185

Subcontractor Report

**Development of a Methodology
for Defining Whole-Building Energy
Design Targets for Commercial
Buildings**

**Phase 2, Development
Concept Stage Report**

**Volume 2: Technical Concept
Development Task Reports**

September 1990

**Prepared by the American Society of Heating,
Refrigerating, and Air-Conditioning Engineers, Inc.,
for Pacific Northwest Laboratory
under Contract DE-AC06-76RLO 1830
with the U.S. Department of Energy**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

NTIS Price Codes, Microfiche A01

Printed Copy

Price Code	Page Range	Price Code	Page Range
A02	1- 10	A15	326-350
A03	11- 50	A16	351-375
A04	51- 75	A17	376-400
A05	76-100	A18	401-425
A06	101-125	A19	426-450
A07	126-150	A20	451-475
A08	151-175	A21	476-500
A09	176-200	A22	501-525
A10	201-225	A23	526-550
A11	226-250	A24	551-575
A12	251-275	A25	576-600
A13	276-300	A99	601-Up
A14	301-325		

**Development of a Methodology for
Defining Whole-Building Energy
Design Targets for Commercial
Buildings**

**Phase 2, Development
Concept Stage Report**

**Volume 2: Technical Concept Development
Task Reports**

**H. N. McKay^(a)
J. J. Deringer^(b)
J. W. Jones^(c)
J. D. Hall^(d)**

September 1990

**Prepared by the American Society of Heating,
Refrigerating, and Air-Conditioning Engineers, Inc.,
for Pacific Northwest Laboratory
under Contract DE-AC06-76RLO 1830
with the U.S. Department of Energy
under Agreement 007099**

**Pacific Northwest Laboratory
Richland, Washington 99352**

-
- (a) Illuminating Engineering Society of North America
(b) American Institute of Architects
(c) American Society of Heating, Refrigerating, and
Air-Conditioning Engineers, Inc.
(d) The Deringer Group, Riva, Maryland**

Project Perspective

The potential advantages of performance-based commercial building design guidelines have been recognized for some time. However, buildings industry acceptance of such performance guidelines has been slow, largely because of concern over the equity of the proposed procedures and the difficulty of applying them to design practice. The buildings industry currently needs a well-defined, easy-to-use methodology for setting performance guidelines.

To hasten industry acceptance and, ultimately, realization of the energy conservation benefits, the U.S. Department of Energy (DOE) Office of Building Technologies (formerly the Office of Buildings and Community Systems) asked the Pacific Northwest Laboratory (PNL) to develop performance-based guidelines for assessing energy efficiency in commercial building design. These guidelines, termed whole-building energy targets, would be indices or yardsticks with which to measure the annual energy performance of an entire building rather than of individual building components or subsystems.

In 1985, the Whole-Building Energy Design Targets project began as part of the Building System Integration Program (BSIP) managed by PNL for DOE. The BSIP comprises a number of research projects dealing with issues of whole-building energy use and systems integration.

The primary focus of the Targets project is to develop a flexible methodology for setting performance guidelines and for determining compliance with these guidelines. Because the problem is complex, computer software will be developed to implement the methodology. The software is referred to as the Targets model.

The Targets project is a two-phase effort. In Phase 1, Planning, the project team--design professionals from various segments of the industry--was assembled to determine the research necessary for developing the Targets methodology. In the concept stage of Phase 2, Development, the project team sought to define the technical and software development concepts upon which the overall Targets methodology will be based. The concept stage work is documented in four volumes, of which this is the second. The other three volumes are

- Volume 1: Summary Report
- Volume 3: Workshop Summaries
- Volume 4: Software Concept Development Task Reports.

The work described in this volume was performed for PNL during the period from late 1987 through early 1989 by project team members representing the American Institute of Architects, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., and the Illuminating Engineering Society of North America. A draft of the final report on the subcontracted activities was submitted to PNL and DOE in February 1989. This volume of the report describes technical development tasks to define the detailed structure for each element or module of the Targets model. The issues considered, results obtained, and conclusions reached while developing the conceptual designs for eight Targets modules are presented.

Contents

Project Perspective	iii
1.0 Introduction	1.1
1.1 Report Organization	1.1
1.2 Context: Targets Applications and Modes of Use	1.3
1.2.1 Voluntary Targets Application	1.3
1.2.2 Standards and Codes Application	1.6
2.0 Input Module	2.1
2.1 Task Objectives and Approach	2.1
2.2 Results	2.1
2.2.1 Taxonomy	2.3
2.2.2 Exhibits to Support the Taxonomy	2.4
2.2.3 Basic Input Linkages Between the Sample Taxonomy Input Sets and the Supporting Exhibits	2.5
2.2.4 Sample Test Application of the Taxonomy and Exhibits	2.5
2.2.5 Minimum Inputs Required	2.6
2.2.6 Consensus Databases and Default Data	2.7
2.2.7 Quality Considerations	2.7
2.3 Major Remaining Issues for Input Module	2.8
2.3.1 Quality-Related Issues	2.8
2.3.2 Maximum Allowable Inputs	2.8
2.3.3 Minimum Allowable Inputs	2.9
3.0 Characteristics Development Module	3.1
3.1 Task Objective and Approach	3.1
3.2 Results	3.1
3.2.1 Definition of "Characteristics"	3.3

3.2.2	Technologies/Design Strategies List	3.3
3.2.3	Technologies/Design Strategies Triggers	3.4
3.2.4	Components of the Characteristics Development Module	3.4
3.3	Major Issues Remaining for Input Module	3.5
3.3.1	Quality-Related Issues	3.5
3.3.2	Priority Energy Issues	3.6
4.0	Analysis Control Module	4.1
4.1	Task Objectives	4.1
4.2	Results	4.1
4.2.1	Basic Requirements	4.1
4.2.2	Analysis Control Capabilities	4.3
5.0	Search Routine Module	5.1
5.1	Task Objectives	5.1
5.1.1	Background	5.1
5.1.2	Context - A Description of the Problem	5.3
5.1.3	Likely Objectives of a Search	5.3
5.1.4	Proposed Four Steps in a Targets Search Process	5.4
5.1.5	An Example Using the Proposed Four Steps: Fenestration Effective Aperture	5.5
5.1.6	A Second Example Using the Four Search Steps: HVAC and Lighting Systems	5.9
5.1.7	History of the Use of Search Routines in Building Energy Analysis	5.10
5.2	Results	5.11
5.2.1	Problem Definition	5.11
5.2.2	Evaluation Criteria for Choosing Alternatives	5.12
5.2.3	Alternative Approaches	5.14
5.2.4	Preliminary Assessment of Options	5.18

5.2.5	Assessment of Alternative Methods and Data Sources Within the Proposed Four-Step Process	5.18
5.3	Discussion	5.23
5.3.1	Objective of Searches--Points or Ranges?	5.23
5.3.2	Disaggregation and Reaggregation	5.23
5.3.3	Annual Energy/Energy Cost	5.25
5.3.4	Impact of the Design Strategies Considered on the Targets Obtained	5.25
5.3.5	Provision for Technological Change	5.26
5.3.6	Combinatorial Nature of the Search Problems	5.27
5.3.7	Selection of Data Source for Search Routines	5.27
6.0	Energy Simulation Module	6.1
6.1	Approach	6.1
6.1.1	Module Requirements Definition	6.1
6.1.2	Energy Simulation Module Review	6.5
6.2	Results	6.7
6.2.1	Energy Simulation Module Criteria	6.7
6.2.2	Other Recommendations	6.10
6.2.3	The Selected Energy Model	6.10
7.0	Building Cost Module	7.1
7.1	Approach	7.1
7.2	Tasks Completed	7.3
7.2.1	Conceptual Approach Formulation	7.3
7.2.2	Experts Meeting and Feedback	7.3
7.2.3	Subsequent Development of Approach	7.3
7.3	Results	7.3
7.3.1	Building Cost Module Criteria	7.4
7.3.2	Building Cost Module Applications	7.5

7.3.3 Existing Building Cost Models	7.5
7.3.4 Proposed Conceptual Structure for the Building Cost Module	7.9
7.3.5 Building Cost Module Taxonomy	7.14
7.3.6 Example Templates	7.16
7.4 Issues, Conclusions, and Recommendations	7.20
7.4.1 Need for Building Cost Module	7.20
7.4.2 Breadth of Building Cost Analysis Needed	7.21
7.4.3 Sources of Cost Data, Rules, and Equations	7.22
7.4.4 Updating of Costs	7.23
7.4.5 Level of Effort	7.23
8.0 Energy Cost Module	8.1
8.1 Tasks Accomplished	8.1
8.2 Results	8.1
8.2.1 Basic Requirements List	8.1
8.2.2 Energy Cost Module Selection	8.3
8.3 Issues, Conclusions, and Recommendations	8.3
9.0 Economic Analysis Module	9.1
9.1 Approach	9.1
9.2 Results	9.1
9.2.1 Basic Requirements for the Economic Analysis Module	9.3
9.2.2 Possible Owner Economic Objectives	9.3
9.2.3 Economic Indicators	9.5
9.2.4 Owner Economic Perspectives and Parameters	9.7
9.3 Issues, Conclusions, and Recommendations	9.8
9.3.1 Economic Objectives	9.8
9.3.2 Equity Issues Across Climate Regions and Building Functional Uses	9.8

10.0	References	10.1
11.0	Acknowledgments	11.1
	Appendix A - Building Characteristic Set Taxonomy	A.1
	Appendix B - Supporting Exhibits	B.1
	Appendix C - Basic Input Linkages/Sample Taxonomy Input Sets	C.1
	Appendix D - Sample Test Application of the Taxonomy and Exhibits	D.1
	Appendix E - Technologies/Design Strategies List and Triggers	E.1
	Appendix F - Priority Energy	F.1
	Appendix G - Search Variables, Ranges, Constraints, and Disaggregation	G.1
	Appendix H - Proposed Optimization Approach Based on Response-Surface Methods	H.1
	Appendix I - Issues Related to Execution Time	I.1

Figures

1.1	Interrelationship of Modules Within the Targets Model	1.2
2.1	Input Module Location Within the Targets Model	2.2
3.1	Characteristics Development Module Location Within the Targets Model	3.2
4.1	Analysis Control Module Location Within the Targets Model	4.2
5.1	Search Routine Module Location Within the Targets Model	5.2
5.2	Annual Energy Results from DOE-2 Runs	5.6
6.1	Energy Simulation Module Location Within the Targets Model	6.2
7.1	Building Cost Module Location Within the Targets Model	7.2
7.2	Proposed Generalized Template Structure for the Building Cost Module	7.10
7.3	The Five Primary Elements of the Proposed Template Concept	7.11
7.4	Hierarchical Nesting of Data Using the Proposed Template Structure	7.13
7.5	Automatic Updating of Cost Data Using an Inheritance Capability	7.15
7.6	Cost Database for the Lighting Templates	7.17
7.7	Sample Template for the Lighting Example	7.20
8.1	Energy Cost Module Location Within the Targets Model	8.2
9.1	Economic Analysis Module Location Within the Targets Model	9.2

Tables

4.1	Analysis Control Module Requirements and Capabilities	4.3
5.1	Assessment of Alternative Approaches	5.19
5.2	Assessment of Alternative Data Sources	5.20
7.1	Decision Matrix for Possible Approaches for the Building Cost Module	7.8
9.1	Data Requirements for Alternative Economic Objectives	9.6

1.0 Introduction

This report documents eight tasks performed as part of the Whole-Building Energy Design Targets project, in which detailed conceptual approaches were produced for each element of the proposed Targets model. The eight task reports together describe the important modules proposed for inclusion in the Targets model:

- input module
- energy module
- characteristics development module
- building cost module
- analysis control module
- energy cost module
- search routines module
- economic analysis module.

The interrelationship of these modules is shown in Figure 1.1.

1.1 Report Organization

The task report in Section 2 describes the input module, which processes data supplied to the Targets model via the user interface to ensure that sufficient and appropriate data is provided for analysis. This task report describes the conceptual work accomplished to define data requirements and structures. The building physical characteristics data requirements are also described in detail in Section 2.

Section 3, characteristics development, describes activities required to convert the input data and defaults into formats appropriate for the various analysis modules. Thus, the characteristics development module operates on data after the initial checking of data inputs and defaults are completed.

In Section 4, the analysis control module is described. This module performs a master control function over the analysis portions of the Targets model by directing the execution of the modules for energy simulation, energy cost, building cost, and economic analysis. In some modes of operation, the output from these analysis modules will be interpreted by the analysis control module and used to define additional analyses that need to be performed.

The task report in Section 5 describes the search routine module. This module will iteratively evaluate alternative combinations of a building's physical and cost characteristics for appropriateness as design solutions for cost-effective custom building designs.

The energy simulation module is discussed in Section 6, which documents the efforts undertaken to identify an appropriate energy simulation tool. The approach is described, as are the results. This section concludes with a summary of specific energy simulation issues and recommendations.

The task report in Section 7 describes the building cost module. Using comparative building cost data, the building cost module would allow Targets users to make economic comparisons among alternative energy design strategies. The development of the building cost module for the Targets model is also detailed in this section.

Figure 1.1. Interrelationship of Modules Within the Targets Model

In Section 8, the energy cost module to be used within the Targets model is described. Based upon the energy design strategies selected, the energy cost module will identify the relative changes in building energy costs. This module will provide outputs that, in conjunction with outputs from the building cost and energy modules, will produce inputs to the economic analysis module routines of the Targets model.

In Section 9, several aspects of a proposed structure for the economic analysis performed within the Targets model are addressed. The economic analysis module will have a central role in assessing cost-effectiveness. Outputs from the energy, energy cost, and building cost modules will be used as inputs to the economic analyses to derive estimates of economic benefits containing alternative building design solutions.

The references cited in this report are listed in Section 10. Detailed supporting information is contained in Appendixes A through I of this volume.

1.2 Context: Targets Applications and Modes of Use

This volume describes tasks that develop data sets to be used by the Targets model, in terms of level of detail, organization, and format. Also described are analysis procedures to test and analyze sets of data so generated. To understand the rationale for the results obtained, it is important to place both the data and the analysis procedures within the context of how the Targets model will be used in different situations.

The authors envision two main applications for the Targets model: a voluntary targets application and a standards and codes application. Within each type of application, the same two modes of use are envisioned: target setting and design analysis/evaluation. However, the operation of the modes of use differ, depending upon the application.

The type of user input data will differ, depending on the mode of operation, i.e., target setting or design analysis/evaluation. Both these modes will be necessary whether the application is used on voluntary guidelines, the development of consensus standards and codes, or on a variety of research uses. It should be noted here that the discussions in Sections 2 through 9 are based on the application of voluntary guidelines, not on consensus standards or codes. The latter applications, while taken into consideration, are outside the scope of this project.

The level of detail or degree of accuracy of the input data will depend on the building project's position in the design process. It is planned that an extensive library and network of defaults will enable the user to use the methodology even at the earliest stages of design, i.e., during the architectural programming phase. There will be a minimum amount of input required to use the methodology, corresponding to a theoretical point at which a building description ceases to be that of a typical building and becomes that of a specific building, appropriate for establishing customized targets.

The two modes of operation of the Targets model relate to the results contained in this volume as follows.

1.2.1 Voluntary Targets Application

For this application, the target setting and design analysis/evaluation modes of use have a number of distinct features. These are described in the following paragraphs.

Target Setting (for Voluntary Targets)

The target setting mode of use establishes building-specific energy performance targets. This may be done in the early stages, based on programming input. It need only be repeated later in the design process if the program changes, or the space functions and their proportions change, or if the physical geometry of the project changes.

Data regarding these aspects need only be entered into the model or modified once, in either mode, in order to be available in the alternate mode.

It is estimated that the target setting mode might be used an average of three times or more during the design process (although there is no limit on its use). This would include the initial target, set during programming or early schematics, an intermediate target, revised when the physical details are more accurately established, and a final target, using the final space function and geometrical factors, and using the most accurate and sophisticated forms of the search routines and energy analysis model.

It is suggested that users would not be able to describe all features of their proposed design in the target setting mode, even in the intended application of voluntary guidelines. To do so would result in a target that is essentially the same as the design and, hence, not really a target in the intended sense. If the targets are to represent energy conserving goals, then it is expected that certain assumptions about materials, systems, and strategies would be made to apply to all, or a group of users employing the model.

It is not the responsibility of the Targets project to determine exactly which factors ultimately will or will not be constrained during the target setting mode. It is just assumed that some will be, and the consensus databases that will be initially provided for this project will form the initial defaults for such constraints.

In this mode of operation, the analysis control module will call on the search routine module to compare sets of characteristics. By comparative search, the search module will seek the objective function, to determine the most cost-effective level of energy efficiency that is reasonable given the specific climatic factors, energy prices, and programmatic needs of the building. In the target setting mode, the search techniques will need to make selections of cost-effective energy-related strategies and components. The procedure will select from a collection of energy-related features that are known to perform well and are accepted by the buildings industry.

Design Analysis/ Evaluation (for Voluntary Targets)

Design analysis/evaluation is the mode of use for interactive and iterative testing and fine-tuning of specific design projects. A consistent methodology must exist to enable the user to show compliance with the targets established in the target setting mode. The capabilities within the proposed design analysis mode will not only reach and educate a whole new group of users, but will also introduce and encourage the use of both standard and innovative energy strategies and technologies with which most users have previously been too unfamiliar to consider.

During initial input, users can choose to use the defaults in the consensus (and other) databases, or provide their own specific data. Then, the design may be refined as more parameters are determined. This mode is intended to be the most interactive and educational, with a variety of user messages or suggested defaults indicating the most appropriate options for improving building performance either to the target level or better.

Most of the data linkages described in this volume would come into play during this mode. The catalogues of energy-related technologies and design strategies (TDS) described in Section 3 will be available to the user during this mode, as well as appropriate costing information for evaluating the economic impact of modeled options.

In the design analysis/evaluation mode of operation, the Targets model may be used in a variety of different ways to assist in improving the performance of building designs in order to meet the target values established for that building. These will include performing "what-if" analyses with architectural, lighting, and heating, ventilating, and air conditioning (HVAC) alternatives.

For example, the user may be interested in comparing two different design alternatives or examining the impact of changes in a specific design parameter over a range of possible values. Or, the user may be interested in harnessing the search capabilities in the model to find the most economically advantageous choices for one or more specific building options. Where these options have important design or qualitative impacts, the user might choose, for example, to generate a matrix of selectively optimized solutions to explore how trade-offs between energy performance and other design objectives can best be managed.

The user can, depending on the stage in the design process, test hypotheses regarding a number of options. For example, the user can repeatedly evaluate different fenestration systems, keeping everything else constant, or select a particular fenestration system, and optimize other factors. Costing parameters can be analyzed for a variety of scenarios, or the maximum first cost can be fixed while other factors vary.

The Targets model must be capable of assuming a wide range of innovative technologies in the design analysis/evaluation mode of use. Since this mode will be used interactively, it is the basis for the speed of execution issues found throughout this report. This mode is not only the most educational mode, but also has the capability to be the most effective mode for accomplishing the energy-conserving goals of the entire project.

To be used effectively for design purposes, the Targets model will require great flexibility in terms of the range of strategies and components that can be addressed. Ideally, the model would be capable of dealing with any design option whose energy performance can be modeled. This would give users the broadest possible capability to address the specific needs of the building program and to experiment with innovative energy solutions. While a wider range of options will need to be dealt with in the design analysis mode than in the target setting mode, use of the search routines during design uses will probably involve fewer variables at any one time. This expectation is based on the assumption that a preliminary design, with many design elements already defined, will typically exist prior to the use of the methodology for design analysis.

The level of detail and ease of use issues are paramount to the success of this mode of use. It is expected that the user will use the design analysis/evaluation mode throughout the design process, singularly to evaluate a total design and repeatedly to test and develop aspects of the design. Options will be available to the user to select quick and approximate, or robust and accurate, evaluation techniques throughout the design process, depending on the level of input available or the level of output desired. Output will include a demonstration of the relationship of each design to the latest target established in the target setting mode, so the user is always informed how well the design meets, or improves upon the target.

During the final design phases of a project, the user will need to analyze the final design and, probably, to generate a final target reflecting any programmatic changes that may have occurred during the course of design. This may involve more rigorous search routines, more detailed energy simulation options, and more sophisticated costing methods.

1.2.2 Standards and Codes Application

This application is expected to be used somewhat by researchers, but primarily by developers of customized versions of the Targets model. Examples of the latter would include teams responsible for developing company or society guidelines, consensus standards, or mandatory regulations. For this application, the target setting and design analysis/evaluation modes of use have different features from their use in the voluntary targets application. These are described below.

Target Setting (for Standards and Codes)

This mode will be used for periodic checking during the standard or code development process. An important issue will be the maximum input allowed. In the final version, the "minimum inputs required" described in Section 2 might well be similar to the "maximum inputs allowed" during target setting for some circumstances, such as mandatory federal standards.

When the application of the two modes is for the development of consensus standards, institutional policy, mandatory codes, or energy research, the user may be interested in assessing the results from the Targets model over a range of buildings, locations, or economic scenarios. In addition, the model can be used in creative ways to assist in the development of voluntary consensus standards. These uses may require that even greater flexibility be designed into the model than would be required for design-oriented use. For example, in a voluntary consensus standards development process, issues of "equity" and "reasonableness" are critical. These issues will likely cause the Targets model to be exercised over a wide range of conditions.^(a)

The user may also be interested in assessing the performance of the Targets model itself. In addition, given the complexity of the model and the importance of verifying its validity, it may be necessary to include features in the model specifically for this purpose. An example of such a feature might be one or more search procedures that, while slow to execute, are extremely robust in the breadth and accuracy of the alternatives examined.

Design Analysis/ Evaluation (for Standards and Codes)

This mode requires both a high degree of input flexibility and considerable internal control of the various paths through the Targets model. This mode is closely related to the design analysis/evaluation mode in the voluntary targets application in its need for a wide range of specificity and detail. Innovative techniques and technologies must be tested as part of a standard or code development process, and it must be easy to establish sets of typical tests and parametric analyses.

The use of historic data generated by the project team in this mode can be used to form the basis of energy response libraries or models, or typical defaults used in later versions of the model. This mode should be highly interactive, although the execution times ultimately expected for use by building designers might not need to be available during this particular project's research and testing stages.

This mode should be as modular as all other modes, to allow incremental testing of components of the Targets model, along with components temporarily borrowed from other models. The final version of this mode will provide the "compliance" methodology necessary to meet the corresponding target limits.

(a) This is precisely what has occurred during the course of the consensus development process for ASHRAE/IES Standard 90.1-1989 for the envelope methodology, developed previously within the ASHRAE SP41 research effort. The consensus process examinations resulted in several important revisions and refinements to the original envelope methodology.

2.0 Input Module

The input module processes data supplied to the Targets model by the user interface to ensure that sufficient and appropriate data is provided for analysis. The location of the input module within the overall Targets model is shaded in Figure 2.1.

2.1 Task Objectives and Approach

The primary objective of the work on the input module during the concept stage was to develop a viable framework or conceptual classification system that would organize the data used throughout the Targets model. To do this, the input data and default data requirements for the analysis control module had to be identified and structured. The input module development task concentrated on producing a taxonomy that structures the data requirements related to the physical characteristics of buildings.

A second important objective was to define an adequate way of dealing with qualitative issues relating to design that are frequently difficult to quantify.

2.2 Results

Six tasks were accomplished:

- developed taxonomy - A building characteristics set taxonomy was defined and related to the building cost and user interface taxonomies as documented in this volume. The three taxonomies interrelate; they are referred to collectively as the Targets taxonomy.
- compiled/originated input formats - Considerable background data, including input structures of DOE-2.1C (Building Energy Simulation Group 1985), ASEAM 2 (American Consulting Engineers Council Research & Management Foundation 1987), and other sources, were compiled. In addition, input forms and data structures were originated.
- established basic input linkages - A first pass was made to identify interactions between various aspects of the Targets taxonomy, especially those related to the levels in the taxonomy hierarchy.
- defined minimum input - A first pass was made to determine the required minimum level of input for the Targets model.
- established approach to quality issues - A first pass was made to incorporate the quality issues into the data sets and analysis procedures currently being developed.
- established a development stage workplan - A workplan was established for future activities related to the input module. This included further developments of the Targets taxonomy and input formats. It was determined that extensive use of case-study buildings, both actual and theoretical, will supplement the development.

Figure 2.1. Input Module Location Within the Targets Model

2.2.1 Taxonomy

The complete building characteristics set taxonomy and supporting information is contained in Appendixes A through D. This section contains an overview of the taxonomy details that can be found in the following appendixes:

- Building Characteristics Set Taxonomy (Appendix A)
- Supporting Exhibits (Appendix B)
- Basic Input Linkages/Sample Taxonomy Input Sets (Appendix C)
- Sample Test Application of the Taxonomy and Exhibits (Appendix D).

Summaries of the information in each of the appendixes is provided below. Other aspects of the overall Targets taxonomy are discussed in this volume as well.

The building characteristics set taxonomy represents the central document around which the characteristic set development has been organized. The taxonomy is a list of the key elements involved in defining a building for energy performance evaluation. In this sense, it is similar to the variety of input forms that have been developed for building energy design tools. It differs in that the order and nature of the presentation conceptually supports the process through which the Targets methodology might be used.

The building characteristics set taxonomy has been developed to only a certain level of detail, consistent with a conceptual stage of development. The supporting exhibits included in Appendix B provide a further level of detail beyond the current level of the taxonomy. These exhibits contain examples of the kind of detail that would exist within the Targets model, either as default or input screens, or as libraries from which the user can choose specific systems. A brief description of key attributes of the taxonomy and its supporting exhibits follows.

Organizational Units: Levels of Hierarchy

Like the other portions of the overall Targets taxonomy, the building characteristics set taxonomy has a hierarchical structure. Building usage has been a major factor in forming the structure. The approach to structuring building data relative to building usage is described below.

Space Functions: The Primary Level of Analysis. The primary level at which the Targets model addresses a building is at the space function level. Space functions can be described as either predominantly thermal or predominantly lighting in terms of inputs to the Targets model. In the functioning of the model, groups of space functions may be aggregated to describe an entire building. Each space function description is defined to a considerable degree of specificity, based on reasonable assumptions and input information required to provide the energy portion of a valid custom energy (or energy cost) target.

A potential path for the Targets model is to develop the characteristics first at the space function level, and then to aggregate the results. A thermal function focuses on the characteristics traditionally addressed in thermal energy and peak load analyses, while a lighting function may include details finer than would be indicated by interior partitioning, such as an individual visual task.

Building Categories, Types, and Subtypes. The Category-Type-Subtype hierarchy carries information at a whole-building level. This hierarchy permits identification of many different types of building configurations, costs, schedules, and thermal zoning layouts, as the building is being addressed by the Targets model. Selections made at this level, however, are to facilitate the interface of the model with the user and to speed up interaction. The selections of category, type, or subtype do not constitute sufficient

or even necessary information for generating the custom targets, which are based, for the most part, on decisions made at the space function level. Category, type, and subtype describe characteristics at a building level, while the thermal and lighting functions break the building down into space functions, which may then be combined into zones, floors, facades, or buildings. A sample list of building category, type, and subtype designations is shown as Exhibit L in Appendix B.

Building Project Descriptors

Within the overall structure provided by the space function hierarchy, the building characteristics taxonomy contains a number of nested levels of data detail. These are described below and listed in Appendix A.

Basic Project Information. This part of the taxonomy includes basic project information, such as project name, location, and economic parameters. Much of the basic project information referencing other portions of the Targets methodology is discussed in some detail in other task reports.

Basic Characteristics. This part of the taxonomy covers the basic characteristics of the envelope and interior subdivisions. Much of this information is easily entered graphically, especially building size, shape, height, and partitioning.

Functional Parameters. This part of the taxonomy describes nonphysical aspects of building operation and use, specifically the nature and scheduling of occupants and loads that are not systems-related, such as occupant density or level of activity (load) per person.

Comfort Criteria. These are organized initially on the basis of space functions, but may be adjusted to a zonal, building, or project average to represent a "characteristic" to be selected for analysis or optimization.

Building Systems. This part of the taxonomy includes all major systems, including the building envelope system. This grouping implies that the building envelope and interior subdivisions should be viewed as a system and forces the Targets user to use a consistent approach for all of these systems.

2.2.2 Exhibits to Support the Taxonomy

As mentioned earlier, the exhibits provide an additional level of detail beyond the current level of development of the taxonomy itself. The exhibits are provided in Appendix B, and each exhibit is referenced within the taxonomy listed in Appendix A.

The exhibits contain the following types of support materials:

- input forms showing typical sets of data that might be required under each taxonomy section
- criteria forms listing basic criteria issues that can be used to develop weighing systems that would allow system selection to be based on key design issues
- lists of items representing a range of possible inputs
- sample input libraries.

The exhibit material was extracted liberally from the DOE-2 and ASEAM 2 manuals (Building Energy Simulation Group 1985; American Consulting Engineers Council Research & Management Foundation 1987), the ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989), and other sources. These represent some of the most credible attempts to address quantitative values for building features related to good energy-conscious design practice.

These are features that the Targets methodology will need to encompass and are therefore a good starting point for examining the ultimate scope of development of the taxonomy. These exhibits represent a resource for the future development of an expanded taxonomy.

The criteria lists, divided into application, economic, and sometimes comfort categories, are an initial attempt to standardize a process through which the Targets methodology can provide an educational resource to a building designer. If criteria can be assigned a relative weight, especially based on specific project information already entered, system recommendations could consist of specific responses to that weighting pattern.

