory
Fraction of area that is nonrefrigerated warehouse
Fraction of area that is food sales (grocery)
Fraction of area that is outpatient health care
Fraction of area that is refrigerated ware house
Fraction of area that is worship space
Fraction of area that is public assembly
Fraction of area that is educational space
Fraction of area that is restaurant
Fraction of area that is inpatient health care
Fraction of area that is strip shopping mall
Fraction of area that is larger shopping mall
Fraction of area that is service

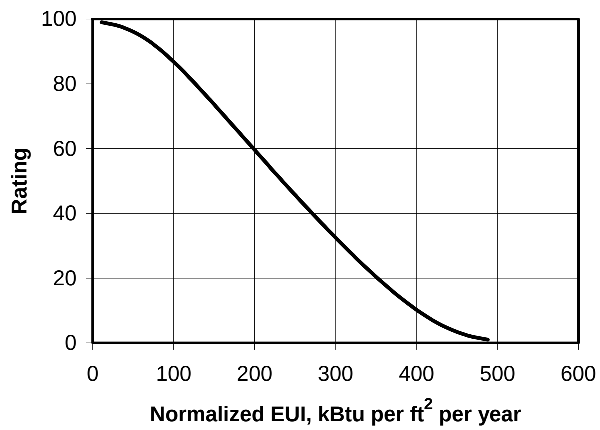

FIGURE 2 Rating scale for the entire U.S. commercial sector. Normalized annual energy unit intensity (EUI) matched to percentile scale. Electricity losses are included.

Rating system analyses for specific types of buildings in the United States have found that about 90% or more of the variation in energy use in a specific building type can be normalized based on reasonable factors. As an example, for offices, in addition to floor area, climate, fraction of building heated or cooled, worker density, personal computer density, and hours of operation shown in the generic model (Table III), the number of floors was also a factor found to be important for normalization. Additional examples of the extensive information on the Energy Star rating system for specific building types can be found on the Energy Star Web site (www.energystar.gov).

Another factor that might be considered important for energy performance rating systems is the unit price of energy in a particular location. The energy unit price is significant; analyses comparing allelectric buildings with those that are not indicate an important statistical difference between the energy use distributions of these two categories, suggesting that they should not be treated as equivalent unless some adjustment is made for the difference. Study has shown that this disparity between all-electric buildings and other buildings can be accounted for fairly well by including electricity losses in total energy use as a surrogate for the typical energy unit price differential and other factors related to remote efficiency losses. But the average unit price of energy also appears to adjust fairly well for these differences between all-electric and other buildings, as well as introducing an adjustment for the local economic incentive to be efficient.

Building energy performance rating systems are important tools that offer reasonably quick building energy performance assessment without rigorous evaluation. In addition, energy performance ratings provide an empirical statement of energy performance not available with other methods, even those that are more rigorous and complicated. Because documenting building energy performance has been determined to be important for many nations, understanding and improving systems for performing such ratings appear to be important for continued progress in commercial building energy efficiency.

5. ENERGY EFFICIENCY VARIATION AND IMPROVEMENT

Energy performance ratings tell what the energy performance of a building is, but if the energy performance of a building is to be improved, the causes of lower than desired performance must be understood, and methods of achieving improved performance must be determined. Causes of variation in energy performance among commercial buildings are understood to a degree, but much remains to be learned.

Estimates of potential improvements in energy efficiency of commercial buildings, i.e., the potential to reduce energy use, have, over many years, indicated that a lot has been and still could be accomplished. Issues of economic incentive and resource allocation influence the estimated savings values, but reductions of 20–40%, on average for the entire sector, appear reasonably achievable if a great enough need exists. In the European Union, a potential savings of 40% has been presented as possible. A savings of 20% of the worldwide annual commercial sector energy use of 30 quads (35 EJ) is 6 quads/yr (7 EJ/yr), which is about 2% of total world energy use. Unfortunately, energy costs are often not large enough, relative to other costs of running a business or organization, to receive major attention, so efficiency improvements have a lower priority.

Research has indicated many reasons why energy efficiency varies so much in commercial buildings. The causes of variation in efficiency can be categorized as variations in: efficiency of operation, efficiency of systems, and efficiency of equipment. Of these three, about half of the potential improvement for the sector would result from operational improvements, with the remainder from equipment and system improvements.

