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ARCHITECT'S AND ENGINEER'S GUIDE TO ENERGY CONSERVATION IN EXISTING BUILDINGS

Volume 1 - Energy Use Assessment and Simulation Methods

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SUMMARY

This first volume of the Architect's and Engineer's Guide to Energy Conservation in Existing Buildings serves as a resource for federal energy managers to assist them in understanding and undertaking energy conservation projects. This volume is a general overview or preview on energy conservation in general, while the second volume deals with 118 specific energy conservation opportunities (ECOs).

Chapter 1.0 is an introduction to the Federal Energy Management Program (FEMP), as well as an overview of this two-volume guide. Chapter 2.0 presents background information on characteristics of the federal buildings sector and reviews pertinent federal legislation concerning energy conservation. Chapter 3.0 provides guidance on how to assess energy use in federal facilities. Included in Chapter 3.0 is a discussion of analysis of utility bills, screening for energy conservation opportunities, analysis of promising opportunities, and identification of supplemental metering needs. With the increasing use of computers, especially personal computers, many building simulations or models are now available to aid energy managers or architects/engineers in analyzing ECOs. Chapter 4.0 discusses the evolution of these diverse computer simulation models, the most common calculational methods and approximations used by the models, the typical data input needed to use these models effectively, how to use the models for ECO analysis, and how to interpret the model results. The last section of Chapter 4.0 discusses some of the limitations associated with using computer models in ECO analysis.

The two-volume guide is based on research performed by Pacific Northwest Laboratory[1] and The Fleming Group for the Federal Energy Management Program within the Office of Conservation.

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[1] Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

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1.0 INTRODUCTION

The federal government is the nation's single largest energy consumer, using 1.9 quads of energy annually at more than 8000 locations worldwide.[1] Both the magnitude of the energy consumed and the potential for energy savings have been the basis for legislative and administrative initiatives and programs for energy conservation in the federal buildings sector. Based on an estimated 1% replacement rate from 1990 forward, new energy-efficient building stock will contribute only about 5% to building energy savings by the year 2000. Thus, savings must be realized largely through retrofits to existing buildings if the federal government is to maximize its energy efficiency (DOE 1983).

1.1 THE FEDERAL ENERGY MANAGEMENT PROGRAM

The Federal Energy Management Program (FEMP) supports the mission of the U.S. Department of Energy (DOE) to achieve effective management of the energy functions of the federal government by providing assistance to federal agencies in planning and implementing programs that will improve the efficiency and fuel flexibility of the federal infrastructure (facilities, operations, and transportation systems).

Since its establishment in 1973, FEMP has evolved and expanded in recognition of the complexity of managing energy use in the federal sector. Better energy management programs in many federal facilities have helped to reduce use and expenditures for energy. Cumulative budget savings for energy since 1977 are estimated to be over $6 billion, a significant reduction in federal spending (DOE 1988). While important strides have been made toward energy efficiency and fuel flexibility, the potential for additional savings in federal facilities and operations remains high.

At the core of the program is the recognition that energy consumption is inextricably linked to the life cycle of the physical infrastructure and that a holistic approach to energy management is needed. The need to rebuild the national infrastructure will be a significant problem facing the United States government during the remainder of this century and beyond. Many construction and rehabilitation decisions will be made over the next several years. These decisions will have energy implications for the next 40 to 50 years.

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[1] U.S. Department of Energy. 1989 (draft). Annual Report on Federal Government Energy Management Fiscal Year 1988. Assistant Secretary, Conservation and Renewable Energy, Washington, D.C.

1.2 OBJECTIVES OF THE ARCHITECT'S AND ENGINEER'S GUIDE

This updated Architect's and Engineer's Guide to Energy Conservation in Existing Buildings (A&E guide) has been prepared by FEMP to provide federal energy managers, facility energy coordinators, contractors, and other decision makers with current information on opportunities for improving energy efficiency and on analysis methods.

As nonrenewable energy sources are depleted and energy demands and costs rise, the potential for energy savings escalates. At the same time, the risks associated with capital investments in efficiency improvements are reduced, and the number of energy-saving options are increased by a better understanding of building energy use and a growing number of conservation technologies and analysis techniques.

Current concern about international competitiveness, global warming as a result of fossil fuel combustion, nuclear power production and waste disposal, and the relatively high cost of alternative energy forms further support aggressive action to increase energy efficiency in the United States.

The advent of low-cost desktop computers and data acquisition systems has made it possible for architects and engineers to model building energy use, calibrate the models to metered data, and then use the models to investigate potential energy conservation opportunities. For this reason, FEMP has supported the development of a public domain program, ASEAM (A Simplified Energy Analysis Method) for simulating energy use in buildings.

This A&E guide provides examples of how ASEAM can be used to evaluate many energy conservation opportunities (ECOs) by taking into account the interactions of energy end-uses, climate and building use. Anyone who uses this A&E guide will surely benefit from courses offered by the General Services Administration on the use of the ASEAM program.

The A&E guide explains how energy is used in buildings, how ECOs work, and how particular ECOs can be evaluated; thus, the guide should be useful to a very wide audience. However, it is important to understand that the results of any energy analysis are only as good as the input data, the analysis tools, and the analyst's knowledge.

1.3 OVERVIEW OF GUIDE

This A&E guide is in two volumes. Volume 1 discusses the characteristics of energy use in the federal buildings sector, federal legislation pertinent to energy conservation, energy use assessment of facilities, and modeling or simulation methods used to analyze ECOs. Volume 2 presents the following specific information on 118 ECOs: implementation of each ECO, information required to analyze each ECO, and use of a personal computer model (ASEAM) to analyze each ECO. These 118 ECOs fall into the following eight categories: building equipment operation, building envelope, HVAC equipment systems, HVAC distribution systems, water heating systems, lighting systems, power systems, and miscellaneous ECOs dealing with control systems and heat recovery.

2.0 BACKGROUND

This section provides a brief overview of characteristics of the federal buildings sector and a review of the legislative authorities that guide the energy improvement activities within federal buildings.

2.1 FEDERAL BUILDING SECTOR

The federal government owns or leases more than 500,000 buildings and facilities, totalling more than 3.3 billion square feet of floor space in the United States.[1] The government owns approximately 93% of this square footage and leases the remaining 7%. The largest single use of federally owned and leased buildings is housing, which accounts for over 24% of the total use. Storage, office space, and service-related space are the next largest uses, combining to total 56% of the building space. The remaining 20% of floorspace is used for other needs as delineated in Table 2.1 (GSA 1988a,b).

The largest building manager and consumer of energy within the federal government is the Department of Defense (DOD). Approximately three quarters of the energy used for federal buildings is used by the DOD. Most of the remaining quarter is used by the following ten civilian agencies: DOE, Veterans Administration (VA), United States Postal Service (USPS), General Service Administration (GSA), National Aeronautics and Space Administration (NASA), Department of Transportation (DOT), Health and Human Services (HHS), Department of the Interior (DOI), Department of Justice (DOJ) and United States Department of Agriculture (USDA). (See Table 2.2.)[a]

TABLE 2.1. Percentage of Building Space by Predominant Usage

Type	Area in Percent
Housing	24
Storage	17
Office	22
Services	17
Hospitals	1
Research and Development	4
Schools	5
Prisons and Other Institutions	3
Industrial	4
Miscellaneous	3

1 U.S. Department of Energy. 1989 (draft). Annual Report on Federal Government Energy Management Fiscal Year 1988. Assistant Secretary, Conservation and Renewable Energy, Washington, D.C.

TABLE 2.2. Federal Energy Use in Buildings and Facilities (For Fiscal Year 1988)

Agency	GSF[a] x 10^3	Btu x 10^9	Btu/GSF[a]
Department of Defense	2,525,897.0	546,449.1	216,339
Department of Energy	75,892.9	56,601.2	745,804
U.S. Postal Service	203,668.0	43,801.4	215,063
Veterans Administration	131,120.0	43,785.6	333,936
General Services Administration	162,047.4	30,314.1	187,070
National Aeronautics and Space Administration	35,737.0	23,804.8	666,110
Department of Transportation	38,424.0	16,460.9	428,401
Department of Health and Human Services	21,575.0	11,930.4	552,974
Department of Justice	25,818.6	10,298.7	398,885
Department of Agriculture	23,700.0	7,589.5	320,230
Department of Interior	54,525.3	7,289.2	133,684
Department of Labor	16,100.0	4,264.2	264,858
Treasury Department	10,119.3	6,601.8	652,394
Department of Commerce	5,663.1	2,683.6	473,883
Tennessee Valley Authority	5,569.2	1,500.1	269,363
Environmental Protection Agency	1,454.9	970.6	667,125
Panama Canal Commission	3,040.0	927.3	305,041
National Science Foundation	901.0	537.1	596,150
Federal Communications Commission	121.0	35.2	290,736
TOTALS	3,341,373.7	815,844.8	244,164

(a) Gross square foot.

Spending approximately $3.7 billion for building energy in 1988, the federal government used 0.8158 quadrillion Btu (quads) of energy for building lighting, heating, ventilation, air conditioning, other standard building services and some process operations.[2] Electricity constituted 62.3%

[2] U.S. Department of Energy. 1989 (draft). Annual Report on Federal Government Energy Management Fiscal Year 1988. Assistant Secretary, Conservation and Renewable Energy, Washington, D.C.

of total federal building energy consumption; 16.6% was accounted for by natural gas; and 11.3% was accounted for by fuel oil. Small amounts of coal, purchased steam, liquified petroleum gas and propane, and "others" (consisting mainly of chilled water and renewable energy) accounted for the remaining 9.8% (EIA 1988).

Although end-use consumption data are not available specifically for federal buildings, commercial buildings data obtained by the DOE Energy Information Administration (EIA) in the Nonresidential Buildings Energy Consumption Survey can be generalized to estimate energy use for similar federal buildings such as offices, health care facilities, schools, service and storage buildings. The average energy consumption by building type for the calendar year 1986 is shown in Table 2.3 (EIA 1989). The building types with the highest energy consumption include offices and mercantile/service buildings. Health care buildings have the highest consumption per square foot (216,900 Btu/ft^2). Building size seems to be negatively associated with consumption per square foot. For the most part, as building size increases, consumption per square foot decreases (186,000 Btu/ft^2 for buildings with 1,000 square feet or less, to about 90,000 Btu/ft^2 for buildings with over 50,000 square feet) (EIA 1989).

Table 2.4 (EIA 1989) highlights regional differences in energy consumption that can be attributed primarily to climate, but also to the average size of the buildings in the area and other uncontrollable factors.

Based on 1985 data, overall functional use of energy in the commercial building category is as follows:

- 55% for space conditioning, two-thirds of which was used for heating, and the remainder for air-conditioning and ventilation

TABLE 2.3. Energy Consumption by Principal Building Activity, 1986

Principal Activity Within Building	Energy Consumed/ft^2 (in Btu)
Assembly	54,900
Educational	87,100
Food Sales	211,600
Food Service	202,600
Health Care	216,900
Lodging	111,600
Mercantile/Services	78,400
Offices	106,000
Public Order and Safety	126,700
Warehouse	54,500
Other	99,500
Vacant	44,000

TABLE 2.4. Energy Intensity by Region, 1986

Region Building Located in	Energy Consumed/ft^2 (in Btu)
Northeast	90,900
North Central	101,900
South	78,600
West	84,600

- 25% for lighting
- 5% for hot water heating
- 15% for miscellaneous use.

These percentages vary among commercial building types and climatic regions (DOE 1989). Of the various end-uses, space conditioning is the most prevalent. As of 1986, 63.2% of all commercial buildings were totally heated, 25.5% were partially heated, and 11.3% were unheated. Additionally, 69.4% of all commercial buildings had air-conditioning (EIA 1988).

Housing is the most common use of federal buildings, and is also the predominant energy user. Generalizations about the way that energy is used within this segment can be made using the available consumption data for non-federal single and multifamily dwellings. In 1985, 60.8% of the energy consumed in the residential sector was used for space conditioning (56.8% for heating, and 4% for air-conditioning). Other residential energy uses include hot water heating (18.0%) and appliance usage (21.2%) (EIA 1987).