2.2.3 Basic Input Linkages Between the Sample Taxonomy Input Sets and the Supporting Exhibits

In Appendix C, linkages are drawn to show basic connections within the sample taxonomy input sets and the supporting exhibits. These are based on relationships that will allow the Targets model to respond to inputs as they are entered, based on previous inputs or default values. At the simplest level, inputs that do not meet good practice would be noted. Mid-level interactive relationships might analyze orientation, shading coefficient, window dimensions, and climate to determine if user inputs create an energy-efficient combination or not. Later, in the characteristics development module, higher-level linkages would bring energy-related technologies and design strategies (TDS) into play, to reveal inconsistencies or to recommend specific design options.

Appendix C also contains example listings of the building characteristics set taxonomy and supporting exhibits, highlighted for each of the modes of use of the Targets model. Each set shows the input values or sets of values appropriate for defining the user's building at that mode of use.

2.2.4 Sample Test Application of the Taxonomy and Exhibits

An energy analysis project from one of the project participants was selected to exemplify a level of detail typically used in design practice to analyze an energy-efficient design. In the example (Appendix D), the values were used to define a typical office building base case for modeling, using a mainframe in-house program based on ASHRAE algorithms. The fact that this input set leaves a significant number of empty input spaces is important.

The Targets methodology is intended to be developed with an integral energy simulation tool and, using a neutral file structure, would provide access and the potential for "hooks" to other detailed energy simulation tools. Given this approach, the Targets model will have an internal level of detail beyond that needed for most design projects. The detail is needed to permit customization under a wide range of situations. However, the extensive detail provided within the model need not surface for most users. This implies computational rigor as well as default input sets that can consider project-specific information for a wide range of projects.

The results of this test application support the intent to allow the Targets methodology to be applicable to a wide range of custom building design situations. The challenge will be to create a manifestation of the integral energy simulation tool (and other analysis tools) which a typical practitioner feels comfortable using during design. In some sense, the Targets model could be perceived as both a "pre-processor" and a

"post-processor" to the integral energy simulation tool (or other energy simulation tool) that is much more user-friendly than what is now available. This sample input set shows areas of discrepancy between complete, detailed input, and what is required for routine design practice energy analysis on a single building.

2.2.5 Minimum Inputs Required

The Targets methodology is based on the concept that the energy characteristics of every building are unique, depending not only on the exterior construction but also on the interior configuration, as well as the priorities of the owner and design team. It was considered to be a misuse of the methodology if certain types of integral assumptions would allow a target to be generated for a "typical" building, without the characteristics of that building selected or assumed, to some degree, by the user. An initial definition of the minimum input required is introduced here.

Suggested Set of Minimum Inputs

At the very least, the user must describe or make assumptions about the items listed below to generate a target (during the target setting mode) or analyze a design (during the design analysis mode). Note that more input, if known, may be entered, but any less input ceases to describe an actual, specific building program or design.

Location. Location is necessary to determine modifiers for energy costs (if actual local costs are unknown by the user) and for local adjustments of building costs. The nearest major U.S. city selected from climate maps is required for climate defaults.

Orientation. For solar, daylighting, and thermal defaults, "Assumed-North" is selected by the user, unless a more specific orientation is known.

Exterior Form. The number of floors and the simplest building shape are selected from typical shapes. Gross dimensions or gross square footage are entered, unless more detailed physical shape characteristics can be described. (This is most easily entered in graphic form at any level of detail).

Space Functions and Interior Geometry. This can be entered initially as programming information, either as text or graphics, as the user wishes. For example, 200,000 ft² (or a graphically highlighted area) is designated as an enclosed office (selected from a list of space-functions), with an average size of 150 ft² (or 10 ft x 15 ft), and a ceiling height of 8 ft 6 in. Alternatively, having specified the area for the entire project, the user can specify 35% of the enclosed office with 20% of it designated as an "open plan with high partitions," 10% designated for conference rooms, 10% designated for corridors, and so on. Again, average room size and ceiling height would also have to be assumed by the user for each space function, with default options offered for assistance. If more information is available during initial input, the user can graphically establish the actual location of the various space functions, and choose the floor, interior or exterior wall, the facade, and the actual floor plan arrangement of partitions.

Schedules. Building-wide occupancy schedules must be selected from the default library and modified if necessary to suit actual hours of occupancy.

Envelope. The basic construction type and materials must be selected from default assumptions or specified in detail from Targets technology catalogues.

Fenestration. The minimum window/wall ratio is selected from default assumptions for the entire building or for each facade and/or the roof.

2.2.6 Consensus Databases and Default Data

The Targets model is dependent on a large system of databases and defaults that serve a variety of functions. For example, "objective" databases related to climate, weather, and solar data are necessary for the operation of the energy analysis module, and are a convenience to the user.

Likewise, databases related to comfort and function of visual and thermal environment, typically based on space functions, are necessary to create a consistent level of energy-conserving constraints between buildings and to protect the quality of the environment for the occupants when setting targets. The information in these databases will be a combination of first principles and the consensus of professional judgment. In addition to the role these data play during the target setting mode, the inherent professional judgment provides an educational aspect and design guidance to the user during the design analysis mode and to the researcher when modifying the input module during standards development.

Defaults related to costs and building design strategies or technologies function in much the same way as consensus-based space function data. Although these databases may be more straightforward and less a matter of design judgment, the order in which they are presented to the user can encourage the use of more effective energy-conserving techniques.

In all modes of use, the default databases and internal user interface rules allow the user to move quickly and effortlessly through a very complex system. It is only necessary to change a few items, when desired, while leaving most values at their original default settings.

The Targets methodology assumes the compilation of databases for energy-related environmental controls that will be developed, to a great extent, by professional consensus judgment. In particular, lighting function and thermal function data will be generated, based on individual space functions. Thus, for a space function called "hotel conference space," there will be specific values or ranges of values for factors such as temperature, humidity, ventilation, air speed, illuminance, luminance ratios, color of sources, glare, surface reflectance, light distribution, and controls.

Although established engineering methods or recommendations are available for some of these factors, the overview of professionals would still be required to apply these methods. In other areas, notably lighting, quantitative methods do not exist for many qualitative aspects critical to the proper functioning of the visual environment. In such cases, new algorithms will be prepared for use as a framework to gather the consensus judgment of lighting professionals.

A first pass at developing matrices for compiling consensus data for lighting was prepared and reviewed. Also prepared were original algorithms to combine engineering factors and consensus factors, to arrive at lighting "characteristics" that can be analyzed or optimized by the Targets model. While still very preliminary and unrefined, this work was somewhat detailed in relationship to other activities in the same area and it is not included in the Appendixes.

2.2.7 Quality Considerations

The issue of quality has a strong influence on the acceptability of voluntary guidelines and mandatory standards alike. In this context the "quality" being referred to is the quality of the environment created for the owner and occupant by the building designer combined with the quality of the architectural/engineering designs. It is important that such quality not be sacrificed in the name of energy conservation, but neither should energy conservation goals be abandoned in the name of quality. To achieve a balance, it is necessary to determine what level of "quality" is necessary for each situation, which are acceptable ranges for various factors that ensure such quality, and which aspects of quality are and are not related to the energy performance of a building.

The consensus databases are the locations within the input module where assumptions about quality are maintained. In many cases, these are based on objective standards, or applications of professional judgment by means of ranges of values or rule-based algorithms. In general, the factors in the consensus database will be bounded by the minimum acceptable quality at one end and energy-conserving aims at the other.

For example, the area of fenestration appropriate for a given space function (factoring in glazing transmission features) will be limited on the high side by concerns for energy conservation due to associated thermal gains and losses. It will be limited on the low side by the occupants' need for view, air, and a connection to the outdoors, and, potentially, the desire to use daylighting. Costs will be associated with the values for effective aperture throughout the range established in the consensus database. Costs will relate to both the first cost of construction and installation and the long-term costs of energy use, operation, and maintenance. The relationship between quality and costs will also be based primarily on the consensus of professionals, due to the difficulty of quantifying qualitative features.

It has been suggested that the consensus databases will provide the basis of required default values for supplementing the "maximum allowable input" during operation in the target setting mode. Whether or not this becomes the case, the consensus databases are still necessary to provide adequate default options to the user in all modes, to render the input process acceptably rapid. In addition, the consensus databases provide a level of credibility and education that will encourage energy-conserving design practices.

2.3 Major Remaining Issues for Input Module

Many key issues relating to quality within owner objectives and maximum input requirements are still being discussed.

2.3.1 Quality-Related Issues

Several key issues relate to quality within the Targets methodology. Within the domain of this task report, the key issue is the combined impacts of the many default values to be defined by consensus. For example, do the default values established by consensus need to consider the often considerable differences in design values for different owner objectives? The default values and choices appropriate for a corporate headquarters office building may differ significantly from those for a speculative office building with a much higher occupant density and a lower unit cost.

2.3.2 Maximum Allowable Inputs

In Section 2.2.5, minimum input data requirements were defined. A more general question involves establishing a point at which user inputs will be considered "enough" for the goals ascribed to the Targets model in the target setting mode of use. The resolution of this question regarding the allowable maximum inputs during target setting involves

- the perception of reliability by the user
- the ability of the developers to create reasonable default values for factors not input by the user
- the tendency to use or abuse the targets to facilitate good practice.

It is fair to assume that once this level of program-related input is set, the modification of this input, even during the design analysis/evaluation mode, would require setting a new target value. Note that the establishment of maximum allowable inputs is not within the scope of the Targets project, even though it has been frequently discussed.

2.3.3 Minimum Allowable Inputs

Note that the topic of "minimum required input" is distinct from the issue of the "maximum input allowed" during target setting. The latter refers to constraints on user input that might be placed by voluntary standards, internal company policy, or mandatory codes, and is beyond the scope of this project.

A building's targets cannot be generated simply based on a designation of building type such as office building, retail mall, or school. The entire Targets methodology uses the space function (conference room, hotel guest room, cafeteria server) as the core unit of analysis, in order to achieve the goal of truly customized targets. This approach also avoids oversimplifications based on "typical" buildings of a particular building type. Every building, regardless of its type, will exhibit very different energy-related characteristics depending on its unique combination of space functions and the associated interior geometry for each space function. In particular, criteria for visual and thermal comfort are sensitive to changes on the space function/geometry level. Based on the user's definition of each particular building at the space function level, the custom energy profile of the building can be evaluated to produce one or more target values.

As pointed out in Section 2.2.1, there are opportunities for the user to define a specific building or parts of a building by descriptors called category, type, and subtype, which appear to be much like the conventional building types. Note that these designations, which are optional input by the user, are not the basis for the energy targets which are generated, and are not sufficient information for any energy analysis within the Targets model. They are introduced because they are extremely useful for expediting the user's path through the input module, by influencing the primary defaults offered to the user in some categories.

For example, if the user's designation of a specific building were a suburban elementary school, then the first graphic building configurations shown would be most typical of that subtype, type, and category. The first occupancy schedules presented to the user would be those most fitting for schools. Likewise, the top of the list of space functions displayed for the user would be those most likely to be found in that setting. However, and this must be emphasized, in the end no choices are withheld from the user, and it is still on the basis of the user's selection of schedules, or description of space functions and geometries that the energy targets procedure is based, and not on the subtype, type, or category selected.

There is a great deal of interest in the study of the human mind, and it is one of the most important branches of knowledge. The study of the mind is not only a scientific study, but it is also a practical study. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind.

A good study of the mind is one that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind.

The study of the mind is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind.

The study of the mind is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind. It is a study that is of great importance to the human race, and it is a study that is of great importance to the human mind.

3.0 Characteristics Development Module

The characteristics development module operates on data after the initial checking of data inputs and defaults is completed. This module is shaded in Figure 3.1.

3.1 Task Objective and Approach

The objective of this task was to define all the steps within the methodology required to convert input and default data from a raw form into sets of characteristics appropriate for use by subsequent search or analysis routines. This conversion is accomplished within the characteristics development module.

This module is the bridge between user input and the control of the analysis procedures within the Targets model. In particular, the multitude of factors compiled by user input and default databases must be processed to form groupings of characteristics, each set of which forms a description of an energy-related building design, so that the sets of characteristics can be tested during the target setting mode or analyzed during the design analysis/evaluation mode. The characteristics development module includes a variety of activities required after the project data for a specific building is entered and before the analysis control and search routine modules are used.

3.2 Results

The following five tasks were accomplished:

- defined components of module - The activities necessary to take the methodology from initial inputs to the analysis control module were identified and examined.
- defined technology and design strategy framework - Technologies refer to the physical components that make up the description of the energy-related aspects of a building. These may be raw materials or assemblies with associated criteria factors and costs. Energy-related design strategies may be as simple as the selection of a particular technology or the selection of one of its criteria, or a complex use of multiple technologies or design techniques to reduce energy use. Specific technologies and strategies were defined, and a framework was provided to start the catalogues for this information. This information is used in both the input module (where technology catalogues are used to describe a specific design description during the design analysis mode) and the characteristics development module to provide some preselection guidance for design strategies. It can also provide a basis for the direction of search in the analysis control module.
- defined preliminary selection criteria - Preliminary selection criteria were developed as a beginning for rule-based preselection in the target setting mode and as guidance during the design analysis mode.
- addressed issues related to quality - Realistic and acceptable targets must address the priorities of owners, managers, and developers in investing in a building project, the goals of the design team, and the needs of occupants for comfort, well-being, and productivity. While all these concerns relate to both the cost and benefit sides of economic and energy use calculations, many are difficult to quantify, and others are difficult to establish, even by consensus. This task sought to examine the problem, identify the issues, and explore some options. However, a specific methodology was not developed.

Figure 3.1. Characteristics Development Module Location Within the Targets Model

- established a workplan - A workplan was established for future activities related to the characteristics development module, which includes the development of characteristics development algorithms, along with the origination of rule-based preselected algorithms and a methodology for dealing with quality-related issues. Extensive use of case-study buildings, both actual and theoretical, will supplement the development stage work.

The results obtained from these tasks include the identification of the components of that module as well as technology and design strategies for meeting the target limits.

3.2.1 Definition of "Characteristics"

Factors input by the user or selected from default databases are, for the most part, based on space functions such as hotel lobby, conference room, inactive filing, cafeteria server, and so on (see Exhibit N, Appendix B, for examples of space functions). Each space function will have a corresponding library of energy-related factors such as dry-bulb temperatures, humidity (thermal functions), and illuminance, glare criteria, surface reflectance (lighting functions), as well as references to schedules for occupancy, lighting, heating, and so on. A specific building description is composed of all of these factors related to the specific space functions, in the specific composition, operating on the specific schedules intended for that project.

The analysis procedures (i.e., the search routine, energy, and cost modules) are limited by acceptable run times in the number and types of factors to be considered. Those factors that are ultimately analyzed by the Targets model are called characteristics. A characteristic may be a single input factor or consensus database value, or a building-wide average of certain factors, or a derivation of several factors. Characteristics represent the units that ultimately describe the energy-related building components and are analyzed by virtue of their interactions by the energy and cost modules.

Thus, factors relating to details such as the color and distribution of light sources appropriate for specific space functions will be adjusted, along with other aspects of the operations of light sources, into a characteristic called a source/ballast factor. This characteristic, which would have a range of values and an associated range of costs, would then be passed on to the next module related to analysis control. One value for this characteristic would be initially selected and combined with discrete values for other related and unrelated characteristics that together comprise a characteristic set that fully describes options for the energy characteristics of the building.

During the target setting mode, this set will be the first considered in an iterative process of search and analysis, to find the best set that meets the objective function of, for example, the lowest energy related owning and operating costs (EROOC). During the design analysis mode, this characteristic set will be the user's preferred design option and will be analyzed outright to compare the proposed design with the targets values. Input factors and default values are translated or developed into characteristics in the characteristics development module.

3.2.2 Technologies/Design Strategies List

Appendix E contains the basic list of energy-related technologies and design strategies that cover reasonable options organized by area of impact. This list provides the structure that must be addressed by the characteristics development module. The module will need to reformat and aggregate raw input and default data into sets of characteristics that relate to the various TDS in the list in Appendix E. A characteristic set for a specific TDS must contain all of the relevant data needed to assess the merit of that TDS versus other TDS.

Thus, both the structure and the contents of the TDS list is critical to the overall conceptual approach of the Targets methodology. For example, options for improving building energy performance might be identified and based on the comparison of performance between the targets and the building design. Performance variation will occur in the basic areas used to organize the TDS list and will allow options to be presented according to the nature of the energy problem, which does not follow the taxonomy organization. Thus, the comprehensiveness of the TDS list used within the Targets methodology will directly influence both the type and magnitude of the energy target values obtained.

3.2.3 Technologies/Design Strategies Triggers

Triggers between the taxonomy and technologies/design strategies lists are shown in Appendix E. These triggers are basic relationships that will generally respond to a comparison of default and user input values and the specific differences between the targets performance set and performance in the design analysis mode of use. These triggers might be used, for example, to provide user interactive guidance messages that could range from a warning about roof U-value to a more detailed message about heating, ventilation, and air-conditioning (HVAC) selection criteria and the relative weighting for the building subtype.

At this point, the linkages defined are fairly intuitive. Both the nature of the many and varied Targets methodology responses as well as the logistics of creating those responses are difficult issues that will need to be addressed.

3.2.4 Components of the Characteristics Development Module

This module includes a heterogeneous mix of processes that are intermediate in the functional sequence of data flow between the initial raw input (influenced or supplemented by databases), and the optimization or analysis procedures. A number of operations were identified; they need not necessarily occur in the following order.

Consolidation

Data based on space functions will, in some cases, need to be assembled into other groupings such as building floors, thermal zones, facades, and/or ultimately into the whole building or project. These groupings include the cumulative summation of some factors, such as costs or features (e.g., lighting controls) or procedures (e.g., maintenance), that occur in some space types or appear in some parts of the building and not in others.

Characteristics Development Algorithms

Certain calculations related to visual and thermal comfort are required to derive factors that can be considered characteristics by the search routines. For example, lamp color may not be a factor that is directly optimized, but functions, instead, as a variable used to obtain the source/ballast factor, a characteristic optimized by the Targets model.

Verification

The direct input of the user should be evaluated against the data generated by the characteristics development algorithms to uncover inconsistencies. After certain intermediate evaluations are made to determine, say, the average effective aperture for daylighting, and are compared with some input data or defaults (e.g., low shading coefficient), initial conflicts can be discovered and pointed out to the user. For example, "Although you indicated a desire to incorporate daylighting in your building, this option does not

appear to be viable based on fenestration selections." This comment, brought to the attention of the user, would allow the user to change the input, if desired, prior to the time-consuming operation of the energy module.

Priority (Discretionary) Energy

For most building projects, a specific use of energy is required by the owner to meet the criteria for which the building is being built. These might range from the use of computers in an office to the use of large areas of glazing for a hotel with a specific view, or to the use of display lighting in a jewelry store. These instances of high priority needs for additional energy use are herein referred to as priority energy, and the description goes somewhat beyond what is customarily considered process energy. The Targets methodology must deal with such requirements in an even-handed, yet energy-conserving way. Priority energy is discussed further in Appendix F.

Procedural Path Determination

A means is needed (which may or may not take place in the characteristics development module) that determines the most efficient path through the operation of the Targets model. This may depend on a number of factors, including user-selected options (e.g., for speed vs. accuracy), or internal analysis of the level of detail (which may vary between components, depending on the stage of the design process) or data generated by the characteristics development algorithms, or the changes made since the previous run, or the type of analyses or output required.

Pre-Selection

Screening the total set of all possible characteristics can be effective in considerably reducing the number of options that are passed on to the analysis control and search routine modules. It is most likely that simple rule-based algorithms could be used to narrow the boundaries of the optimization problem to only those parameters that are clearly viable for the given situation. The example above would rule out optimizing daylighting controls, for example, if the selection of a shading coefficient and an effective window aperture were both too low to achieve an energy savings from daylighting techniques.

Formatting

The values for all the characteristics to be considered for analysis may need to be translated into the format required for the search routine or energy simulation module. (Alternatively, this may take place prior to the actual operation of the energy module for one set of characteristics at a time).

3.3 Major Issues Remaining for Input Module

Different issues concerning the minimum selected level of quality and the corresponding levels of required energy are still under consideration.

3.3.1 Quality-Related Issues

A primary concern is whether the search routines within the methodology will select while ensuring quality throughout the range of values, or always select the lowest value associated with the minimum acceptable level of quality. Given the assumption that the objective function of the search procedure is economically based and will choose the lowest EROOC, then quality will need to be balanced by first cost.

In most cases, it is assumed that quality will stay constant. Greater energy savings can then be achieved for greater cost, i.e., by use of more sophisticated equipment or strategies. The impacts of this assumption will need to be examined.

3.3.2 Priority Energy Issues

It has not yet been determined at which stages in the Targets methodology priority energy is best considered (see Appendix F). Input data could be categorized differently or weighted to indicate a level of priority. Certain defaults normally required during the target setting mode could be overridden or flagged. Costs could be adjusted to reflect a need for greater owner investment for priority energy uses. Greater or less energy use could be assumed, depending on corresponding levels of energy controls required or selected.

4.0 Analysis Control Module

The proposed concept for the analysis control module is described in this section. This module's location within the overall Targets model is shown in Figure 4.1.

User input data and instructions, via the user interface, will be merged in the input module with defaults from the consensus databases. Then, this information will be processed in the characteristics development module. The analysis control module will use this information to control the flow of analyses conducted by the various elements of the Targets model.

The analysis control module will carry out a variety of analysis functions depending on the mode of use and/or the request of the user. During a building design process these functions include using search routines to set a custom energy target for design, evaluating the performance of various possible design configurations, and generating an assessment of the energy performance for the final design.

The analysis control module will perform a master control function over the analysis portions of the Targets model. This master control function will involve directing the execution of the energy simulation module, the energy cost module, the building cost module, and the economic analysis module. In some modes of operation, the output from these modules will be interpreted by the analysis control module and used to define additional analyses that need to be performed.

The analysis control module will need additional capabilities to facilitate use of the Targets model in developing standards, in research activities, and in validating the Targets methodology during future work on the Targets project.

4.1 Task Objectives

The first objective of this task was to define a detailed conceptual structure that would control the flow of analyses, and the inputs and outputs related to those analyses, under the different modes of use defined for the Targets model. The second objective was to develop workplans that permit further exploration and development of the analysis control module.

4.2 Results

Three tasks were accomplished in the analysis control portion of the work. First, the basic requirements for analysis control module operation were defined. Second, analysis control capabilities were defined for the various Targets applications and modes of use (described in Section 1). Third, a workplan was developed for the next stage of the project.

4.2.1 Basic Requirements

The basic requirements for the analysis control module are listed in Table 4.1. The requirements are grouped according to the major applications and modes of use. For each alternative, the set of control requirements is listed.

Figure 4.1. Analysis Control Module Location Within the Targets Model

4.2.2 Analysis Control Capabilities

Eight required capabilities were identified for the analysis control module. For each capability, the module will need to provide a different path through the sequence and number of iterations of the various Targets modules. The eight capabilities are listed in Table 4.1.

Table 4.1. Analysis Control Module Requirements and Capabilities

Use Mode	Requirement	Capability ^(a)
Target Setting	Generate a target	1
Design Analysis/ Evaluation	Run comparison analyses	1, 3, 6
	Run a matrix of analyses	7, 8
	Find least-cost value(s) for design factors	1
Standards and Codes Development	Display least-cost relationship(s)	1, 2, 3
	Analyze a specific building design	5, 6
Research	Generate a series of targets	2, 3, 4

^(a)SEARCH ROUTINES

1. subset search - Search for the objective function related to unfixed values for specific parameters and given fixed values for all others parameters. The design analysis mode use of search routines is conceptually the same, except that the range of parameters that could be considered would be larger, while the number of parameters to be considered at any one time would probably be smaller.
2. parameter search - Apply search techniques over a range of values for a specific design factor. For example, such an analysis might show how other design factors could optimally be changed in response to changes in a particular design factor, such as window-to-wall ratio. This option might also be used in a research application to show how the target for a building might change in different geographic locations.
3. sensitivity search - Apply search techniques over ranges for more than one design factor. For example, such an analysis might show how other design factors could optimally be changed in response to changes in several design factors, such as the window-to-wall ratio, the shading coefficient, and the exterior shade option. The analysis would show what is possible, what is important, and how sensitive results are to specific variables.

TESTING OF SEARCH ROUTINES

4. verify search - Verify the performance of the normal search procedures against a slower search procedure that offers proof or near proof of optimality.

ANALYSIS

5. specific analysis - Run a specific analysis, typically, for a proposed design.
6. multiple analyses - Run multiple specific analyses and compare results, for example, to evaluate the impact of several proposed design changes.

7. parametric analyses - Run analyses over a range of values for a specific design factor, for example, to evaluate the impact of changes to glass shading coefficients over a range of possible values.
8. sensitivity analyses - Run analyses over ranges for more than one design factor, for example, to evaluate the interactions between the window-to-wall ratio, the glass shading coefficient, and the electric lighting options.

5.0 Search Routine Module

In the search routine module, alternative combinations of a building's physical and cost characteristics will be evaluated. Those combinations of characteristics that define custom targets for building designs will be identified and selected. The search routine module is located within the Targets model as shown in Figure 5.1.

Effective search techniques are critical to the success of the overall Targets methodology; the search routines are needed to identify energy-efficient and cost-effective design solutions. These routines will be used to identify one or more sets of building features (both physical and cost characteristics) that combine to define an economically sound energy target for a building design. The search routines must be accurate, reliable, and sensitive to be capable of identifying appropriate customized targets.

5.1 Task Objectives

Two objectives were defined for the search routine module task. The first objective was to define detailed conceptual approaches for selecting reasonable combinations of building features (i.e., sets of characteristics) that will define cost-effective custom energy targets.

The second objective was to develop workplans that permit the further exploration and development of the conceptual approaches and structures for the search routine module, based upon the results of work toward the first objective.

5.1.1 Background

Search techniques are considered a critical element of the target setting mode of the Targets methodology, as was described in Section 1. Search methods will be the primary method of identifying desirable and cost-effective design solutions within the target setting mode. It is proposed that search techniques be used to determine one or more sets of building features--both physical and cost characteristics--that together will permit the definition of an energy/economic target for a building design. In the target setting mode, as an example, the search techniques will probably select features based on their performance as measured by the objective of the search, e.g., the total energy-related owning and operating costs (EROOC).

To do this, an automated method is required for selecting energy-related building features based on their performance as measured by a complex energy simulation model, an energy cost model, a building cost model, and an economics model. In this context, building design features being selected may be referred to as search variables, while the objective of the search techniques (e.g., to determine a reasonable solution of EROOC), may be referred to as the objective function.

The problem is very complex and challenging, both conceptually and technically. It has not been attempted before at this level of detail on commercial buildings and with integral economic evaluation. Therefore, the development of a conceptual structure for using search techniques within the Targets methodology is an extremely important task, and is discussed in detail in this section. Before discussing alternative search routines, a conceptual overview of the problem and typical steps in its solution are presented to provide a context.

Figure 5.1. Search Routine Module Location Within the Targets Model

5.1.2 Context - A Description of the Problem

Within the target setting mode, a target is proposed to be set using space functions as the basic units used for defining a building. The space functions (e.g., office, retail, gymnasium, classroom) are to be identified by the functional program of a specific building.

Each space function will have well-defined ranges of criteria for comfort, productivity, quality, patterns of use, and priority energy use. These will be available via a database of factors generated by consensus. Specific values for these criteria can be defaulted or selected by a user to customize the building program requirements. These criteria, coupled with constraints defined by the building program, will constitute a set of constraints on the choice of building systems and components. Each space function will also have well-defined ranges of building systems and components that constitute options that can be selected to satisfy the criteria and constraints for the given circumstances.

The search routines will be used to identify and to select some set (or sets) of building system and component characteristics for each space function that best satisfy the energy and economic objectives. For example, this could be a set of building systems and components that are either most cost-effective or sufficiently cost-effective. The building systems and components selected by the search routines will be processed through the energy, cost and economic analysis modules of the Targets methodology. The results for individual space functions and for combinations of space functions will constitute the whole building energy targets to be achieved by the building design.

Thus, having search routines that are accurate, reliable, and sensitive is critical to the identification of appropriate customized targets.

5.1.3 Likely Objectives of a Search

In the economic analysis task report, a number of possible owner objectives were examined. Five were identified as prime candidates for further consideration for inclusion in the Targets methodology. They are as follows:

1. Minimize the energy-related owning and operating cost (EROOC) of the building to the owner.
2. Minimize the life-cycle cost (LCC) of the building to the owner.
3. Minimize energy cost, within an upper limit on construction cost.
4. Attain energy cost lower than a stated value, at the lowest possible building construction cost.
5. Minimize energy consumption.

Of these five possible objectives, the first--EROOC--has been identified as the objective to receive the most emphasis. It is also the most complex. The second objective--LCC--is very similar, and the other objectives can easily be addressed as subsets of EROOC.^(a) Each of the above alternatives could define an objective function for a search routine. Also, combinations of these objectives could be used to define an objective function. For example, the economic objectives for an owner of a multifamily highrise building

---

(a) This is discussed in more detail in Section 8 of this report.

can change markedly depending upon the split of energy bills to be paid by the owner (generally related to central systems) or by the tenants (generally related to distributed systems).^(a)

5.1.4 Proposed Four Steps in a Targets Search Process

Within the context defined above, conducting a search is conceptually envisioned as a four-step process:^(b)

1. Preselect.
2. Select first set and run initial analysis.
3. Select subsequent sets.
4. Use historic information.

The purpose of each of these steps is discussed briefly below.