Many studies have shown the importance of operational improvements, with typical savings of 10–20% possible in a wide range of buildings. Other studies show significant savings from equipment and systems improvements. The United States Federal Energy Management Program is responsible for achieving reductions in annual energy intensity for most U.S. government buildings. Significant reductions have been achieved through attention to all three areas of efficiency improvement: operation, equipment, and systems. From 1975 to 1985, a reduction in annual energy intensity of about 20% was achieved. After 1985, additional goals were required by Executive Order and other means, and the annual energy intensity of U.S. government buildings is on track to reduce annual energy intensity an additional 30% by the year 2005 relative to the year 1985 (Fig. 3).

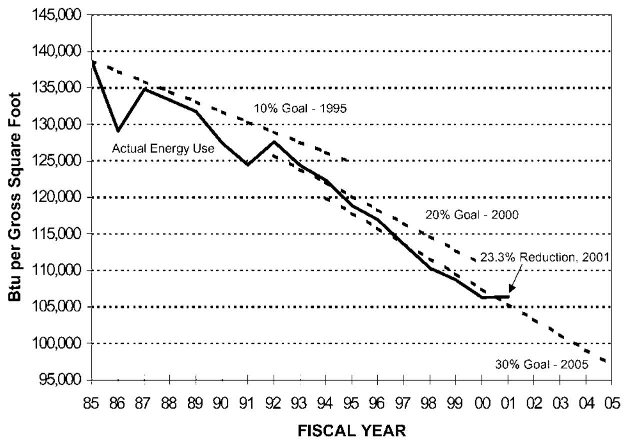

FIGURE 3 Energy efficiency progress for government buildings in the United States. Electricity losses are not included in the annual energy intensity.

The potential for improvement in energy efficiency in the commercial sector is large, if the desire to improve is there, as witnessed by the progress in U.S. government buildings. European estimates also show a large savings potential. If the sources of energy inefficiency in commercial buildings can be reduced through attention to the three major areas of efficiency improvement, about a 2% reduction in world energy use appears achievable.

6. SECTORAL DATA AND MODELING

Extensive data are collected on energy use and sectoral characteristics throughout the world. Sectoral data covering energy use of major economic energy sectors are available for many countries, and world data are available from the International Energy Agency and from some major nations. The commercial sector, as defined here, is often called by other names, such as "general" or "tertiary," indicating the "everything else" nature of the sector, including all buildings other than residential, industrial, or agricultural.

As an example of data for a nation with one of the most specialized commercial sectors in the world, the United States collects extensive energy data for this sector, including consumption by fuel type, prices by fuel type, and expenditures by fuel type for the overall sector. The special sampling survey of 5000 to 6000 buildings that is conducted every 4 years provides detail on the annual consumption of each fuel and extensive characteristics data, allowing additional extensive analyses to be performed and supporting national modeling of energy use in this sector.

Energy data provide a historical record and are used to forecast trends into the future. Several organizations model world energy use, although often not with the commercial sector separated. Many individual nations also track historical energy use and forecast future energy use. The National Energy Modeling System (NEMS), used in the United States for energy use forecasts and other analyses, provides an example of an extensive sectoral and national modeling system. The NEMS Commercial Sector Demand Module is a simulation tool based on economic and engineering relationships; it models commercial sector energy demands, with breakout detail at the geographic level of nine census divisions, using 11 distinct categories of commercial buildings.

Projections of future energy use involve selections of equipment for the major fuels of electricity, natural gas, and distillate fuel, and for the major services of space heating, space cooling, water heating, ventilation, cooking, refrigeration, and lighting. The equipment choices are made based on an algorithm that uses life-cycle cost minimization constrained by factors related to commercial sector consumer behavior and time preference premiums. The algorithm also models demand for the minor fuels of residual oil, liquefied petroleum gas, coal, motor gasoline, and kerosene. The use of renewable fuel sources (wood, municipal solid waste, and solar energy) is also modeled. Decisions regarding the use of distributed generation and cogeneration technologies are performed using a separate cash-flow algorithm.

The NEMS Commercial Module generates midterm (20- to 30-year) forecasts of commercial sector energy demand. The model facilitates policy analysis of energy markets, technological development, environmental issues, and regulatory development as they interrelate with commercial sector energy demand. Input to this model is quite extensive, and in addition to the sectoral energy data includes building lifetime estimates, economic information such as demand elasticities for building services and market forecasts for certain types of equipment, distributed electricity generation/cogeneration system data, energy equipment market data, historical energy use data, and short-term energy use projections from another model. The primary output of the modeling process is a forecast of commercial sector energy consumption by fuel type, end use, building type, census division, and year. The module also provides forecasts of the following parameters for each of the forecast years:

- Construction of new commercial floor space by building type and census division
- Surviving commercial floor space by building type, year of construction, and census division
- Equipment market shares by technology, end use, fuel, building type, and census division
- Distributed generation and cogeneration of electricity and fuels used
- Consumption of fuels to provide district services
- Nonbuilding consumption of fuels in the commercial sector
- Average efficiency of equipment mix by end use and fuel type

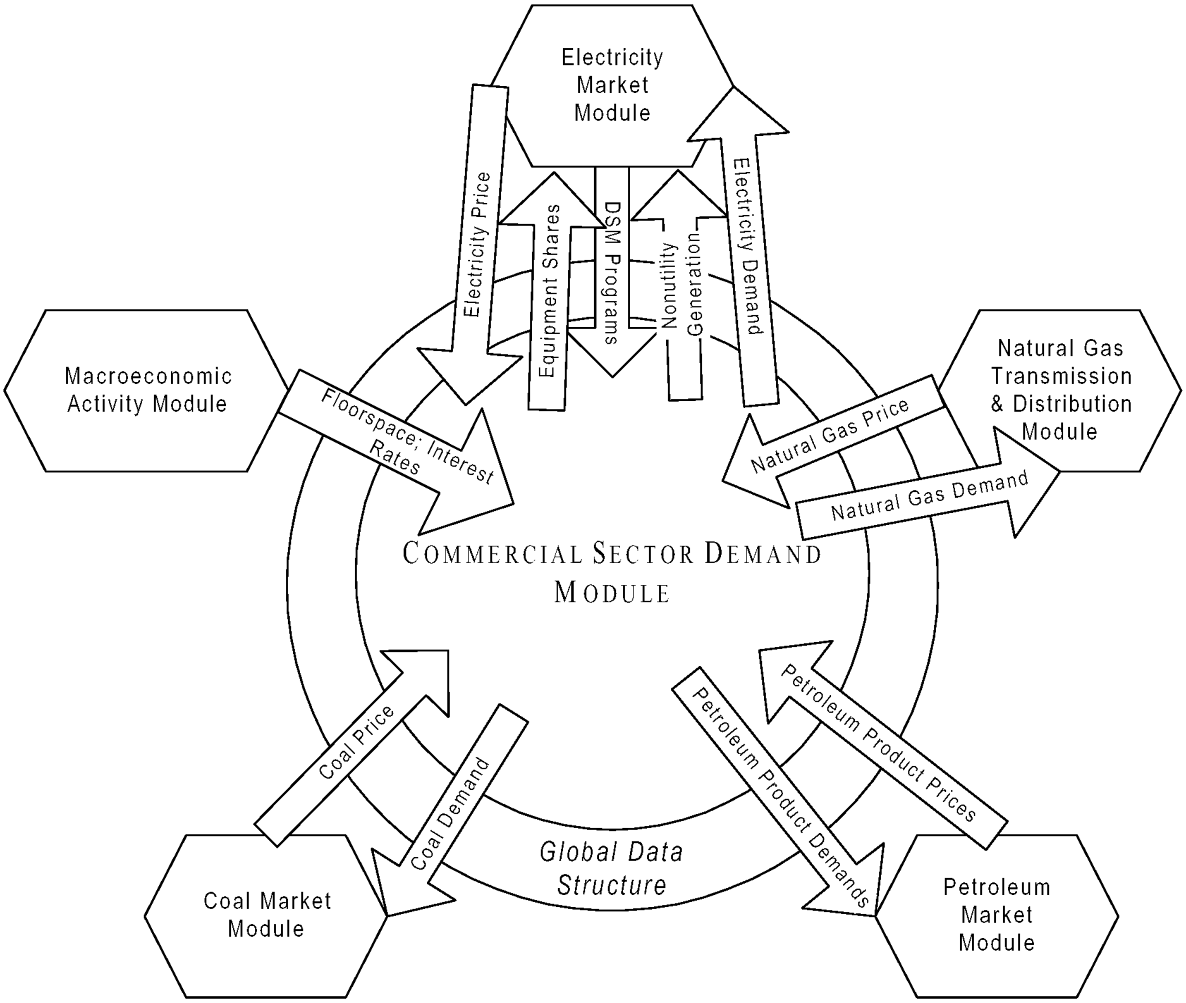

FIGURE 4 Relationship of the commercial sector and other National Energy Modeling System modules. DSM, Demand-side Management.

The NEMS Commercial Module interacts with and requires input from other modules in NEMS. This relationship of the Commercial Module to other components of NEMS is depicted schematically in Fig. 4. Not shown are the other sectoral modules and the central controlling module in NEMS that integrates and reconciles national level results for all sectors.