2.2 FEDERAL LAWS APPLICABLE TO FEDERAL BUILDING ENERGY IMPROVEMENTS

In recognition of the magnitude of the energy-savings potential in the federal government, Congress has enacted a number of laws since 1973 that have served to define the direction of federal energy improvement activities. This section provides a brief overview of the pertinent aspects of this legislation.

2.2.1 Energy Performance Targets

The Federal Energy Management Improvement Act of 1988 established a fiscal year 1995 energy performance goal for federal buildings. The act states that each agency shall apply energy conservation measures and improve the design of new construction such that the energy consumption per gross square foot of its buildings in use in fiscal year 1995 is at least 10% less than the energy consumption per gross square foot in 1985. To achieve this goal and identify high priority projects, each agency is required to

- prepare or update a plan for achieving the 10% reduction in energy use

- perform energy surveys of its facilities to the extent necessary

- apply life-cycle costing (LCC) methods in the design of new buildings and in the selection of conservation measures for existing buildings.

2.2.2 Energy-Efficiency Standards

The Omnibus Reconciliation Act of 1981 established the Building Standards in Federal Facilities Program, which required that energy-efficiency standards for federal buildings be developed and disseminated to federal agencies.

The current energy-efficiency standard for existing federal buildings is the DOE Standard, which was first issued in November 1988. This standard, which is voluntary for the private sector, is mandatory for federal buildings. The DOE Standard is a slightly modified version of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/ Illuminating Engineering Society (IES) Standard 90.1. This standard was developed for new buildings, but it is applicable as a cost-effective method for retrofitting existing buildings when it is coupled with DOE's LCC procedures.

The standards are expected to be used in the following way for any major building retrofit project. First, the building would be audited to compare the energy efficiency of its walls, roof, HVAC equipment, and other components with those specified for that climate in the DOE Standard. Second, the retrofit measures necessary to bring the building close to the DOE Standard would be subject to the net benefit analysis of the LCC procedure to determine the applicability of each energy-saving measure. The measures would then be prioritized according to the savings-to-investment ratio (SIR) calculation of the LCC procedure. Third, a retrofit plan would be developed to include those measures that are cost-effective under the DOE LCC procedures.

2.2.3 Shared Energy Savings Contracting

Shared-energy savings (SES) is a contracting method whereby the contractor incurs "costs of implementing energy savings measures, including at least the costs (if any) of providing energy audits, acquiring and installing equipment, and training personnel, in exchange for a share of any energy savings directly resulting from implementation of such measures during the term of the contract."

Legislative authority for federal agencies to enter into multi-year shared-energy savings contracts was granted on April 7, 1986, when President Reagan signed the Consolidated Omnibus Budget Reconciliation Act of 1985 (P.L. 99-272). In October 1988, the Federal Energy Management Improvement Act was enacted. One provision of this act that has the greatest potential impact on federal shared-energy savings is that each agency is required to establish a program of incentives for conserving and otherwise making more efficient use of energy as a result of entering into SES contracts. The heart of this program is that the head of the agency can utilize any savings from the annual energy expenses (e.g., the difference between the amount budgeted and the amount spent) to undertake additional energy-conservation measures.

The following are two significant advantages of SES contracting in the federal environment:

- No up-front funding is required. By law, all payments to the contractor are made from the agency's annual building operating (utility) budget. Thus, the waiting time and uncertainty surrounding funding for needed capital improvements are greatly reduced.

- Because the contractor provides all of the expertise and the funding, the technical and economic risk to the government is reduced.

Because the concept of SES contracting is new to the federal government and runs contrary to many conventional procurement practices, there can be extensive learning curve time and expense for the first SES projects implemented by an agency. Because of the time and expense involved with first projects, it is critical that agencies select candidate projects that have the highest probability for these pilot SES contracts to succeed.

2.2.4 Life-Cycle Costing

The LCC methodology issued in December 1980 (Ruegg 1980) is used as the primary criterion for allocating funding for energy conservation retrofit measures to existing federal buildings. This method of economic evaluation takes into account all relevant costs (design, system, component, material, and practice) of a building over a given period of time, adjusting for differences in the timing of these costs.

The above data on cost and savings from a project can be combined in a number of different ways to evaluate its economic performance. For evaluating potential FEMP projects, one or more of the following modes of analysis are required:

- total life-cycle costs (TLCC) - TLCC is the sum of all significant dollar costs of a project discounted to present value.

- net life-cycle savings (NS) - NS is the decrease in the TLCC of a building or building system that is attributable to an energy conservation or renewable energy project.

- savings-to-investment ratio (SIR) - The SIR is a numerical ratio. The numerator is the reduction in energy costs, net of increased non-fuel operation and maintenance costs; the denominator is the increase in investment cost, minus increased salvage values, plus increased replacement costs.

- payback period (PB) - The PB is the elapsed time between the initial investment and the time at which cumulative savings in energy costs, net of other future costs associated with the project, are just sufficient to offset the initial investment costs.

The four modes of analyses are not equally suitable for choosing among alternative new building designs, for designing and sizing projects for new and existing buildings, or for ranking available retrofit projects in terms of their relative cost-effectiveness. For instance, TLCC is generally best for choosing among alternative designs for a new building, while SIR is best for ranking retrofit projects according to their effectiveness.

Based on these analyses, priority is given to projects with the highest LCC savings-to-investment ratio. The NECPA requires that changes in operations and maintenance procedures have priority over measures requiring substantial structural modification or installation of equipment. Energy-efficiency considerations are not to adversely impact the mission responsibilities of the agencies (DOE 1983).

3.0 ENERGY USE ASSESSMENT

Assessing the efficiency of energy use is central to energy management programs. Such an assessment entails establishing an energy management team, understanding present energy-using systems and conservation options, and implementing methods to track the effectiveness of energy use. The most successful energy management programs continuously monitor energy use and track progress toward realistic efficiency goals. In this way, the effects of investments in efficiency improvement are determined so that the program can build upon successes while learning from occasional failures.

This chapter provides general guidance for starting or improving an existing energy management program. Several common activities have critical bearing on program success. These ingredients include configuring an effective energy management committee, analyzing historical utility billing records, screening for energy efficiency opportunities, analyzing promising measures, and identifying supplemental metering needs.

When this guidance is combined with the detailed information in Volume 2 of this A&E guide regarding assessment of ECOs, the facility energy manager and consultants will have a sound framework for conducting the energy management program.

3.1 TEAMWORK - THE KEY TO PROGRAM SUCCESS

Achieving optimal energy use efficiency requires the coordinated action of many individuals working toward a set of common objectives. Not only must energy-using systems be designed with efficiency in mind, but the equipment must be properly operated and maintained over its useful life. The system designs should account for the overall impacts on the utility suppliers and the environment, and energy conservation measures should not jeopardize amenity levels, productivity, or mission readiness.

The energy management program team may include the following:

- facility energy management staff - to include the energy coordinator, the operations and maintenance foreman, and the utility clerk
- servicing utility representatives - to include the principal fuel suppliers
- facility tenant representatives - to include the principal building occupants and users
- energy specialists - to include any consultants or contractors involved with designing or assessing facility energy use.

This team should meet at least once every six months to review energy-use levels and program efforts. More frequent meetings and communication among subsets of this team should be conducted on an as-needed basis to resolve problems and develop new program initiatives.

One of the first tasks of the energy management team is to determine the present energy end-uses and to establish achievable goals for improving energy efficiency. These activities necessitate a careful accounting of energy flows and a reasonably comprehensive understanding of the characteristics of energy-using systems. The amount of measured data available for facilities is often limited, so initial program investments should be focused on overcoming these limitations by assembling the available data, identifying information gaps, and carrying out energy-use surveys and metering projects.

3.2 ANALYSIS OF UTILITY BILLING DATA

In most cases utility billing data are the best place to begin the assessment. The following information should be assembled:

- prior billing records for the past three to five years including the quantities of energy consumed, the meter reading dates, and the utility rate structures

- meteorological summaries for the facility indicating the daily minimum and maximum temperatures

- salient characteristics and documents pertaining to the facility, such as the square footage of the buildings and construction documents; history of additions, demolitions, or other changes in the building stock or tenancy; central plant capacities and operation logs; and prior energy studies or conservation initiatives.

These data should be assembled and summarized in an electronic spreadsheet for subsequent analysis. As the sensitivity of energy use levels to weather and environmental parameters is explored, the billing records can be normalized for changes in climate. This is accomplished by matching the billing records to the exterior temperature conditions during the same period and conducting statistical regressions to explain historical variations in energy use. Once these baseline conditions are established, the aggregate performance of energy conservation initiatives can often be determined and energy cause and effect relationships can be more fully understood.

3.3 SCREENING FOR ENERGY-EFFICIENCY OPPORTUNITIES

The first task to be undertaken when screening a facility (or facilities) for energy-efficiency improvements is to assemble accurate information on the facility's characteristics and on conservation opportunities. The three types of audits that should be or could be undertaken are discussed in this section. The information to be gathered in each audit and analysis methods using the data will be detailed. Some of the more common ECOs will then be highlighted. An example of an ECO analysis will be shown using a sample building and a PC-based simulation model. Results of examining the effects of a wide variety of ECOs on the example building will be presented.

3.3.1 Types of Energy Audits for Buildings

Most energy audits fall into three categories or types:

- preliminary or walk-through audits
- building/system audits
- end-use/equipment audits.

These are discussed in detail below.

Preliminary or Walk-Through Audit

The information to be gathered during the preliminary audit can be divided into four categories: overall facility information, information on major energy-using systems/equipment, types of systems/equipment contained in the building, and energy billing data. A complete list of information to be obtained in the preliminary audit is included in Appendix A, Table A.1.

Of particular importance are the billing data, which are used to calculate the Energy Utilization Index (EUI), in Btu/ft^2. These data can be compared with other facilities under study to allow the focus to fall on the poorest performers in the group. Also, the EUI can be compared to EUIs for functionally similar buildings, i.e., offices, warehouses, etc. The EUIs for one building can be compared over time to note any significant changes.

Conducting a walk-through audit of the building will allow the analyst to identify functional areas or zones of the building that will be useful for the next audit step. A zone consists of a portion of the building that shares common features such as

- operating schedule
- thermostat setpoints
- similar loads (e.g., lighting watts/ft^2)
- type of HVAC system
- outside wall/roof exposure.

If possible, blueprints of architectural, electrical, and mechanical systems should be used for zoning. Ensure that all updates to the systems have been noted on the blueprints.

Also on the walk-through audit, a description and location of all major energy-using systems should be obtained, including HVAC equipment, lighting systems, and control equipment. Any other major uses of energy in the building, such as computers, laundry, or food services, should also be noted. Additionally, the fuel and energy usage of the equipment should be noted, if possible.

Building/Systems Audit

After gathering preliminary audit data, decide whether or not to proceed to the next audit step: the building audit. While the preliminary audit may be conducted by the building manager, the building audit may be more cost-effectively done by a professional audit company. In many areas of the country, the local utility may offer a free energy audit that includes a list of potential ECOs. The information gathered during the building audit will be used to model the energy use of the building, as well as to identify ECOs. The model used should be able to show the effect of implementing various ECOs.

A list of the information that should be gathered during a building audit is included as Table A.2 in Appendix A. This information is divided into the following five categories or types of data:

- building envelope or shell
- heating, ventilating, and air conditioning
- lighting and electrical systems
- central plant systems
- weather.

End-Use/Equipment Audit

The final audit type, the end-use/equipment audit, should be undertaken only if the building audit shows a need for further information or that a particular ECO may be warranted. For example, a complete boiler analysis may be identified as a need in the building audit. In most cases, a professional boiler expert or engineer will need to perform this audit. Similarly, a professional HVAC engineer will be needed to evaluate the performance of the cooling plant components. Another method of gathering more detailed data for some systems (e.g., lighting and electrical) is to meter or monitor the end-uses of energy in the building. This allows the total energy use in the building to be disaggregated to a significant degree. This last audit step is very expensive and time-consuming and is usually only undertaken if it seems likely that significant savings will result from the identification of ECOs.