Step 1 - Preselect

The purpose is to perform the initial screening of characteristics to weed out those that are clearly inappropriate. The intent is to reduce execution time by limiting the number of functional evaluations to only those cases where characteristics are clearly viable for the specific conditions. There should be little chance of eliminating a viable yet unlikely option.

Step 2 - Select First Set and Run Initial Analysis

The purpose is to 1) establish an initial set of characteristics that represent a reasonable starting point for the search routine, presumably an efficient point close to the expected final result, to save computation time; or 2) find a starting point for a search routine that evaluates the extremes (best possible conditions for given characteristic), to rule out options that are clearly not viable, even under those ideal conditions.

Step 3 - Select Subsequent Sets

The purpose is to move toward a solution to the search in the most efficient way, i.e., requiring the fewest iterations of sequentially selected sets to meet the criteria.

Step 4 - Use Historic Information

The purpose is to use data generated from Steps 2 or 3 to 1) influence the direction of characteristic values to be used for subsequent sets; or to 2) modify or verify information employed for procedures and for search-related data sources (such as libraries or models). Use of historical information is also an effective way to conduct a check on the reasonableness of the solution obtained.

(a) Such economic issues strongly influence the design of multifamily buildings and often constrain the building system choices. This can be especially true if an owner plans for future conversion to condominiums.

(b) We do not imply that this is the only sequence that can be used. However, the authors found it very convenient for presenting the concepts and issues involved in a search process within the methodology.

The purpose of each of the four steps may be achieved in a number of ways. The alternatives are discussed in Section 5.2, where a preliminary evaluation is made.

5.1.5 An Example Using the Proposed Four Steps: Fenestration Effective Aperture

An example presented here helps describe details of the process. The example also presents some complexities and issues that are discussed in Section 5.3, Discussion.

An important factor in selecting which search methods to use for a given problem is the structure of the problem being addressed. The example explored here indicates that such structures can vary considerably, even within a single area of analysis. The example also indicates that the structure of the problem can change radically, depending upon the number and type of factors considered and their level of interaction.

The example is taken from envelope research done by S. Selkowitz et al. in 1982-1983 as part of the ASHRAE Special Project 41 (SP41). The objective of these early analyses within SP41 was to assess the effects of fenestration effective aperture (EA) on annual energy use of two perimeter zones of a prototypical office building. The impacts were assessed by varying the following building system and component characteristics:

- effective aperture (EA) as a combined function of window-to-wall ratio (WWR) and shading coefficient (SC)
- overall wall U-value (U_o), including fenestration
- lighting levels (W/SF)
- presence and absence of daylight dimming controls for the perimeter lighting systems.

Results from these parametric DOE-2 runs are presented graphically for the north and south perimeter zones for two very different climate locations--Lake Charles, Louisiana (hot, humid), and Madison, Wisconsin (cold). Figure 5.2 shows the summary annual energy results. Results are shown for both the nondaylighting cases (solid lines) and the daylighting cases (dashed lines).

The analysis and results contained in this example provide a useful vehicle for discussing the four search steps described above. A very simple analysis method is used to expedite discussion: visual inspection of parametric data. This does not imply that this is the type of search solution method being proposed for the search routine module of the Targets model. Alternative search methodologies being examined are described in Section 5.2.

Step 1 - Preselect

This step performs the initial screening of characteristics and eliminates those that are clearly inappropriate. In the example study, the preselection was done by judgment, and quite broadly, to fit the objectives of a parametric effort:

- EA was varied from 0.0 to 0.40, using several combinations of WWR x SC.
- U_o was varied from 0.128 to 0.256 in Madison and from 0.203 to 0.410 in Lake Charles.
- Three lighting power levels were examined: 0.7, 1.7, and 2.7 W/SF.

MADISON SOUTH WSQFF=1.7 OVERH=NO TYPE=0 UO=-128

MADISON NORTH WSQFF=1.7 OVERH=NO TYPE=0 UO=-128

LAKECHARLES SOUTH WSQFF=1.7 OVERH=NO TYPE=0 UO=-270

LAKECHARLES NORTH WSQFF=1.7 OVERH=NO TYPE=0 UO=-270

Figure 5.2. Annual Energy Results from DOE2 Runs

- Presence and absence of daylight dimming controls (solid lines connecting solution points indicate no daylighting, while dotted lines connecting solution points indicate daylighting).

The selection of these variables and their allowable ranges constitutes the preselection or initial screening. It is expected that the ranges of variables in the targets consensus data for space functions would not be nearly so broad as they are in this example.^(a)

The second aspect of preselection is the application of rules or algorithms that apply to the combination of characteristics. In the example, part of the prescreening was the choice, by judgment, of the most important variables to allow to vary. A number of other variables that could affect the results were held constant. In this example, there is no consideration of variation in factors such as

- external shading (e.g., overhangs) or internal shading
- schedule
- internal loads from people and equipment (which, in modern office space functions, can equal or exceed the lighting W/SF)
- details of the relationships between WWR and SC
- variations in glazing visible transmittance (T_{vis}) versus SC (which can vary by a factor of 2 and strongly impact daylighting and thermal relationships)
- HVAC systems or equipment
- costs of any of the items.

In short, the example is a simple one for the problem being addressed, and ignores a number of potentially significant interactions. It also does not address a number of potentially important energy-conserving design strategies.

Steps 2, 3, and 4 for the Nondaylighting Case

If the objective function of the search is to minimize energy use, then Steps 2 through 4 of the search can be combined for the nondaylighting case. In this example, the solution is reached by inspection of the graphs. For virtually all nondaylighting cases, the minimum annual energy use is for a fenestration effective aperture of $EA = 0.0$, that is, no glass at all!^(b)

Due to the strong qualitative benefits of windows for occupancy, it is unlikely that the Targets model would include a lower boundary of effective aperture of $EA = 0.0$, except for a few space functions. For office-related space functions, perhaps an absolute minimum of $EA = 0.1$ might be used for low cost

---

(a) The objective of the parametric study was not to find the "best" solution, or range of solutions, but rather to determine the pattern of the relationships. This broader objective led to selection of a wide range for each variable considered.

(b) Some anomalies occur for high U_o values on the north orientation, especially in Madison. In an actual analysis, these would need to be addressed. For discussion purposes here, they are ignored.

construction, and a minimum of $EA = 0.2$ for higher quality might be set by consensus. In any event, the minimum EA set by consensus would also turn out to be the optimum EA determined by the search routine for the nondaylighting cases cited.

If economics are included, then the result would be the same, only stronger. This is because fenestration construction costs are virtually always higher than opaque wall construction costs.

This result points out the critical role that the judgment embedded in the consensus database will play in determining the results of any search routine within the Targets model. The energy and cost results shown in Figure 5.2 drive the solution directly to $EA = 0.0$.

Yet this result runs strongly counter to the design of the nondaylighted office buildings in this country, in which important comfort, quality, and rentability factors tend to drive EA as high as possible within budget limitations. For the case cited here, the lower boundary condition set within the consensus constraints will be the result of the search. The impact of this on building quality needs to be explored thoroughly in developing the search models for the Targets methodology.

Steps 2, 3, and 4 for the Daylighting Case

By inspection of the daylighting solutions to the parametrics (solutions with dotted lines connecting the points), it is clear that the solution is not immediately available. Thus, Steps 2 through 4 in the process need to be conducted separately.

Step 2 - Select First Set and Run Initial Analysis: For the south orientation, visual inspection for the daylighting case in both Madison and Lake Charles shows a consistent pattern, one that is different from the nondaylighting case. In this example, a likely starting point is probably somewhere in the range of $0.1 < EA < 0.25$. A closer inspection might indicate the pattern of shifts with climate, lighting level, etc. A number of techniques could be used in the search routines to select a reasonable starting point.

For the north orientation, visual inspection for the daylighting case in both Madison and Lake Charles shows yet another pattern. The patterns have strong implications for the selection of search routines. Under some conditions, the patterns are similar to those for the south orientations. This is true for Lake Charles, and for high light levels in Madison. However, when W/SF levels for lighting are low, it appears that any EA will do about equally well. Total annual energy impacts across the full range of EA appear almost negligible.

For most parametric situations, the differences in results are so minor across the EA range that selecting a starting point, or even doing a search, seems arbitrary. Conducting any further search steps under these conditions appears unnecessary. In fact, finding a minimum point would mask the important point that any EA solution will perform about as well as any other. In this case, prior decisions for one building system (daylighting controls and low light levels) might impact the search approach needed for another building system.

Step 3 - Select Subsequent Sets: For the south orientation (and applicable north orientation conditions), a number of search techniques can be applied to move from the initial point selected to a best point or to a reasonable range of points. Information about both magnitude and slope can be used to speed the search.

Step 4 - Use Historic Information: For the south orientation (and some north orientation conditions), the curves are convex and well-behaved, under this particular set of circumstances. This historical information from parametric runs can be used to greatly improve the efficiency of the search

conducted in Step 3, as well as the efficiency of the initial selection in Step 2. Rules or equations (or a combination of both) could be developed to speed the search process in this relatively simple case.

Summary: Applying the Four Steps to the Example

A number of issues and conclusions have surfaced from the discussion of the above example. Should the search methods focus on optimum points, or on reasonable ranges, or both? How should this be done and be presented?

Disaggregation: Disaggregation involves the breakdown of the problems into smaller problems of independent variables. Since disaggregation reduces search efforts, how much is necessary, possible, and beneficial as part of the Targets search methods? Disaggregation needs to be addressed at least in terms of space functions, building geometry, and design strategies.

Annual Energy/Energy Cost: How will the search routines address the mix of annual, monthly, and diurnal energy patterns in determining cost-effective solutions?

Design Strategies: The set of strategies included or excluded can strongly affect the results obtained. Which strategies should be included? What should be the inclusion/exclusion criteria? What are the impacts on the results and the conclusions to be drawn from those results? How much provision is needed within the methodology to incorporate technological change?

Each of these topics is discussed in some detail in Section 5.3.

5.1.6 A Second Example Using the Four Search Steps: HVAC and Lighting Systems

In this section, aspects of applying search techniques relative to HVAC and lighting systems are briefly discussed for the four steps.

Step 1 - Preselect

Relative to a particular space function or combination of space functions, preselection involves the identification of a set of systems for further consideration and the elimination of systems that obviously won't meet the objective function in a specific situation. How many systems choices are needed to permit development of a customized target relative to these important building energy systems?

Many factors are involved in addition to energy and economics, as a few examples will indicate. In a small office building, the choice of HVAC system is influenced by the number of stories, with most likely choices changing if a building is 1, 2, 3, or 4 stories. Further, for the same building type, likely system choices will differ if the building is intended to be a low-cost speculative structure or a classy corporate headquarters. It is anticipated that the number of potential system choices that need to be preselected will vary by space function and by geography.

Given the great complexity involved in the preselection process, it is expected that preselection will depend largely upon consensus judgment. Some tools are available that appear to be quite useful for structuring this judgment. For example, in recent years ASHRAE TC 9.1 has proposed formulae for expressing ways to evaluate and rank the numerous factors involved in selecting HVAC systems. This approach used indices for four factors with a number of rating variables identified for each:

- comfort (8 variables)
- first cost (1 variable)
- owning and operating costs (7 variables)
- application (8 variables).

The variables involved are listed and discussed in Appendix G. More recent suggestions for formulae and variables for HVAC evaluation include Tao's suggested formulation for assessing cooling energy efficiency (Tao 1983) and Neuman and Guven's (1987) suggested simple ranking method for choosing systems. Pre-selecting lighting systems for space functions presents a similar level of complexity and number of variables.

Steps 2, 3, and 4 - Select First Set and Run Initial Analysis; Select Subsequent Sets; and Utilize Historic Information

The problems, issues and complexities involved for these search steps for HVAC and lighting systems are expected to parallel those discussed above for envelope systems.

5.1.7 History of the Use of Search Routines in Building Energy Analysis

Widespread use by researchers of computer simulation for the analysis of energy use in buildings began roughly a decade ago. The earliest efforts to make use of search techniques in conjunction with building energy simulation that the authors could find date back to approximately 1980. These early efforts were directed mostly at residential buildings and employed simplified energy models rather than the detailed hourly simulations planned for the Targets model. The efforts are described below. Several early efforts have been identified.

Residential

For residences, four different products have been produced. These are

- Computer Instrumented Residential Audit (CIRA) developed for CPM-based personal computers at Lawrence Berkeley Laboratory in the early 80s to determine economically efficient sets of retrofit options for residential buildings - CIRA employs a degree-hour-based energy model and evaluates life-cycle cost performance of nearly 100 energy options.
- Economics of Energy Design Options (EEDO), a proprietary version of the CIRA program, adapted to DOS-based personal computers, developed by Burt Hill Kosar Rittelmann Associates in the mid-80s
- Conservation Optimization Standard for Savings in Federal Residences (COSTSAFR), a DOS-based personal computer program developed in the mid-80s - This program is similar to CIRA in a number of respects, but was designed for use with new residences, and uses an energy database generated from DOE-2.1A simulations. It employs a type of steepest descent search method.
- Automated Residential Energy Standard (ARES), a program that uses a database of residential energy consumption generated using DOE-2.1C, which is sufficiently sophisticated for use for design analysis - The program is being developed for the Voluntary Residential Standards Project. It determines least life-cycle cost sets of options and uses these sets of energy conservation options to define cost-effective levels of energy performance. It employs an exhaustive search method.

Commercial

Only a single example of search method use is known for commercial buildings, and this was accomplished for a small set of typical buildings under constrained conditions. This is the Bonneville Power Administration/ Energy Simulation (BPA/ENSIM), a study that used an annual bin method energy analysis on about 10 prototypical commercial buildings of different types. ENSIM is a proprietary annual bin precursor to the public domain monthly bin ASEAM-2.1 program. A search methodology was used on a selected list of about 10 variables from ANSI/ASHRAE/IES Standard 90A-1980 using a parametric processor with ENSIM to generate annual energy results. The study was done in the mid-80s by The Fleming Group.

Significant differences exist between these early energy programs using search routines and the planned Targets methodology. The early efforts incorporating search techniques were very simple, compared to those envisioned for Targets. Important simplifying constraints include the following:

- Building configuration was highly constrained.
- All buildings analyzed were typical or prototypical.
- Interactions among search variables (representing design options) were highly constrained.
- Only annual energy was considered, and not the monthly and diurnal patterns needed for robust commercial building energy cost analyses.
- Space function mix did not vary.

Thus, it is difficult to extrapolate from these early efforts or to assume that the same types of techniques necessarily will be applicable to the Targets requirements.

5.2 Results

The various aspects and issues related to the search problem were defined. The basic requirements for the search routines were defined and evaluated for their importance to the Targets model.

Possible alternative approaches for search routines were identified, and evaluation criteria were developed for selecting from among those approaches. An evaluation matrix was developed for conducting the evaluation. An optimization expert was brought onboard to assist in subsequent efforts and to define the search variables and the objective function. The most appropriate methods and data sources were narrowed to a few, and further evaluation was outlined for selection of final methods during the next stage of the project.

The results achieved to date are discussed in detail in the following sections.

5.2.1 Problem Definition

In this section, the search problem is briefly described. The challenge to be met by the selection of the search routines in the Targets model and the way in which the problem varies for different applications and modes of use are discussed. The search problem has the following key attributes.

Generalized Domain

The search procedure needs to select from among a wide range of building technologies under a wide range of circumstances (e.g., locations, space/building types, economic scenarios). The procedure ideally would be capable of dealing with any reasonable commercial building in the United States and its possessions. It is anticipated that the domain within which the optimization procedure will operate will be larger in the design analysis/evaluation mode than in the target setting mode.

Binary, Discrete, and Continuous Variables

The problem involves search variables that are binary (the option is either present or not present), variables that can have a series of discrete values, and variables that can vary continuously over a specified range. The problem is referred to in optimization as a "mixed problem." When disaggregated, the variables may continue to combine into mixed problems.

Nonlinear

Most of the relationships between the variables to be evaluated and the objective function are not strictly linear. A substantial amount of research has been performed examining these relationships. In general, many of these relationships have been found to be monotonic, i.e., curved in only one direction throughout the range of interest and, although nonlinear, are predictable and well-behaved.

5.2.2 Evaluation Criteria for Choosing Alternatives

Eight major criteria were developed for evaluating the suitability of alternative search methods for use in the Targets model. Many of the criteria have subelements, as indicated in the following paragraphs.

Accuracy

The procedure needs to be as effective as possible in locating cost-effective sets of building characteristics. In particular, differences between runs need to be reasonable and explainable. There inevitably will be tradeoffs between accuracy and execution speed. This tradeoff can be addressed by providing options for several different execution time/precision levels.

For standards and codes applications of Targets, it is important that at least one performance level provide the most accurate results that can reasonably be attained. Also, it is important that the level of accuracy being attained (or not attained) be known. This is especially important when approximation methods are being used. The question here is, how much accuracy is being sacrificed for execution speed? This is consistent with the rationale for the use of search methods in the Targets model so that the strategy sets selected perform well. Thus, it is important to know what level of confidence can be expected by the results. It is also important that the search methods operate consistently, so that incremental changes to building programs produce incremental and plausible changes to the energy targets.

It is often a difficult problem, in search routines, to establish what would appear to be a global solution when, in all actuality, it is often just a local solution. Because the Targets model may provide information on the characteristics that underlie the target and not just the target values themselves, mistaking a local solution for a global one could result in very different information being transferred to the user. The seriousness of this misinformation transfer needs to be considered.

Obviously, in the interests of accuracy, it is desirable that global solutions be found consistently. For a standards and codes application of Targets, the consequences of a procedure mistaking a local solution for a slightly lower than global solution would not only be a small loss in precision in the target value but

also a potential for introducing disturbing inconsistencies between target values. It will be desirable to select at least one search routine that is highly effective in finding true global solutions to examine this potential problem and establish a known degree of accuracy.

Adaptability

The procedure needs to work well over a wide range of variables, including

- building type (e.g., office, warehouse) and space-function type (e.g., library reading room, cafeteria server)
- energy-conserving design strategies and technologies
- locations having differing climates, utility rate structures, and building costs
- economic objectives, such as minimizing life-cycle costs or minimizing energy costs while construction costs are held constant.

It is desirable that the search procedure be highly versatile and/or easily adaptable to future changes. It is expected that the Targets methodology will need to address new sets of design strategies and building technologies in the future. There may also be changes in the ways design strategies, technologies, or space functions are characterized for energy performance and cost. Rather than being customized for the solution of a specific problem, the search procedure needs to be structured so that it will work effectively with changing requirements as well as under new applications.

The user must be able to select among fast and accurate procedures or modes of operation, to suit objectives. That is, the user should be able to specify the level of accuracy (or speed) that is desired.

Reliability

The reliability criterion has three parts:

- stability of the search - The search procedures, on the whole, must be stable and reliable; they must not terminate execution unexpectedly with a final result far from the most effective solution. There may be reasons, however, to employ algorithms that are not always stable. The search procedures will need to deal gracefully with the failure of components of the procedure, such as search algorithms that fail to converge.
- reproducibility of exact results - Search routines relying on random selections could produce results that were not exactly reproducible in subsequent runs. If this were the case, it might prove troubling to some users. It would appear to be especially troublesome in standards and codes applications of the Targets methodology.
- sensitivity - The sensitivity of the result to changes in costs and future costs can be very important and is mathematically different from reliability. For example, a sensitivity analysis can give a good indication of what could go wrong if costs were not estimated correctly.

Execution Speed

Speed is an important issue for the characteristics selection process. Within the set of search methods finally selected for use with the Targets methodology, at least one option should be present with a sufficiently quick execution speed for inclusion in a responsive, interactive tool. This is especially

important for design applications of Targets. If sufficient accuracy cannot be maintained in procedures that operate quickly, then slower and more precise search routines will need to be provided. In a research setting, execution times as long as a week might be justifiable if they provided high or known levels of accuracy. In setting the initial targets, execution times approaching several hours may be acceptable.

In formulating specific criteria for execution speed of the search routines, it may be useful to break down the time requirements for the search procedures into their constituent parts: time required for function evaluations and time required for execution of search algorithms in various applications. These constituent parts correspond with the two major areas of opportunity for reducing execution time: reducing the number of function evaluations and selecting search algorithms that execute quickly.

Disk Storage and CPU Memory Requirements

The computational environment for which the Targets methodology is being developed is the high end of the personal computer market that will be available in the early to mid-1990s. Disk storage and random access memory (RAM) capacities are not expected to pose major constraints for the search routine module; however, the Targets model will need to operate within the constraints of the equipment.

Reasonable Cost

Initial development of the optimization procedures and any required updating must be achievable within reasonable time and cost constraints. In addition, the cost of updating the module or related data files must be commensurate with the benefits of the module's use.

Public Domain

The search methodologies and supporting software routines must be in the public domain. Any software used must be available in source code as well as in its executable form. This does not, however, preclude the use of proprietary routines, which may be necessary for expediency, during the module's development phase. However, most of the expense in developing programs is in developing and documenting the interface. Therefore, bringing an algorithm into the public domain may be no more expensive than building an interface to an existing algorithm.

Understandable Methods

The search methods used must be understandable from an engineering perspective, i.e., they must be intelligible from a first principles perspective and make sense intuitively. User acceptance may be impaired if the procedures that are employed are incomprehensible to the user community or, more important, to the developers of consensus standards.

5.2.3 Alternative Approaches

Possible approaches to the search routines used in the Targets methodology are discussed below. The options include a variety of techniques, including true optimization and heuristics. All of the options listed could potentially fulfill the objective of search routines to be used within the Targets model: finding a set of characteristics that reasonably achieves the objective function.

Issues and Options

A number of general issues and options are common to many of the approaches that could be used in the search routine module of the Targets model. Some of these general issues and options are briefly discussed here.

Individual steps in the characteristics selection process could be based on professional judgment, or they could be based on robust search routines, or a combination of the two. Search results could either be precalculated at the time the Targets model is developed or be performed on a truly custom basis in response to user input, or be determined by a combination of the two approaches. Precalculated information can be stored in the form of libraries, modules based on statistical methods, or heuristics.

Customized search procedures could be developed specifically for the Targets model, and/or existing search methods and algorithms could be used. Customized procedures could use such techniques as special rules for defining an initial set of characteristics, predefined sequences and conditions for evaluating options, and exhaustive evaluations of remaining combinations. Existing search and optimization algorithms have been designed to solve specific types of problems. Problems can be characterized as linear or nonlinear; mixed integer, pure integer, or binary; and constrained or unconstrained.

Some methods of searching, called direct search methods, work by means of repetitive function evaluations, while others require equations that define the objective function. Where equations of the objective function are not available, as when the results of a complex simulation module define the objective function, approximations of the objective function can be used. Iterative solutions are necessary for unconstrained nonlinear problems. (The Targets search problems tend to be nonlinear but generally constrained.) Algorithms for solving these problems vary in terms of how they select the starting point, how they determine the direction in which to move for the next evaluation, and how they determine how far to move in the given direction. Some methods for determining the direction in which to move require information about the derivatives of the objective function, while others do not require derivatives.

Screening and Disaggregation

Two strategies appear to be essential to any approach to the search routine module for the Targets model. These are 1) initial screening of variables for appropriateness and 2) disaggregation of the problem. Whatever approaches are selected, they will employ these two components because they, in effect, make the problem smaller and easier to solve.

The initial screening of options for appropriateness is essential to ensure that characteristics that are inappropriate for reasons related to building quality or design considerations are not selected. This same process could be used to screen out options that are clearly not cost-effective for the building project being evaluated. This step may or may not prove necessary. However, it does hold the potential for substantially reducing the difficulty of the problem.

Disaggregation involves dividing the problem into multiple smaller problems whenever feasible. In general, components of the problem can be disaggregated when they are not interdependent. Due to the combinatorial nature of multidimensional searches, modest simplification through screening and disaggregation can dramatically reduce the difficulty and execution time required to reach for a solution.

Available Approaches

The available approaches fall into four major categories:

1. rule-based
2. artificial intelligence (heuristics)
3. iteration
4. customized.

The most effective procedure will likely employ a number of these approaches in some combination.

1. rule-based characteristic selection (implemented using a conventional computer language) - The distinguishing characteristic of this method is that the selection of characteristics is based on a set of predefined rules rather than on the execution of analytical models. A good example of this approach is the set of rules that underlies the heating and cooling criteria in the envelope section of ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989).

The rules would be based on the professional judgment of some group of individuals with knowledge about energy use in buildings. This knowledge could be augmented by studies of the literature on energy use in buildings and by specific analyses using the energy simulation module. The selection procedure would take the form of logical statements and, perhaps, simple algorithms implemented in a conventional procedural programming language.

2. artificial intelligence (AI) framework (to implement or develop selection heuristics) - This option is similar to option 1, but differs in the way in which selection rules and algorithms would be implemented and in the way they might be developed. Rules developed in the same way as in option 1 could be implemented using an AI framework or programming language. An alternative method for developing selection heuristics would be to use machine learning techniques to convert the results from robust optimization techniques into heuristics. Heuristics are frequently used in conjunction with optimization when the optimization problem is computationally so difficult that the optimal solution cannot be found within the time frame required to affect the decision being optimized.
3. methods based on iteration - This approach involves repetitive evaluations of the objective function to find the optimum. Two subsets of this option have been examined:
  - exhaustive search - Combinations of discrete variables are evaluated exhaustively, and continuous variables must be evaluated twice near the same point to establish the slope of the objective function at that point. These methods are often called direct search methods, in contrast to methods that rely on derivative information to determine the direction of search. Where equations that define the objective function are very complex or nonexistent (as in a complex module), there may be no alternative to the use of methods based entirely on iteration. These methods tend to be time-consuming.
  - iterative refinement - Once a good starting point or initial set of building characteristics has been established, the initial set of characteristics would be refined and verified by iterative execution of the energy cost, building cost, and economic analysis modules. This could be done by conducting a series of single-dimension searches iteratively or by using multidimension searches where experience shows these to be useful because of variable interaction. The distinguishing features of this approach are its reliance on rules for the initial characteristic set and direct searches using the energy cost, building cost, and economic analysis modules.

4. **customized procedural methods** - This approach uses a specialized sequence of steps designed to identify the solution for the particular problem. The approach used in the economic proof-of-concept model during Phase 1 of the Targets project (Crawley et al. 1987b) is an example of this type of approach.

Instead of starting with a single initial set, the proof-of-concept model started with the set of all possible solutions and followed a procedure that sequentially eliminated options to arrive at the best one. The search procedure first attempted to eliminate entire classes of solutions (e.g., those with automatic daylighting controls) by demonstrating that even under the most favorable assumptions they would be outperformed. Those option combinations that could not be eliminated in this way were compared against one another directly. Single-dimension searches were applied to continuous variables and these were repeated to address parameter interactions.

Many variations on this procedural idea are possible. The distinguishing features of the approach are that they build on a series of logical steps and that the procedure is customized for the particular problem.

Data Sources

The selection of a data source is secondary to the search approached outlined above. Relevant data sources can be categorized into libraries and modules. Any of the four data sources listed below could be used with any of the approaches described above.

1. **library of search results** - This data source would involve an extensive library of search results to be generated during the development phase of this project using robust search routines. Interactive use of the procedure by the end user could involve a look-up process. Sets of cost-effective building characteristics would be stored in a library and indexed, based on the building program characteristics. After retrieval, these characteristic sets would be used to generate the target for the project using the energy simulation module.

The use of a library implies that the selection of characteristics would work according to stepped functions and categorical variables. The particular combination of space function, climate, energy costs, and other factors would cause a specific library record to be used to define building characteristics.

2. **libraries of energy response data** - The use of this data source would involve generating a library of energy model input and output data during the development phase of the project. The precalculated energy output data would be distributed as part of the Targets methodology and would substitute for energy data generated by the energy simulation module on a custom basis during the search process. To perform a search for the objective function, economic parameters (including energy costs) would be applied to that portion of the energy response library data relevant to the building project. For example, EROOC would be calculated for each search variable combination, and the least costly combination would be selected. This characteristic set would then be simulated using the energy simulation module to generate the building's targets. Results from energy analysis runs would be used recursively to improve the library and generate improved estimates.

Because a library look-up function would substitute for execution of the energy simulation module, this approach would greatly increase the speed with which a set of characteristics could be selected. In addition, the energy response library would be extremely useful in the research and standards development modes of use.

3. **module of search results** - This data source, similar to the library of search results, differs primarily in the way precalculated results would be created, stored, and applied to specific building projects. Under this approach, characteristic sets for a wide range of space configurations would be generated using search methods. From these, a module capable of approximating the characteristic selections of actual solutions would be created.

While the library data source would assign a set of building characteristics from a specific library record to each space function, a module of search results would offer a more flexible approach to the same basic process. Rather than creating stepped functions for characteristic selections, a module of search results could interpolate continuously between the search results that were used to generate the module. Multidimensional, nonlinear interpolations could be performed in making characteristic selections.

4. **response-surface model** - As in the library of energy response, the development of this data source would involve generating a set of energy input/output data during the development phase of the project. Rather than storing this input/output data in a library as in option 2 above, the data would be used to develop a response-surface model using regression analysis that relates input parameters to energy module results. Economic parameters, including energy costs, would be applied to the response-surface model to determine a least-cost set of characteristics. These characteristics are used in the actual energy simulation module, and results from the simulation are used, in turn, to update the original response-surface model. The module proceeds recursively, alternately improving the approximation model based on actual simulation results and generating an improved estimate of the solution based on the improved approximation of energy input/output relationships.