In contrast to such extensive sectoral models that are used to provide forecasts of energy use, the energy performance rating systems presented previously provide another type of model for the commercial sector; that allows additional understanding of current energy use and the influence of certain operating parameters of buildings. The type of information and the understanding of the commercial sector generated by different modeling approaches differ in perspective and ability to understand potential for improvements in energy efficiency. Effects of these differing perspectives are presented next.

7. SECTORAL VIEWS FORMED BY MODELS

Energy models such as NEMS can be called economic-engineering models. Such models use engineering data and analysis results to feed into and partially interact with an economic model of commercial sector changes and demand for energy. Because changes in the efficiency of buildings and the energy use patterns of buildings tend to take many years to evolve, such economic-engineering models often do a good job of representing the energy use of a large group of buildings, including the entire commercial sector in a country. These models can also forecast the end uses of energy in buildings (Table IV) and are usually good at doing so.

TABLE IV

NEMS Commercial Sector Energy End-Use Baseline and Forecast[a]

Use	Year						
	2000	2001	2005	2010	2015	2020	2025
Space heating	2.13	1.95	2.22	2.26	2.3	2.37	2.42
Space cooling	1.35	1.39	1.35	1.37	1.39	1.41	1.43
Water heating	1.15	1.12	1.21	1.26	1.3	1.35	1.39
Ventilation	0.56	0.55	0.55	0.56	0.56	0.56	0.57
Cooking	0.38	0.37	0.39	0.41	0.42	0.44	0.45
Lighting	3.34	3.31	3.54	3.73	3.81	3.87	3.89
Refrigeration	0.69	0.69	0.71	0.73	0.75	0.77	0.78
Office equipment (PC)[b]	0.5	0.52	0.6	0.74	0.85	0.95	1.05
Office equipment (non-PC)	0.98	0.99	1.12	1.44	1.8	2.21	2.69
Other uses	6.13	6.56	6.89	7.65	8.54	9.6	10.6
Total	17.2	17.44	18.59	20.15	21.72	23.52	25.33

[a] In quads/year; electricity losses are included.
[b] PC, Personal computer.

Although NEMS forecasts about a 50% increase in U.S. commercial sector energy use between the years 2001 and 2025, the energy intensity of these buildings remains almost constant over this forecast period. This information indicates that growth in commercial sector energy use is attributed almost exclusively to growth in floor area, and that any efficiency improvements are modeled as offset by growth in end uses of energy not affected by the efficiency improvements. Clearly, with little change in annual energy intensity over a 25-year period, a tendency to limit certain types of change can be seen in this modeling approach. In addition, although the model provides a breakout of energy according to end uses such as heating, cooling, lighting, and seven other uses (Table IV), data on the impacts of the density of workers or occupants, schedule of operations, and density of personal computers in buildings are not modeled and are not known. To forecast total energy use, this type of normalization of energy is not required, because it represents a different way of looking at the sector, and normalized energy is not the desired output.

Economic-engineering models are also capable of forecasting impacts of new energy technologies and more efficient operations on energy use, but new energy technologies and impacts of those technologies on new buildings are more capably modeled in NEMS than are improvements in operations, which must typically be treated as changes in annual energy intensity. Unfortunately, this characteristic means that impacts of improvements in energy system operations are not understood and cannot be estimated well with this modeling approach.

Detailed engineering simulation models such as DOE-2, Energy Plus, and BLAST, which have the capabilities to model energy use in commercial buildings, also have difficulty modeling improvements in energy system operations, because the simulation routines are all set up to model systems and components that work correctly. Simulating improvements in operations often requires knowing the answer first, and then tricking the simulation program into calculating the correct results. Again, the limitations of the models influence decisions about appropriate energy efficiency improvements for buildings. Limitations in ability to model impacts of operational improvements on energy efficiency lead to a view of the commercial sector that essentially ignores the potential of such improvements. A problem with this situation is that policy officials typically also do not receive information on the potential of operational improvements and lack an understanding of the importance of improving operations in commercial buildings. Because improvements in operations represent about half of the potential energy savings that could be achieved in the commercial sector, acceptable means of modeling impacts and potential efficiency benefits would be helpful. Until acceptable means of modeling are developed, the benefits of operational improvements must continue to be determined empirically.

Improved understanding of commercial sector energy use, and the potential of operational improvements for saving energy in commercial buildings, would result from the ability to model the effects of operational improvements on forecasts of energy use in the commercial sector. Improved understanding of the potential for energy efficiency improvements appears possible through modeling of normalized energy use for the sector, whereby adjustments for a few key factors known to cause variation in energy use in commercial buildings, together with performance rating values, could allow analysis and pursuit of scenarios of improvement toward minimum ratings. Advances in modeling such as these could be important for the future, if the percentage increase in commercial sector energy use in advancing economies becomes a challenge for world energy efficiency and climate impacts.