3.3.2 Energy Conservation Opportunities (ECOs)

The most common ECOs found in existing commercial buildings fall into the following nine categories:

1. building equipment operation

2. building envelope

3. HVAC systems

4. HVAC distribution systems

5. water heating systems

6. lighting systems

7. power systems

8. energy management control systems

9. heat recovery/reclaim systems.

An ECO may be realized either by implementing operation and maintenance (O&M) measures or by incorporating available technologies. Each of these energy conservation areas is briefly described below. Volume 2 of this document provides a detailed listing and discussion of ECOs in each of these areas.

Building Equipment Operation

An enormous amount of energy is wasted because building equipment is operated improperly and unnecessarily. When the building is not occupied, the building systems should be turned off or their operation reduced to a minimum. Depending on building operations, the following systems' operating hours can be curtailed during slack time: HVAC systems, water heating systems, lighting systems, escalators and elevators, and other equipment and machinery. Care must be taken to ensure that the reduction in hours has no adverse impact on building operations and systems.

Building Envelope

The amount of heat (sensible and latent) supplied to or extracted from the indoors in order to maintain a comfortable indoor environment is directly proportional to the difference in temperature and humidity between indoors and outdoors. Consequently, one should lower the heating and raise the cooling temperature setpoints and/or lower the humidification setpoints and raise the dehumidification setpoints to minimize the space conditioning requirements. Another ECO is to set the heating setpoints back when the building is not ocupied. Care must be taken to ensure that the slight discomfort of the occupants does not reduce their productivity.

Energy is saved when the heat exchange between the building and the outside environment is reduced and/or solar and internal heat gains are controlled. The primary way to reduce heat conduction through ceilings/roofs, walls, and floors is by adding insulation. Another method is to install vapor barriers in ceilings/roofs and walls. To control or reduce solar heat gains through the roof or glazing areas, a reflective surface or film can be used. For glazing areas, the installation of interior or exterior shading will also help control solar heat gain. The installation of storm windows or multiple-glazed windows will also reduce heat conduction and long-wave radiation through glazing areas.

Infiltration is the unintended entry of unconditioned air into the building through doors, windows, and other openings in the building envelope. Infiltration can result in large increases in heating and cooling loads. Many infiltration control strategies are inexpensive and relatively simple to implement. Energy can be saved by sealing vertical shafts and stairways, caulking and weatherstripping doors and windows, or installing vestibules and revolving doors.

HVAC Systems

The HVAC systems in the building are made up of energy conversion equipment, which transforms electrical or chemical energy to thermal energy, and distribution and ventilation systems, which transport the thermal energy and supply fresh outdoor air to the conditioned space. Energy may be saved in HVAC systems by reducing ventilation requirements; improving the performance of space conditioning equipment such as boilers, furnaces, chillers, air conditioners, and heat pumps; using energy-efficient cooling systems; and reducing the occurrence of reheating or recooling.

HVAC Distribution Systems

HVAC distribution systems transport the heating and cooling fluids (generally air, water, or steam) from the central plants (chillers, boilers, etc.) to the conditioned space. The system is made up of a network of pipes, ducts, fans, pumps, grills, etc. Energy is required by the fans and pumps that transport the working fluids. In addition, thermal energy is lost from the distribution systems, reducing heating or cooling capacity. Consequently, ECOs for distribution systems fall into two areas: reduction of energy required to transport fluids, and reduction of energy losses during transport.

Water Heating Systems

In general, heating and distribution of hot water consumes less energy than space conditioning and lighting. However, for some cases, such as hospitals, restaurants, kitchens, and laundries, water heating amounts to substantial energy consumption. Water heating energy is conserved by reducing load requirements, reducing distribution losses, and improving the efficiency of the water heating systems.

Lighting System

Lighting accounts for a significant fraction of electrical energy consumed in a building. Energy is saved and electric demand is reduced by reducing illumination levels, improving lighting system efficiency, curtailing operating hours, and using daylighting. Reduction of lighting energy can also increase the energy use of building heating and decrease cooling system consumption, since internal heat gains are reduced. However, this heat-of-light is often a relatively expensive method of heating a building. If the building cooling plant is to be replaced, implementation of lighting ECOs will reduce the required plant size.

Power Systems

The inefficient operation of power systems stems mainly from a low power factor. Power factor correction is cost-effective when utility penalties are imposed. Low power factors can be improved with power factor correction devices and high-efficiency motors. Additional energy can be saved by installing energy-efficient transformers and replacing existing motors with smaller and/or higher efficiency motors, or by installing variable-speed motor drives.

The peak power demand can be reduced by load-shedding, cogeneration, or cool storage systems that produce cold water or ice during off-peak hours. Load-shedding may also reduce the total power consumption, as well as the demand. Cogeneration systems will increase the use of onsite energy, but can also replace electricity consumption with less expensive fossil energy. Also, the waste heat from the cogeneration equipment can meet thermal loads. Cool storage systems shift the chiller demand to off-peak periods, reducing on-peak demand.

Evaluation of these ECOs requires a determination of the building demand profile. Several weeks of data in 15-minute intervals should be taken with a recording meter. The measurements may have to be taken both in the cooling and heating season. Most electric utilities will provide this service at a nominal charge.

Energy Management Control Systems

Energy can be saved by automating the control of energy systems through the use of energy management and control systems (EMCS). Rising energy costs and decreasing prices for computers and microprocessors have encouraged the use of EMCSs. An EMCS can efficiently control the heating, ventilating, air conditioning, lighting, and other energy-consuming equipment in the building. It selects optimum equipment operating times and setpoints as a function of electrical demand, time, weather conditions, occupancy, and heating and cooling requirements. The basic control principles for building energy conservation are

- operate equipment only when needed
- eliminate or minimize simultaneous heating and cooling
- supply heating and cooling according to actual needs
- supply heating and cooling from the most efficient source.

About 100 companies manufacture EMCSs, and new technology is continually being developed. Potential users should be thoroughly familiar with currently available EMCSs.

Heat Recovery/Reclaim Systems

Heat recovery is the reclamation and use of energy that is otherwise rejected from the building. When applied properly, heat reclaim systems may be used to reduce energy consumption, as well as peak power demand. The effectiveness of a heat reclaim system for energy conservation depends on the quantity and temperature of the heat available for recovery, as well as the application of the reclaimed heat.

3.4 ANALYSIS OF ENERGY CONSERVATION OPPORTUNITIES

All building energy consumption can be viewed conceptually as a rate of use multiplied by time (energy = rate X time). The maximum rate is specified or limited by parameter specifications of capacity or by intensity, such as wall U value, lighting watts/ft^2, or chiller tonnage. The rate over time is specified by the operating schedule or weather variables. The type of parameter and how it varies over time can be used to select the appropriate analysis technique. For example, an external lighting system uses energy at a constant rate, usually operates on a known schedule, and has no interaction with other patterns of building energy consumption. Therefore, a change in installed kW (rate) or operating schedule (time) can be calculated manually with precision.

For most ECOs, however, an accurate calculation is not that simple. For example, the performance of heating and cooling systems is affected by internal heat gains and weather variables, which vary in a complex fashion over time. The efficiencies of the plant equipment and HVAC systems vary with percentage of load. Therefore, using an energy model rather than manual techniques offers the following accuracy improvements:

- Building parameters can be precisely scheduled.
- The impact of weather can be precisely determined.
- Equipment performance can be specified at part-load.
- Variable interactions, such as the effect of internal lighting reductions on heating and cooling loads, can be calculated.

Before personal computers were widely used, building energy analysts had limited choices of calculation methods for evaluating ECOs. Typically, they used manual calculation methods and nomographs. Those methods are simple and require a relatively low level of effort from the user. However, those methods are not as accurate and comprehensive as automated methods of calculation.

In the past, automated calculation methods were usually available only on mainframe computers and their use was costly, complicated, and time-consuming. However, those methods provided much greater accuracy and could evaluate building energy use hourly. With the advent of the personal computer, automated methods for analyzing building energy became accessible to a wider range of building professionals. Today, many software packages for analyzing building energy are available for the personal computer.

ASEAM is such a model and was used to analyze the effects of several of the ECOs discussed above. ASEAM is a modified bin method program for calculating the energy consumption of residential and simple commercial buildings. ASEAM runs on an IBM-PC and compatibles with at least 256 kilobytes of memory and two disk drives.

Like most building energy analysis programs, ASEAM performs calculations in four segments:

- loads - Thermal heating and cooling loads (both peak and "diversified," or average) are calculated for each zone by month and by outside bin temperature. Lighting and miscellaneous electrical consumption are calculated in this segment.

- systems - The thermal loads calculated in the loads segment are then passed to the systems' segment, which calculates "coil" loads for boilers and chillers. (The system coil loads are not equal to the zone loads calculated above because of ventilation requirements, latent cooling, humidification requirements, economizer cycles, reheat, mixing, etc.) Some building energy requirements are calculated in the systems' segment (e.g., heat pump and fan electricity requirements).

- plant - All of the systems' coil loads on the central heating and cooling plant equipment are then combined, and calculations are performed for each central plant type. (Plant equipment can also impose loads on other plant equipment, such as cooling tower loads from chillers and boiler loads from absorption chillers or domestic hot water.) The plant calculations result in monthly and annual energy consumption figures for each plant type.

- economic (optional) - Energy consumption from all the building end-use categories is then totaled and reported. If specified, the LLCs of the total energy requirements, combined with other parameters, are calculated and reported. In the parametric and ECO calculation modes, a base case may also be compared with alternative cases.

The ASEAM program is recommended as the initial energy-use assessment tool for residential and commercial buildings. It is relatively simple and inexpensive to use, does a good job of accounting for the complexities of energy use, and facilitates the examination of most ECO costs and benefits. This tool is further discussed in Chapter 4, and example applications are described in Volume 2 of this A&E guide.

3.5 SELECTION OF SUPPLEMENTAL METERING POINTS

An understanding of energy-use effectiveness is often severely constrained by a lack of scientific data on energy system performance. Measurements taken on a regular basis are most useful to assess energy-efficiency levels and the effects of operational or design changes. Measurements may be continuous, such as utility meters, or may be for short periods of time, such as combustion efficiency tests. Some of the most critical measurements are listed below:

- electrical consumption levels by type of day (working and nonworking days) and month of year
- electrical demand levels by hour of day and season of year
- interior lighting levels, efficacy, and schedules
- interior temperature levels by hour of day and season of year
- chiller and boiler efficiency levels under part-loads
- make-up water requirements for steam and hot water distribution systems
- exterior temperature, humidity, and solar radiation
- areas of heated, cooled, and unconditioned space
- capacity ratings and hours of operation for major equipment such as pumps, fans, and street lighting systems

- thermal conductance (U-value) of conditioned building envelopes

- submetered electrical consumption for major buildings and equipment loads such as fans, pumps, lighting, and process equipment

- submetered hot water, chilled water, and steam measurements for individual buildings and/or central plant headers

- hours of operation and other facility production/use factors.

The costs of collecting and processing data are often a significant barrier to scientific investigations of energy use and conservation potential. The need for more accurate data must be balanced against the higher costs of collecting and processing it. Continuing developments in energy metering and analysis techniques are reducing measurement costs while improving the quality and amount of data available. While some of the measurements identified above require sophisticated equipment and skilled technicians, others may be readily available for the asking from the building designers, servicing utilities, the National Weather Service, or the O&M staff.

The analyst must verify the quality of the data before incorporating it into an analysis. Typically, this requires a skeptical attitude on the part of the user and a comparison of measurements and/or use of engineering calculations. While errors cannot always be found, inaccuracies in major items such as meter readings, motor capacities, square footage calculations, and meter multipliers and reading dates should be found and corrected.

To facilitate the identification of metering points and the collection of data, the FEMP has developed four Mobile Energy Laboratories (MEL) for application to federal facilities. These laboratories provide equipment, skilled technicians, and standardized testing and measurement procedures on a cost-shared basis to federal facilities that are willing to offset the costs associated with MEL use. If supplemental metering is required, the energy management committee should consider making use of this capability or obtaining the professional services of a qualified energy consultant.