The iterative approach of approximating the objective function is used most often with complex algorithms or models that execute too slowly for strictly iterative methods to be feasible. In considering the feasibility of using function approximations, development time for the response-surface model needs to be considered relative to the number of times that the same model will need to be called during search routines.

5.2.4 Preliminary Assessment of Options

Each alternative was assigned an overall rating from low, to medium, to high, based on an informal assessment of its strengths and weaknesses. The results of this assessment are shown in Table 5.1.

The various possible data source alternatives were also given a cursory evaluation and were rated in a similar way. The results of this assessment are shown in Table 5.2.

5.2.5 Assessment of Alternative Methods and Data Sources Within the Proposed Four-Step Process

Based on the initial assessment of options, a preliminary effort was made to identify which alternative methods and data sources might best be used during the overall Targets search procedure. The intent was to identify which search methods and data sources hold the greatest potential for use in the Targets methodology, so that they may be the basis for further analysis and prototype testing in the development stage. This includes a discussion of which methods are best suited to perform which functions within the framework of the Targets methodology, as well as the potentially unique nature of the problem when the criteria are related to disaggregated parts, modes of use, size of problem, or steps to be performed.

Table 5.1. Assessment of Alternative Approaches

1. Rule-Based Methods

- Strengths - familiar, fast execution, moderately easy development
- Weaknesses - limited responsiveness, some arbitrariness inevitable, would necessitate separate after-the-fact economic analysis of the targets
- Overall Rating - low, not really compatible with the concepts of custom targets and economics as integral part of the module; high for screening of initial set

2. Methods Based on Heuristics (Artificial Intelligence)

- Strengths - very fast
- Weaknesses - little research to build on, not robust, still might require use of traditional optimizations in development phase as basis, not general or necessarily adaptable
- Overall Rating - low, uncertain, potentially very expensive to develop

3. Methods Based on Iteration

Exhaustive Search

- Strengths - easy to develop, most precise at finding global optimums
- Weaknesses - slow execution (to the extent of unfeasibility)
- Overall Rating - low, would require severely restricting the extent of characteristic selection using economics, due to execution-time limitations
  - rating would be high if used in combination with other methods, i.e., if only utilized to find global optimum when at a local optimum, or relatively close
  - high for refinement and accuracy

Iterative Refinement

- Strengths - improved speed, based on understandable techniques
- Weaknesses - still probably very slow, potential discontinuities between rules and analytical methods, significant potential for finding local optimums that are not global optimums
- Overall Rating - medium, too slow, would necessitate restricted scope
  - rating would be higher if search methods were used to find good starting point

4. Customized Procedural Methods

- Strengths - improved speed, understandable techniques, amenable to incremental refinement
- Weaknesses - still very slow, tradeoff between speed and generality not completely adaptable (e.g., over time)
- Overall Rating - medium, too slow

Table 5.2. Assessment of Alternative Data Sources

1. Library of Optimization Results

- Strengths - fast execution
- Weaknesses - does not provide custom targets, not easily updatable over time
- Overall Rating - low, only considered as a fall-back position; however, may be useful in selecting first set

2. Methods Using Libraries of Energy Response Data

- Strengths - easy to develop, improved speed, potentially robust, general and versatile, potential spin-off benefits for design analysis
- Weaknesses - must be combined with iterative process for fine-tuning
- Overall Rating - medium to high
- good results for time investment if used in combination with other data sources and methods

3. Model of Optimization Results

- Strengths - fast execution
- Weaknesses - does not provide true custom targets, not easily updatable over time
- Overall Rating - low, only considered as a fall-back position

4. Models Based on Function Approximations

- Strengths - potentially fast enough, potentially robust, general and versatile, potential spin-off benefits to design analysis, may be possible to use canned optimization engine
- Weaknesses - requires method for approximation development, involves unfamiliar, sophisticated optimization techniques, more difficult to develop than most options
- more costly to maintain/update
- Overall Rating - medium
- has the potential for true, custom targets generated by an interactive tool
- spin-off benefits may not mitigate potential execution time deficiencies, development difficulty, and maintenance costs

Step 1 - Preselect

- **purpose** - The characteristics are initially screened to weed out those that are clearly inappropriate. This step is not absolutely necessary but will probably be used. The intent is to save execution time by reducing the number of functional evaluations to only cases in which characteristics are viable for specific conditions. There should be no chance of eliminating a viable, yet unlikely, option.
- **application** - Occurs during operation of characteristics development module.
- **potential methods** - Two methods could work. One, the rule-based process, is primarily a professional judgment, based on various forms of pre-calculated libraries presented in the form of "if-then" statements. This is the authors' preferred method because it is easily developed, promotes user confidence, and is conservative. However, it may not eliminate many other options that are marginal and would ultimately prove not to relate to the solution. The second method, the search-based process, uses libraries of data containing constraints on certain search variables under certain conditions.

Step 2 - Select First Set and Run Initial Analysis

- **purpose** - This step has two purposes: 1) to establish an initial set of characteristics that represent a reasonable starting point for the search routines, presumably an efficient point close to the desired solution, to save computation time; or 2) to find a starting point for an approximation routine that evaluates the extremes (best possible conditions for a given characteristic), to rule out options that are clearly not viable, even under those ideal conditions.
- **application** - This step is part of the search routine module, controlled by the analysis controller or, for some approaches, finding the first set may simply be a minor process of the search routine operating in Step 3.
- **potential methods** - Customized approximation algorithms reduce options for the first set of characteristics by applying project-related economic factors to the data source. The intent is to find a good starting point before using the energy simulation module by employing one of the following data sources: 1) the energy response library, 2) the response-surface model (starting set should get reasonably close to a solution very quickly, using either application), or 3) the library of pre-optimized sets (because it is not customized, the starting set may not be close to the solution at all).

Step 3 - Select Subsequent Sets

- **purpose** - The purpose of Step 3 is to move toward a global solution in the most efficient way, i.e., requiring the fewest iterations to meet criteria.
- **application** - This involves the primary application of the analysis control module and search routine module during target setting.
- **methods and substeps** - This deals with the use of customized algorithms in conjunction with an iterative refinement and recursive update, for the following steps:

- determine direction and slope
  - test extremes
  - determine increment (moderate to fine level of refinement)
  - verify direction from last run and correct
  - analyze only new characteristics or new disaggregated sets
  - verify that solution is global and not local.
- data sources - Two data sources might be used during this step: the energy response library and the response-surface model.

Step 4 - Use Historic Information

- purpose - Use data generated from previous analysis to influence the direction of characteristic values to be used for subsequent sets; or modify or verify information employed for rules, libraries, approximation modules, user interface, and so on.
- application - part of search routine module
- potential methods - iterative refinement
- appropriate data sources - Two data sources might be used: the energy response library and the response-surface model.

Conclusions

From the above evaluations, it appears that the best solution for the search routine module ultimately will be a combination method, using rule-based preselection, customized algorithms, iterative refinement, and recursive update.

This approach would involve the use of a set of rules and algorithms to screen out nonviable search variables. Customized algorithms would find the first set and the direction and movement by subsequent sets to approximate areas of potential solutions. Next, user-input economic parameters, including energy costs, would be applied to those portions of the data source relevant to the building. Fine-tuning would use direct search methods to determine global and local solution areas. Use of the energy module for function evaluations during the fine-tuning would update the selected data source and recursively improve the precision of the search.

This combination uses the approaches best suited to each step in the search process while considerably reducing execution time. The most probable data sources would be the energy response library and/or the response-surface model.

At the end of the concept stage, the authors concluded that the use of energy response libraries presented a better data source for the Targets model than response-surface models. It was thought that the library has the greater likelihood of successful development and provides the most acceptable benefits for the resources available for development and maintenance. This decision is discussed in greater detail in Section 5.3.

5.3 Discussion

In this section, issues identified earlier are discussed. Where possible, conclusions and recommendations of the authors are given. However, in most cases, further analysis will be necessary to achieve a final resolution of the issues.

5.3.1 Objective of Searches -- Points or Ranges?

Issue

Should the search methods focus on optimum points, or on reasonable ranges, or both? How should this be done and be presented?

This issue focuses on the objective of using search techniques within the context of the Targets methodology. What is the information about a target that should be presented to a user? Presenting results about an energy or cost minimum focuses on a single best solution, but says little about the terrain nearby. There may be a few alternatives that are virtually as good, or there may be a wide range of results.

The fenestration effective aperture example in Section 5.1.5 contains results that bear directly on this issue. For the north orientation and, to some extent, the results for the south orientation, the daylighting results present a pattern of some importance. The curves are quite shallow. At least from an energy efficiency perspective, there is a wide range of effective aperture (EA) options that a designer could select to produce results very close to the minimum or optimum point. For the north orientation and low lighting levels, the range includes virtually the entire EA range examined in the study.

Conclusion

An important conclusion from the example is that the search routines within the Targets model must be sensitive to not only solution points but also to the breadth of the area of nearby points that approach "reasonably close to" the optimum. It is expected that many such cases will exist. The expectation of ranges of good solutions increases, given the uncertainties involved in specifying some key variables in economic analyses projecting into the future. In such cases, it may be much more important for the search routines to identify that the width of the solution valley is either 10 feet wide or 3 miles wide than to identify the precise height above sea level at the very bottom of the valley.

Recommendation

The next stages of development of the search routines should examine this issue thoroughly. If the ranges of solutions are as broad as they are anticipated to be, the search methods used should generate results that provide information clearly about the range of good solutions rather than, or at least in addition to, minimums. Specific output formats should be developed to facilitate this.

5.3.2 Disaggregation and Reaggregation

Disaggregating the search problem involves breaking it up into smaller subproblems whenever possible. In general, components of the search problem can be disaggregated when they are not interdependent. A general question is, should the Targets methodology optimization problem be disaggregated? Since disaggregation reduces search efforts, how much is necessary, possible, and beneficial as part of the Targets search methods? Disaggregation needs to be addressed at least in terms of space functions, building geometry, and design strategies.

Normally, a disaggregated problem is more tractable. For example, different search techniques might be applied to subcomponents of the problem after it is disaggregated. If this disaggregation is to be done, then further questions need to be addressed. The subject of disaggregation has a number of related issues discussed below.

Issue

Is there a need to further disaggregate space functions?

Disaggregating buildings to the space function level is a cornerstone of the basic approach to the Targets methodology. Two basic types of space functions have been designated: thermal and lighting. In different circumstances, each can be a subset of the other. Questions remain about how much additional disaggregation relative to space functions is beneficial or necessary within the search routines. Should the space functions related to thermal and lighting criteria be further reduced to "tasks"? Or are there circumstances where grouping of space functions should be disaggregated into interior and exterior zones?

Conclusion

To generate custom targets under some circumstances, disaggregation in addition to the space function level will be required. For example, the fenestration effective aperture parametric example in Section 5.1.5 contained separate analyses for north and south orientations of the same space function. For innovative designs, a designer would likely want to have the target setting procedure generate a target reflecting different amounts of glazing (and perhaps types of glazing) per orientation. If only typical, noncustom designs are considered, then equal glazing amounts and treatments on all orientations might be acceptable.

Issue

What techniques are required to aggregate space function searches to whole-building searches?

It is possible that different parts of a target setting search procedure would be done at varying levels of disaggregation. Envelope system searches might be done at an orientation level within space functions. Would there be circumstances when envelope searches could and should be aggregated across space functions for one or more orientations? Lighting system searches might be needed at different levels of aggregation. The HVAC system searches might be done across a group of space functions or an entire floor, depending upon the systems involved. What will be the techniques for reaggregating from the results of disaggregated searches?

Conclusion

It is expected that focused analyses will need to be conducted in the next stage of the project to address and to resolve these questions.

Issue

What is the potential for disaggregation related to the impacts of different energy-conserving design strategies?

Large numbers of design variables are inherent in commercial buildings. Thus, it is possible for interactions between or among them to occur. If some subsets of these variables can be isolated as only marginally interacting, then the search routines can be both simpler and quicker. How much accuracy will

be lost if known interactions are ignored? Should a user of the Targets methodology be able to choose how much interaction to consider, at a cost of possibly much longer run times to conduct a search?

Issue

What forms (e.g., curves) will the various parts take under different circumstance (e.g., linear, convex, discontinuous)?

The "shape" of the solutions encountered will determine the appropriate types of search methods that might be used. The feasibility of solving a problem, the time required to solve it, and the most appropriate methods for solving it are all a function of the nature of the relationships between variables and the object of the search.

Conclusion

By recognizing ways that a large problem can be disaggregated, the search problem can be dramatically reduced in difficulty.

Recommendation

Opportunities to disaggregate the search problem should be thoroughly explored in the next stages of the work.

5.3.3 Annual Energy/Energy Cost

Issue

How can such searches be reasonably disaggregated across the range of factors addressed in the previous issue on disaggregation?

Very little work has been done using search routines that involve the complex energy cost rate structures applicable to many commercial buildings. Searches involving some rate structures will require examining information about annual, monthly, and diurnal energy patterns.

Conclusion

Focused analyses will need to be conducted in the next stage of the project to address and resolve this question.

5.3.4 Impact of the Design Strategies Considered on the Targets Obtained

Issue

How many design strategies or technologies need to be considered in the search routines for targets setting within the Targets methodology?

How would "target" results change with changes in the design strategies being considered? Should a user of the Targets methodology have a choice about which design strategies are to be considered in setting a custom target for a building design? Review of the fenestration example in Section 5.1.5 provides direct answers to some of these questions.

Conclusions

The fenestration example points to two conclusions about the number and type of design strategies considered.

Magnitude of Results Change. The levels of "desirable" energy conservation indicated by the Targets search routines can vary substantially, depending upon the design strategies selected or excluded. From the example, at least at a perimeter orientation level, a Targets "search" that excludes daylighting will show annual energy results from 0% to 20% higher than a search that includes daylighting.

Nature of Conclusions Change. If daylighting is not considered, the obvious conclusion from the example is almost invariably that "less glass is best." If daylighting is considered, the conclusion changes drastically to "a modest to substantial amount of glass is best."

These observations indicate that the number and type of design strategies and technologies included in the Targets search routines can substantially change both the magnitude and nature of the results obtained. For example, efforts to keep the number of strategies limited for the sake of simplicity or speed of execution could produce radically suboptimal energy and/or cost results.

In a voluntary use of the Targets methodology, some users may want to determine their target using an array of innovative design strategies, while other users may not wish to consider such strategies because they do not intend to use them in the actual building design. Often, decisions to not use newer technologies have less to do with efficiency or economics than a strong reluctance to accept the risk of using a technique that is not well proven in practice.

Recommendations

Examine Impacts. The impact of technology inclusion/exclusion on overall Targets methodology results should be examined thoroughly in the next stages of work. The results of this examination are expected to provide valuable information for any group that will be using the Targets methodology to develop a standards and codes application.

Develop Technologies List. The Targets team should develop a list of technologies that will be included within the target setting mode for the voluntary target application. This list is expected to include a small number of technologies (e.g., daylighting) that may be included or excluded by user option.

5.3.5 Provision for Technological Change

Issue

How much provision should be included in the Targets methodology for future technological change?

Again, the fenestration effective aperture example provides instructive information. Since that work was done, major advances have occurred in glazing materials on the market. Today, glazing products with low emissivity or with high visible transmittance relative to thermal transmittance are both gaining increasing market shares.

Because of the recent market penetration of these advances, if the example study were done today, it is quite likely that glazing characteristics would be considered a variable of major importance. And the glazing types used would substantially alter the results. Low-emissivity glass would substantially improve the energy results for higher EA in the cold Madison climate, for both nondaylighting and daylighting

cases. Glass with high visible transmittance would substantially improve the effectiveness of high EA for the daylighting cases in the hot, humid Lake Charles climate.

Conclusion

Strong provisions for including new technologies need to be built into the Targets methodology. Otherwise, it is likely to have an effective life span shorter than its gestation period.

5.3.6 Combinatorial Nature of the Search Problems

Issue

How seriously will time constraints affect the robustness of the search routines that can be used?

Multivariable searches are difficult and often time-consuming to conduct because of the large number of possible sets of solutions. The exact number of parameters to be searched has not been set, and the time each function evaluation will require is not precisely known. It is clear that as the number of variables examined increases, so does the time required for exhaustive searches.

Conclusion

The tradeoffs between search accuracy and number of variables examined is a major one to be examined further in the next stages of development of this part of the Targets effort.

5.3.7 Selection of Data Source for Search Routines

Issue

Should the primary effort in development of a data source for the search routines focus on energy response libraries, response-surface models, or some other data source?

Considerable effort is required to develop any data source for the Targets model. The development effort follows this sequence:

- Step 1 - Identify variables to consider and ranges of the variables.
- Step 2 - Develop an experimental design to permit assessing the impacts of the variables across the ranges identified, both singly and in combination. This development includes developing test vehicles for typical or prototypical building or for space function situations. It also includes identifying the level and type of data outputs to be saved.
- Step 3 - Develop possible alternative forms for equations.
- Step 4 - Test the fit of forms and select one that is most appropriate and sufficiently accurate.

Considerable "art," judgment, and indepth knowledge of the subject area are required for the entire process.

Energy Libraries. Steps 1 and 2 above are sufficient for the development of energy libraries and are involved and expensive to accomplish.

Response-Surface Models. Steps 3 and 4 are required for the development of a response-surface model. Steps 3 and 4 can involve substantial effort, especially if the forms of the equations are to make any sense on a first principles basis. This part of the process becomes more difficult as variables are added or deleted, for the forms of the equations will change, sometimes radically.

The use of a response-surface approximation model is discussed at some length in Appendix H. This was initially proposed as the preferred data source, but the authors have several strong reservations about the model. The reservations are as follows:

- It underestimates the complexity of the problem.
- It requires considerable resources.
- It has a short life span.

Each of these reservations is briefly discussed in the following paragraphs.

Complex Problem: The problem being addressed is very complex, as indicated in examples provided in this section. The proposal contained in Appendix H appears to seriously underestimate complexity involved to develop the method to a level acceptable to the design community. The technical support for the proposed method has included a very simple "proof of concept" model developed during Phase 1 (see Crawley et al. 1987b). Early during Phase 2, a simple example was presented using several variables on a very narrow subset of the problem. Consequently, the authors feel that there is not adequate evidence presented to assess the ability of the proposal presented in Appendix H to address the problem at hand.

Development Resources Required: The method will require considerable resources to develop. An historical example will provide some context for development complexity and resources required. The regression-based approach for envelope annual loads in SP41 and in ASHRAE/IES Standard 90.1-1989 was expensive in both time and money. The effort began in 1982, and extensive work was done by LBL. Three complete iterations through the process were required over 2 years to produce an acceptable result that contained appropriate forms for the expressions that made reasonable sense and produced results felt to be reasonable. In all, some 10,000 DOE-2 runs were made in this process. These results were included in a report published in late 1983.

The method was then reviewed by the ASHRAE SSPC 90R. It was determined that the interactions of thermal mass and insulation were not delineated in enough detail. To remedy this, the entire regression development process was repeated a fourth time in 1985-1987. This effort required several thousand additional DOE-2 runs and considerable re-evaluation of the form of the equations.

More importantly, the entire effort required massive amounts of thinking by highly knowledgeable and experienced people. The authors estimate that the cost of this effort is approximately \$750,000.

The envelope product mentioned above directly calculates annual loads on the heating and cooling systems for four major orientations for external zones. It is done only for walls, not for roofs. Major expansions or revisions of this methodology to produce a complete envelope method will require a reassessment of the forms of the equations, a redevelopment of an experimental design, and the running of numerous DOE-2 runs. Or it will require a separate effort for roofs and skylights.

An effort to develop robust regression-based expressions for HVAC systems, equivalent to the effort made for walls, is conservatively estimated to cost \$ 1,000,000+ and to entail several years of elapsed time. If lighting systems are treated in a cursory fashion, using watts/square foot, the effort may not be too extensive. But, if the factors involved in selecting alternative lighting systems, fixtures, controls, etc., are also considered, then developing the regression-based expressions for lighting systems could cost, say, \$500,000. Together, these estimates indicate the need for considerable resources to develop the method to a reasonable level of detail.

Short Life Span: Once the method is developed, new regressions will need to be redone to handle changes in technologies or new technologies, or to simply improving the method. Regressions have a liability that tends to give them a short life expectancy. They must be completely redone to be modified. Thus, if new technologies become available, or if new aspects of existing technologies must be considered, or simply if the developers "missed" something that reviewers later consider important, then the entire effort to develop the regressions must be redone. It is likely that the regressions would need to be revised routinely, given rates of change of building technologies. In such situations, making new computer runs is trivial. The difficult and expensive part (that also requires much expertise), is the reassessment of the forms of the regression equations, and establishing the new experimental design.

Conclusion

It seems imprudent at this point in the development of the project to select, or to sponsor, a method that has the following attributes:

- only very general supporting documentation relative to the problem at hand
- appears based upon a serious underestimation of the complexity of the effort involved
- very high anticipated development costs
- short life expectancy.

Consequently, the authors do not recommend the method presented in Appendix H at this point in the project as the path to take. Given sufficiently detailed information about the proposed approach to satisfy the concerns expressed above, the proposed method may deserve further consideration in parallel with other promising approaches, in particular energy response libraries.

6.0 Energy Simulation Module

The Targets methodology will require an effective, time-efficient, and accurate microcomputer-based building energy simulation tool to achieve its objectives. This energy simulation tool must be able to accommodate the computational speed and accuracy requirements of a wide range of energy analysis tasks that occur throughout the Targets model. Furthermore, it must operate efficiently as a part of iterative cost and economic analyses. It must also accomplish these tasks on an affordable desktop computer.

Significant effort was directed toward determining which of the existing building energy simulation tools might be adapted to meet these criteria. Unfortunately, the conclusion is that none of the existing tools is entirely satisfactory. The microcomputer versions of the mainframe analysis tools are too cumbersome and time-consuming to be used as part of iterative cost and economic analysis procedures or in an interactive design analysis mode. The simplified procedures, designed for use on the current generation of microcomputer, are not sufficiently robust. They are not able to explore a broad enough range of the available building and system design strategies and technologies. Nor do they provide the level of detail required if one is to examine the interactions among space loads, systems, and equipment that must be considered if one is to develop a truly energy-efficient building design.

If a 'kernel' simulation program--a third-generation modular building energy analysis model proposed in both the U.S. and Europe--were available, it would be by far the best place to start. However, it does not appear that a 'kernel' program will be available within the timeframe anticipated for this project. Therefore, it has been concluded that one or more of the existing building energy simulation tools must be modified and improved to meet Targets model needs. Modifications are required to match energy model input and output with the information provided by, or required by, other elements of the Targets model. Improvements will be required in both analysis technique and in software efficiency. The speed and capacity of microcomputer hardware will also require improvement. It appears that the microcomputer hardware improvements will come as a natural consequence of broad market forces pushing for increased speed and capacity. However, the improvements in analysis technique and software will come only if motivated by this or a similar project.

This section documents the efforts undertaken to identify an appropriate energy simulation tool. The approach is described, as are the results. The relationship of the energy simulation module to other modules in the Targets model is shown in Figure 6.1.

6.1 Approach

A two-pronged approach was used to select a building energy simulation tool to use as the energy simulation module. First, the Targets project team defined those module attributes that would be required to meet the Targets methodology objectives. Once the basic module requirements had been defined, several alternative approaches were formulated. The Targets team then sought the review and advice of a group of energy simulation experts. This group met in March 1988 to review the requirements and the proposed alternative approaches and to provide the requested advice. Each of these activities is described below.

6.1.1 Module Requirements Definition

The energy simulation module is an essential element in both the voluntary and the standards and codes applications of the Targets model.

Figure 6.1. Energy Simulation Module Location Within the Targets Model

In the voluntary application, use will be motivated by a designer's (or owner's) personal interest in designing an energy-efficient and cost-effective building. To ensure that these users will utilize the energy requirements option, the Targets model must be flexible, easy to use, and provide sufficient useful information. It must be able to provide appropriate custom targets and allow a designer to quickly examine a number of "what if" questions that might arise while designing a building to meet the target.

In the standards and codes application, the Targets model may function in three ways. First, it might function as a whole-building performance path within a broad consensus standard (which might also include prescriptive and component performance paths) such as ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989). In a second setting, the Targets model might be used by a governmental entity or by a corporate or institutional owner to set targets for specific building needs. In this instance, the targets generated might apply to a specific building project or to a number of buildings. It should be noted, however, that the Targets model is not intended to be used to generate fixed tables of target values by building type or subtype without regard to individual project function requirements and design constraints. The final potential application of the Targets model is in the development or revision of prescriptive or component performance type codes.

Each application makes different demands of the energy simulation module. These differences can be clarified by a more detailed description of each application.

Voluntary Targets for Building Design

In a voluntary targets application, the energy simulation module may be used in setting a target and evaluating a proposed design. Both processes must begin at a point in the design where they can contribute to the design of an energy-efficient building before the design is set, while it can still be changed to accommodate energy concerns.

Target Setting. The target setting mode defines a cost-effective custom energy use target that can be achieved through energy-efficient design. The target will be set based on the definition of the building function and its scheduled use, site considerations, and local costs and economic considerations. These factors are introduced to account for design requirements that may significantly affect energy use but are outside a designer's control. The Targets methodology is dynamic, considering the interaction of energy, cost, and economic constraints, in a way not possible in prescriptive standards. To run this comprehensive analysis, the process requires extensive time and intensive iterations.

The target setting process must not burden the design process unnecessarily. A designer or an owner must be able to generate a building energy target reasonably quickly, within an hour or so. Because the target setting process is iterative, an energy simulation will be required for each set of design and cost parameters considered. Thus, to set a target in an hour may require the energy simulation module to run in seconds.

The design constraints that set the value of the targets may change as the owner and the design team refine the building program, cost, and economic criteria during the design process. In such a case, a series of targets might be generated, reflecting the effects of the redefinition of the design constraints that occurs as the design progresses, with the final targets being defined only at the end of the design process.

The input, analysis, and output characteristics required of the energy simulation module in the target setting mode can be summarized as follows:

- User input applies to the Targets model in general rather than directly to the energy simulation module. The items from the general input that will be used in the energy simulation module are the basic set of building design constraints (location and site, intended functions of the spaces in the building, operating schedule, and comfort and amenity criteria).
- The remainder of the data needed to drive the energy simulation module will be provided by the characteristics development module of the Targets model. This module will provide an appropriate set of initial characteristic values to initiate the energy analysis process. These characteristic values will be selected from the range of allowable parameters defined in the consensus database with the assistance of cost/economic analysis search routines.
- To minimize the complexity of the analysis, the energy simulation module will begin at whatever level of disaggregation is necessary to clearly define the productivity, comfort, and amenity level required to meet the objective of the space being designed. The level of disaggregation required to generate the targets may vary depending on the stage of the design. The energy analysis could begin at a zone, space function, or even at a task level if necessary.
- The output will be a task, space function, zone, or whole-building target to be used as an energy use goal in the design process. Again, the level of disaggregation may vary depending on the stage of design. The final targets, however, will be at the whole-building level.

Design Analysis/Evaluation. The design analysis/evaluation mode provides the designers with the means to explore the energy consequences of the options available to them to meet the targets. There will be no internal limits on the unconstrained design parameters in this mode. The user-defined input will therefore be more extensive than in the target setting mode. The energy simulation module operating in this mode must provide a more detailed output to allow the evaluation of the relative merit of the full range of design approaches and technologies the designer may choose to meet the targets. For example, it will need to be able to consider a wider range of variations in ventilation, external shading, and mass options than might be considered in the target setting mode. It will also need to be capable of examining a very broad range of systems and equipment options.

Run speed and input time requirements may also present a problem in the design analysis/evaluation mode. To be effective in design analysis, the energy simulation module will have to operate interactively. It must also provide a clear definition of peak loads and energy use requirements at the space load, system load, and equipment levels if designers and owners are to properly evaluate the energy and cost impact of specific design decisions.

Accuracy is a greater concern in the final design evaluation. However, a somewhat longer run time may be acceptable at this stage in the design. The simulation tool selected must be capable of balancing run time with accuracy requirements at the various stages in the design process. The balance shifts from needing to minimize time in the early analysis stages to providing some measure of precision in the final evaluation. Issues related to module execution time are discussed in Appendix I.

The input, analysis, and output characteristics required of the energy simulation module in this mode of operation can be summarized as follows:

- For the design analysis, the input would consist of the design constraints (e.g., space function, site, schedule) and the characteristics defining the options to be examined during design. For the final evaluation, the input would consist of the final definition of the design constraints and economic perspective and the full set of design characteristics that define the final building design.

- The analysis required for this mode will be more complete and perhaps more complex than that needed in the target setting mode. More algorithms may be required to evaluate a broader range of options.
- The output in the design analysis mode would be an estimate of the peak load and design energy use for each option considered. A means of storing the input and output for each set of options considered, as well as a final comparative output display, would be necessary. For the final design evaluation mode, the output would be an estimate of whole-building energy use to be compared with the final target.

Development of Standards and Codes

The Targets model has three potential uses in development of standards and codes: 1) inclusion as part of a consensus standard; 2) as an aid in developing specific corporate or government standards or codes; and 3) as a research tool in support of the development or revision of standards and codes. Each of the uses is described in more detail below.

Consensus Standards. The Targets model would simply be included as a whole-building performance path within a standard such as ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989). In this instance, the input, analysis, and output requirements would be essentially the same as those described for the voluntary targets application.

