Appendix A

Development of End-Use Intensity Estimates

The end-use estimates had two main sources: the 1989 Commercial Buildings Energy Consumption Survey (CBECS) and the Facility Energy Decision Screening (FEDS) system. The CBECS provided data on building characteristics and total energy consumption (i.e., for all end uses) for a national sample of commercial buildings. Using data collected by the CBECS, the FEDS engineering modules were used to produce estimates of energy consumption by end use. The FEDS engineering estimates were then statistically adjusted to match the CBECS total energy consumption.

This appendix briefly describes the 1989 CBECS, the FEDS load estimation methodology, the statistical adjustment procedure, and the remaining steps necessary to produce the final end-use estimates presented in this report.

The Commercial Buildings Energy Consumption Survey

The Energy Information Administration (EIA) is responsible for publishing national-level statistics on energy consumption by end users. Currently, the EIA publishes statistics for the residential, residential transportation (personal vehicles), commercial, and manufacturing sectors. For the commercial sector, consumption data are collected via a nationwide survey of commercial buildings, the CBECS.

The CBECS was designed to collect data on energy consumption, energy expenditures, and energy-related characteristics of commercial buildings. The sample consists of about 6,000 buildings, drawn from 119 locations nationwide. The survey is conducted in two stages: a Building Characteristics Survey and an Energy Suppliers Survey. The Building Characteristics Survey consists of personal interviews with knowledgeable respondents at each of the 6,000 buildings. The interview covers physical characteristics of the building, building occupancy patterns, major equipment, conservation practices, and the types and uses of energy in the building.

At the end of the interview, respondents are asked to provide the names and addresses of the companies that supply energy to their buildings in the form of electricity, natural gas, fuel oil, or district heating and cooling, and to sign a form authorizing the EIA to collect billing information directly from these energy supply companies. A separate mail survey, the Energy Suppliers Survey, asks these energy suppliers to provide data on the amounts and costs of energy delivered to the building during the survey year.

Additional details may be found in Appendix A, "How the Survey Was Conducted," of the two 1989 CBECS survey data reports.[3,4]

The Facility Energy Decision Screening Engineering Estimates

The energy consumption data provided by energy suppliers cover all end uses performed within commercial buildings. The total energy consumption can be disaggregated into end-use consumption by several approaches: engineering simulations, statistical modeling, or a hybrid approach known as statistically adjusted engineering (SAE). The 1989 CBECS end-use estimates were developed by using the SAE approach, with the FEDS system providing the initial engineering estimates.

The FEDS software was developed for the Department of Energy’s Federal Energy Management Program (FEMP) and the U.S. Army Construction Engineering Research Laboratory as a tool for screening groups of buildings on federal facilities (such as Army bases) for energy efficiency retrofits.[2] The engineering modules, which estimate the energy load to be subjected to retrofit optimization, are the latest in a series of well-known building energy simulations, which include DOE-2 and ASEAM. In some ways FEDS is similar to Quick Input versions of ASEAM, in that it can operate from sparse data input. In other ways, such as its use of hourly load profiles rather than a bin method, FEDS is similar to DOE-2. The FEDS uses high-level installation information (number, age, size, and types of buildings and energy systems), an internal data base of typical energy-system configurations and performance data, and sophisticated energy simulation and optimization models to estimate the net present value of potential energy retrofits in federal installations. Release 1 of FEDS was used for the 1989 CBECS end-use estimates; Release 2 will be used for the 1992 CBECS end-use estimates.

The advantages of FEDS were that FEDS (without its retrofit optimization routines) can execute fairly quickly and that it does not demand a great deal of detailed data on each building. Both of these factors were important for the CBECS application, since there were nearly 6,000 buildings (with an average of two energy sources per building) and the only data available were those obtained from hour-long personal interviews.