4.0 SIMULATION METHODS

A building simulation is a mathematical representation of the way in which a building functions. A simulation cannot precisely replicate a real building because all building simulations are based upon a set of underlying assumptions. The accuracy of the simulation will be determined by the validity of the assumptions.

Even if a building simulation were a theoretically perfect representation of how a building functioned, it still could not replicate the actual operation of the building. Climate can vary annually by ±15%. Systems and equipment never operate precisely as predicted by part-load performance curves. Even two apparently identical chillers or boilers can vary in performance by several percent. Performance will also vary with age of equipment and with the number of operating hours since the last major cleaning or overhaul. Finally, no set of operating schedules can duplicate the way people operate and interact with a building.

Therefore, the results of any building simulation are a relative representation of how the building does or could function. Care should be used in interpreting such results in an absolute sense. However, a building simulation is a valuable tool if properly applied and interpreted. For example, comparisons between two or more systems, made under the same basic set of assumptions, will yield a valid comparison. Furthermore, for an existing building, the simulation can be fine-tuned and validated against energy bills and operating data. A simulation can be adjusted to closely replicate a building's monthly energy consumption.

A clear and general understanding of a simulation program's methodologies and limitations is essential if the simulation is to be successfully applied to a particular building. Failure to do this could result in under- or over-specification of building input data, or could lead to unrealistic expectations in interpreting simulation results. Therefore, the user is advised to become familiar with the methodologies used in a building simulation, especially if a sophisticated or complex analysis is to be attempted. To that end, this chapter includes a discussion of modeling methods (Section 4.1), calculation techniques (Section 4.2), and the type and organization of data (Section 4.3). A discussion of level of detail considerations is presented in Section 4.4.

There are several basic reasons for using building simulations. The first is for buildings research. Building simulations permit the researcher to explore the behavior of various types of buildings and their response to changes in their systems or in building operating strategies.

Building simulations are an important design tool. They can be used to examine design strategies, compare various combinations of systems or components, and explore the impacts of control strategies or operational requirements. Building simulations can also be used to test for conformance to a design energy budget.

Building simulations are often used as an aid in selecting and sizing building systems or components. (They should never be used in place of the judgment of an experienced design professional, however.) Simulations are especially useful in evaluating the interactions of two or more systems or components, a situation which is virtually impossible to deal with manually. Energy conservation retrofit analysis is another area in which building simulations are widely used.

Finally, the value of building simulations in the marketing of building components or systems has always been important. Simulations are a convincing means of demonstrating to prospective customers the performance of a given system against competing products.

4.1 BUILDING ENERGY USE SIMULATION MODELS

The evolution of building simulations has paralleled the development of the computer. Early computer models were written for main frame computers. Initially, only the largest available machines had the speed and capacity to perform building energy simulations. Today, some of the micro-computer models are approaching the sophistication of the main frame computer models. Furthermore, programs such as DOE-2, which were originally written for main frame computers, now run satisfactorily on mini-computers and can be run, although slowly, on desktop computers.

Building simulations can be classified in two ways: the type of simulation and the type of calculation.

For the purposes of this discussion, simulations can be classified by the type of analysis: whole building, component, parametric and sensitivity, and retrofit analysis. Calculations are classified by the time step used: static, incremental and dynamic.

In this section these two classification schemes are presented, followed by a discussion of the development of building energy simulations.

4.1.1 Types of Building Energy Simulations

Building energy simulations can be described under one of the following classifications.

4.1.1.1 Comprehensive or Whole Building Analysis

In a comprehensive or whole building analysis, the energy consumption of an entire building is simulated, including the effects of weather, performance of mechanical/electrical systems, and the building occupants. A comprehensive analysis is typically used to

- determine long-term energy costs
- examine a design for conformance to an energy budget
- satisfy energy code compliance
- determine the performance of various HVAC systems in a given building design
- determine component interactions.

4.1.1.2 Component Analysis

In a component analysis, the energy consumption of a single part of a building or several integrated parts is simulated. A component might be a roofing system, a lighting system, HVAC systems, a thermal storage system, or an atrium. Component analyses can be used to compare the relative merits of different systems without performing a whole building analysis. The comparison is relative rather than absolute because interaction with all building systems cannot be taken into account. However, determining that one system is 50% more energy efficient than another may be sufficient for system selection. Component analyses can be used for selecting and sizing components; demonstrating code compliance for specific components; marketing a specific component by demonstrating its performance in comparison to competing products; or determining the interaction of two components (e.g., additional roof insulation and a night setback control).

4.1.1.3 Parametric and Sensitivity Analyses

In both parametric and sensitivity analyses, one or more building parameters are varied incrementally. In a parametric analysis, the goal is to optimize building energy performance. For example, different chillers with unique performance curves and capacities could be examined.

In a sensitivity analysis, the goal is to determine whether an incremental change in a building parameter has a significant impact on energy consumption. If this is found to be the case, extra care can be taken in specifying and installing the building component that is affected. For example, the performance of a heat pump might be very sensitive to a 10% change in supply CFM. On the other hand, a furnace may exhibit little change in efficiency at part-load rates of 50% to 100%, which would mean that the exact sizing of the furnace is not critical to efficient energy performance.

4.1.1.4 Retrofit Analysis

This type of simulation is used to examine energy improvements in an existing building. Either comprehensive or component analyses may be used. Component analyses are less expensive to perform and are often used. Comprehensive analyses have an advantage in that a base case simulation can be compared with actual energy consumption taken from utility bills.

4.1.2 Life Cycle Costing

Life cycle costing is an integral part of many building simulation methods. While the purpose of many building simulations is to save energy, the bottom line for the building owner is to save money. It often makes sense to complement the building simulation with an equally comprehensive economic analysis. Since an energy-conserving building will often cost more initially than a standard building, a life cycle cost analysis is used to compare the total cost of various designs. Life cycle costing takes into account initial cost, the cost of money, energy costs, operation and maintenance costs, component replacement costs, salvage value, and other factors that will affect cost over the entire life of the project.

4.1.3 Types of Calculations

Another way to characterize or classify building simulations is the way in which they simulate changes in conditions over time. In this section, three basic types of calculations are discussed. In Section 4.2, methods and approximations used in present day building simulations are discussed.

4.1.3.1 Static Calculations

The simplest building energy calculation is a steady state calculation in which all building parameters are fixed. This type of calculation is used to determine peak thermal loads and has been used by engineers for many years to size space heating and cooling equipment. However, building parameters do change over time. Outside air temperature, relative humidity, wind speed and direction, and solar gain are constantly changing. Building occupancy, lighting levels, miscellaneous equipment usage, and thermostat setpoints vary over the course of a day. The operating parameters of building systems and plants vary as well.

The first attempt at quantifying annual energy usage was accomplished by the Tennessee Valley Authority in the 1930s. The heating degree day concept was developed using 65°F as a base. The number of heating degree days can be calculated and correlated to heating energy requirements by subtracting 65 from the average daily temperature in °F. Heating degree days were used in the static peak load calculation in place of the design temperature difference (indoor-outdoor) to produce an annual, rather than a peak, heating consumption estimate. Of course, all other variables (such as heating system efficiency) had a single annual value. This approach worked reasonably well for predicting the electrical consumption of populations of resistance-heated, non-air-conditioned and poorly insulated (by today's standards) residences. However, it is a poor approximation for modern commercial buildings with larger internal loads, coincident heating and cooling requirements, and significant ventilation requirements.

4.1.3.2 Incremental Calculations

One method of improving the static calculations is to perform a series of calculations at various conditions. The method of accomplishing this varies from simulation to simulation and is discussed in Section 4.2. The most common time step is hourly variation. This provides 24 distinct "states" in a day, 8760 in a year. Furthermore, hourly weather data have been taken at numerous observation stations worldwide. Because performing 8760 calculations to determine annual energy consumption requires considerable computer power for a detailed building simulation, there has been considerable research into methods of reducing the required number of calculations. Typical day analysis and bin methods are examples of incremental calculations that require less than 8760 calculations to simulate a year.

4.1.3.3 Dynamic Calculations

In some instances, one-hour time steps are not sufficient. It may be desirable to study a non-linear passive solar effect. The fact that the chiller ran for an hour and satisfied the hourly load in the space does not mean the occupants were comfortable for the entire hour. Studying the effects of building mass is another reason for using dynamic calculations. Whatever the reason, a situation may occur in which something interesting is happening in between the specified time stops. If the time interval between the incremental calculations is made infinitesimally small by the use of integral calculus, the calculations are dynamic and represent the most realistic simulation of actual conditions possible.

Dynamic calculations can be extremely complex and time-consuming. The data necessary to verify them are typically available only in specialized studies. Fortunately, incremental calculations are quite sufficient for most building simulations.

4.1.4 Development of Energy Simulations

Energy analysis software was first developed in the early 1960s. Development proceeded from automation of steady state calculations to the advancement of a variety of component load applications, such as equipment part-load operating curves. Combining the individual component analyses led to the first energy analysis programs.

Whole building energy analysis software was originally developed in the private sector. In 1967, the American Gas Association (AGA) launched its Gas for the Advancement of Total Energy (GATE) Program. The purpose of this program was to market gas-powered total energy systems for building complexes.

Energy analysis software was used to show building developers the benefits of total energy systems compared with conventional systems. The approach was successful, and in 1971, AGA introduced the E-CUBE computer program. Other utility groups also developed software. The Edison Electric Institute (EEI) introduced its AXCESS Program in 1971 as well.

The first large-scale program to be developed by a federal agency was also introduced in 1971. The U.S. Post Office developed the USPO Program to analyze double-bundle heat recovery systems and other energy-conserving designs they were investigating for use in their buildings. Many of the features of this program were incorporated into later public and private sector models. The first comprehensive energy analysis program to be developed by a profit-making company was the TRACE® Program, introduced by the Trane Company in 1973.

The oil embargo of 1973, and the resultant need for a national energy policy, led to the large-scale development of public sector energy analysis software. In 1977, DOE's predecessor, the Energy Research and Development Administration (ERDA), and the State of California introduced the CAL-ERDA Program. This program has evolved into the DOE-2 Computer Program, which is supported by the Lawrence Berkeley Laboratory for DOE. At the same time, the U.S. Army Civil Engineering Research Laboratory developed the Building Loads Analysis and System Thermodynamics (BLAST) Program. These programs have been continuously supported and updated since their introduction. They have furthered the art of building energy analysis, and many of their features have been incorporated into private sector programs. While both of these programs were originally written for main frame computers, mini-computer versions are now available. The DOE-2.1C version can also be run on a desktop computer using proprietary software.

In the late 1970s and 1980s, literally hundreds of energy analysis computer programs were developed (ASHRAE 1986). They are used for building research, energy analysis, education, load forecasting, marketing, and as design tools. Much of the software development has centered around ease of input. Program output is targeted to the needs of the user and may now include graphics. As the capacity of desktop computers increases, there is emphasis on models that the user can purchase and run in-house on a personal computer (PC). DOE-2 and BLAST, however, remain the standards against which other programs are measured. The following is a brief description of some of these programs.

4.1.5 Main Frame Simulation Programs

The two major public sector programs continue to be DOE-2 and BLAST. Both of these programs have been supported and updated numerous times since their introduction. DOE-2 and BLAST use sophisticated hourly load calculation methods, which take into account the climate, operating schedules, and interactions with the building mass. Their major difference is in the mathematical methods used to calculate space heating and cooling loads. Both

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APPENDIX A

INFORMATION TO BE GATHERED DURING AUDITS

Appendix A consists of two tables containing information to be gathered during audits. Table A.1 contains information that should be gathered during the preliminary audit of a building and is divided into the following four categories: overall facility information, information on major energy-using systems/equipment, the types of systems/equipment contained in the building, and energy billing data. Table A.2 contains information that should be gathered during the building audit and is divided into the following five data categories: building envelope/shell, HVAC systems, lighting and electrical systems, central plant systems, and weather. A discussion of these audits is contained in Chapter 3.