Mandatory Standards and Codes. The Targets model might be used by a government entity or by a corporate or institutional owner to set targets for their specific building needs. In such cases, the definition of allowed parameter ranges in the database and/or the procedure for selecting specific parameter values to be used to set the targets might be more tightly prescribed. They might be defined to meet a specific set of energy use objectives or constrained by a more limited set of cost and economic factors. The procedure for applying the methodology would be essentially the same as that described for target setting. The energy simulation module requirements would again be the same. The procedure for verifying compliance with the targets established would be that described under design evaluation, and the same set of attributes would be required for the energy simulation module in this mode of use.

Research. In the research application, the Targets model would support development of prescriptive or component performance codes and standards. In such cases, the model might be used to test the prescriptive or component performance criteria and compare them with targets. In this application, run time requirements for the energy simulation module would be considerably less stringent.

6.1.2 Energy Simulation Module Review

After the proposed energy simulation module and its operating characteristics and attributes necessary to meet the project objectives had been defined, members of the project team met with nine building energy simulation experts in March 1988 to review the requirements outlined in Section 6.1.1 and to determine the best approach for satisfying these requirements.

Requirements

The objective of the workshop was to obtain advice from experts familiar with the existing energy simulation models as to which energy simulation model(s) would best serve the Targets methodology needs. This workshop provided a great deal of useful information; the discussions have had a major impact on the formulation of the energy simulation module concept presented in this report. A summary of this meeting is provided in *Volume 3: Workshop Summaries*.

Structure Options

The energy simulation experts also reviewed alternative energy simulation module structures at the meeting. Three basic approaches to structuring the energy simulation module were considered. The first approach was the development of a regression-based correlation. This would be an extension of the approach used in the envelope section of ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989) and would involve the development of similar procedures for HVAC and lighting systems. The second approach considered was the development of a flexible, easily updated compact analysis procedure that would use an hourly energy analysis but would also use an abbreviated input data set, run on a high speed desktop computer, and be optimized to the extent necessary to reduce run times. The compact analysis procedure would clearly define the energy use, peak loads, costs, and benefits of the various design strategies and technologies considered but still reduce computational time. The final structure considered was to provide "hooks" to an external energy analysis program and not include an energy simulation module within the Targets model at all. This option would require the development of an interface to allow interaction between the Targets procedures and the external energy simulation model(s).

Although the compact analysis procedure appeared to most nearly meet project objectives, none of the basic structures appeared to have all the desired characteristics or to meet all the defined criteria. Six options were presented for review at the energy simulation experts' meeting:

1. Select and modify, to the extent necessary, a single energy simulation model capable of serving in all aspects of the Targets model.
2. Select more than one model. Choose a range of models, starting with a fast, relatively simple model to function in the initial target setting mode and in the early stages of design analysis. Then select one or more additional models with capabilities that build to a comprehensive module that can meet the requirements of the final target setting and final design evaluation mode.
3. Select a fast module that would be part of the Targets model but would deal with just the initial target setting and design analysis tasks. Then develop an interface/translation capability that would allow for the use of more powerful external models in the later stages of design and for the final target setting and final design evaluation tasks.
4. Do not include an energy simulation module in the Targets model. Instead, develop a set of interface/translation capabilities to allow the use of one or more external energy simulation models to serve the energy analysis tasks. Make no attempt to modify the structure or enhance the capabilities of the external models.
5. Develop a regression-based correlation procedure to serve the energy analysis needs of the project. To meet the overall objectives of the Targets methodology, additional regression-based correlation models, to define the peak load and seasonal impacts of design decisions would also be needed.
6. Develop a procedure for using regression-based correlations to replace some, but not all, of the calculation procedures in one or more of the hourly simulation models.

Those attending the workshop were asked which of these options they would recommend. They were also asked if they felt there were other options that would better serve the Targets project needs.

6.2 Results

The formulation of the energy simulation module concept proposed in this report was a combination of activities involving the Targets project team, consultants, and building energy simulation experts. The results of these activities can best be described in terms of the criteria this group has recommended for structuring the energy simulation module.

6.2.1 Energy Simulation Module Criteria

Four principal criteria are needed to judge energy simulation module performance: time, flexibility, consistency, and accuracy. Unfortunately, these criteria are often in conflict. Those actions that can be taken to reduce time tend to reduce flexibility and accuracy as well. Those approaches that increase flexibility and accuracy tend to increase both run time and input time. The challenge has been to try to find the balance between these criteria.

Once the Targets team had defined the range of analysis capabilities and operating requirements of the energy simulation module in its various modes of use, the next step was to determine which set of these criteria would require the most comprehensive module. The team decided that the needs of the design analysis/evaluation mode, required for both the voluntary and standards and code development applications, are the most taxing and should be used to define the overall range of capabilities required in the energy simulation module. A module that meets the criteria set for this mode of use will also meet the needs of the target setting mode.

General and specific sets of requirements were then developed, again within the Targets team, in consultation with the building energy simulation experts. These are documented in the next two sections.

General Requirements

The following general requirements were defined as criteria for the energy simulation module:

- The module must be easily integrated into the overall Targets model.
- The module must be capable of providing both a full detailed analysis and an abbreviated or compact analysis. Whether the module will be run in one mode or the other will depend on the stage of the design process and on the level of precision required.
- The module must be capable of providing distinct output of space loads (including the effects of variable space temperatures), system loads, and equipment (plant) energy use. Space, system, and equipment loads will need to be available on at least an hourly basis for appropriate periods if peak loads and dynamic effects are to be analyzed.
- The module must be sufficiently modular so that the space loads, systems loads, and equipment energy use models can be run separately as well as a unit.
- The systems and equipment models must have the capability to build HVAC systems from selected components rather than being tied to fixed system descriptions.
- The energy simulation module must be able to accommodate multiple thermal zones and multiple lighting zones within a thermal zone. Each thermal and lighting zone must be capable of having its own schedules and lighting system features.

- The energy simulation module must provide output in a time frame compatible with its use in an interactive mode. This does not mean that it has to complete the analysis in a matter of seconds, but it does have to provide useful intermediate results rapidly enough that the user does not lose interest while the calculations proceed. These intermediate outputs must also be able to be captured for reporting if desired.

These are challenging criteria because of the parallel requirements for minimizing run time, maintaining flexibility, and ensuring a reasonable level of accuracy.

Time Requirements

Time is a major criterion. The time of concern comes during the time required to set design targets, to complete a design analysis, or to set a final target and carry out a final evaluation. Each of these times includes the time to prepare the input, the actual computation/analysis time required by the computer, and the time to interpret and evaluate the output.

The actual time necessary to run an analysis on a desktop computer is one part of the problem. Currently, to complete a simulation of a simple five-zone building, running DOE-2 on a MicroVAX™ requires about 20 minutes (1200 seconds). This is obviously too much time for either an iterative or an interactive analysis.

In the interactive (design analysis) mode, it would be desirable to produce results in 10 to 15 seconds. This would represent a run time reduction of two orders of magnitude. This requirement might be relaxed somewhat by providing intermediate output to occupy the user's attention while the computer completes its analysis. An example of this might be to display input load profiles and climate data, space loads, systems loads, and energy use for a selected number of days in multiple windows on the screen in a sequence. With the initial output within an approximate 10-second boundary, having the final results in perhaps a minute or two might be acceptable.

In the target setting mode, with perhaps a thousand iterations, even 10 to 15 seconds per energy analysis may be too long. However, if a procedure could be developed to limit the number of iterations to a few hundred per analysis, 10 to 15 seconds per analysis might be acceptable.

For a final evaluation, run times up to an hour or so might be reasonable if the program could run in the background while allowing other computer activities to continue simultaneously. However, run times on the order of minutes would be most desirable.

A definition of how much input time is acceptable is difficult. The input time for setting an initial target, or the input time before the analysis begins to provide feedback in the design analysis procedure should be as short as possible, preferably less than an hour. As the design analysis proceeds interactively, additional time for more detailed input may not seem burdensome.

On the output side, the primary time issue is how to present the output for rapid review. The output should be graphical with the possibility of tabular data for backup when desired. Both the graphical and tabular outputs should be available in hard copy upon request. Here, the primary challenge is to design the graphical output to provide the maximum amount of information possible in the minimum amount of time.

™ MicroVAX is a registered trademark of the Digital Equipment Corporation, Maynard, Massachusetts.

The following time requirements are recommended as performance goals for an energy simulation module in the development work:

- It should be possible to define the initial Targets model input in a reasonable time (perhaps an hour or so) with options to refine/extend the detail as the process moves to the design analysis/evaluation mode.
- A single energy analysis should run in 10 to 15 seconds, as multiple energy analyses are involved in both target setting and design analysis/evaluation modes.
- Output should be available in both graphical and tabular form to minimize the time required to review results. The output should be structured so that several options can be compared visually without a great deal of effort. The time required to review summary output should be no more than 5 to 10 minutes. Both the graphical and the tabular data should be available for a more detailed review when desired.

It is recognized that these goals will not be easily reached. The prototype modules will require considerably more time to execute than indicated above. However, it is essential that these long-term time objectives be kept in mind, even in the prototype stage. Once a complete set of prototypes is in place, it will be possible to better define the run times necessary to satisfy various groups of Targets model users.

Flexibility Requirements

Maximum flexibility is required. The most extensive program that can be modified to meet Targets methodology criteria must be selected. The range of simulated envelope, lighting, and HVAC options must be as broad as possible, and the program must be structured so that additional options can be added as the new technologies are developed and introduced into the marketplace.

The simulation procedure selected must be capable of handling a series of short analysis periods (daily input profiles representing a variety of load conditions, but which may not occur as a continuous sequence of days) as well as a full 8760-hour analysis. It would be desirable if the analysis procedure selected were capable of using variable time steps in system and equipment simulation.

The energy simulation module selected must provide access to hourly load and energy use output at space, systems, and equipment levels. Output that defines illumination levels, thermal criteria, and the state of the air flow at each point in the HVAC system is desirable. Having these data available for diagnostic/educational purposes significantly increases the value of the Targets model.

Accuracy Requirements

The final set of requirements identified deals with the issue of accuracy. It is evident that the variability of weather and use patterns will lead to greater estimated energy use differences than will the use of a more or less precise energy simulation module. Thus, the emphasis must be on the selection of an energy simulation module that will operate consistently and efficiently in all aspects of the Targets methodology.

The following requirements for accuracy were decided upon:

- A single energy simulation model should be used. Using different procedures might give inconsistent or even conflicting signals to the designer at various stages of the design process.

- The project team should not attempt to mix and match between programs. Doing so will consume time and effort that should be directed toward the development of an effective user interface.
- As the objective of the methodology is to provide an evaluation of the energy use resulting from a proposed design that can be reasonably compared to a target that was generated with the same analysis tool, emphasis should be placed on consistency and the relative accuracy of the results.
- Project efforts should not be directed toward defining a tool for accurately predicting the annual energy use of a building. Instead, the project should address those issues critical to the success of the Targets methodology in guiding the design of energy-efficient and cost-effective buildings.

6.2.2 Other Recommendations

The energy simulation experts also provided the following specific recommendations:

- Select a single program quickly, modify it to meet the necessary basic project objectives, and concentrate on the user interface and data management issues.
- Select a single 8760-hour public domain program as a starting point. Among the alternatives are BLAST (U.S. Army Construction Engineering Research Laboratory 1979; Herron, Walton, and Lawrie 1981); DOE-2 (Simulation Research Group 1989); and HVACSIM⁺ (Clark 1985; Clark and May 1985; Park, Clark, and Kelly 1986).
- Do not rely on regression-based correlation approaches.
- Adopt the compact analysis approach. However, the procedures used in a compact analysis should be consistent in detail with those of a full 8760-hour analysis approach. The full 8760-hour analysis should remain as an option for setting the final targets and in the final energy use evaluation.
- Implement the analysis on the fastest desktop computer available, as early in the development as is possible. It will be important to benchmark the time on current equipment early in the development stage to evaluate the need for improved speed for the final hardware selection.
- The initial choice of an energy simulation model will not be as critical if the Targets model shell is designed to ultimately accommodate an interface with existing and future public domain, private sector, and energy analysis programs. The Targets methodology objectives of flexibility, user confidence, and convenience can best be met if a variety of tools are available. This should be accomplished through the development of standard input/output procedures. Hooks should be developed to allow interfacing with a number of analysis tools in both the public domain and in the private sector.

6.2.3 The Selected Energy Model

It has been recognized from the beginning that the "perfect" analysis tool does not exist. The proposed kernel approach would probably be the best starting point, but it will not be available during the Targets project timeframe. An existing simulation tool must be chosen and modified to the extent necessary to meet the project objectives. Therefore, a choice that involves some compromise must be made.

The basic analysis tool selected for the Targets model must be in the public domain. The necessity of modifying the code to some extent to meet the project objectives reinforces the need to choose an accessible public domain code.

After the specific criteria defined in Section 6.2.1 and the recommendations discussed in Section 6.2.2 were carefully considered, DOE-2.1D (Simulation Research Group 1989) was selected as the starting point for development of the initial energy simulation module. Despite its limitations in specific areas, DOE-2.1D appears to be the most complete and flexible approach now available. The 2.1D version includes specific daylighting analysis capability, provides increased flexibility to modify systems for a variety of control options, and provides more extensive thermal storage system option analysis capabilities than are available in BLAST. Its input structure is more convenient to use than that of HVACSIM+ (Clark 1985; Clark and May 1985; Park, Clark, and Kelly 1986). The Targets team concluded that DOE-2.1D can be modified to provide the required output and to run in the compact analysis mode.

Although the considerations outlined above led the team to select DOE-2.1D as the basis of the energy simulation model, the decision was made reluctantly and only after extended discussion. The efforts within this project should encourage, and support to whatever extent is possible, the development of better energy analysis tools.

DOE-2.1D needs to be modified to more fully meet the criteria described in Section 6.1. This work should begin as soon as possible. These modifications will require considerable time and effort during the development stage of the Targets project.

7.0 Building Cost Module

The building cost module is a major component of the Targets model. Comparative building cost data must be available to enable Targets users to make economic comparisons among alternative energy design strategies. The development of the building cost module is detailed in this section. The location of the building cost module relative to other modules is shown in Figure 7.1.

The primary objective of the proposed building cost module is to provide the relative first costs of a wide range of energy conservation design strategies. These will permit economic comparisons to be made among the strategies. The information on relative first-cost data can be presented directly to the user or be used by the economic analysis portion of the Targets model. Most of the effort required to develop the building cost module will be to meet this overall objective. To accomplish this, the building cost module is expected to have two main functions: 1) accessing and manipulating cost information contained in databases; and 2) evaluating costs of building components involved in alternative design strategies.

This section documents

- the approach taken to delineate a conceptual direction
- a set of criteria identified for the functioning of a building cost module
- the conceptual structure of the proposed module
- selected examples indicating how the proposed module will work.

7.1 Approach

According to the Phase 1 report (Crawley et al. 1987b, p. 4.6), the major effort to develop the building cost module would be required "to build or manipulate a database of building construction costs to yield arithmetic expressions relating to the energy performance of building components to component costs." This is the approach proposed here.

Developing a conceptual approach for a building cost module for the Targets model has been, and will continue to be, a challenge for several reasons:

- Unlike the energy simulation module, a ready-made public domain building cost model that will meet the needs of the Targets model does not exist; available building cost models do not adequately handle cost estimating of energy-related building assemblies and systems. Thus, a module must be developed from scratch, or a major overhaul of a public domain cost model written for other purposes must be perfected. Either option is a major undertaking, relative to the amount of effort required to incorporate one or more existing energy simulation models into the Targets model.
- A user cannot be expected to enter building cost data for each project. This would be prohibitive in terms of the knowledge and time required and would violate the objective that the Targets model be "easy to use." Thus, cost data must be provided by the building cost module.
- Considerable cost detail is needed to adequately address building cost changes resulting from many energy design strategies. This level of detail is often simply not available in current cost databases.

Figure 7.1. Building Cost Module Location Within the Targets Model

- Even further cost detail is expected to be required so that users can be reassured that the basis for the costs being used is reliable.
- Cost data available to the Targets model must be kept reasonably up-to-date, while keeping maintenance costs for such updating to a minimum.

7.2 Tasks Completed

Three main activities were completed during the concept stage. First, the project team formulated a basic proposed approach to the building cost module. Second, the team sought assistance and advice from a group of building cost experts. Third, based upon the input received from the experts, the approach to the building cost module was refined and detailed. Each of these activities is briefly described below.

7.2.1 Conceptual Approach Formulation

The project team developed a detailed conceptual approach early in the concept stage. Because the building cost module involves a great deal of data with many complex interactions, the original formulation of the approach attempted to identify the data requirements as well as the data manipulation requirements. The team provided copies of this conceptual approach formulation to the building cost experts before the latter met with the team.

7.2.2 Experts Meeting and Feedback

To obtain assistance in determining a proper direction for building pricing within the Targets model, the project team met for 2 days in Washington, D.C., with building cost experts to discuss project objectives and possible approaches. The experts' feedback has been extremely valuable in determining a course of action for the building cost module conceptual development. A major recommendation from that meeting was to use generalized "templates" to structure the access and manipulation of cost databases. The minutes of the 2-day workshop and the experts' written comments are presented in *Volume 3: Workshop Summaries*.

7.2.3 Subsequent Development of Approach

Since the meeting, the template approach has been developed in some detail and further refined. Several examples have been developed as vehicles for exploring, developing, and presenting the concepts contained in the template approach. These examples constitute a major part of the results of the work accomplished to date.

7.3 Results

Four main results were produced from the tasks completed:

- Criteria were defined for the building cost module.
- A conceptual approach was proposed using a cost "template" structure.
- A taxonomy for logically structuring and accessing the building cost module was designed.
- Building cost examples were developed as vehicles for defining details of the template approach.

Each result is described below.

7.3.1 Building Cost Module Criteria

The building cost experts' recommendations have guided the development of the proposed conceptual approach to the building cost module. Their major recommendations about the attributes needed in a building cost module are listed below. The consultants thought these attributes were important for the proper operation of a building cost module within the Targets model:

- The cost estimating procedure should be automated. The user should not have to either develop cost estimating expertise or spend considerable time and effort developing specific cost estimates. This involves two basic steps:
  - Have necessary costs available for the building cost module in the form of a cost database.
  - Have expressions for converting cost data to cost estimates that relate to the building, the system and components in the specific design situation, and the energy strategy involved.
- The outputs should be formatted to clearly indicate that the results are very "soft" estimates. Two format options were discussed at the meeting:
  - Indicate a reliability factor next to each cost data item.
  - Present the user with expected ranges of cost values as opposed to a single dollar value.
- Linkages should be provided to allow the user to access a preferred unit cost database. The most desirable types of databases include DataSource,™ Design Estimator II,^(a) and a user's customized in-house cost database.
- Users should need to address only summary cost data; they should not have to deal with cost estimating details unless they want to.
- Full supporting cost data and calculation details must be readily available to the user for review. Otherwise, the user will not have confidence in the cost data presented.
- Users must have full editing capabilities for all cost data and cost estimating methods, since many will want to use their own tried and tested data and methods.
- Users must be able to readily enter building cost data about new and innovative design strategies. Also, users should be encouraged to explore any and all newly developed design strategies. This feature is very important to prevent obsolescence due to insufficient design strategy choices to satisfy the wide variety of expected users.
- A facility must be included to update all cost data using either automated or semi-automated approaches.

™ DataSource is a registered trademark of the R. S. Means Co., Inc., Kingston, Massachusetts.

(a) Design Estimator II is available from Dodge MicroSystems, Princeton, New Jersey.

- Cost data must be believable. The most accepted form of cost data is historical project cost data that has been thoroughly reviewed by competent building cost estimators. It is important that cost data be modified or isolated whenever unusual circumstances or questionable data are found. Then, the historical data should be sorted by several key building descriptors and filtered to remove such elements as the foundation costs and costs associated with unusual site conditions.

7.3.2 Building Cost Module Applications

The building cost module will serve distinct functions within each of the two primary modes of use within the Targets methodology.^(a) The uses of the building functions are briefly described below.

Target Setting

In the target setting mode, the building cost module will be accessed automatically to establish the cost of alternative building energy design strategies selected by the analysis control module. The analysis control module will then feed this information to the economic analysis module. The characteristics development module uses the output from the economic analysis module to establish the custom target for the building under study. Because target setting mode access to the building cost module is automatic, a Targets user will not need to use the building cost module in the target setting mode.

Design Analysis/Evaluation

In the design analysis/evaluation mode, the building cost module has two purposes. First, a Targets user can compare the construction costs and the economic impact of alternative energy-related design strategies for one or more building designs. Second, a Targets user can compare the costs of one or more building design solutions against the costs automatically determined by the Targets model in the target setting mode. If appropriate, a revised target, along with its associated construction costs, can be generated from within this mode.

In the design analysis/evaluation mode, the Targets user has complete access to the building cost module data to modify or generate cost data to reflect expected construction costs for a building under design. For ease of use, it is planned that building costs will be presented in a brief summary format (by default). The user then has the option of progressively accessing and editing nested levels of detailed cost data that support the summaries presented.

7.3.3 Existing Building Cost Models

The features and limitations of various cost databases and cost estimating methods are briefly discussed in this section.

Approaches Considered

The building cost module will require some unique capabilities. A survey of existing costing databases and cost estimating models revealed that they do not include many of these capabilities. The following discussion identifies the cost databases and cost estimating models investigated.

(a) These two "modes" may be used within two different "applications" of the Targets methodology: 1) voluntary targets for building designs and 2) development of standards and codes. These various options are discussed in Sections 1 and 6 of this volume.

Cost Databases. The most popular cost databases include those available from F. W. Dodge, R. S. Means, the National Price Service, and the Trade Service Corp. These cost databases are incomplete in several areas important to the Targets methodology. The Targets model will require detailed cost information for most energy-related building materials, assemblies, and subsystems. However, the levels of detail needed are not available in the current databases. Specific examples of missing data details are

- costs of fenestration components (e.g., costs for various high performance glazing options are not available)
- costs of lighting components important to energy decisions (e.g., separate costs for various lamps, ballasts, and controls are not available)
- costs of important energy-related HVAC components.

Because of the large number of missing cost data items, these existing databases are of limited value as sources of energy-related construction cost data needed by the Targets model.

Numerous in-house proprietary cost databases, developed by large corporations, also exist. These databases may be more complete than commercially available databases. However, because these databases are proprietary, they are of limited value to the Targets project.

One promising cost database is the Computer Aided Cost Estimating Software (CACES) package, developed by the U.S. Army Corps of Engineers (1987). This database is reported to be very detailed and is maintained annually. The current CACES database for any given year is not available in the public domain. However, when an annual update is completed, the previous year-old version of the database then becomes publicly available.

Cost Estimating Methods. Several commercial cost estimating programs are available. These existing cost methods were developed primarily for evaluating costs associated with building construction. These include

- ASTRO, a facilities estimating program developed by the R. S. Means Company, Kingston, Massachusetts
- the Interactive Cost Estimating® (ICE) System® developed by Management Computer Controls, Inc., Memphis, Tennessee
- Price and Cost Estimating Program (PACE II), developed by the NASA Marshall Space Flight Center in 1977 - It is currently available from and maintained by the Computer Software Management and Information Center (COSMIC) in Athens, Georgia.
- CostPro, currently marketed by InPro, Inc., of Albuquerque, New Mexico
- Generic Estimator, recently developed and being sold by Generic Software in Bothell, Washington, as an add-on for its Generic CADD program.

A public domain, PC-based cost estimating program called PC-QUEST is available from Los Alamos National Laboratory.^(a) This program, designed for professional cost estimators only, is the prototype of CostPro. InPro, Inc.'s CostPro is the friendlier, but proprietary, version of this program.

Evaluation of Cost Estimating Modules

The Targets methodology objectives require the building cost module to provide several specialized capabilities, including

- cost estimating during the early conceptual and schematic design stages, when detailed descriptions of each building system do not exist
- defining multiple building assemblies, design strategies, or design technologies (for which cost estimates may be required)
- developing multiple simultaneous cost estimates for similar but alternative building assemblies, design strategies, or design technologies (for comparative purposes)
- an ability to review the constituent costs of building assemblies, design strategies, or design technologies, in incremental layers of increasing detail
- editing capability for various cost databases
- automated and manually controlled updating for various cost databases.

Some of these capabilities are not available in some of the existing cost estimating packages. Another difficulty is that many existing estimating programs are written for mainframe computer implementations. For Targets purposes, they would need to be ported to a desktop computer environment. A further potential difficulty involves proprietary restrictions. The many proprietary cost estimating methods may be either commercial products for which the source code is not publicly available, or in-house software programs. Their use may well involve either a purchase cost or a licensing fee. Proprietary restrictions notwithstanding, the very high anticipated costs of developing a complete cost estimating method for Targets purposes provides a strong incentive for exploring the potential modification of one or more of these proprietary programs for use within the Targets model.

Table 7.1 summarizes the relative advantages and disadvantages of the costing methods available. This matrix confirms the advice received from the building cost experts. Not one of the available methods is capable of satisfying the building cost module criteria outlined in Section 7.3.1.

The authors identified two approaches that may best satisfy the basic criteria for the building cost module:

- Option 1 - Develop a totally new customized cost estimating software program that accesses multiple cost databases.
- Option 2 - Develop a module that will allow the user to use one of several available cost estimating methods.

---

^(a) For further information on PC-QUEST, contact Roger Stutz, Los Alamos National Laboratory, Los Alamos, New Mexico.

Table 7.1. Decision Matrix for Possible Approaches for the Building Cost Module

Capabilities	Existing Cost Estimating Packages								New Custom Software
	ASTRO	Dodge	CACES	PACE II	ICE	Los Alamos	CostPro	Generic Estimator	
Automated cost estimating of design strategies	1 ^(a)	1	1	1	1	1	2	1	2
Internal reliability checks	1	1	1	1	1	1	1	1	2
Linkages to other cost databases	0	0	0	1	1	1	0	0	2
Hierarchical layering of data	1	1	1	1	1	1	2	1	2
Editing utility	1	1	1	1	1	1	2	1	2
Capability to add new design strategies and technologies	1	1	1	1	1	1	2	1	2
Automated updating	0	0	0	0	0	0	1	0	2
Public domain	0	0	0	0	0	1	0	0	2
TOTAL	5	5	5	6	6	7	10	5	16

(a) Scoring criteria

2 = Existing program is acceptable.

1 = Existing program needs major modification.

0 = Existing program does not include this capability.

Each option has benefits and liabilities. Because Option 1 involves the development of a whole new estimating method, several new features not generally available in existing cost estimating tools can be incorporated. Some of these new features could be

- simplified access to cost data that may be stored in several different cost databases
- a capability to develop several cost estimates simultaneously for comparative purposes
- hierarchical layers of increasing cost detail for each design strategy or technology, with access controlled by the user
- automated and manual updating capabilities of the cost databases.

Option 1 provides an effective approach to meet the criteria established for the building cost module and offers the potential for much more flexibility to a building designer than existing methods offer. However, the resources to develop such a new cost estimating methodology will be considerable and may be beyond the scope of the Targets project.

Option 2 offers an approach that would be more restrictive for the Targets user. The new features identified in the bullets above are not available in existing cost estimating programs. If these capabilities are to be incorporated into the building cost module, existing cost estimating tools will need to be modified. Also, user interface will likely need to be enhanced to meet the Targets requirements. The task of modifying one or more of the existing cost estimating modules is likely to be less expensive than building a module from scratch would be. However, it would still be a major undertaking.

A decision on which option to pursue has not been made at this time. Further evaluation of existing cost estimating programs, such as CostPro (which has an open architecture), may indicate that pre- and post-processing capabilities can be developed so that all the building cost module criteria can be satisfied. However, given the lack of a cost model that meets most of the criteria, the conceptual development has focused on Option 1, developing a complete new cost model. The approach developed to date is described in the following section.

7.3.4 Proposed Conceptual Structure for the Building Cost Module

The conceptual approach developed for the building cost module is based on a hierarchical structure of templates. Like the attributes listed above, this concept was discussed with the building cost experts. The proposed approach is to develop an extremely modular structure for the building cost module. This will facilitate incremental development and future modifications and enhancements.

Interaction with Other Targets Modules

The building cost module conceptual structure was developed for interactive use with the analysis control module, as well as with the other major analysis modules (energy simulation, energy cost, and economic analysis) of the Targets model. The anticipated mode of operation has several implications for the projected building cost module:

- A building cost value is needed for every design strategy selected by the search routine module.
- The building cost module needs, as input from the search routine module, enough information about the physical characteristics of a specific design strategy (in relation to the space functions being addressed) to select cost data and to apply rules and equations.
- The building cost module will need built-in rules for selecting among alternative costs in response to combinations of design strategies, building geometries, and space functions.
- Enough information is needed from the user to determine which cost adjustment factors (e.g., for local conditions, economic perspectives) to apply.

These factors have guided the conceptual development of the template approach.

Template Structure for the Building Cost Module

The templates are intended to provide a consistent format for developing, entering, reviewing, and editing all building cost-related data, regardless of the format of the original cost database. The template approach also provides a flexible structure that will enable various existing cost estimating programs to be used as the primary basis for building cost estimating in the building cost module. Important features of the template approach are briefly discussed below.

Generalized Template Format. The templates have a uniform structure for all cost data editing and reviews. The uniformity can be attributed to the use of

- standard classes of data
- specific instances of data classes
- inheritance of format, data, or procedures (see below).