8. DRIVING TOWARD ENERGY EFFICIENCY

As the need for energy efficiency becomes more pronounced, the drive toward efficiency in the commercial sector will be impeded by its complicated mix of building sizes and uses, the complicated systems often used in commercial buildings, and the relative lack of understanding of operations factors impacting energy use and how to achieve efficiency.

In the United States, commercial energy use has increased from 10 to 17% or more of national energy use between the years 1960 and 2000. A significant reason for this increase is the low cost of energy relative to the other costs of conducting business, but the difficulty in understanding energy systems and energy use in commercial buildings is also an important contributing factor. Policy officials often have difficulty understanding discussions of the needs for improvements in commercial buildings.

As economies advance and commercial sector energy use begins to grow relative to other sectors, an improved understanding of methods of measuring commercial energy performance, and the means of achieving efficiency improvements in this sector, will be important in any drive toward efficiency.

One warning sign of the need to increase understanding of energy performance is an increase in the use of air conditioning in commercial buildings. When air conditioning use increases, energy system complexity and indoor space quality issues also increase significantly. If air conditioning use is increasing, any proposal for increased efficiency that relies heavily on thermal insulation should be treated warily, because insulation optimization becomes more difficult, and other system complexities tend to become much more important.

A warning should be given overall for energy standards for buildings, as they currently exist around the world, because, despite the existence and use of these standards for many years, the effect of standards has been only moderate in most cases. The shortcoming of existing standards is that they rely too heavily on simulation of expected performance, without conducting true empirical studies to verify the effectiveness of what the standards achieve. One major reason such empirical studies have been conducted in only limited and mostly ineffective fashion is that an empirical method of measuring energy performance of commercial buildings, although still adjusting for legitimate building use differences, has only recently been established in concept, only for certain building types, and not with the stated intent of being a performance standard (Energy Star label for buildings). Interestingly, however, if such energy performance standards existed, energy standards currently in use, with their typically complicated requirements, would not necessarily be needed any longer as standards.

Use of energy performance certificates may be necessary to overcome the difficulty users, occupants, code and policy officials, and owners have in understanding commercial energy use and performance. Without certification of energy performance, the complexity of systems and uses makes understanding energy performance by anyone other than an expert, and even by some experts, difficult. However, without increased understanding of the most appropriate means to normalize energy use for legitimate differences in building function and use, energy performance certificates may offer an unsatisfactory solution, due to inequities that will be obvious to many, if reasonable normalizations are not applied.

Increased energy efficiency in the commercial sector is an important piece of the national efficiency strategy in advanced economies, in which the priority for efficiency must be increased. Complexities in commercial buildings have made progress in energy efficiency for this sector less than desirable in notable cases. Fortunately, methods and knowledge needed to increase success in this sector have begun to be developed, and better solutions can be offered in the near future to help increase energy efficiency in the commercial sectors of countries where the need is pressing.

9. FUTURE ENERGY PERFORMANCE AND USE

Current forecasts call for solid growth in world energy use over the next 20 years, potentially increasing 60% above current use. With the forces in place to keep energy use patterns the same, a safe, conservative assumption would be that the commercial sector will contribute about 12% to final total energy consumption in the year 2020. If world energy use grows to 600 quads, or 630 EJ, by the year 2020, and total final consumption in the energy-using sectors is about 400 quads, or 420 EJ, final consumption in the commercial sector, at 12%, would be about 50 quads/yr (or about 50 EJ), without electricity losses included. This energy use would be two-thirds more than the energy use in the year 2000.

Without significant changes in energy performance of commercial buildings, this scenario of 50 quads of commercial energy use in the year 2020 is likely to occur, absent major world upheaval. If important progress on improving the energy performance of commercial buildings in the advanced economies can be made, potentially a reduction of 2–4 quads or more in commercial sector worldwide use in 2020 (a 4–8% reduction) could be achieved. Such an achievement would require that energy performance certifications become the norm, that operational standards increase significantly, and that 25–40% of buildings in the advanced economies see significant improvements in their performance.

Methods for certifying the energy performance of commercial buildings have been developed to the conceptual and practical applications stages. However, these methods are in their infancy. Energy policy and research attention to the commercial sector have been lacking relative to the growth observed. Without increased attention to improving commercial sector energy efficiency, energy use growth relative to other sectors will continue to make this sector a challenge when decreased energy use and emissions are sought.

Further Reading

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