TABLE A.1. Information to be Gathered During Preliminary Audit

OVERALL FACILITY INFORMATION

- Floor area of building (ft^2) and of different functional parts (e.g. offices, warehouses, etc.)
- Volume of building (ft^3) and of different functional part
- Age of building (date of construction, remodels, additions and descriptions of changes
- Blueprints of architectural, mechanical, and electrical systems
- Lighting types, amount, and operating schedule (interior and exterior)
- Insulation levels (type, amount, location)
- Building operating hours (seasonal, weekly, holiday changes)
- Occupancy (seasonal, daily, weekly changes)
- Any planned changes to the building

MAJOR ENERGY-USING SYSTEMS/EQUIPMENT INFORMATION

- Type, size, design, specs, age, etc.

TABLE A.1. (contd)

- Fuel used for heating, cooling, and water heating
- Location noted on blueprints
- Operating hours and schedules
- Control schemes or equipment used

TYPES OF SYSTEMS/EQUIPMENT TO BE CONSIDERED

- HVAC distribution systems
- Heating systems (boiler, furnace, heat pump)
- Cooling systems (chiller, cooling tower, air conditioner)
- Water heater
- Freezer/refrigeration compressors
- Auxiliary Equipment (pumps, fans, etc.)
- Other systems (food service, laundry, computers)

ENERGY BILLING DATA

- For all types of energy used (electricity, natural gas, oil, steam, etc.)
- For as many years as possible
- In as much detail as possible
- Per unit cost (including any changes in cost per season, time-of-day, etc.)
- Demand changes

TABLE A.2. Information to be Gathered During Building Audit

BUILDING ENVELOPE/SHELL

- Floor area
- Number of zones and zone identification
- Area by zone
- Thermostat schedules and setpoints
- Occupancy schedules
- Sensible and latent heat gain from people
- Exterior walls (materials of construction)
- Roof
- Windows (type, area, weatherstripping, etc.)
- Shading and overhangs
- Doors (type, area, etc.)
- Underground walls
- Miscellaneous conduction (e.g., freezer walls)
- Insulation (type, location, area, etc.)
- Infiltration

HVAC DATA

The data required is for both distribution systems and unitary equipment (e.g. heat pumps).

- System label and type
- Zone assignments to systems
- Heat source for systems (plant type)
- Cooling source for systems (plant type)

TABLE A.2. (contd)

- System availability and schedules

- System specific information as required such as:
  - deck temperatures
  - controls
  - outside air and damper control
  - humidification
  - preheat and reheat
  - fan power and flow rate
  - loop temperature
  - backup heating

- Unitary system information as required such as:
  - design COPs for air conditioners and heat pumps
  - efficiency and parasitic losses for furnaces
  - unloading ratios for DX cooling systems

LIGHTING AND ELECTRICAL SYSTEMS

Most of this information is per zone

- Lighting levels (watts/ft^2, footcandles)

- Control scheme for lights (switches, schedules)

- Location of fixtures

- Type and size of lights (fluorescent, incandescent, etc.)

- Motors (Type, HP, amperage, etc.)

- Location and condition of transformers and switch boxes

- Power factor of building (if applicable)

CENTRAL PLANT SYSTEMS

This includes specifications of the primary energy-using systems such as boilers, chillers, cooling towers, circulating pumps, and water heating systems.

TABLE A.2. (contd)

- Boiler specifications such as:
  - fuel usage and cost
  - number of units
  - capacity
  - design efficiency
  - controls
  - minimum part load ratio
  - boiler pump kW
  - standby/parasitic losses

- Cooling plant specifications such as:
  - fuel usage and cost
  - number of units
  - capacity
  - design COPs
  - controls
  - unloading and part load ratios
  - water temperatures and flow rates
  - load management system specifications
  - pump kW's

- Cooling tower specifications such as:
  - heat rejection capacity
  - number of cells
  - fan kW per cell
  - water temperatures and flow rates
  - pump kW's
  - approach temperature
  - controls

- Domestic water specifications such as:
  - fuel usage and cost
  - heating capacity
  - average usage
  - inlet and supply temperatures
  - circulation pump kW and scheduling
  - design efficiency
  - standby losses

WEATHER DATA

The auditor should select an available weather station which most closely corresponds to the location of the building being analyzed.

- Air temperature (average daily and monthly)

- Relative humidity or humidity ratio
- Wind speed
- Wind direction
- Insolation or cloud cover
- Average heating and cooling degree days (if average temperatures are not available).

APPENDIX B

SIMULATION MODEL INPUTS FOR ASEAM VERSION 2.1

Appendix B is an abbreviated listing of the input variables for ASEAM Version 2.1. The actual entry of the data into the model is done with numerous "user friendly" screens. Each screen provides a menu of input options and available defaults. The input forms are divided into the following four data types: building load data (loads), HVAC systems data (systems), plant equipment data (plant), and economics data (Federal Building Life Cycle Costing - FBLCC).

ASEAM LOADS INPUT FORMS (ABBREVIATED)

Bldg/Project	Building File Name	________
Bldg/Project	Building Name	________
Bldg/Project	Project Number	________
Bldg/Project	Building Address	________
Bldg/Project	Building Type	________
Bldg/Project	**Building Gross Floor Area**	________ ft
Bldg/Project	**Building Net Conditioned Area**	________ ft
Bldg/Project	**Number of Zones**	__
Bldg/Project	**North Latitude (Use '-' for South Lat)**	____ deg
Bldg/Project	**West Longitude (Use '-' for East Long)**	____ deg
Bldg/Project	**Typical weekday occupancy starting hour**	__
Bldg/Project	**Typical weekday operating hours per day**	__
Bldg/Project	**Summer thermostat schedule beginning month number**	__
Bldg/Project	**Summer thermostat schedule ending month number**	__
Bldg/Project	**Time Zone Number**	__
Bldg/Project	**Daylight Savings Time Used (Y/N)**	_

Bldg/Project	**Operating Schedules**	**Weekdays .... from**	____	**to**	____
Bldg/Project	**Operating Schedules**	**Saturdays ... from**	____	**to**	____
Bldg/Project	**Operating Schedules**	**Sundays ..... from**	____	**to**	____

(The following two screens apply to the entire building)

Shading	Window Model Name (or 'NA')	_____	_____	_____
Shading	Window Width	_____	_____	_____
Shading	Window Height	_____	_____	_____
Shading	Overhang Depth	_____	_____	_____
Shading	Top of Window to Overhang	_____	_____	_____
Shading	Overhang extension beyond left edge of window	_____	_____	_____
Shading	Overhang extension beyond right edge of window	_____	_____	_____
Shading	Depth of vert projection at end of overhang	_____	_____	_____
Shading	Depth of left fin	_____	_____	_____
Shading	Left fin extension above top of window	_____	_____	_____
Shading	Distance from left edge of window to left fin	_____	_____	_____
Shading	Dist from left fin bottom to bottom of window	_____	_____	_____
Shading	Depth of right fin	_____	_____	_____
Shading	Right fin extension above top of window	_____	_____	_____
Shading	Dist from right edge of window to right fin	_____	_____	_____
Shading	Dist from right fin bottom to bottom of window	_____	_____	_____

Month Sch	Month	**Mon Sch 1**	**Mon Sch 2**	**Mon Sch 3**	**Mon Sch 4**
Month Sch	January	___	___	__	__
Month Sch	February	___	___	__	__
Month Sch	March	___	___	__	__
Month Sch	April	___	___	__	__
Month Sch	May	___	___	__	__
Month Sch	June	___	___	__	__
Month Sch	July	___	___	__	__
Month Sch	August	___	___	__	__
Month Sch	September	___	___	__	__
Month Sch	October	___	___	__	__
Month Sch	November	___	___	__	__
Month Sch	December	___	___	__	__

ASEAM2 LOADS INPUT FORMS (ABBREVIATED) Zone # ___

Zone	Zone label				
Zone	Zone function (Opt)				
Zone	Zone area				ft
Zone	Zone volume				ft3
Zone	(or) Floor to ceiling height			ft	
Zone	Summer occupied temperature setpoint			F	
Zone	Winter occupied temperature setpoint			F	
Zone	Winter unoccupied temperature setpoint			F	
Lighting	Function name (or 'NA')				
Lighting	Average function area (ft)				
Lighting	Installed watts/ft				
Lighting	(times) Percent of function area				
Lighting	(or) Total installed watts				
Lighting	Daylighting (Y/N)				
Lighting	Controlite filename (if appl)				
Lighting	Lighting system type (Opt)				
Lighting	Percent light heat to space (%)				
Lighting	'A' classification				
Lighting	'B' classification				
Lighting	Diversity Factor Occupied				
Lighting	Diversity Factor Unoccupied				
Lighting	Monthly Diversity Factor Table #				
Daylighting	Function name (or 'NA')				
Daylighting	Window orientation (N,NW,etc)				
Daylighting	Ground reflectance (%)				
Daylighting	Typical room window area (ft2)				
Daylighting	Glass visible transmittance (%)				
Daylighting	Room depth from window (ft)				
Daylighting	Room length (ft)				
Daylighting	Ceiling height (ft)				
Daylighting	Wall reflectance (%)				
Daylighting	Present footcandles in space				
Daylighting	Design footcandles for space				
Daylighting	Sensor location				
Daylighting	Percent of lights controlled				
Daylighting	Control type ('D'im or 'S'tep)				
Dayl-Controls	Function name (or 'NA')				
Dayl-Controls	For Dimming Control Only				
Dayl-Controls	Minimum FC maintained by lights				
Dayl-Controls	% of total power at min FC (%)				
Dayl-Controls	For Stepped Control Only				
Dayl-Controls	Number of Steps (max=4)				
Dayl-Controls	Step 1 artificial FC				
Dayl-Controls	Step 1 lighting watts				
Dayl-Controls	Step 2 artificial FC				
Dayl-Controls	Step 2 lighting watts				
Dayl-Controls	Step 3 artificial FC				
Dayl-Controls	Step 3 lighting watts				
Dayl-Controls	Step 4 artificial FC				
Dayl-Controls	Step 4 lighting watts				
People	Number of people in zone				
People	(or) Square feet per person				
People	BTUH load per person	Sensible			
People	Diversity Factor Occupied ___	Unoccupied			

ASEAM LOADS INPUT FORMS (ABBREVIATED) Zone # ____

Misc Elect	Electric equipment name (or 'NA')
Misc Elect	Installed watts/ft
Misc Elect	(times) Percent of zone area
Misc Elect	(or) Total installed watts
Misc Elect	Hooded (Y/N)
Misc Elect	Diversity Factor Occupied
Misc Elect	Diversity Factor Unoccupied
Misc Elect	Monthly Diversity Factor Table Number
Misc Sens	Load source name (or 'NA')
Misc Sens	Installed BTUH/ft
Misc Sens	(times) Percent of zone area
Misc Sens	(or) Total installed BTUH
Misc Sens	Hooded (Y/N)
Misc Sens	Diversity Factor Occupied
Misc Sens	Diversity Factor Unoccupied
Misc Sens	Monthly Diversity Factor Table Number
Wall	Name (or 'NA')
Wall	Wall Orient (N,NE,etc)
Wall	Area (ft)
Wall	U-Factor (BTUH/ft-)
Wall	Wall Construction Group
Wall	Color Correction
Roof	Name (or 'NA')
Roof	Area (ft)
Roof	U-Factor (BTUH/ft-)
Roof	Roof Construction Code
Roof	Color Correction
Roof	Susp Ceil Plenum (Y/N)
Window	Name (or 'NA')
Window	Window orient (N,NE,etc
Window	Fenestration area (ft)
Window	Shading coefficient
Window	U-Factor (BTUH/ft-)
Window	Space mass code
Window	Crack length (lin ft)
Window	Leakage coefficient
Window	Window shading model #
Window	Percent window area
Door	Name (or 'NA')
Door	Area (ft)
Door	U-Factor (BTUH/ft-)
Door	Crack length (lin ft)
Door	Leakage coefficient
Infiltration	Occupied air change rate — air changes per hour
Infiltration	Unoccupied air change rate — air changes per hour
Misc Conduct	Name (or 'NA')
Misc Conduct	Area (ft)
Misc Conduct	U-Factor (BTUH/ft-)
Misc Conduct	Reference temperature at design summer F)
Misc Conduct	Reference temperature at design winter F)