This uniformity allows the template structure to be readily expanded to accommodate additional cost data or to modify existing data. The uniform structure of the templates also provides a simplified user access to

various cost database formats; in a sense, the template structure acts as a neutral file format for organizing cost data that can be drawn from different sources. The templates provide a single interface structure that will allow access to data in several cost databases simultaneously, yet will shield the Targets user from having to cope with the different database formats. This concept is shown schematically in Figure 7.2.

Separation of Elements Within a Template. Five key structural elements are used to develop a template:

1. cost data - This contains building material and labor costs and various regional adjustment factors.
2. data rules - The rules used to select and format specific cost data items. These function as a preprocessor for the cost estimating calculation module. They also contain rules that determine limits, reasonableness, and appropriate application of cost data to the current building situation.
3. cost equations - This calculation module is the primary element of the building cost module. It performs all calculations on the data to produce aggregated unit costs for each energy-related design strategy and/or design technology.

Figure 7.2. Proposed Generalized Template Structure for the Building Cost Module

4. template rules - These are a postprocessor for the cost equation calculation module, which reformats the cost results (from possibly different calculation modules) into the formats used by the templates (and thus by the other major modules of the Targets model).
5. templates - This standardized format is used for displaying all input and output (I/O) to the user and for structuring cost data elements for data transactions among the various modules within the Targets model.

The interrelationships between these five elements are shown schematically in Figure 7.3. Each of these elements is discussed in more detail below.

Cost Data. An important objective of the building cost module is to efficiently access appropriate and sufficient cost data. Several types of cost-related data, other than building component unit costs, need to be provided in this module. These include

- wage rates by trade, including both union and non-union rates
- city cost index; factor for regional variations in costs
- historical cost index; factor for variations since date of cost data publication

Figure 7.3. The Five Primary Elements of the Proposed Template Concept

- volume discount; cost variation due to size and type of project as well as size and type of contractor
- contractor mark-up; overhead and profit
- contingency; allowance for oversights and unknowns
- design fee.

These values should be accessible to the user for modification or for updating. Likely sources of this cost data include R. S. Means' DataSource, F. W. Dodge's Design Estimator II, CACES (U.S. Army Corps of Engineers 1987), and a user's own database of costs. However, several problems have been identified with the accessing of such data:

- Available cost databases are not complete.
- Each database has a distinctly different structure.
- Detailed data on energy-related building components is significantly lacking.
- Mechanisms for updating the cost data are nonexistent or very crude.

The building cost experts clearly indicated that multiple cost databases might be needed to accommodate the range of building cost data required by the building cost module. They also stated that a supplementary database of costs associated with innovative energy-related building components needs to be developed by the Targets team, since such a database does not currently exist.

Data Rules. The quantity of cost data accessible from within the building cost module is expected to be very large. In most cases, the cost data will be distributed among several databases. It is anticipated that sets of rules will be developed to identify the physical location, organization, and contents of the various databases. These data management rules will allow the building cost module to understand the structures in the databases. One function of these rules will be to retrieve needed cost data and effectively translate it into an input format usable by the cost equation calculation module being used.

The rules for accessing and manipulating the cost data will constitute an important part of the building cost module. Considerable professional judgment will be required in their development and application.

Cost Equations. The cost equations provide a rigorous method of evaluating the relative cost of various design strategies and technologies. The information of greatest interest to the building cost module user is the relative cost of various energy-saving design strategies or design technologies. These design strategies and technologies often involve many building components in each of several different major building systems (e.g., electrical, HVAC, plumbing). Cost equations are needed to calculate the cost of these groupings or sets of building components.

Several existing cost estimating programs still require evaluation as potential cost estimating calculation modules for the building cost module. Ideally, the user will be able to specify one of several different existing cost estimating modules within the building cost module.

Template Rules. The template rules identify, search, retrieve, and display the cost information required for each template display. The rules will translate the format of the output files from the user-specified cost estimating model into the display formats of the building cost module.

The display templates will be used primarily to display summary cost comparisons for various energy-efficient building design strategies or technologies. However, should the user choose to see more detailed information about building costs, several layers of increasingly detailed costs can also be displayed. The display format for each layer of detail will be standardized. However, the individual line items within each display will vary with each design strategy or technology under consideration. Rules are required to determine which cost data are needed for presentation in the current I/O display template.

Templates. The templates are standard formats used for displaying cost data to the user. Ideally, different template formats should be used to present different layers of detailed cost information. However, the number of different template formats should be kept to a minimum for simplicity and clarity. At a given layer of detail, the same general template formats can be used for all cost data, regardless of the cost database being accessed. The only difference in the templates at a given level of cost detail is the number of line items within a given cost template.

Hierarchical Layers of Detail. The hierarchical layering of cost-related data involves separating the large amount of cost data into small, closely interrelated subsets of data, as shown in Figure 7.4. The primary advantages of such a data structure are that cost data of interest can be

- identified by the user in terms of the user's current general interest (e.g., cost summary for the fenestration system selected)

Figure 7.4. Hierarchical Nesting of Data Using the Proposed Template Structure

- automatically accessed using a program-controlled procedure
- presented to the user in the context that the user requested.

Generally, the user will be presented with relative total cost summaries of energy-related design strategies or technologies. The user may obtain details of the basis of any specific piece of data simply by selecting the next lower level (subset) of cost data. In contrast, conventional databases are usually structured so that the user must search through lengthy lists of data before accessing the desired data value. The user must then manually transport or manipulate the data in order to interpret it.

A hierarchical approach to data storage greatly simplifies the data manipulation problem. Consider the following brief explanation of how building cost data may be accessed to determine the cost of an energy-related design strategy. A building component that significantly affects energy use is often a primary element of several distinct energy-related design strategies. The hierarchical approach allows a single data record for each building component. These individual records may be accessed several times within the program, for each of several design strategies. Thus, the user can be efficiently provided with the same data record in several different contexts.

Inheritance. Many of the attributes (variable values) of the cost variables in the higher levels (i.e., design strategy summary levels) of the hierarchical structure can be inherited by the cost variables in the lower levels of the hierarchy.

The expected benefit of inheritance is exemplified by the case where the user chooses to update a piece of cost-related data (e.g., wage rates) in a certain layer of the templates. When the user completes the entry, the inheritance feature will allow the cost module to automatically make appropriate changes throughout the rest of the cost templates. This concept is shown schematically in Figure 7.5.

7.3.5 Building Cost Module Taxonomy

This section describes how the building cost module will relate to the user interface of the Targets model (see Volume 4). A taxonomy was developed for the building cost module and has been coordinated with two other taxonomies for structuring a building's physical characteristics and for structuring user interface access to the Targets model. The detailed taxonomies are provided in the appendixes of this volume.

For all of these taxonomies, a primary objective is to provide maximum user flexibility in accessing and editing data. For the building cost module, several parallel paths have been identified for exploring building costs. These paths include accessing building cost data according to

- space function
- major building systems
- building geometry.

The primary levels of data within each of these three cost estimating paths are outlined below.

Space Function Path Through the Building Cost Module

- lighting space function summary level (lowest level)
- thermal space function summary level

Figure 7.5. Automatic Updating of Cost Data Using an Inheritance Capability

- space function summary level
- floor summary level
- building summary level (highest level)

Major Building Systems Path Through the Building Cost Module

- subcomponent summary level (lowest level)
- component summary level
- subsystem summary level
- system summary level (highest level)

Building Geometry Path Through the Building Cost Module

- orientation summary level (lowest level)
- floor summary level
- building summary level (highest level)

Users will access the building cost module in several different ways depending on the type of building cost data required at the given time. For example, a user may review the detailed cost of a given design strategy from a sublevel within the major building systems path. The user could then choose to review the cost data from a different sublevel within the space function path.

7.3.6 Example Templates

As part of the process of developing, refining, and testing the template concept for the building cost module, three cases exemplifying three building systems were developed. These three examples are

- lighting system design strategy - Compare first costs for energy saving ballasts for fluorescent lighting fixtures to electronic ballasts.
- HVAC system design strategy - Compare first costs of a hot-water baseboard heating system to terminal units with electric reheat.
- envelope system design strategy - Compare first costs of bronze tinted glass to bronze reflective glass.

Several assumptions were made to facilitate the completion of the example templates. The hypothetical Optima Building^(a) was used for the examples. All costs were generated for a single typical 15,000-ft² floor of the office tower. Each floor measures 100 ft by 150 ft. The assumed location of the building was Washington, D.C. Other specific assumptions used to develop the templates included

- the exterior face of the envelope if it is brick
- the window-opening-to-total wall ratio if it is at least 40% or more
- the roof of the building if it is flat.

Since all cost data are not yet available, the cost data generated for the example templates were not developed using the fully proposed methodology for the building cost module. In the simplistic examples, system and subsystem costs were generated based both on historical data and on the experience of professional cost estimators.^(b) In the proposed building cost module (as opposed to the example templates), the system and subsystem costs would be automatically calculated based on component-level cost data. Thus, the raw cost data for design strategies would be input using component-level templates, and the total cost of design strategies would be automatically tabulated in the subsystem- and system-level templates.

A detailed discussion of the underlying structure of the lighting template follows. Each of the five major components of the template structure--i.e., cost data, data rules, cost equations, template rules, and templates--is described.

Cost Database for the Lighting Example

All building cost data is stored in the cost database. For this simple example, a small set of unit costs for lighting system components is presented in Figure 7.6.

(a) For detailed descriptions of this building, see the user interface screen displays contained in Appendixes B and C of Volume 4.

(b) The cost data in the lower-level templates were priced with actual manufacturers' prices for materials and a labor rate of about \$20 (as a cost to the subcontractor).

FIXTURE DATA		COSTS			
NO.	TYPE	UNIT	MATL	LABOR	TOTAL
1	GRID, 2X4	EA	65.00		65.00
2	GRID, 2X4	EA	75.00		75.00
3	GRID, 2X4	EA	40.00		40.00
4	GRID, 2X4	EA	50.00		50.00
5	GRID, 2X2	EA	80.00		80.00
6	GRID, 2X2	EA	110.00		110.00
7	GRID, 2X2	EA	60.00		60.00
8	GRID, 2X2	EA	90.00		90.00
9	CONT./PENDANT	FT	45.00		45.00
10	CONT./PENDANT	FT	50.00		50.00
11	CONT./LIN. TROFF.	FT	35.00		35.00
12	CONT./LIN. TROFF.	FT	40.00		40.00

LAMP DATA		COSTS			
NO.	TYPE	UNIT	MATL	LABOR	TOTAL
1	FL. OPTION 1	EA	1.65		1.65
2	FL. OPTION 2	EA	1.70		1.70
3	FL. OPTION 3	EA	1.75		1.75
4	FL. OPTION 4	EA	1.80		1.80

BALLAST DATA		COSTS			
NO.	TYPE	UNIT	MATL	LABOR	TOTAL
1	STANDARD	EA	20.00		20.00
2	WATT MISER	EA	25.00		25.00
3	ELECTRONIC	EA	45.00		45.00
4	HI PWR FCTR	EA	22.00		22.00

CONTROLS DATA		COSTS			
NO.	TYPE	UNIT	MATL	LABOR	TOTAL
1	SINGLE LEVEL	EA	50.00		50.00
2	BI-LEVEL, GANGED	EA	65.00		65.00
3	BI-LEVEL, REMOTE	EA	70.00		70.00
4	PROGRAMMABLE TIMER	EA	75.00		75.00
5	LUMEN MAINTENANCE	EA	75.00		75.00
6	DS, CONT. DIMMING	EA	75.00		75.00
7	DS, MULT. STEP DIM	EA	75.00		75.00
8	DS, ON/OFF	EA	75.00		75.00
9	OCCUPANCY SENSOR	EA	75.00		75.00

Figure 7.6. Cost Database for the Lighting Templates

The following concepts related to the cost database are presented in this lighting example:

- organization of each element of data based on the appropriate classification of each building component
- use of multiple classification systems (e.g., the Construction Specification Institute [CSI] and American Institute of Architects/Professional Systems Division [AIA/PSD] specification systems)
- inheritance of attributes (e.g., the labor rates) for each element of data.

The example does not indicate several features that would be desirable in the building cost module database:

- The system of units for the data items should be user-controlled. The user may wish to choose to view unit area costs, or total costs, for example.
- The labor costs should be based on crew size and productivity, trade type, and wage rates. This approach allows the data to be modified and updated more effectively. For example, regional variations for each of these descriptors can be readily incorporated into the data.
- Several databases should be simultaneously accessible to the building cost module.

Existing building cost databases are very large, many containing costs for as many as 10 to 20 thousand building components. One of the major problems in the building cost module will be to access the required data efficiently. This is one of the primary purposes of the data rules discussed below.

Data Rules for the Lighting Example

The data rules are used to access and manipulate the data in the cost databases discussed above. The data rules organize the cost data into the format required to begin specific cost estimating tasks. The basic tasks demonstrated by the sample data rules include

- identification and location of general classifications of building components required for a given energy-related design strategy or technology
- identification and location of specific constituent building components of a given energy-related design strategy or technology
- identification and location of other factors that will likely affect the cost of the specified design strategy or technology
- organization of a temporary working database of building component or assembly information required for a given design strategy or technology.

To perform the tasks listed above, the data rules should contain information about the structure of each of the databases to which the building cost module is expected to have access. The data rules should also contain information about each of the component elements of each energy-related design strategy and design technology. This built-in information should be generalized so that new information or modifications to the existing information can be made at any time.

Cost Equations for the Lighting Example

The cost equations evaluate the cost of individual design strategies or technologies. Based on this information, the relative cost of alternative design strategies can then be established. The basic tasks completed by the cost equations presented in the lighting example are

- preliminary calculations of several types of non-cost information (quantities, sizes, capacities) as required
- calculations of costs for each of several subsystems or assemblies
- calculations of the overall cost of each of several given design strategies or technologies.

This calculation model will accomplish the primary computational effort within the building cost module in the performance of the above tasks. Once these costs are evaluated, the results should be stored in the temporary working database created by the data rules, for possible future access within the current project. These cost results will be useful as the building details change from early conceptual design through detailed design phases. An optional capability should be provided to the Targets user to permanently save this temporary database for use on other, similar projects.

Template Rules for the Lighting Example

The template rules collectively serve as a postprocessor of the output from the cost equation engine. The primary tasks for which the template rules should be responsible include

- identification of template required
- identification of line items required
- identification of location of appropriate cost data required for each line item
- management of display screen (or monitor) space.

Similar to the data rules, the template rules will require built-in information. The template rules should be able to access information about each of the standard template formats, as well as information about the specific limitations of the user's display monitor.

Templates for the Lighting Example

The last major element of the template structure is the templates themselves. The templates are standard formats for displaying cost data to the Targets user. A few sample templates for this lighting example are presented in Figure 7.7. The concepts related to the templates presented in the lighting example are the hierarchical layering of cost data and standard format of each hierarchical layer of information.

An editing capability must also be provided. With this editor, the user should be able to readily modify existing cost data or add new cost data to the cost databases. The editor should also assist with the modifications to the rules associated with database structure, the component elements of design strategies and technologies, and the formatting of template I/O.

SYSTEM SUMMARY LEVEL

DESCRIPTION	BLDG GSF	UNIT	COST	% TOTAL
EXTERIOR ENCL	XXX	SF	10.00	16%
ROOFING	XXX	SF	0.60	1%
SUPER-STRUCTURE	XXX	SF	13.00	21%
INTERIOR ARCH.	XXX	SF	10.00	16%
PLUMBING	XXX	SF	1.00	2%
FIRE PROTECT.	XXX	SF	1.25	2%
HVAC	XXX	SF	15.00	24%
ELECTRIC	XXX	SF	12.00	19%

TOTAL	XXX	SF	62.85	
MARK UP @		10 %	6.29	
CONTINGENCY @		10 %	6.91	

TOTAL			76.05	

Figure 7.7. Sample Template for the Lighting Example

7.4 Issues, Conclusions, and Recommendations

Several important issues arose during the building cost module development task. For those issues that have already been resolved, specific recommendations to implement changes in the development stage are stated. For the unresolved issues, specific action steps toward their resolution are recommended. The conclusions and recommendations expressed here are those of the authors.

7.4.1 Need for Building Cost Module

Issue

Given the lack of an appropriate existing public domain cost module and the complexity and the high anticipated cost of developing a new building cost module from scratch, is the inclusion of a building cost module cost-effective?

Several approaches to developing a building cost module were suggested:

- Option 1 - Proceed with the development of a full-featured building cost module (needed for inclusion of economics in Targets methodology, but very expensive to develop).

- Option 2 - Provide limited cost information, at system summary level only, in the building cost module. (This limits economics to voluntary applications only, at early design stages. Economics cannot be used for standards and codes applications, for lack of compliance tools).
- Option 3 - Do not include a building cost module in the Targets model at all. This option is low in cost and eliminates much complexity, but also eliminates the possibility of economic evaluation within the Targets model.

Conclusions

Option 1 is clearly the most desirable. However, it is by far the most resource-intensive in terms of developing a working Targets model, for two reasons. First, is the considerable effort required to develop a detailed and easy-to-use building cost module that meets the Targets needs. Second, the inclusion of economics increases the level of complexity of the other elements of the Targets model, thus increasing the resource levels required for other Targets elements.

Recommendations

The authors strongly recommend that a full-featured building cost module be developed, if resources permit. One way to reduce resource requirements might be to consider a joint development with one or more private sector organizations with existing modules that already meet some of the Targets criteria. A second way might be to seek sources of joint funding for development. For example, utility companies might be very interested in the projected capabilities of the Targets model. In preparation for a decision, a more detailed estimate of resources required to develop the building cost module should be prepared.

Another option might be a phased approach, in which early releases of the Targets model assess only energy use, until the resource and technical issues involved in completing a proper building cost module as a basis for robust economic analysis, have been resolved. However, this is risky, given the importance of reliable cost data in the economic comparison of alternative energy-saving design technologies.

7.4.2 Breadth of Building Cost Analysis Needed

Issue

Should the building cost analysis be limited to just the costs of the energy systems? Should costs of impacted non-energy systems also be included? Should the cost of the entire building be included?

A decision about the breadth of the cost analysis could have major impacts on both the level of development resources required and the capabilities of the final product.

Three options surfaced from the discussions:

- Option 1 - Limit the construction cost analysis to only those building systems and components in which energy strategies occur.
- Option 2 - Extend the construction cost analysis to include non-energy systems and components whose costs are impacted by the energy strategies.
- Option 3 - Extend the breadth of the construction cost analysis to include costs for all building systems--a whole-building cost.

Conclusions

Option 3 should be pursued, for the following reasons. Option 1, while the simplest to implement, does not provide sufficiently accurate building cost analyses for the often-complex economic tradeoffs involved in many energy-related building decisions. Option 1 could be used for research purposes, but not for the custom building design objectives for which the Targets methodology is intended. The conclusion from a number of discussions is that design practitioners would find the construction costs and ensuing economic analyses misleading. Thus, they would not trust any results of the building cost module that are based on this data. Under these conditions, it is likely that the entire Targets methodology would be considered simplistic and placed under suspicion by designers.

Option 2 overcomes the inaccuracy problems of Option 1, relative to delta-costs. However, this option does not provide a comparison of delta-cost within the context of total building costs. It precludes several of the economic objectives considered desirable for the Targets model (defined in Section 9). Furthermore, it is sometimes very difficult to distinguish clearly between costs that are energy-related and those that are not.

Recommendations

A whole-building cost estimating program is needed if the project objectives are to be fully met. Developing an accurate whole-building cost model is an ambitious undertaking. However, if the cost module is not going to be accurate, on both the global and specific levels, it is not worth doing. Furthermore, the level of effort required to develop the whole-building portion of the building cost module, although significant, may be incidental compared to the effort required to develop the detailed cost methodology for each of the energy design strategies. Therefore, the authors feel that Option 3 should be selected.

7.4.3 Sources of Cost Data, Rules, and Equations

Issue

Is there a need to generate detailed databases for energy-related cost information?

Many design strategies involve accessing detailed costs about components (e.g., for lighting, alternative ballasts or lamp types; for envelope, alternative glazing types, including various types of high performance glass). Such detailed data are required for Targets model analyses, even during the early stages of building design. Cost data at this level of detail are simply not available in current databases.

Issue

What mechanisms are required within the building cost module to access cost data in various cost databases (with different storage formats and structures)?

Conclusions

No decisions have been made on the best sources of cost data. Several sources have been identified. However, each of these data sources is incomplete. At a minimum, it is likely that a major effort will be required to develop a supplemental database of costs for many energy-related building components.

Recommendations

Two or three of the best existing cost databases should be reviewed in detail. The review will begin to identify the specific energy-related building components for which cost data are unavailable.

7.4.4 Updating of Costs

Issue

What mechanism used for updating the energy design strategy-related costs is required within the building cost module?

Conclusions

If a building cost module is to be included in the Targets model, its accuracy and validity will depend upon up-to-date detailed energy-related building cost data. Some maintenance efforts seem to be required in this case. Such efforts might be minimized if private sector organizations now maintaining cost databases could be encouraged to increase the level of detail published relative to energy components and systems.

Recommendations

New options for cost data maintenance need to be explored. For example, updating could be done by a user-controlled automated procedure within the Targets model, or it might be done (manually) by a master cost database.

- automated user-controlled updating method - This approach places a tremendous responsibility on the Targets user. The user could accidentally seriously damage the integrity of the cost database if this mechanism were to be used improperly. However, the user does have greater control over, and thus can develop greater confidence in, his/her cost data. One approach to protecting the original cost database would be to format it as "read-only." Whenever modifications are made, changes are saved in a new copy of the original cost database.
- manual updating of a "master" Targets building cost database - The costs of maintaining and regularly redistributing updated cost data to Targets users can be very high, depending on the size of the database itself and the size of the Targets user base. A subscription fee may be one approach used to cover these costs.

Another approach may be to periodically update small portions of the cost data. This approach has the advantage of a reduced investment for each update. However, this approach will require significant ongoing planning to provide for funds to do the updating.

7.4.5 Level of Effort

Issue

How much effort will be required to develop a database of building costs?

The development of the building cost module is a big job. It is likely that approximately 6 person-years would be needed to develop an appropriate building cost module. Another 6 person-years would

likely be required for developing a sufficiently detailed energy-related building cost database. This indicates a total resource requirement of 12 person-years.

Recommendations

Before undertaking such an effort, a pass through the program should be made. To make that pass, a hypothetical building should be brought to schematic design, and a number of alternatives should be proposed. Detailed estimates and a paper simulation of a pass through the program should be made. That process should reveal appropriate hierarchies on a system-by-system basis. That process will also begin to flesh out graphics requirements and alert the team to holes in the methodology.

8.0 Energy Cost Module

The proposed structure of the energy cost module to be used within the Targets model is described in this section. The energy cost module will identify the relative changes in building energy costs over time that are caused by changes in building energy use and demand, based upon the energy design strategies selected. This module will provide outputs that, in conjunction with outputs from the building cost and energy simulation modules, will provide inputs to the economic analysis module of the Targets model. The location of the energy cost module within the Targets model is shaded in Figure 8.1.

8.1 Tasks Accomplished

Three tasks were completed during the concept stage. First, the requirements for the proposed energy cost module were developed. Second, available energy cost models in the public domain that meet all or most of the requirements were identified. Third, a development plan was generated for testing and refining the available models.

8.2 Results

This effort resulted in three products:

- a list of basic requirements for the energy cost module
- the selection of a model to use for the next stages of the project, especially for prototype development and testing
- a proposed plan of activities for developing the energy cost module.

8.2.1 Basic Requirements List

The basic requirements for the energy cost module were identified. The module should possess the following capabilities and characteristics:

- To ensure access to algorithms, the module should be in the public domain.
- The module must be able to accept as inputs the results from 1) hourly energy simulation programs; 2) different energy simulation programs, including both those in the public domain and those in the private sector; 3) actual local energy costs (rather than regional or national averages); and 4) formats from a wide variety of utility rate structures.
- The module must be able to produce energy cost outputs that reflect variations in 1) energy use for three time domains--annual, monthly (in conjunction with demand charges), and diurnal (in conjunction with time-of-day rates); and 2) demand charges, to include at least the monthly and time-of-day time domains.

Figure 8.1. Energy Cost Module Location Within the Targets Model

8.2.2 Energy Cost Module Selection

Because it meets most of the basic requirements, the energy cost model within DOE-2 was provisionally selected for use in the next stages of development of the Targets model (Simulation Research Group 1989). It is readily available in the public domain and is consistent with the selection of DOE-2 as the primary energy simulation analysis tool for the next stages of methodology development. This energy cost model appears to satisfy the input requirements, at least relative to DOE-2, and will be used in developing initial Targets prototypes.

If the DOE-2 energy cost model is to be used as the final energy cost module, then it will need several modifications. First, it must be modified to address outputs from other energy analysis programs. Second, the set of energy construction model routines will need to be extracted from DOE-2 and accessed as a separate module, to meet the requirement that the energy cost module interface with other energy programs. Third, a "neutral file" data input front-end will need to be designed and coded to permit interfacing the energy cost module with other energy programs. Fourth, modifications of and/or expansions to the DOE-2 energy cost routines may be necessary to meet all of the detailed requirements of the Targets methodology operation.

An important adjunct to the energy cost module will be a set of typical utility rate structures, along with access to data sources for up-to-date local utility costs. The Gas Research Institute annually updates a set of utility rate schedules for 48 major utilities throughout the United States (e.g., Casazza, Schultz, & Associates, Inc. 1989). This work is currently being computerized and should be available for use in the Targets methodology.

8.3 Issues, Conclusions, and Recommendations

Very few issues surfaced relative to the energy cost module itself. However, many issues that directly affect the nature of the energy cost module have surfaced in discussions about other parts of the Targets model. This has been especially true about issues raised concerning both the energy simulation module (Section 6) and the economic analysis module (Section 9). Indeed, the level of detail perceived as required of the energy cost module is a direct consequence of decisions made in these other two areas. Likewise, issues that have been raised (and not resolved at this point) about the development of a building cost module may strongly affect the priority and sequence of developing a detailed energy cost module.

Issue

How much effort should go into developing a reasonable set of typical utility rate structures and associated data?

The Targets methodology user will enter the current local energy costs to the energy cost module. Consistent with the concept that the user be provided with as many defaults for options as well as for data, a number of different utility rate structures should be available for use with the energy cost module. This will likely involve defining the applicable local utility rate structure, an extremely complicated task, given the plethora of rate structures and constant changes to those structures.

Given the overall objectives of the Targets methodology to have the targets reflect economic cost-effectiveness, this complexity cannot be sidestepped. However, every effort will need to be made to keep this part of the methodology as simple as reasonably possible. Details of utility rates and structures can

strongly impact the cost-effectiveness of entire sets of energy-conserving design strategies. On the other hand, to expect a user to deal directly with this complexity would seriously impair the ease-of-use objective of the Targets methodology.

Conclusion

One solution would be to develop a set of typical rate structures for use in conjunction with the energy cost module, and to identify and provide access to data sources for up-to-date local utility costs. Each of these tasks can involve extensive effort, but the result, if successful, would represent a major enhancement of the ease-of-use and data reliability of this portion of the methodology. The Gas Research Institute annually updates a set of utility rate schedules for 48 major utilities throughout the U.S. (Casazza, Schultz, & Associates, Inc. 1989). This work is currently being computerized and should be available for the Targets model. The accuracy and reliability of the data entering the energy cost module is of major importance to the overall reliability of the economic results of the proposed Targets model.

9.0 Economic Analysis Module

This section addresses several aspects of a proposed structure for the economic analyses to be performed within the Targets model: purposes, economic objectives, economic measures, owner perspectives, data, and defaults. The Targets model is to have economics as an integral part of the evaluation of energy cost-effectiveness to an owner.

The economic analysis module will have a central role in assessing cost-effectiveness. In an iteration of the Targets procedures, the economic analysis module would be the last calculated element. As indicated in Figure 9.1, outputs from the energy, energy cost, and building cost modules will be used as inputs to the economic analysis module to derive estimates of economic benefits containing alternative building design solutions.

9.1 Approach

The approach to the economic analysis module focused on the identification of several factors:

- possible owner economic objectives
- measures to be used to assess economic performance
- issues relative to owner economic perspectives, data needs, and default values.

The development of actual economic analysis modules was not addressed for two reasons. First, calculations of economic benefits will occur within the analysis control and search routine modules of the Targets model. Second, economic analysis procedures are already available in the public domain. It is expected that these can be adapted with minimal effort to meet the needs of the Targets model.

9.2 Results

Five products resulted from this effort:

- a list of basic requirements for the economic analysis module
- identification of the types of economic objectives that the economic analysis module should be able to address
- identification of economic indicators to be considered
- definition of approaches to economic perspectives and parameters
- a proposed plan of activities for developing the economic analysis routines.

The first four products are discussed in this section.

Figure 9.1. Economic Analysis Module Location Within the Targets Model

9.2.1 Basic Requirements for the Economic Analysis Module

The following requirements were identified for the economic analysis module. The calculation procedures should be

- fully available for review within the public domain
- capable of analyzing the time value of money, including
  - public and private sector economic parameters
  - full treatment of private sector factors, including depreciation and cost of money during both construction and occupancy periods.
- capable of assessing economic benefits from a wide array of energy conservation strategies, including those dependent upon demand reduction or time-of-day rates
- capable of addressing a range of owner economic objectives and perspectives.

These requirements are addressed in the following sections.