The FEDS engineering models are designed to produce estimates for five end uses: space heating, cooling, ventilation, lighting, and water heating. Two other end uses, cooking and refrigeration, are also calculated internally by the model, although they are not part of the normal FEDS output. These seven end uses, plus an "other" end use, represent the FEDS accounting for total building end use. Estimates for office equipment energy use were not provided by the FEDS model.

Estimates for the first five end uses are based on detailed building engineering simulations. Estimates for the latter two are more sketchy and rely on parameters developed in the Regional End-Use Monitoring Program (REMP, formerly known as the End-Use Load and Consumer Assessment Program (ELCAP)) study.[6] REMP was a large end-use monitoring project sponsored by the Bonneville Power Administration. As designed to be used in facilities, only a general description of a building need be input for the building energy loads to be estimated interactively, relying on an extensive series of internal default values. Some of these defaults were based on data from the 1986 CBECS but many were based on REMP study. For use with the 1989 CBECS to produce the estimates in this report, the interface was changed from interactive to batch, with the 1989 CBECS data supplying as many values as possible.

Besides values relating to the building characteristics, the engineering estimates also required hourly weather profiles. For each calendar month, the average temperature during each hour of the day was calculated and input to the model.

Statistically Adjusted Engineering Estimates

The FEDS estimates were based on building characteristics and weather only. At the statistically adjusted engineering (SAE) stage, the consumption data were brought into play. The basic idea behind the SAE method is simple. Let eui_{bfu} be the end-use consumption per square foot estimated by the FEDS model for building b, fuel f, and end use u, and let eui_{bf} be the total energy consumption (from the CBECS Energy Suppliers Survey) per square foot for building b and fuel f. Then a set of coefficients a_{fu} can be estimated statistically, i.e., by multiple regression, such that

$$e\hat{u}i_{bf} = \sum_{u} a_{fu} eui_{bfu}.$$

The coefficients adjust the FEDS engineering estimates upward or downward to match the reported energy use. The $e\hat{u}i_{bf}$ are referred to as SAE estimates.

In practice, this simple version of SAE proved difficult. Instead of following the simple model, energy use was partitioned into two parts, seasonal and nonseasonal. The two parts were then statistically adjusted separately.[1]

The SAE procedures were produced for aggregates of buildings by principal building activity. Only buildings with 12 months of reported 1989 billing data were used. The adjustments were performed separately for electricity and natural gas. Due to the limited number of cases, fuel oil and district heat SAE estimates were produced by using parameters estimated for natural gas.

The Final End-Use Estimates

Because the SAE procedure calibrated the engineering estimates to the reported data for aggregates of buildings, SAE estimates for individual buildings could still vary from the values on the 1989 CBECS Master File. For the final end-use estimates, those used in this report, the value on the CBECS Master File (whether reported or imputed) was prorated in proportion to the SAE estimates.

The office equipment estimate was also made after the SAE by using REMP estimates.[5] These estimates were based on data collected from mid-1986 to late 1988 and so are roughly contemporaneous with the 1989 CBECS. The REMP estimates were used to estimate the office equipment share of the "other" end use energy consumption. Included in office equipment were large computer equipment (if the CBECS data indicated the presence of a computer area with a separate air-conditioning system), personal computer equipment, and general office equipment (typewriters, copiers, cash registers, etc.).

The Calculation of Energy Intensities

The energy intensities presented in this report for different sets of buildings are ratios of aggregate energy consumption to an aggregate measure of the demand for energy. The general equation was

$$Intensity = \frac{\sum_b w_b e_b}{\sum_b w_b d_b},$$

where w_b is building *b*'s weight (the number of buildings represented by building *b* in the sample), e_b is the amount of energy (total or end use) consumed by building *b*, and d_b is the demand measure (discussed below) for building *b*. The quantities are summed for all buildings in a particular category before dividing.

For intensity per square foot, the demand d_b is simply building *b*'s total square footage. For more involved intensities, the measure of demand is calculated for each building before summing. For example, for intensity per square foot-hour, the demand d_b calculated for each building *b* is the product of the square footage and the annual operating hours for building *b*.

References

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