ASEAM2 SYSTEMS INPUT FORM (ABBREVIATED)

Total number of systems _

System #	System Label	System Type
1	____________________	__
2	____________________	__
3	____________________	__
4	____________________	__
5	____________________	__
6	____________________	__
7	____________________	__
8	____________________	__
9	____________________	__
10	____________________	__

System Types

1=DDMZ 2=CVRH 3=VAVR 4=CBVAV 5=SZRH 6=FCU 7=WSHP 8=AAHP
9=BB 10=FURN 11=UH 12=HV 13=WAC

Zone Number	Zone Label	Heating Cooling System #	Heating ONLY System #	Cooling ONLY System #
NOTE - THE ZONE NUMBERS AND LABELS (AS DEFINED IN LOADS INPUT) WILL BE PRINTED HERE		__	__	__
		__	__	__
		__	__	__
		__	__	__
		__	__	__
		__	__	__
		__	__	__
		__	__	__
		__	__	__
		__	__	__

ASEAM2 SYSTEMS INPUT FORM (ABBREVIATED) System # ___

Heating coil plant type (Use Codes Below) _
0=None 1=Boiler 2=Elect Resist 3=Dist Heat 4=DB Chiller 5=Furn
Outside temperature above which heating is off ___F
Heating available beginning month # __
Heating available ending month # __
Design heating coil discharge temperature ___F
Discriminator Control (Y/N) (DDMZ ONLY) _
Outside temperature at maximum hot deck temperature (DDMZ ONLY) ___F
Maximum hot deck temperature (DDMZ ONLY) ___F
Outside temperature at minimum hot deck temperature (DDMZ ONLY) ___F
Minimum hot deck temperature (DDMZ ONLY) ___F

Cooling coil plant type (see codes below) _
0=None 1=DX 2=Centrifugal 3=Absorption 4=District Cooling
5=Double Bundle 6=Cooling Tower (WSHP only) 7=Reciprocating
Outside temperature below which cooling is off ___F
Cooling available beginning month # __
Cooling available ending month # __
Design cooling coil discharge temperature ___F
Discriminator control (Y/N) _
Maximum cooling coil discharge temperature ___F

Preheat coil plant type (Use Heating Codes 0 - 3) _
Outside temperature above which preheat is off ___F
Preheat available beginning month # __
Preheat available ending month # __
Design preheat coil discharge temperature ___F

Humidification plant type (Use Heating Codes 0 - 3) _
Outside temperature above which humidification is off ___F
Humidification available beginning month # __
Humidification available ending month # __
Humidification available during unoccupied cycle (Y/N) _
Minimum relative humidity maintained __ % RH

Baseboard plant type (Use Heating Codes 0 - 3) _
Outside temperature above which baseboard is off ___F
Baseboard available beginning month # __
Baseboard available ending month # __
Baseboard control type (1=thermostatic 2=OA reset) _
Percent of design heating load satisfied at design winter ___%
Percent of design heating load satisfied at balance temp ___%

Total supply fan power required (blank=default) ___ KW
(or) Supply fan power per 1000 CFM ___ KW/KCFM
Supply fan temperature rise (blank=default) ___
Total return fan power required (blank=default) ___ KW
(or) Return fan power per 1000 CFM ___ KW/KCFM
Return fan temperature rise (blank=default) ___F
(VAV) Minimum percent of design air volume-when heating ___%
(VAV) Air volume control method (1=Speed 2=Discharge 3=Inlet) _
Occupied cycle fan control method (1=On Continuously 2=Cycles) _
Unoccupied cycle fan control method (1=On Continuously 2=Cycles) _

Unocc

Outside air damper control method (see codes below) _
1=No Outside Air 2=Fixed Dampers 3=Dry Bulb 4=Enthalpy
Minimum percent outside air intake ___%
Dry bulb switchover temperature ___F

ASEAM2 SYSTEMS INPUT FORM (ABBREVIATED) System # ___

(Heat Pump and Window Air Conditioner only)
Zonal total cooling capacity method (l=User Entered 2=Autosized) _
(if autosized) Percent of design total load satisfied ___ %
Zonal sensible cooling capacity method (l=User Entered 2=Autosized) _
(if autosized) Percent of design sensible load satisfied ___ %
Design coefficient of performance ___
Outside temperature at minimum fluid loop temperature ___ F
Minimum fluid loop temperature ___ F
Outside temperature at maximum fluid loop temperature ___ F
Maximum fluid loop temperature ___ F

Zonal heating capacity method (l=User Entered 2=Autosized) _
(if autosized) Percent of max heat pump load satisfied ___ %
AAHP backup heating source (l=Furnace 2=Electric Resistance) _
Outside temperature below which backup heating is on ___ F
Zonal electric resistance backup heating capacity method _
(l=Capacities Entered by Zone 2=Autosized)
(if autosized) Percent of design heating load satisfied ___ %
Design heating coefficient of performance ___

Furnace fuel source (see codes below) _
l=Electric 2=Natural Gas 3=#2 Oil 4=#4 Oil 5=#6 Oil
Furnace capacity (blank=autosize) ____ KBTUH
(if autosized) Percent of design load satisfied ___ %
Furnace efficiency at design load ___ %
Losses as percent of design load (at design load) ___ %
Losses as percent of design load (at no load) ___ %
Pilot gas annual consumption ___ therms

Zonal air volume method (l=User Entered 2=Autosized) _
(if autosized) Percent of design default air flow ___ %
Zonal fan power method (l=User Entered 2=Autosized) _
(if autosized) Percent of design default fan KW ___ %

DX total cooling capacity (blank=autosized) _____ tons
(if autosized) Percent of design total load satisfied ___ %
Design coefficient of performance ___
Minimum unloading ratio (% of, capacity) ___ %
Minimum hot gas bypass ratio (% of capacity) ___ %
Condenser fan KW (blank=default) ___ KW
Outside temperature below which condenser fan is off ___ F

Loads Zone #	Zone Name or Label	Zone CFM	Zone Fan KW	Zone Tot Clg Cap (Tons)	Zone Sen Clg Cap (Tons)	Zone HP Htg Cap (Tons)	Zone HP Bkup Htg Cap (KW)
NOTE - THE ZONE NUMBER AND LABEL FOR EACH ZONE ASSIGNED TO THIS SYSTEM IS PRINTED HERE							

ASEAM2 PLANT INPUT FORMS (ABBREVIATED)

Fuel Type	Energy Units	Unit Cost $ / Unit	Conversion Factors (BTU/Unit) Site	Source
Electricity	KWH	____	____	____
Natural Gas	Therms	____	____	____
#2 Oil	Gallons	____	____	____
#4 Oil	Gallons	____	____	____
#6 Oil	Gallons	____	____	____
Dist Heating	MBTU	____	____	____
Dist Cooling	MBTU	____	____	____

Label for Miscellaneous Energy Consumption	Fuel Units (See Codes Below)	Annual Consumption in Energy Units
____________________	_	________
____________________	_	________
____________________	_	________
____________________	_	________
____________________	_	________

Fuel Code	Fuel Type	Energy Units
1	Natural Gas	therms
2	Oil	gallons
3	Electricity	KWH
4	Dist Heating	MBTU
5	Dist Cooling	MBTU

ASEAM2 PLANT INPUT FORMS (ABBREVIATED)

	Type 1	Type 2	
Centrifugal chiller cooling capacity (per chiller)	____	____	tons
(or) Percent design load satisfied per chiller	___	___	%
Number of chillers of this capacity	_	_	
Design coefficient of performance	___	___	
Minimum unloading ratio (% of capacity)	__	__	%
Minimum part load ratio (% of capacity)	__	__	%
Load management/operation (l-always on 2=as needed)	_	_	
Chilled water temperature at design load	___	___	F
Chilled water temperature at minimum load		___	F
Chilled water flow (blank=autosized)		___	gpm
Chilled water pump KW (blank=autosized)		___	KW

	Type 1	Type 2	
Absorption chiller cooling capacity (per chiller)	____	____	tons
(or) Percent design load satisfied per chiller			%
Number of chillers of this capacity	_	_	
Heat input *energy* source (l=Boiler 2=Dist Heat)	_	_	
Design coefficient of performance	___	___	
Minimum part load ratio (% of capacity)	__	__	%
Number of absorption stages	_	_	
Load management/operation (l=always on 2=as needed)	_	_	
Chilled water temperature at design load			F
Chilled water temperature at minimum load			F
Chilled water flow (blank=autosized)			gpm
Chilled water pump KW (blank=autosized)			KW

	Type 1	Type 2	
Double Bundle chiller cooling capacity (per chiller)	____	____	tons
(or) Percent design load satisfied per chiller	___	___	%
Number of chillers of this capacity	_	_	
Design coefficient of performance	___	___	
Minimum unloading ratio (% of cap - clg mode)	__	__	%
Minimum unloading ratio (% of cap - htg mode)	__	__	%
Minimum part load ratio (% of capacity)	__	__	%
Load management/operation (l=always on 2=as needed)	_	_	
Chilled water temperature at design load	___	___	F
Chilled water temperature at minimum load	___	___	F
Chilled water flow (blank=autosized)	___	___	gpm
Chilled water pump KW (blank=autosized)	___	___	KW
Design heat recovery temperature	___	___	F
Heat recovery backup (l=Boiler 2=Dist Htg)	_	_	

	Type 1	Type 2	
Reciprocating chiller cooling capacity (per chiller)	___	___	tons
(or) Percent design load satisfied per chiller	___	___	%
Number of chillers of this capacity	_	_	
Design coefficient of performance	___	___	
Minimum unloading ratio (% of capacity)	__	__	%
Minimum part load ratio (% of capacity)	__	__	%
Load management/operation (l=always on 2=as needed)	_	_	
Chilled water temperature at design load	___	___	F
Chilled water temperature at minimum load	___	___	F
Chilled water flow (blank=autosized)	___	___	gpm
Chilled water pump KW (blank=autosized)	___	___	KW

ASEAM2 PLANT INPUT FORMS (ABBREVIATED)

Cooling tower total heat rejection capacity	_____	tons
(or) Percent of design heat rejection load satisfied	___	%
Number of tower cells (blank=autosized)	_	
Fan KW per cell (blank=autosized)	___	KW
Number of fan speeds (1 or 2)	_	
Approach temperature	__	F
Condenser water temperature at design load	___	F
Condenser water temperature at minimum load	___	F
Condenser water flow rate (blank=autosized)	___	gpm
Condenser water pump KW (blank=autosized)	___	KW

DHW Energy Source (0=None 1=Elec 2=Gas 3=Oil 4=Blr 5=Dist)	_	
(if oil) Oil Type (2 or 4 or 6)	_	
(if gas) Annual pilot consumption	___	therms
Domestic Hot Water Heating Capacity (blank=autosized)	____	KBTUH
(if autosized) Peak hourly DHW usage	____	gal/hour
Average hourly DHW usage - occupied cycle	____	gal/hour
Average hourly DHW usage - unoccupied cycle	____	gal/hour
Domestic hot water supply temperature	___	F
DHW inlet temperature - design summer	__	F
DHW inlet temperature - design winter	__	F
Circulating pump KW - occupied cycle	___	KW
Circulating pump KW - unoccupied cycle	___	KW
Design DHW heating efficiency	___	%
DHW losses - occupied cycle	_____	BTUH
DHW losses - unoccupied cycle		BTUH

	Type 1	Type 2	
Boiler Energy Source (1=Elect 2=Nat Gas 3=Oil)	_	_	
(if oil) Oil type (2 or 4 or 6)	_	_	
(if gas) Annual pilot consumption	____	____	therms
Boiler heating capacity (per boiler)	______	______	KBTUH
(or) % max heating load satisfied (per boiler)	___	___	%
Number of boilers with this capacity	_	_	
Load management/operation (1=always on 2=as needed)	_	_	
Boiler efficiency method (1=user entered 2=calc)	_	_	
Design boiler efficiency (if user entered)	____	____	%
(if calc) Combustion air temperature	___	___	F
(if calc) Stack temperature	___	___	F
(if calc) Air-Fuel ratio	____	____	Lb/Lb
Minimum part load operating ratio (% of capacity)	__	__	%
Boiler pump KW (blank=autosized)	___	___	KW
Boiler losses - percent of capacity	__	__	%
Boiler losses - percent of load	__	__	%