9.2.2 Possible Owner Economic Objectives

Within the Targets model, economic analysis occurs primarily during efforts to find the preferred ranges of solutions for a given objective. This section defines a set of formats for possible owner objectives to be included in the Targets model.

Primary Economic Objective

Energy-related owning and operating costs (EROOC) were identified as the primary economic objective. Thus, the development of an economic analysis routine capable of assessing EROOC continues to be a long-term goal.

Additional Objectives

In addition to EROOC, other economic objectives are needed to allow building owners to address likely economic scenarios. Furthermore, some owners may have energy and economic objectives (e.g., public image) that emphasize energy conservation levels in addition to those levels purely justifiable from an economic point of view. In addition, some noneconomic objectives appear very useful for possible research and development uses of the Targets methodology.

Consequently, several other economic and noneconomic objectives were identified as desirable and to be included in part of the Targets economic analysis module. Some are composed of both energy costs and building costs; others include only energy costs. Still others include only building costs, and some exclude all costs entirely.

Both Energy Costs and Building Costs

1. **Minimize the energy-related owning and operating costs to the owner.** To fully consider the benefits of building energy conservation, both benefits and costs must be considered over the expected life of the investment. This includes consideration of all the energy-related costs of designing, constructing, and operating the building over an expected lifetime of investment. This alternative is considered to

be the most desirable one for the Targets model; it most completely meets the criteria for addressing fuel choice options within the model. Its main drawback is its complexity.

2. **Minimize total life-cycle costs (LCC) to the owner.** This alternative is very similar to the EROOC approach. The major difference is that it considers all owning and operating costs, not just those related to energy. While the intent of the Targets model is to address just the energy-related costs of buildings and building components, it is not always easy to determine what share of the costs are energy-related. For example, if two light fixtures have different costs and performances related to energy, and one is also in gold leaf while the other is painted metal, how are the energy-related costs broken down? Detailed procedures for doing this have yet to be identified. Therefore, the LCC option is presented here for completeness along with EROOC.
3. **Minimize energy cost, within an upper limit on construction cost.** Organizations (e.g., corporations and government agencies) will often set a not-to-exceed construction cost budget for a new building. This economic objective is a likely choice for a money-conscious company in which the responsibility for construction costs is separate from the responsibility for operations costs. Many chain stores and franchises have this division of responsibility for major cost elements. One division of the company is responsible for construction (and managers in that division are rewarded for their construction-oriented performance), while other divisions are responsible for building operations (and rewarded accordingly).
4. **Attain an energy cost lower than a stated value, at a lowest possible construction cost.** This option is similar to Option 3, but has a stronger emphasis on building construction costs. The energy cost target is specified as a limit (say, \$1.25 per square foot per year), and within that energy cost limit, the effort is to achieve the lowest possible construction cost.

Building Costs Only

5. **Minimize energy consumption, with an upper limit on construction cost.** This option is similar to Option 3, except energy consumption instead of energy cost is minimized. Some organizations may have strong reasons to strive for a minimum building energy use, rather than a minimum energy cost, within an overall building construction cost constraint (e.g., image focusing on energy conservation rather than simply saving money, environmental concern, social concern, and government policy).
6. **Attain energy consumption at a lower than stated value, at the lowest possible construction cost.** This is much like Option 4. If an energy consumption target level has been set, then the Targets Methodology can be used to determine the lowest possible building construction cost alternatives to achieve the stated energy consumption target.

Energy Costs Only

7. **Minimize energy cost.** This option excludes building construction costs. The lack of building construction costs prevents assessing the tradeoff between the up-front costs occurred during construction against the longer-term energy costs. However, minimizing energy cost does provide a way to balance energy consumption and demand effects.
8. **Attain an energy cost lower than a stated value.** The previous option asks, "How well can we reduce energy costs?" In contrast, this option simply finds solutions better than a given limit. To use this option, a limit on energy cost must first be set. This option might be useful if an owner has a fix on desirable energy cost levels, and good building cost data is not available.

Energy Only (No Costs)

9. **Minimize energy consumption.** This is a noneconomic objective. Construction costs could be very high and, thus, unacceptable to most building owners. However, this objective could be very useful to test the overall capabilities of the Targets model, especially the impacts of the set of technologies being considered within the module along with the module's ability to generate energy-efficient solutions in the absence of economic constraints. Essentially, this objective provides an estimate of the technical energy conservation limit attainable by the Targets methodology in a given location.

This objective would be useful to both test and update the module. For example, there are reasons to limit the number of design strategies that the Targets model can address in the target setting mode (e.g., calculation speed, controlling complexity). Because of this, various reduced technology sets have been considered as being suitable. However, limited sets of design strategies might seriously reduce the module's ability to give realistic results for more stringent target levels such as the set of technologies chosen, which, in some sense, defines the effective range of operation for the Targets model. Using this objective is one way to test the impact of various sets and types of technologies. Also, as the module is updated in the future, using this objective will permit an assessment of changes that will be needed to cover the range of module operations.

Potential users of this objective are 1) the developers of the Targets model (for testing); 2) researchers interested in examining energy impacts of new technologies; and, 3) building owners interested in showcase buildings in which strong energy conservation outweighs construction cost considerations.

10. **Attain energy consumption at a lower than stated value (or lower than a set of stated component criteria).** This is essentially the old Building Energy Performance Standards (BEPS) approach. The modification in parentheses would be used to check against, say ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989).

Table 9.1 shows the data requirements for each of the options. It indicates that the EROOC (and similar LCC) economic analysis methods are the most complex. They require the most data elements and contain the most analysis procedures. If the Targets model is developed to the point of being capable of handling the complexity of the EROOC/LCC approaches, then the other analysis methods can be addressed easily by disengaging certain portions of the EROOC/LCC analysis methods. The only additional requirements left to fulfill would be to add simple procedures to calculate the various objectives and to provide user options for these calculations.

9.2.3 Economic Indicators

For many of the economic objective options described in Section 9.2.2, a number of alternative economic indicators or measurement indices may be used (Pacific Northwest Laboratory 1983, Sec. 8). These include

- construction cost (first cost)
- discounted payback
- simple payback
- present value (PV)
- equivalent annuity (EA)
- return on investment (ROI)
- internal rate-of-return (IRR)
- cash flow.

Table 9.1. Data Requirements for Alternative Economic Objectives

		<u>Annual Energy</u>	<u>Monthly Energy</u>	<u>Monthly Demand</u>	<u>Energy Time- of-Day</u>	<u>Demand Time- of-Day</u>	<u>Current Energy Cost</u>	<u>Future Energy Cost</u>	<u>Bldg. Constr. Cost</u>	<u>Bldg. O&M Cost</u>
Both Energy Costs and Building Costs										
1.	MIN. EROOC	REQ	Pos	Pos	Pos	Pos	REQ	Pos	REQ	REQ
2.	MIN. LCC	REQ	Pos	Pos	Pos	Pos	REQ	Pos	REQ	REQ
3.	MIN. ENERGY \$, CONSTRUCTION \$ < X	REQ	Pos	Pos	Pos	Pos	REQ	Pos	REQ	Pos
4.	ENERGY \$ < X, LOWEST CONSTRUCTION \$	REQ	Pos	Pos	Pos	Pos	REQ	Pos	REQ	Pos
Building Cost Only										
5.	MIN. ENERGY, CONSTRUCTION \$ < X	REQ	---	---	---	---	---	---	REQ	---
6.	ENERGY < X, LOWEST CONSTRUCTION \$	REQ	---	---	---	---	---	---	REQ	---
Energy Cost Only										
7.	MIN. ENERGY \$	REQ	Pos	Pos	Pos	Pos	REQ	Pos	---	---
8.	ENERGY \$ < X	REQ	Pos	Pos	Pos	Pos	REQ	Pos	---	---
Energy Use Only										
9.	MIN. ENERGY	REQ	---	---	---	---	---	---	---	---
10.	ENERGY < X	REQ	---	---	---	---	---	---	---	---

NOTES: REQ = Required data for alternative.

Pos = Possible data for alternative. This data may be REQUIRED for a full analysis of complex situations, but may not be required for simplified cases (e.g., for rate structures with no demand charges or time-of-day charges, then Monthly Energy, Monthly Demand, Energy Time-of-Day, and Demand Time-of-Day would not be required).

Construction cost by itself is limited, for it does not consider energy expenditures, operation and maintenance costs, or replacement costs. Both simple and discounted payback methods are often used; their simplicity is an advantage, but their disadvantage is that they consider only short-range benefits that occur up to the payback period.

The PV and EA are essentially the same; the EA spreads the PV into equal payments over the study period. These have two advantages: 1) they include all costs of concern (see Table 9.1), and 2) they can be calculated for all cases to be analyzed. However, their major disadvantage is that their use requires the assumption of constant benefits.

The ROI and the IRR both have very desirable features: they can be compared across building functional uses, changes in building quality, geographic regions, and other categories. However, they cannot be calculated when, during an iterative process, energy consumption and first cost of the present case are both lower or both higher than the previous case examined or when, for the present case, energy cost is higher and construction cost is lower than the previous case. Both of the above situations can be expected to occur frequently enough within the characteristics development optimization search routines to prevent the use of either the ROI or the IRR within these routines. This is expected to severely limit the use of ROI or IRR as comparison metrics. However, it may be possible to use them as metrics in limited situations, perhaps after the search routine module has been used in several different circumstances, to compare the results of different runs of the search routine module.

9.2.4 Owner Economic Perspectives and Parameters

To generate custom Targets for specific building situations, the Targets model must provide flexibility in defining ownership, economic perspectives, and parameters. Approaches to these factors are discussed in this section.

Owner Economic Perspectives

Previous studies suggest that a minimum of four types of owner economic perspectives will provide a reasonable range of options to imbed within the economic analysis (Pacific Northwest Laboratory 1983). These owner economic perspectives are speculative owner, owner-occupant, not-for-profit owner, and government owner. Some additional options may need to be included to address subtleties within some of these categories.

Economic Parameters

In most previous studies, economic parameters for each owner perspective have been established by judgment assuming typical values. These are important assumptions, given how strongly certain parameters can affect the overall outcome of the economic analysis. For example, values chosen for the study period, the discount rate, and the fuel escalation rates over time can strongly influence the outcome of any economic-based analysis.

It is anticipated that typical values for all economic parameters will be provided as defaults to users of the Targets model. Because Targets users will be able to change these values and create new sets of defaults for further use, the initial selections may not be too critical.

An additional safeguard might be provided in the form of estimated upper and lower boundary conditions for key economic parameters. If an option is then provided to run additional economic analyses that check results for both sets of limits, then a user has a further check on the effectiveness of the economic results over a reasonable range of potential scenarios. If the results for the boundary conditions are in line with those for the typical values of the economic parameters, then the user can have more

confidence in the results than if the results at the boundaries had differed substantially from those obtained using the typical values for the parameters.

9.3 Issues, Conclusions, and Recommendations

The key issues that surfaced during work on the economic analysis module are summarized in this section. Recommendations for their resolution are offered.

9.3.1 Economic Objectives

Issue

Which economic objective(s) should be included in the Targets methodology?

Recommendations

1. The economic analysis should be constructed to permit the use of multiple, alternative economic objectives. A minimum set should include
  - Option 1 - Minimize the EROOC to the owner.
  - Option 2 - Minimize total LCC to the owner.
  - Option 3 - Minimize energy cost, within an upper limit on construction cost.
  - Option 4 - Attain energy cost lower than a stated value, at lowest possible construction cost.
  - Option 5 - Minimize energy consumption.
2. The primary focus for development should be Option 1.
3. In voluntary uses of the Targets methodology, a user should be able to choose the most appropriate economic objective for his/her purposes from among the several available.

9.3.2 Equity Issues Across Climate Regions and Building Functional Uses

Issue

Regional equity is considered important for the selection of energy conservation design strategies and technologies for standards setting applications. How can it be analyzed, attained, or approximated?

Issue

Equity of cost effective energy conservation across various building function uses is considered important in standards setting applications. How can it be analyzed, attained, or approximated?

Recommendations

The PV will need to be used as the basic economic indicator for the search routines within the Targets model because of its convenience. However, the use of PV should focus on specific building projects.

In any standards development efforts using the Targets methodology, equity issues should be examined very closely with regard to both regional variations and building function use variations. It appears that ROI and/or IRR should be used to assess equity issues across regions, design strategies, energy conservation technologies, and building functional uses.

10.0 References

American Consulting Engineers Council Research & Management Foundation. 1987. *ASEAM 2-1 - A Simplified Energy Analysis Method*. Washington, D.C.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. 1989. "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings." *ASHRAE/IES Standard 90.1-1989*. Atlanta, Georgia.

Building Energy Analysis Group. 1981. *DOE-2 Users Guide - Version 2.1A*. LBL-8688 Rev. 2, Lawrence Berkeley Laboratory, Berkeley, California.

Building Energy Simulation Group. 1985. *Overview of the DOE-2 Building Energy Analysis Program*. LBL-19735, Lawrence Berkeley Laboratory, University of California, Berkeley, California.

Casazza, Schultz, & Associates, Inc. 1989. *Electric and Gas Rates for the Residential and Commercial Sectors: 1988*. GRI-89/0065, Gas Research Institute, Chicago, Illinois.

Clark, D. R. 1985. *HVACSIM+ Building Systems and Equipment Simulation Program Reference Manual*. NBSIR 84-2996, National Bureau of Standards, U.S. Department of Commerce, Gaithersburg, Maryland.

Clark, D. R., and W. B. May, Jr. 1985. *HVACSIM+ Building Systems and Equipment Simulation Program - Users Guide*. NBSIR 85-3243, National Bureau of Standards, U.S. Department of Commerce, Gaithersburg, Maryland.

Crawley, D. B., R. S. Briggs, J. W. Jones, W. W. Seaton, J. E. Kaufman, J. J. Deringer, and E. W. Kennett. 1987a. *Development of Whole-Building Energy Design Targets for Commercial Buildings - Phase I Planning, Volume 1: Final Report*. PNL-5854 Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

Crawley, D. B., R. S. Briggs, J. W. Jones, W. W. Seaton, J. E. Kaufman, J. J. Deringer, and E. W. Kennett. 1987b. *Development of Whole-Building Energy Design Targets for Commercial Buildings - Phase I Planning, Volume 2: Technical Report*. PNL-5854 Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

Herron, D., G. Walton, and L. Lawrie. 1981. *Building Loads Analysis and System Thermodynamics (BLAST) Program Users Manual--Volume One - Supplement Version 3.0*. CERL-TR-E-171, U.S. Army Construction Engineering Research Laboratory, Champaign, Illinois.

Pacific Northwest Laboratory. 1983. *Proceedings of the Designing and Managing Energy Conscious Commercial Buildings Workshop*. CONF-820733, National Technical Information Service, Springfield, Virginia.

Park, C., D. R. Clark, and G. E. Kelly. 1986. *HVACSIM+ Building Systems and Equipment Simulation Program: Building Loads Calculation*. NBSIR 86-3331, National Bureau of Standards, U.S. Department of Commerce, Gaithersburg, Maryland.

Simulation Research Group. 1989. *DOE-2 BDL Summary - Version 2.1D*. LBL-8688 Rev. 5, Lawrence Berkeley Laboratory, Berkeley, California.

Tao, W. 1983. "Air Conditioning Systems - An Overview of Operating Principles and Features." Reprint from *Building Operating Management* magazine, December 1983.

U.S. Army Construction Engineering Research Laboratory. 1979. *BLAST - The Building Loads Analysis and System Thermodynamics Program - Users Manual Volume One*. CERL-TR-E-153, Champaign, Illinois.

U.S. Army Corps of Engineers. 1987. *Computer Aided Cost Estimating System (CACES) - Final Estimate Generator (FEG) - Users Manual*. CEHNDSP 87-205, Huntsville, Alabama.

11.0 Acknowledgments

Producing this report was a team effort; numerous people contributed to the technical work and to the writing of this report. The project team participants are listed below with indication of their roles.

Management Team Members

J. J. Boulin	Team Leader DOE
C. M. Gardner	Program Manager DOE
D. B. Crawley	Project Manager PNL
W. W. Seaton	ASHRAE Subcontract Manager
J. E. Kaufman	IES Representative
E. W. Kennett	AIA Representative

Technical Team Members

ASHRAE/AIA/IES

J. J. Deringer	AIA Technical Manager
J. W. Jones	ASHRAE Technical Manager
H. N. McKay	IES Technical Manager
J. D. Hall	User Interface, Building Cost Model
J. Holton	Characteristics Development
D. Anderson	Characteristics Development
H. Deimer	Characteristics Development
R. D. Busch	Energy Model
C. S. Barnaby	Energy Model
K. G. Sigel	Building Cost Model
L. G. Bellenger	Building Cost Model
G. A. Hauser	Optimization

PNL

D. B. Crawley	Project Manager
R. S. Briggs	Optimization and Building Cost
P. K. Alley	General Software Support, Software Engineering
B. K. Johnson	Staff Support
J. Arthur	Optimization

Technical Support Staff

Also, some elements of the work have been produced with technical input from staff members from PNL and from The Deringer Group. These include

PNL Staff

J. R. Lewis	Software Engineering
K. L. Schuchardt	Software Engineering
D. L. Hadley	Climate Compaction Analyses
P. K. Alley	General Software Support, Software Engineering
J. L. Julyk	User Interface Graphics
S. M. Thelen	User Interface Graphics and Scripts

The Deringer Group Staff

P. Dillingham	User Interface Graphics
S. Hunt	User Interface Graphics

Appendix A

Building Characteristics Set Taxonomy

Appendix A

Building Characteristics Set Taxonomy

I. APPLICATIONS:

Voluntary targets
Standards and codes

II. MODES OF USE

Target setting
Design analysis/evaluation

III. LEVEL OF HIERARCHY (ORGANIZATIONAL UNITS)

- A. Lighting function/space function related (see exhibits L and N: ASHRAE/IES Std. 90.1P)
- B. Thermal function/space function or zonal (see exhibit L and L1: ASEAM2)
- C. Subtype (see exhibit L)
- D. Type (see exhibit L)
- E. Category (see exhibit L)

IV. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client
  - 4. Location
  - 5. Description
- B. Climate location
- C. Energy model
- D. Economic parameters
  - 1. Energy cost information
  - 2. Building cost information
  - 3. NBSLCC (see exhibit H: ASEAM2 NBSLCC input forms)
- E. Quality level (high, normal, competitive)

V. BASIC CHARACTERISTICS (VARIOUS HIERARCHY LEVELS)

- A. Size (numeric)
- B. Configuration
  - 1. Building shape (graphic)
  - 2. Number of floors (graphic/numeric)
  - 3. Height changes of 1 story or more (graphic)
  - 4. Internal adjacencies (graphic/numeric)
    - a. percent of perimeter adjacent to other spaces with which a high temperature difference exists.
    - b. percent of perimeter that is at exterior wall
  - 5. Partitioning (open/closed offices, partition height) (graphic/numeric; at space function or zonal function levels)
- C. Orientation (graphic)
- D. Site adjacencies (numeric/graphic)

VI. FUNCTIONAL PARAMETERS (VARIOUS HIERARCHY LEVELS)

A. Occupancy

1. Occupant density
2. Load (per person)
  - a. sensible
  - b. latent
3. Special requirements
  - a. age distribution (lighting, thermal)
  - b. handicap requirements

B. Internal gains

1. Receptacles
2. Priority (process and other)
  - a. sensible
  - b. latent
3. Miscellaneous
  - a. sensible
  - b. latent
4. Vertical transportation

C. Schedules: select/modify

(see exhibits S1 & S2: ENERGY program input forms
exhibit S3: DOE2 schedule library
exhibit S4: ASHRAE/IES 90.1 schedule library)

1. Occupancy
2. HVAC
3. Lighting
4. Equipment
5. DHW
6. Vertical transportation
7. Miscellaneous

VI. COMFORT CRITERIA (LIGHTING, THERMAL, OR ZONAL SPACE FUNCTION LEVEL)

A. Temperature

1. Cooling
  - a. Sensible (see exhibit T)
  - b. Mean radiant temperature (MRT) (see exhibit T)
2. Heating
  - c. Sensible (see exhibit T)
  - d. Mean radiant temperature (MRT) (see exhibit T)

B. Humidity

1. Cooling (see exhibit T)
2. Heating (see exhibit T)
3. Special requirements (see exhibit T)

C. Air movement

1. Cooling (see exhibit T)
2. Heating (see exhibit T)
3. Special requirements (labs, kitchens) (see exhibit T)

D. Fresh air

1. Cooling (see exhibit T)
2. Heating (see exhibit T)
3. Special requirements (labs, kitchens) (see exhibit T)

- E. Illuminance
  - 1. Recommended ranges
  - 2. Ambient/Task/Wall percentage
  - 3. Task contrast
  - 4. Direction
  - 5. User characteristics
  - 6. Task difficulty/duration

- F. Luminance
  - 1. Luminance ratios
  - 2. Surface reflectances
  - 3. Glare
  - 4. Veiling reflections

- G. Lighting visibility/quality
  - 1. Distribution
  - 2. Color rendering
  - 3. Color temperature
  - 4. Shadows/diffusion
  - 5. Clarity/contrast
  - 6. Orientation/organization
  - 7. Flicker
  - 8. Adjustability
  - 9. Flexibility

H. Special visual requirements

I. Acoustic (HVAC, ballast, etc.)

(see exhibits AA thru EE)

VII. BUILDING SYSTEMS (VARIOUS HIERARCHY LEVELS)

A. Envelope

- 1. Roof/ceiling
  - a. Basic information
    - (1) Area
    - (2) Slope & slope orientation

b. Selection criteria

(see exhibits CC and DD)

c. Input library

(exhibit U: ASHRAE Des. Heat Trans. Coeff.)

d. Input form

(see exhibit V)

2. Walls (opaque)

a. Basic information

(1) Area

(2) Orientation

(3) Tilt

b. Selection criteria

(see exhibit EE)

c. Input library

(exhibits R1: ASHRAE Wall Const. Group Desc.
and R2: ASHRAE Design Heat Trans. Coeff.)

d. Input form

(see exhibit W & W1: DOE2 Input Form)

3. Floor

a. Basic information

(1) Area

b. Selection criteria

(see exhibit DD)

c. Input library

d. Input form

(see exhibit X)

4. Doors (exterior)
  - a. Basic information
    - (1) Area
    - (2) Orientation
  - b. Selection criteria
  - c. Input library
  - d. Input form (see exhibit Y)
5. Fenestration
  - a. Basic information
    - (1) Area
  - b. Selection criteria
  - c. Input library
  - d. Input form (see exhibit Z)
6. Infiltration
  - a. Occupied air change rate
  - b. Unoccupied air change rate
- B. Interior sub-divisions
  1. Floor/Ceiling
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  2. Partitions
    - a. Basic information
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit W2)
- C. Lighting
  1. Selection rules
  2. Criteria (see exhibit BB)
  3. Typical systems library (see exhibit M: LIGHTING Space Function input forms)
  4. Input forms (see exhibit B: ASEAM2 loads input forms and exhibit B1: DOE2 input form)
  5. Daylighting
    - a. Daylighting parameters (see exhibit C: ASEAM2 loads input forms)
    - b. Daylighting controls (see exhibit D: ASEAM2 loads input forms)
- D. HVAC
  1. Selection rules (see exhibit Q: ASHRAE TC 9.1)
  2. Criteria (see exhibit AA)
  3. Typical systems library (see exhibit GG: DOE2 list)
  4. Input forms
    - a. Systems (see exhibit E: ASEAM2 systems input forms and exhibit E2: DOE2 input form)
    - b. Plants (see exhibit F: ASEAM2 plants input forms, and exhibit F1: DOE2 input form)
- E. Service water heating
  1. Selection rules
  2. Criteria
  3. Typical systems library
  4. Input forms

F. Power

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

G. Vertical transportation

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

Appendix B

Supporting Exhibits

Appendix B

List of Supporting Exhibits for Building Characteristic Set Taxonomy

Exhibit

A: Shading Input Forms (ASEAM2)
B: Lighting Input Forms (ASEAM2)
B1: Lighting Input Forms (DOE 2.1C)
C: Daylighting Input Forms (ASEAM2)
D: Daylighting Controls Input Forms (ASEAM2)
E: Systems Input Forms (ASEAM2)
E1: Recommended Input Status of HVAC Systems Factors
E2: HVAC Systems Input Forms (DOE 2.1C)
F: Plant Input Forms (ASEAM2)
F1: Plant Input Forms (DOE 2.1C)
H: NBSLCC Input Forms (ASEAM2)
I: Miscellaneous Electric Input Forms (ASEAM2)
J: Miscellaneous Input Forms (ASEAM2)
K: Miscellaneous latent load data
L: Building Classification
L1: Thermal Functions (ASEAM2)
M: Lighting Database Format, Input Forms
N: Lighting Functions List (ASHRAE/IES Std. 90.1P)
S1: Schedule Library (ENERGY program)
S3: Schedule Library (DOE 2.1C)
S4: Schedule Library (ASHRAE/IES Std. 90.1P)
T: Temperature, Humidity, and Ventilation Parameters
V: Roof/Ceiling Input Form
W: Walls (Opaque) Input Form
W1: Exterior Wall Input Form (DOE 2.1C)
W2: Interior Partitions Input Form
X: Floor/Ceiling Input Form
Y: Doors (Exterior) Input Form
Z: Fenestration Input Form
Z1: Window Description Input Forms (WINDOW 2.0)
Z2: Glass Type Input Form (DOE 2.1C)
Z3: Window Input Form (DOE 2.1C)
AA: Criteria for HVAC Systems Selection
BB: Criteria for Lighting Systems Selection
CC: Criteria for Roof Selection
DD: Criteria for Plenum Selection
EE: Criteria for Opaque Wall Selection
GG: Typical Systems Library (DOE 2.1C)

A	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	_____	_____	_____

B	Lighting	Function name (or 'NA')	_____	_____	_____
	Lighting	Average function area (ft ²)	_____	_____	_____
	Lighting	Installed watts/ft ²	_____	_____	_____
	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 #	_____	_____	_____

C	Daylighting	Function name (or 'NA')	_____	_____	_____
	Daylighting	Window orientation (N,NW,etc)	_____	_____	_____
	Daylighting	Ground reflectance (%)	_____	_____	_____
	Daylighting	Typical room window area (ft ²)	_____	_____	_____
	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'in or 'S'tep)	_____	_____	_____

D	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	_____	_____	_____

B1

Code-word	LIGHTING-TYPE
SUS-FLUOR	Suspended fluorescent
REC-FLUOR-NV	Recessed fluorescent - not vented
REC-FLUOR-RV	Recessed fluorescent vented to return air
REC-FLUOR-RSV	Recessed fluorescent vented to supply and return air
INCAND	Incandescent

For mixed types of lighting within the same space, the recommended procedure is to select the dominant type and adjust the percentage of heat produced by the lighting, using the LIGHT-TO-SPACE keyword.

PEOPLE-HG-SENS	P-H-S	=	_____	Btu/hr/ person	(Note 5)	0.	2000.
LIGHTING-SCHEDULE	L-SCH	=	_____	U-name	(Note 7)	-	-
LIGHTING-TYPE	L-T	=	_____	code-word	SUS-FLUOR	-	-
LIGHTING-KW	L-KW	=	_____	kW	(Note 2)	0.	200.
LIGHTING-W/SQFT	L-W	=	_____	W/ft ²	(Note 2)	0.	10.
LIGHT-TO-SPACE	L-T-S	=	_____	fraction	1.(Note 6)	0.	1.
TASK-LIGHT-SCH	T-L-SCH	=	_____	U-name	(Note 7)	-	-
TASK-LIGHTING-KW	T-L-KW	=	_____	kW	(Note 3)	0.	200.
TASK-LT-W/SQFT	T-L-W	=	_____	W/ft ²	(Note 3)	0.	10.