FBLCC Input Forms

PROJECT INFORMATION

Project Title: ____________

LCC Analysis Type
  1 = Energy Conservation or Renewable Energy Projects (NBS 135) -
  2 = Non-Energy Related Projects (OMB Circular A-94)

Study Period (Years) -
Occupancy Year (e.g. 1987)
DOE Region (1-11) -
Building Type -
  1 = Residental 2 = Commercial 3 = Industrial

CAPITAL COMPONENTS DATA

Capital Component Component # _ (repeat for each capital component)

Component Name (or 'NA') ____________
Initial Cost of Component (dollars) ________
Initial Conservation-Related Cost ________
Expected Component Life (Years) - Use '999' for Land
Average Escalation Rate During Planning/Construction Period
Average Escalation Rate During Occupancy
Resale Value Factor (Percent of Initial Cost)

COST PHASING SCHEDULE BY YEAR OF PLANNING/CONSTRUCTION PERIOD AND AT OCCUPANCY

Capital Component Component # ___ (repeat for each capital component)

Enter Percentage of Cost for Each Year
  Planning/Construction Year 1 (1987) _____ %
  Planning/Construction Year 2 (1988) _____ %
  At Occupancy (1989) 100.00

REPLACEMENTS TO CAPITAL COMPONENTS

Capital Component Component # __ (repeat for each capital component)

	Replacements to Capital Component 1	2	3	4
Year of Replacement (from occupancy or 'NA')	__	__	__	__
Init Cost of Replacement (unadjusted)	_______	_______	_______	_______
Expected Replacement Life (years)	__	__	__	__
Resale Value (% of replacement cost)	____	____	____	____

OPERATING AND MAINTENANCE COSTS
Annually Recurring Costs
 Annual Recurring Cost (Base-Year Dollars) ________
 Average Annual Rate of Increase (%) ______
Non-Annually Recurring Costs
 Number of Non-Annually Recurring Costs _
 Average Annual Rate of Increase (%) ______

Non-Annually Recurring Costs (Base Year Dollars)
(Note: Years begin with Occupancy; e.g. 1,2,...50)

No	Year	Amt	No	Year	Amt	No	Year	Amt	No	Year	Amt	No	Year	Amt
1	__	______	11	__	______	21	__	______	31	__	______	41	__	______
2	__	______	12	__	______	22	__	______	32	__	______	42	__	______
3	__	______	13	__	______	23	__	______	33	__	______	43	__	______
4	__	______	14	__	______	24	__	______	34	__	______	44	__	______
5	__	______	15	__	______	25	__	______	35	__	______	45	__	______
6	__	______	16	__	______	26	__	______	36	__	______	46	__	______
7	__	______	17	__	______	27	__	______	37	__	______	47	__	______
8	__	______	18	__	______	28	__	______	38	__	______	48	__	______
9	__	______	19	__	______	29	__	______	39	__	______	49	__	______
10	__	______	20	__	______	30	__	______	40	__	______	50	__	______

ENERGY COST DATA
Number of Energy Types _
Cumulative General Inflation from Mid-1987 to Date (%) ______
(For DOE Escalation Rates ONLY)

	Energy Type 1	Energy Type 2	Energy Type 3
Energy Type Code l=Electricity 2=Distillate Fuel Oil 3=Residual Fuel Oil 4=Natural Gas S=Liquified Petroleum Gas (LPG) 6 = Coal	-	-	
Annual Consumption (MBTU)	________	________	________
Price per MBTU (Use F8 for DOE default)	______	______	______
Demand (or other) Charge	______	______	______
Price Escalation Method 1 = User Entered 2 = Defaulted	_	_	_
Average Annual Rate of Increase (%) During Plan/Construction	_____	_____	_____

ENERGY ESCALATION
Fuel Type # ______ (repeat for each fuel type)
Number of Discrete Time Intervals ____

#	Dur Yrs	Annual Rate %	#	Dur Yrs	Annual Rate %	#	Dur Yrs	Annual Rate %	#	Dur Yrs	Annual Rate %	#	Dur Yrs	Annual Rate %
1	__	______	11	__	______	21	__	______	31	__	______	41	__	______
2	__	______	12	__	______	22	__	______	32	__	______	42	__	______
3	__	______	13	__	______	23	__	______	33	__	______	43	__	______
4	__	______	14	__	______	24	__	______	34	__	______	44	__	______
5	__	______	15	__	______	25	__	______	35	__	______	45	__	______
6	__	______	16	__	______	26	__	______	36	__	______	46	__	______
7	__	______	17	__	______	27	__	______	37	__	______	47	__	______
8	__	______	18	__	______	28	__	______	38	__	______	48	__	______
9	__	______	19	__	______	29	__	______	39	__	______	49	__	______
10	__	______	20	__	______	30	__	______	40	__	______	50	__	______

APPENDIX C

PARAMETRIC INPUT AND OUTPUT VARIABLE LIST FOR ASEAM VERSION 2.1

Appendix C is a listing of the input variables that can be selected to be changed in a parametric simulation using ASEAM Version 2.1. Up to 20 of these input variables can be changed for parametric run. Also included in Appendix C is a listing of the output variables that can be selected to be determined using the parametric program. Again, up to 20 output variables can be selected for parametric run.

Parametric Input Variable List

Input Variable Number	Variable Type	Description of Variable	Notes Number	Entry Type	Remarks
1	Loads	Orientation Adjustment	1	N2	See Notes
2	Loads	Weather Data Type	2	N2	See Notes
3	Loads	Weather Data Filename	3	C	See Notes
4	Loads	Solar Data Filename	3	C	See Notes
5	Loads	Starting Hour for Occupancy	4	N2	(1 to 24)
6	Loads	Occupied Hours/Day	5	N2	See Notes
7	Loads	Summer Stat Start Month #		N2	(1 to 12)
8	Loads	Summer Stat Ending Month #		N2	(1 to 12)
9		NOT ASSIGNED			
10		NOT ASSIGNED			
11	Loads	Summer Stat Setpoint		N	(deg F)
12	Loads	Winter Stat Setpoint (OCC)		N	(deg F)
13	Loads	Winter Stat Setpoint (UNOCC)		N	(deg F)
14		NOT ASSIGNED			
15	Loads	Wall U-Factor		N	
16		NOT ASSIGNED			
17	Loads	Roof U-Factor		N	
18		NOT ASSIGNED			
19	Loads	Window U-Factor			
20	Loads	Window Shading Coef		N	(0 to 1)
21	Loads	Window Leak Coefficient		N	
22	Loads	Window Shading Model #		N2	(1,2,3)
23		NOT ASSIGNED			
24	Loads	Daylighting Glass Transmittance		N	(to 100)
25	Loads	Daylighting Wall Reflectance		N	(to 100)
26	Loads	Daylighting Present FC		N	
27	Loads	Daylighting Design FC		N	
28	Loads	Daylighting Sensor Location		N2	1
29	Loads	Daylighting Control Type		C	D or S
30		NOT ASSIGNED			
31		NOT ASSIGNED			
32	Loads	Daylighting Min FC Maintained	6	N	
33	Loads	Daylighting Min % Power at Min FC	6	N	(to 100)
34		NOT ASSIGNED			
35		NOT ASSIGNED			
36	Loads	Div Factor - People (OCC)	7	N	(to 100)
37	Loads	Div Factor - Lights 1 (OCC)	7	N	(to 100)
38	Loads	Div Factor - Lights 2 (OCC)	7	N	(to 100)
39	Loads	Div Factor - Lights 3 (OCC)	7	N	(to 100)

40	Loads	Div Factor - Lights 4 (OCC)	7	N	(to 100)
41	Loads	Div Factor - Equip 1 (OCC)	7	N	(to 100)
42	Loads	Div Factor - Equip 2 (OCC)	7	N	(to 100)
43	Loads	Div Factor - Misc Sens 1 (OCC)	7	N	(to 100)
44	Loads	Div Factor - Misc Sens 2 (OCC)	7	N	(to 100)
45	Loads	Div Factor - People (UNOCC)	7	N	(to 100)
46	Loads	Div Factor - Lights 1 (UNOCC)	7	N	(to 100)
47	Loads	Div Factor - Lights 2 (UNOCC)	7	N	(to 100)
48	Loads	Div Factor - Lights 3 (UNOCC)	7	N	(to 100)
49	Loads	Div Factor - Lights 4 (UNOCC)	7	N	(to 100)
50	Loads	Div Factor - Equip 1 (UNOCC)	7	N	(to 100)
51	Loads	Div Factor - Equip 2 (UNOCC)	7	N	(to 100)
52	Loads	Div Factor - Mist Sens 1 (UNDCC)	7	N	(to 100)
53	Loads	Div Factor - Mist Sens 2 (UNOCC)	7	N	(to 100)
54		NOT ASSIGNED			
55	Loads	Door U-Factor		N	
56	Loads	Door Leak Coef		N	
57		NOT ASSIGNED			
58	Loads	Occupied Air Change Rate	8	N	See Notes
59	Loads	Unoccupied Air Change Rate	8	N	See Notes
60		NOT ASSIGNED			
61	Loads	Misc Cond U-Factor			
62	Loads	Misc Cond Ref Temp at Des Sum		N	(deg F)
63	Loads	Misc Cond Ref Temp at Des Win		N	(deg F)
64		NOT ASSIGNED			
65	Loads	Lighting - Total Watts		N	
66	Loads	Lighting - Watts/ft2			
67	Loads	Lighting - Percent Heat to Space		N	(to 100)
68		NOT ASSIGNED			
69	Loads	Number of People		N	
70	Loads	Square Feet per person		N	
71		NOT ASSIGNED			
72	Loads	Misc Elect - Total Watts		N	
73	Loads	Misc Elect - Watts/ft2		N	
74		NOT ASSIGNED			
75	Loads	Misc Sensible - Total BTUH	9	N	
76	Loads	Misc Sensible - BTUH/ft2		N	
77		NOT ASSIGNED			
78	Loads	Ext Shading - Overhang depth	10	N	See Notes
79	Loads	Ext Shading - Recess depth	11	N	See Notes
80		NOT ASSIGNED			
81		NOT ASSIGNED			
82		NOT ASSIGNED			
83		NOT ASSIGNED			
84		NOT ASSIGNED			

85	Systems	TOA Heating Off		N	(deg F)
86	Systems	Maximum Heating Temp		N	(deg F)
87	Systems	Discriminator Control-HTG (DDMZ)	12	C	Y or N
88	Systems	TOA at Maximum Hot Deck Tern (DDMZ)		N	(deg F)
89	Systems	Maximum Hot Deck Temp (DDMZ)		N	(deg F)
90	Systems	TOA at Minimum Hot Deck Temp (DDMZ)		N	(deg F)
91	Systems	Minimum Hot Deck Temp (DDMZ)		N	(deg F)
92		NOT ASSIGNED			
93	Systems	TOA Cooling On		N	(deg F)
94	Systems	Minimum Supply Temp CLG	13	N	See Notes
95	Systems	Discriminator Control - Cooling	12	C	Y or N
96	Systems	Max Cooling Supply Temp (Disc)	14	N	(deg F)
97		NOT ASSIGNED			
98	Systems	TOA Preheat Off		N	(deg F)
99	Systems	Design Preheat Discharge Temp		N	(deg F)
100		NOT ASSIGNED			
101	Systems	TOA Humidification Off (OCC)		N	(deg F)
102	Systems	Winter Relative Humidity (%)		N	(to 100)
103		NOT ASSIGNED			
104	Systems	TOA Baseboard Off		N	(deg F)
105	Systems	Baseboard Control Method	15	N2	See Notes
106	Systems	Percent Load Satisfied - Des Win		N	(to 100)
107	Systems	Percent Load Satisfied - Min Load		N	(to 100)
108		NOT ASSIGNED			
109	Systems	Total Supply Fan KW	16	N	
110	Systems	Supply Fan KW/1000 CFM		N	
111	Systems	Supply Fan Heat		N	(deg F)
112	Systems	Total Return Fan KW	16	N	
113	Systems	Return Fan KW/1000 CFM		N	
114	Systems	Return Fan Heat		N	(deg F)
115	Systems	Minimum Percent Flow (VAV)		N	(to 100)
116	Systems	Fan Control Method (VAV)	17		
117	Systems	Fan Operating Method (OCC)	18		
118	Systems	Fan Operating Method (UNOCC)	19	N2	See Notes
119		NOT ASSIGNED			
120	Systems	Outside Air Control Method (OCC)	20	N2	See Notes
121	Systems	Min Percent Outside Air (OCC)		N	(to 100)
122	Systems	Dry Bulb Switchover Temp (OCC)		N	(deg F)
123	Systems	Outside Air Control Method (UNOCC)	20	N	See Notes
124	Systems	Min Percent Outside Air (UNOCC)		N	(to 100)
125	Systems	Dry Bulb Switchover Temp (UNOCC)		N	(deg F)
126		NOT ASSIGNED			
127		NOT ASSIGNED			
128	Systems	Furnace Capacity (KBTUH)	21	N	

129	Systems	Furnace % Load Satisfied (auto)	22	N	(to 100)
130	Systems	Furnace Efficiency (%)		N	(to 100)
131	Systems	Furnace Off Loss - % at Des Win		N	(to 100)
132	Systems	Furnace Off Loss - % at Min Load		N	(to 100)
133	Systems	Furnace Pilot Consumption (therms)		N	annual #
134		NOT ASSIGNED			
135		NOT ASSIGNED			
136	Systems	HP/WAC - % Total Load Satisfied	22	N	(to 100)
137	Systems	HP/WAC - % Sensible Load Satisfied	22	N	(to 100)
138	Systems	HP/WAC - COP Cooling		N	
139	Systems	WSHP - TOA at Min Fluid Temp		N	(deg F)
140	Systems	WSHP - Min Fluid Temp		N	(deg F)
141	Systems	WSHP - TOA at Max Fluid Temp		N	(deg F)
142	Systems	WSHP - Max Fluid Temp		N	(deg F)
143		NOT ASSIGNED			
144		NOT ASSIGNED			
145	Systems	HP - % Heating Load Satisfied	22	N	(to 100)
146	Systems	HP - TOA Heat Pump HTG Off (AAHP)		N	(deg F)
147	Systems	HP - % Load Satisfied - Backup HTG	22	N	(to 100)
148	Systems	HP - COP (Heating)		N	
149		NOT ASSIGNED			
150	Systems	Percent Design Air Flow (Central)	22	N	(to 100)
151	Systems	Percent Design Zonal Fan KW (Unit)	22	N	(to 100)
152		NOT ASSIGNED			
153	Systems	DX - % Total CLG Load Satisfied	22	N	(to 100)
154	Systems	DX - COP			
155	Systems	DX - Minimum Unloading Ratio		N	(to 100)
156	Systems	DX - Min Hot Gas Bypass Ratio		N	(to 100)
157	Systems	DX - Condenser Fan KW		N	
158	S W ;	DX - TOA Condenser Fan Off		N	(deg F)
159		DHW Capacity		N	(KBTUH)
160	Plant	DHW Occupied Cycle Average Usage		N	(Gal/Hr)
161	Plant	DHW Unoccupied Cycle Average Usage		N	(Gal/Hr)
162	Plant	DHW Efficiency (percent)		N	(to 100)
163	Plant	DHW Occupied Cycle Losses		N	(BTUH)
164	Plant	DHW Unoccupied Cycle Losses			(BTUH)
165	Plant	Chiller Cooling Capacity (tons)	24	N4	
166	Plant	Chiller % Max Load Satisfied	25	N	(to 100)
167	Plant	Chiller COP			
168	Plant	Chiller Unloading Ratio		N	(to 100)
169	Plant	Chiller Min Part Load Ratio		N	(to 100)
170	Plant	Chiller Unloading Ratio (Heating-DB)		N	(to 100)
171	Plant	Chiller Design Heat Ret Temp (DB)		N	(deg F)
172		NOT ASSIGNED			
173		NOT ASSIGNED			

174		NOT ASSIGNED		
175	Plant	Cooling Tower - % Load Satisfied	25	N (to 100)
176	Plant	Cooling Tower - Number Cells		N2
177	Plant	Cooling Tower - # Fan Speeds		N2
178		NOT ASSIGNED		
179		NOT ASSIGNED		
180	Plant	Boiler - Heat Capacity (KBTUH)	24	N
181	Plant	Boiler - % Heat Load Satisfied	25	N (to 100)
182	Plant	Boiler - Efficiency		N (to 100)
183	Plant	Boiler - Combustion Air Temp		N (deg F)
184	Plant	Boiler - Stack Temp		N (deg F)
185	Plant	Boiler - Air-Fuel Ratio		N
186	Plant	Boiler - Min Unloading Ratio		N (to 100)
187		NOT ASSIGNED		
188		NOT ASSIGNED		
189		NOT ASSIGNED		
190		NOT ASSIGNED		
191	Loads	Building Latitude		N (deg)
192	Loads	Building Longitude		N (deg)
193	Loads	Building Time Zone		
194	Loads	Daylight Savings Time		C (Y or N)
195		NOT ASSIGNED		
196		NOT ASSIGNED		
197	Loads	Loads Input Filename		C (Use F8)
198	Systems	Systems Input Filename		C (Use F8)
199	Plant	Plant Input Filename		C (Use F8)
200	LCC	LCC Input Filename		C (Use F8)

Notes:

Entry Type - 'N' represents a numeric input
'N2' represents a numeric input using the 'new value' method for changing
'C' represents a character input

There are no error checks for valid input values.

1 Orientation Adjustment - Enter a number from 1 to 7 that corresponds to the amount of clockwise rotation in increments of 45 degrees. For example, if you enter "2" (indicating a 90 degree rotation), all south orientations entered in the base input file will become west orientations for the calculations. If no rotation is desired, enter either 0 or 8.^T

2 Weather Data Type - Enter one of the following:
1- ASHRAE Bin Weather (filename extension - '.awd')
2 - Battelle Bin Weather (filename extension - '.bwd')
3 - DOD Bin Weather (filename extension - '.dwd')

3 Bin and Solar Weather Filenames - Enter the eight character weather file name. These data files must also be stored on your data disk. See also the notes on (2) above.

4 Starting Hour for Occupancy - Enter integer value from 1 to 24

5 Occupied Hours/Day - Enter one of the following - 8, 10, 12, 14, or 16. Any other entry is invalid.

6 Daylighting - Note that all THREE daylighting functions will be changed by this entry.
The sensor location should be one of the following:
1 - Max location (closest to window)
2 - Mid location
3 - Min location (farthest from window)

The daylighting control type should be entered as either 'D' for dimming or 'S' for stepped control. Note that capital letters should be used.

7 Diversity Factors - ALL zones diversity factors will be changed. This entry should be in percent (e.g. 70, not .7)

8 Infiltration Air Change Rate - Since the parametric processor changes all zones to this value, you may want to select the first method (multiply base value by percent) for changing this variable. By using this method, the interior zones (assuming no infiltration) would not be changed.

9 Miscellaneous Loads - the BTUH value is positive for heat gains and negative for heat losses.

10 Overhang depth - this entry is in inches. See notes on (11) below. ALL three exterior shading models will be changed.

11 Recess depth - this entry is in inches. This will change three base case entries simultaneously - the left, right, AND overhang depth.

12 Discriminator Control - The character entry should either be 'Y' or 'N'. Capital letters must be used.

13 Minimum Supply Temp - if you have selected 'autosizing' for the system air flow, changing this value may change the system sizing.

14 Maximum Cooling Supply Temp - used only if discriminator control is used in the cooling mode

15 Baseboard Control Method - enter one of the following
1 - Thermostatic Control
2 - Baseboard heating reset by outside air temperature

16 Fan KW - this entry has precedence over the 'KW/1000 CFM' entry

17 Fan Control Method (VAV) - use one of the following:
1 - Variable Speed
2 - Discharge Dampers

3 - Inlet Vanes

Any other entry is invalid.

18 Fan Operating Method (Occupied Cycle only) - this entry only applies to systems that are 'zonal' (systems that normally cycle day and night). This entry does not affect the central systems such as CVRH, DDMZ, VAV, HV, SZRH. Use one of the following:

1 - On Continuously
2 - Cycles with Load

19 Fan Operating Method (Unoccupied Cycle only) - this entry only applies to all systems. Use the 1 or 2 code described in note (18) above.

20 Outside Air Control Method - use one of the following codes:

1 - No Outside Air
2- Fixed Percent Outside Air
3 - Dry Bulb Economizer
4 - Enthalpy Economizer

21 Entered Capacity - this entry has precedence over the autosizing option.

22 Autosizing - only used if autosizing is selected

23 TOA Heat Pump Heating Off - for Air/Air Heat Pump Only. When the outside air temperature is below this value, backup heating is used.

24 Plant Capacity - enter value per unit (e.g. if two chillers or boilers are specified in the base file, entry the capacity of each chiller or boiler - not the combined capacity)

25 Plant Capacity (autosizing) - enter percent of,maximum load per unit (e.g.) if two chillers or boilers are specified in the base file, entrY the percent capacity of each chiller or boiler - not the combined capacity)

Parametric Output Variables

OUTPUT VARIABLE NUMBER	VARIABLE TYPE	DESCRIPTION VAR!:BLE	UNITS
1	Heating Energy	Electric Resistance	KWH
2	Heating Energy	Heat Pump	KWH
3	Heating Energy	Gas Boiler	therms
4	Heating Energy	Oil Boiler	gal
5	Heating Energy	Electric Boiler	KWH
6	Heating Energy	District Heating	MBTU
7	Heating Energy	Gas Furnace	therms
8	Heating Energy	Oil Furnace	gal
9	Heating Energy	Electric Furnace	KWH
10	Cooling Energy	Direct Expansion	KWH
11	Cooling Energy	Centrifugal Chiller	KWH
12	Cooling Energy	Absorption Chiller	KWH
13	Cooling Energy	District Cooling	MBTU
14	Cooling Energy	Double Bundle Chiller	KWH
15	Cooling Energy	Reciprocating Chiller	KWH
16	Cooling Energy	Window A/C Units	KWH
17	Cooling Energy	Heat Pump	KWH
18	DHW Energy	Domestic HW Heater	therms
19	DHW Energy	Domestic HW Heater	gal
20	DHW Energy	Domestic HW Heater	KWH
21	DHW Energy	Domestic HW Heater	MBTU
22	Building Misc.	Lights	KWH
23	Building Misc.	Equipment	KWH
24	Building Misc.	Miscellaneous	KWH
25	System Misc.	Fans	KWH
26	Not Assigned		
27	Plant Misc.	Cooling Tower	KWH
28	Plant Misc.	Pumping	KWH
29	Not Assigned		
30	Monthly Gas Consumption		therms
31	Monthly Oil Consumption		gal
32	Monthly Electric Consumption		KWH
33	Monthly District Heating Consumption		MBTU
34	Monthly District Cooling Consumption		MBTU
35	Peak Loads Report (See Note Below)		
36	Not Assigned		
37	Not Assigned		
38	Not Assigned		
39	Not Assigned		
40		Total Gas Consumption	therms

41		Total Oil Consumption	gal
42		Total Electrical Cons	KWH
43		Total District Heating	MBTU
44		Total District Cooling	MBTU
45	Not Assigned		
46	Not Assigned		
47	Not Assigned		
48	Not Assigned		
	Not Assigned		
50		Total Energy Cost	
51	Not Assigned		
52	Not Assigned		
53	Not Assigned		
	Not Assigned		
54		Total Site Energy	MBTU
56	Not Assigned		
57	Not Assigned		
58	Not Assigned		
	Not Assigned		
59		Total Source Energy	MBTU

NOTE - Output variable numbers 30 to 35 are used to store monthly consumption and zone peak loads analysis. An separate output file for these results is generated at the end of the calculations. This file can be imported into LOTUS with the template.