E

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=WSEH	8=AAEP
9=BB	10=FURN	11=UH	12=HV		13=WAC		

Zone	Zone
Number	Label

Heating	Heating	Cooling
Cooling	ONLY	ONLY
System #	System #	System #

NOTE - THE ZONE NUMBERS AND LABELS
(AS DEFINED IN LOADS INPUT)
WILL BE PRINTED HERE

ASAM2 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

Heating available beginning month #

Heating available ending month #

Design heating coil discharge temperature

Discriminator Control (Y/N) (DDMZ ONLY)

Outside temperature at maximum hot deck temperature (DDMZ ONLY)

Maximum hot deck temperature (DDMZ ONLY)

Outside temperature at minimum hot deck temperature (DDMZ ONLY)

Minimum hot deck temperature (DDMZ ONLY)

Cooling coil plant type (see codes below)

0=None 1=DX 2=Centrifugal 3=Absorption 4=District Cooling

5=Double Bundle 6=Cooling Tower (WSEF only) 7=Reciprocating

Outside temperature below which cooling is off

Cooling available beginning month #

Cooling available ending month #

Design cooling coil discharge temperature

Discriminator control (Y/N)

Maximum cooling coil discharge temperature

Preheat coil plant type (Use Heating Codes 0 - 3)

Outside temperature above which preheat is off

Preheat available beginning month #

Preheat available ending month #

Design preheat coil discharge temperature

Humidification plant type (Use Heating Codes 0 - 3)

Outside temperature above which humidification is off

Humidification available beginning month #

Humidification available ending month #

Humidification available during unoccupied cycle (Y/N)

Minimum relative humidity maintained

Baseboard plant type (Use Heating Codes 0 - 3)

Outside temperature above which baseboard is off

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)

(or) Supply fan power per 1000 CFM

Supply fan temperature rise (blank=default)

Total return fan power required (blank=default)

(or) Return fan power per 1000 CFM

Return fan temperature rise (blank=default)

(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)

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

Occup Unocc

% %

°F °F

ASACAM SYSTEMS INPUT FORM (ABBREVIATED)

System # _____

(Heat Pump and Window Air Conditioner only)

Zonal total cooling capacity method (1=User Entered 2=Autosized)

(if autosized) Percent of design total load satisfied

Zonal sensible cooling capacity method (1=User Entered 2=Autosized)

(if autosized) Percent of design sensible load satisfied

Design coefficient of performance

Outside temperature at minimum fluid loop temperature

Minimum fluid loop temperature

Outside temperature at maximum fluid loop temperature

Maximum fluid loop temperature

Zonal heating capacity method (1=User Entered 2=Autosized)

(if autosized) Percent of max heat pump load satisfied

AHP backup heating source (1=Furnace 2=Electric Resistance)

Outside temperature below which backup heating is on

Zonal electric resistance backup heating capacity method

(1=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)

1=Electric 2=Natural Gas 3=#2 Oil 4=#4 Oil 5=#6 Oil

Furnace capacity (blank=autosize)

(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

Zonal air volume method (1=User Entered 2=Autosized)

(if autosized) Percent of design default air flow

Zonal fan power method (1=User Entered 2=Autosized)

(if autosized) Percent of design default fan KW

DX total cooling capacity (blank=autosized)

(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)

Outside temperature below which condenser fan is off

Loads	Zone Name	Zone	Zone	Zone Tot	Zone Sen	Zone HP	Zone HP
Zone #	or Label	CFM	Fan KW	Clg Cap	Clg Cap	Stg Cap	Brkup Htg
				(Tons)	(Tons)	(Tons)	Cap (KW)

NOTE - THE ZONE NUMBER
AND LABEL FOR EACH ZONE
ASSIGNED TO THIS SYSTEM
IS PRINTED HERE

RECOMMENDED INPUT STATUS OF HVAC SYSTEM FACTORS

A. Minimum Input Required for DOE 2.1 System Simulation Subroutine Execution

Inside Design Temperature, Heating: Blind default for target setting, default with user confirmation for design analysis and final evaluation.

Inside Design Temperature, Cooling: Blind default for target setting, default with user confirmation for design analysis and final evaluation.

Minimum Supply Air Temperature, Cooling: Blind default for target setting, default with user confirmation for design analysis and final evaluation.

Maximum Supply Air Temperature, Heating: Blind default for target setting, default with user confirmation for design analysis and final evaluation.

Induction Ratio: Required only for induction systems; blind default for target setting, default with user confirmation for design analysis and final evaluation.

Reheat Delta T: Required only for reheat systems; blind default for target setting, default with user confirmation for design analysis and final evaluation.

Minimum Fluid Temperature: Required only for water-source heat pump systems; blind default for target setting, default with user confirmation for design analysis and final evaluation.

Maximum Fluid Temperature: Required only for water-source heat pump systems; blind default for target setting, default with user confirmation for design analysis and final evaluation.

B. Optional Program Input with Significant Energy Impact

Minimum Percentage of RH: Blind default (based on library of values for various space functions) for target setting; default with user confirmation for design analyses and final evaluation.

Maximum Percentage of RH: Blind default (based on library of values for various space functions) for target setting; default with user confirmation for design analyses and final evaluation.

O.A. CPM per Occupant: Blind default (based on library of code-required values for various space functions) for target setting; default with user confirmation for design analysis and final evaluation.

Outside Design Conditions: User input (LOADS subroutine) for target setting, design analyses and final evaluation (ASHRAE Fundamentals reference). Note that, without this input, DOE 2.1 will calculate peak loads from climatic data rather than design loads (e.g., ASHRAE 2-1/2° column for summer design condition). User input of Outdoor Design

Conditions will permit accurate calculation of zone CFM (rather than estimating CFM/SF), which can then be used to more accurately simulate supply fan power consumption.

Central Supply/Return Fan Static Pressures: User input for target setting, design analyses and final evaluation with message link to display table of S.P. ranges for various system types and, where appropriate, subcategories of duct construction classification (concern is that fan power consumption is a significant energy issue, and current DOE 2.1 KW/CFM default values do not adequately address the range of values that could occur in practice). Link to calculated zone CFMs, system type and supply fan efficiency values will permit more accurate estimation of fan power consumption.

Central Supply/Return Fan Efficiencies: Blind default from table of values (motor size vs. efficiency) at target setting, confirmed default for design analyses, user input for final evaluation.

Central Fan Control: Blind default for target setting, confirmed default for design analyses, user input for final evaluation.

Outside Air Economizer: Blind default for target setting, user input of various free-cooling/heat recovery options for design analyses and final evaluation.

TO BE CONTINUED . . .

E2

U-name _____ SYSTEM-CONTROL or S-C (User Worksheet)

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
MAX-SUPPLY-T	MAX-S-T	= _____	*F	Note 1	50.	200.
HEATING-SCHEDULE	H-SCH	= _____	U-name	Note 2	-	-
HEAT-CONTROL	H-C	= _____	code-word	Note 1	-	-
HEAT-SET-T	H-S-T	= _____	*F	Note 1	50.	200.
HEAT-SET-SCH	H-S-SCH	= _____	U-name	-	-	-
HEAT-RESET-SCH	H-R-SCH	= _____	U-name	Note 3	-	-
MIN-SUPPLY-T	MIN-S-T	= _____	*F	Note 1	45.	70.
COOLING-SCHEDULE	C-SCH	= _____	U-name	Note 2	-	-
COOL-CONTROL	C-C	= _____	code-word	Note 1	-	-
COOL-SET-T	C-S-T	= _____	*F	Note 1	45.	70.
COOL-SET-SCH	C-S-SCH	= _____	U-name	-	-	-
COOL-RESET-SCH	C-R-SCH	= _____	U-name	Note 4	-	-
MAX-HUMIDITY	MAX-H	= _____	per cent R.H.	Note 1	30.	80.
MIN-HUMIDITY	MIN-H	= _____	per cent R.H.	Note 1	0.	70.
BASEBOARD-SCH	B-SCH	= _____	U-name	Note 5	-	-
ECONO-LIMIT-T	E-L-T	= _____	*F	Note 6	45.	80.
PREHEAT-T	P-T	= _____	*F	Note 1	-50.	70.

- 1) See the proper Applicability Table (Sec. B.4 of this chapter) for applicability or the default value. If the keyword is not listed in the table, it is not applicable to the system being specified.
- 2) If no data entry is made for this keyword, the program assumes that the subject schedule has not been specified, and that the subject component or quantity is "always on" or "always available when needed", i.e., THRU DEC 31 (ALL) (1,24) (1).
- 3) A data entry for this keyword is required if the data entry for the keyword HEAT-CONTROL is the code-word RESET. If otherwise, this keyword is not applicable.

= SYSTEM-AIR or S-A (User Worksheet)

U-name

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	=	U-name	-	-	-
SUPPLY-CFM	S-CFM	=	cfm	Note 1	10.	1.x10 ⁷
RATED-CFM	R-C	=	cfm	-	10.	1.x10 ⁷
RETURN-CFM	R-CFM	=	cfm	Note 2	10.	1.x10 ⁷
MIN-OUTSIDE-AIR	M-O-A	=	fraction	Note 3	0.	1.
MIN-AIR-SCH	M-A-SCH	=	U-name	-	-	-
OA-CONTROL	O-CTRL	=	code-word	Note 4	-	-
RECOVERY-EFF	REC-E	=	Btu/Btu	Note 5	0.2	0.8
DUCT-AIR-LOSS	D-A-L	=	fraction	Note 5	0.	1.
DUCT-DELTA-T	D-D-T	=	*F	Note 5	0.	10.
MAX-OA-FRACTION	M-D-F	=	fraction	Note 5	0.	1.
VENT-TEMP-SCH	V-T-SCH	=	U-name	*	-	-
NATURAL-VENT-AC	N-V-A	=	number	*	0.	100.
NATURAL-VENT-SCH	N-V-SCH	=	U-name	*	-	-

---

*This keyword is optional and applies only to RESYS system.

- 1) If no data entry is made for this keyword, the program will assume that fan capacity is the same as system design flow (see discussion in Sec. D.1 of this chapter and in the SYSTEM-AIR instruction).
- 2) If no data entry is made for this keyword, the program will use for this quantity the system design supply air flow rate minus the sum of the zone exhaust flow rates (for systems equipped with a return air fan).
- 3) See Sec. D.1 of this chapter for a discussion of how the program uses this keyword and/or alternative keywords to determine outside air flow rate.
- 4) TEMP, when applicable to the system being specified. This will simulate a temperature-controlled economizer.
- 5) See the proper Applicability Table (Sec. 8.4 of this chapter) for applicability or the default value. If the keyword is not listed in the table, it is not applicable to the system being specified.

= SYSTEM-FANS or S-FANS (User Worksheet)

U-name

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
FAN-SCHEDULE	F-SCH	= _____	U-name	Note 1	-	-
FAN-CONTROL	F-C	= _____	code-word	Note 2	-	-
SUPPLY-DELTA-T	SUP-D-T	= _____	*F	Note 3	0.	30.
SUPPLY-KW	S-KW	= _____	kW/std cfm	Note 3	0.	.01
SUPPLY-STATIC	S-S	= _____	inches W.G.	Note 3	0.	15.
SUPPLY-MECH-EFF	S-M-E	= _____	fraction	-	0.1	1.
SUPPLY-EFF	S-E	= _____	fraction	Note 3	0.1	1.
MOTOR-PLACEMENT	M-P	= _____	code-word	Note 4	-	-
FAN-PLACEMENT	F-P	= _____	code-word	Note 5	-	-
RETURN-DELTA-T	RET-D-T	= _____	*F	Note 6	0.	30.
RETURN-KW	R-KW	= _____	kW/cfm	Note 6	0.	.01
RETURN-STATIC	R-S	= _____	inches W.G.	Note 6	0.	10.
RETURN-EFF	R-E	= _____	fraction	Note 6	0.1	1.
MAX-FAN-RATIO	MAX-F-R	= _____	number	Note 2	1.	1.5
MIN-FAN-RATIO	MIN-F-R	= _____	fraction	Note 2	0.1	1.
LOW-SPEED-RATIOS	L-S-R	= (_____)	list of four values	Note 7	0.	1.
NIGHT-CYCLE-CTRL	N-C-C	= _____	code-word	Note 2	-	-
FAN-EIR-FPLR	F-E-FPLR	= _____	U-name of a linear, quadratic, or cubic CURVE-FIT	-	-	-

..

- 1) If no data entry is made for this keyword, the program assumes that the fan(s) are always available when needed, i.e., THRU DEC 31 (ALL) (1,24) (1).
- 2) See the proper Applicability Table (Sec. B.4 of this chapter) for applicability or the default value. If the keyword is not listed in the table, it is not applicable to the system being specified.

_____ = SYSTEM-TERMINAL or S-T (User Worksheet)
 U-name

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
REHEAT-DELTA-T	R-D-T	= _____	"F	Note 1	0.	100.
INDUCTION-RATIO	I-R	= _____	number	Note 2	1.	10.
MIN-CFM-RATIO	M-C-R	= _____	fraction	Note 3	0.	1.

- 1) This is a required entry for the Constant-Volume Reheat Fan System (RHFS). Default value for systems with optional zone heat coils (i.e., SZRH, SZCI, CBVAV, VAVS, PSZ, HVSYS, and PVAVS) is zero. The keyword is not applicable to other types of systems.
- 2) This is a required entry for TPIU and FPIU systems.
- 3) This keyword is applicable to SZRH, MZS, DOS, RHFS, PSZ, and PMZS where its default value is 1.0. It is also applicable to VAVS, CBVAV, and PVAVS where its value is calculated (from outside air requirement or peak heating load) if not input.

U-name = SYSTEM-EQUIPMENT or S-EQ (User Worksheet)

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
COOLING-CAPACITY	C-CAP	= _____	Btu/hr	Note 1	0.	1.x10 ⁸
COOL-CAP-FT	C-C-FT	= _____	U-name of a bi- linear or bi-quadratic	Note 1	-	-
COOLING-EIR	C-EIR	= _____	Btu/Btu	Note 1	0.	1.
COOL-EIR-FT	C-E-FT	= _____	U-name of a bi- linear or bi-quadratic	Note 1	-	-
COOL-EIR-FPLR	C-E-FP	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
COOL-SH-CAP	-	= _____	Btu/hr	Note 1	0.	1.x10 ⁸
COOL-SH-FT	C-S-FT	= _____	U-name of bi- linear or bi-quadratic	Note 1	-	-
COOL-FT-MIN	C-FT-MIN	= _____	*F	Note 1	0.	120.
RATED-CCAP-FCFM	R-CC-FC	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
RATED-CEIR-FCFM	R-CE-FC	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-

Keyword	Abbrev.	User input	Input Desc.	Default	Range	
					Min.	Max.
RATED-SH-FCFM	R-S-FC	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
COIL-BF	C-BF	= _____	cfm/cfm	Note 1	0.	.99
COIL-BF-FCFM	C-BF-FC	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
COIL-BF-FT	C-BF-FT	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
COOL-CTRL-RANGE	C-C-R	= _____	*F	Note 1	0.	15.
MIN-UNLOAD-RATIO	M-U-R	= _____	fraction	Note 1	0.	1.
MIN-HGB-RATIO	M-H-R	= _____	fraction	Note 1	0.	1.
MAX-COND-RCVRY	M-C-R	= _____	number	Note 1	.0	1.
CRANKCASE-HEAT	C-H	= _____	kW	Note 1	.0	1.
CRANKCASE-MAX-T	C-M-T	= _____	*F	Note 1	0.	100.
OUTSIDE-FAN-KW	O-F-KW	= _____	kW	Note 1	.0	20.
OUTSIDE-FAN-T	O-F-T	= _____	*F	Note 1	.0	200.
OUTSIDE-FAN-MODE	O-F-M	= _____	code-word	Note 1	-	-
COMPRESSOR-TYPE	C-TYPE	= _____	code-word	Note 1	-	-
HEATING-CAPACITY	H-CAP	= _____	(-)Btu/hr	Note 1	-1.x10 ⁸	0.
HEAT-CAP-FT	H-C-FT	= _____	U-name of a bi-linear or bi-quadratic	Note 1	-	-

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
HEATING-EIR	H-EIR	= _____	Btu/Btu	Note 1	0.	2.
HEAT-EIR-FT	H-E-FT	= _____	U-name of a bi-linear or bi-quadratic	Note 1	-	-
HEAT-EIR-FPLR	H-E-FP	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
RATED-HCAP-FCFM	R-HC-FC	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
RATED-HEIR-FCFM	R-HE-FC	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
ELEC-HEAT-CAP	E-H-C	= _____	(-)Btu/hr	Note 1	-1.x10 ⁹	0.
MIN-HP-T	M-H-T	= _____	°F	Note 1	-30.	70.
MAX-ELEC-T	M-E-T	= _____	°F	Note 1	-30.	70.
DEFROST-T	D-T	= _____	°F	Note 1	0.	70.
DEFROST-DEGRADE	D-D	= _____	U-name of a linear, quadratic, or cubic	Note 1	-	-
HCOIL-WIPE-FCFM	H-W-FC	= _____	U-name of a linear, quadratic, or cubic	Note 2	-	-
FURNACE-HIR	F-HIR	= _____	Btu/Btu	Note 3	1.	1:75
FURNACE-AUX	F-A	= _____	Btu/hr	Note 3	0.	1.x10 ⁴

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
FURNACE-OFF-LOSS	F-O-L	= _____	U-name of a linear, quadratic, or cubic	Note 3	-	-
FURNACE-HIR-FPLR	F-H-FP	= _____	U-name of a linear, quadratic, or cubic	Note 3	-	-

- 1) See the proper Applicability Table (Sec. B.4 of this chapter) for default curve U-name or default value. If the keyword is not listed in the table, it is not applicable to the system being specified. See Table IV.39 for default curve coefficients.

Note that for "zonal" systems (UHT, UVT, TPFC, FPFC, TPIU, FPIU, HP, and PTAC) the keywords COOLING-CAPACITY, HEATING-CAPACITY, and COOL-SH-CAP may be specified here in the SYSTEM-EQUIPMENT subcommand or in the ZONE instruction, or both. If an entry is not made in a ZONE instruction, the entry made here in SYSTEM-EQUIPMENT will be used. If an entry is made both in ZONE and here in SYSTEM-EQUIPMENT, the entry made in ZONE takes precedence. If an entry is made only here in SYSTEM-EQUIPMENT, it applies to every ZONE in the SYSTEM.

- 2) This keyword is applicable only to MZS, DDS, and PMZS. There is no default.
- 3) The user may specify an auxilliary furnace here in the SYSTEMS Chapter. Alternatively, or additionally, an auxilliary furnace may be specified in PLANT. There is no default for FURNACE-OFF-LOSS. Note: In addition to specifying the above furnace keyword values, it is necessary to specify HEAT-SOURCE equal to either GAS-FURNACE or OIL-FURNACE in the SYSTEM command.

F

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

AS2AM2 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 (1=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 (1=Boiler 2=Dist Heat)	_____	_____	
Design coefficient of performance	_____	_____	
Minimum part load ratio (% of capacity)	_____	_____	%
Number of absorption stages	_____	_____	
Load management/operation (1=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 (1=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 (1=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 (1=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
DEW 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)	_____	KBTUE
(if autosized) Peak hourly DEW usage	_____	gal/hour
Average hourly DEW usage - occupied cycle	_____	gal/hour
Average hourly DEW usage - unoccupied cycle	_____	gal/hour
Domestic hot water supply temperature	_____	°F
DEW inlet temperature - design summer	_____	°F
DEW inlet temperature - design winter	_____	°F
Circulating pump KW - occupied cycle	_____	KW
Circulating pump KW - unoccupied cycle	_____	KW
Design DEW heating efficiency	_____	%
DEW losses - occupied cycle	_____	BTUE
DEW losses - unoccupied cycle	_____	BTUE
Boiler Energy Source (1=Elect 2=Nat Gas 3=Oil)	Type 1 _____	Type 2 _____
(if oil) Oil type (2 or 4 or 6)	_____	_____
(if gas) Annual pilot consumption	_____	therms
Boiler heating capacity (per boiler)	_____	KBTUE
(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	_____	%

F1

PLANT-PARAMETERS or P-P

(User Worksheet)

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
<u>Chillers</u>						
CHILLER-CONTROL	=		code-word DEMAND-ONLY	-	-	-
CHILL-WTR-T	=		*F	44.	32.	80.
CHILL-WTR-THROTTLE	=		*F	2.5	1.	15.
COMP-TO-TWR-WTR	=		gpm/ton	3.	1.	5.
MIN-COND-AIR-T	=		*F	65.	0.+	100.
					(Note 1)	
DBUN-TO-TWR-WTR	=		gpm/ton	3.	1.	5.
ABSOR1-HIR	=		Btu/Btu	1.6	0.+	3.
ABSOR2-HIR	=		Btu/Btu	1.0	0.+	3.
ABSOR3-HIR	=		Btu/Btu	1.6	0.+	3.
ABSOR-TO-TWR-WTR	=		gpm/ton	3.6	0.+	100.
HERM-CENT-COND-PWR	=		Btu/Btu	0.	0.	1.
HERM-CENT-COND-TYPE	=		code-word	TOWER	-	-
HERM-CENT-UNL-RAT	=		ratio	0.1	0.	1.
HERM-REC-COND-PWR	=		Btu/Btu	0.03	0.	1.
HERM-REC-COND-TYPE	=		code-word	TOWER	-	-
HERM-REC-UNL-RAT	=		ratio	0.25	0.	1.
OPEN-CENT-COND-PWR	=		Btu/Btu	0.	0.	1.
OPEN-CENT-COND-TYPE	=		code-word	TOWER	-	-
OPEN-CENT-MOTOR-EFF	=		ratio	0.9	0.+	1.
OPEN-CENT-UNL-RAT	=		ratio	0.1	0.	1.
OPEN-REC-COND-PWR	=		Btu/Btu	0.03	0.	1.
OPEN-REC-COND-TYPE	=		code-word	TOWER	-	-
OPEN-REC-MOTOR-EFF	=		ratio	0.9	0.+	1.
OPEN-REC-UNL-RAT	=		ratio	0.25	0.	1.
DBUN-CAP-COR-REC	=		fraction	-	0.+	1.
DBUN-COND-T-ENT	=		*F	85.	60.	100.
DBUN-COND-T-REC	=		*F	105.	80.	120.
DBUN-EIR-COR-REC	=		fraction	-	1.	2.

Notes:

1. A minimum of "0.+" means that any positive number in the range is acceptable, but zero itself is not, as this value may be used as a divisor.

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
DBUN-HT-REC-RAT		= _____	Btu/Btu	0.95	0.+ (Note 1)	1.
DBUN-UNL-RAT-DES		= _____	ratio	0.1	0.	1.
DBUN-UNL-RAT-REC		= _____	ratio	0.3	0.	1.
<u>Cooling Tower</u>						
MIN-TWR-WTR-T		= _____	*F	65.	32.	100.
RFACT-CFM-EXPONENT		= _____	number	0.9	0.+	2.
TWR-CELL-MAX-GPM		= _____	gpm/gpm	1.5	1.	3.
TWR-DESIGN-WETBULB		= _____	*F	75.	32.	100.
TWR-FAN-CONTROL		= _____	code-word	ONE-SPEED	-	-
TWR-FAN-LOW-CFM		= _____	cfm/cfm	0.5	0.+	1.
TWR-FAN-LOW-ELEC		= _____	kW/kW	0.125	0.+	1.
TWR-FAN-OFF-CFM		= _____	cfm/cfm	0.18	0.	1.
TWR-IMPELLER-EFF		= _____	fraction	0.77	0.+	1.
TWR-MOTOR-EFF		= _____	fraction	0.9	0.+	1.
TWR-PUMP-HEAD		= _____	ft	60.0	0.	100.
TWR-TEMP-CONTROL		= _____	code-word	FLOAT	-	-
TWR-WTR-SET-POINT		= _____	*F	80.	32.	100.
TWR-WTR-THROTTLE		= _____	*F	10.	1.	20.
DIRECT-COOL-MODE		= _____	code-word	NOT- AVAILABLE	-	-
DC-MAX-T		= _____	*F	55.	35.	65.
DC-CHILL-WTR-T		= _____	*F	50.	30.	60.
DIRECT-COOL-SCH		= _____	U-name	Note 2	-	-
DIRECT-COOL-KW		= _____	kW/ton	Note 3	0.0	1.0

Notes:

1. A minimum of "0.+" means that any positive number in the range is acceptable, but zero itself is not, as the value may be used as a divisor.
2. The schedule values default to one for all 24 hours of the day. This means that direct cooling is available all the time.
3. Defaults to 0.02 if DIRECT-COOL-MODE = THERMO-CYCLE and to 0.0 if DIRECT-COOL-MODE = STRAINER-CYCLE.

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
<u>Boilers</u>						
BOILER-BLOW-RAT	=	_____	lb/lb	0.07	0.	1.
BOILER-CONTROL	=	_____	code-word DEMAND-ONLY		-	-
BOILER-FUEL	=	_____	code-word FUEL-OIL		-	-
E-HW-BOILER-LOSS	=	_____	Btu/Btu	0.02	0.	1.
E-STM-BOILER-LOSS	=	_____	Btu/Btu	0.02	0.	1.
HW-BOILER-HIR	=	_____	fraction	1.25	0.+ (Note 1)	3.
MAKEUP-WTR-T	=	_____	*F	55.	32.	212.
RECVR-HEAT/GLOW	=	_____	Btu/Btu	0.5	0.+	1.
STM-BOILER-HIR	=	_____	fraction	1.3	0.+	3.

Domestic Hot-Water Heaters

DHW-HIR	=		fraction	1.39	0.+	3.
DHW-HEATER-FUEL	=		code-word NATURAL-GAS		-	-
ELEC-DHW-LOSS	=		Btu/Btu	0.03	0.	1.

Furnaces

FURNACE-HIR	=		fraction	1.35	0.+	1.75
FURNACE-FUEL	=		code-word NATURAL-GAS		-	-
FURNACE-AUX	=		Btu/hr	800.	0.	2000.

Generators

DIESEL-FUEL	=		code-word DIESEL-OIL		-	-
MAX-DIESEL-EXH	=		lb/kW	15.	0.+	100.
GTURB-FUEL	=		code-word NATURAL-GAS		-	-

Notes:

1. A minimum of "0.+" means that any positive number in the range is acceptable, but zero itself is not, as the value may be used as a divisor.
4. See keyword description for alternative default value.

Keyword	Abbrev.	User Input	Input Desc.	Default	-Range	
					Min.	Max.
MAX-GTURB-EXH		= _____	lb/kW	40.	0.+ (Note 1)	100.
STURB-EXH-PRES		= _____	psig	-12.7 (Note 4)	-15.	1000.
STURB-PRES		= _____	psig	15. (Note 4)	-15.	700.
STURB-SPEED		= _____	rpm	5000.	0.+	1.x10 ⁴
STURB-T		= _____	*F	378.7 (Note 4)	212.	1000.
STURB-WTR-RETURN		= _____	lb/lb	0.97	0.+	1.
STM-PRES		= _____	psig	15. (Note 4)	-15.	700.
STM-SATURATION-T		= _____	*F	253.7 (Note 4)	212.	500.

Solar

MIN-SOL-COOL-T		= _____	*F	180.	80.	212.
MIN-SOL-HEAT-T		= _____	*F	100.	60.	212.
MIN-SOL-PROCESS-T		= _____	*F	140.	60.	212.

Pumps

CCIRC-DESIGN-T-DROP		= _____	*F	10.	0.+	20.
CCIRC-HEAD		= _____	ft	60.	0.	100.
CCIRC-IMPELLER-EFF		= _____	fraction	0.77	0.+	1.
CCIRC-LOSS		= _____	ratio	0.01	0.	1.
CCIRC-MOTOR-EFF		= _____	fraction	0.9	0.+	1.
HCIRC-DESIGN-T-DROP		= _____	*F	30.	0.+	100.
HCIRC-HEAD		= _____	ft	60.	0.	100.
HCIRC-IMPELLER-EFF		= _____	fraction	0.77	0.+	1.
HCIRC-LOSS		= _____	ratio	0.01	0.	1.
HCIRC-MOTOR-EFF		= _____	fraction	0.9	0.+	1.

Notes:

1. A minimum of "0.+" means that any positive number in the range is acceptable, but zero itself is not, as the value may be used as a divisor.
4. See keyword description for alternative default value.

H

NBSLCC Input Form

LCC PROJECT DATA

Project Title	_____
Study Period	_____ years
Construction Period	_____ years
Base Year (e.g.1987)	_____
Tax Status Code (see reference manual page 84) (1=for profit 2=owner-occupied 3=non-profit)	_____
Discount Rate Type (1=Real (non-profit only), 2=Nominal)	_____
General Inflation Rate (%/Year Average over Study Period)	_____ %
Discount Rate	_____ %
Marginal Federal Income Tax Rate	_____ %
Marginal State Income Tax Rate	_____ %
Property Tax Rate	_____ %
Capital Gains Adjustment Factor	_____ %
Depreciation Recapture Code (see reference manual page 91) (0=none 1=capital gain 2=ordinary income 3=combination)	_____
Depreciation Basis Adjustment Factor	_____ %
Sales Tax Rate	_____ %
DOE Region (for Default Energy Prices)	_____
Building Type (1=Residential 2=Commercial 3=Industrial)	_____

CAPITAL COMPONENTS DATA

Capital Component Data for Component # _____ (repeat for each capital component)

Component Name (or 'NA')	_____
Initial Cost of Component (dollars)	_____
Percent Subject to Sales Tax	_____
Expected Component Life (Years - Use '999' for Land)	_____
Depreciation Method Code	_____
0 = no depreciation calculated	
1 = straight line	
2 = declining balance (accelerated)	
3 = sum of years digits	
4 = depreciation table (user entered)	
Depreciation Life (years)	_____
Depreciation Acceleration Rate (%) (Code 2 only)	_____
Depreciation Salvage Value (Percent of Initial Cost)	_____
Additional First Year Depreciation Factor	_____
Average Escalation Rate During Planning/Construction Period	_____
Average Escalation Rate During Occupancy	_____
Property Tax Assessment Factor (%)	_____
Tax Credit Rate (Percent of Initial Cost)	_____
Resale Value Factor (Percent of Initial Cost)	_____

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

Capital Component Data for Component # _____ (repeat for each capital component)

Enter Percentage of Cost for Each Year	
Planning, Construction Year 1 (1987)	_____
Planning, Construction Year 2 (1988)	_____
Planning, Construction Year 3 (1989)	_____
At Occupancy (1990)	100.00

NBSLCC Input Form

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	Ant	No	Year	Ant	No	Year	Ant	No	Year	Ant	No	Year	Ant
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	2	3
Energy Type Code	—	—	—
1=Electricity	—	—	—
2=Distillate Fuel Oil	—	—	—
3=Residual Fuel Oil	—	—	—
4=Natural Gas	—	—	—
5=Liquefied 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 Annual	#	Dur Annual	#	Dur Annual	#	Dur Annual	#	Dur Annual
Yrs	Rate %	Yrs	Rate %	Yrs	Rate %	Yrs	Rate %	Yrs	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	—

NBSLCC Input Form

REPLACEMENTS TO CAPITAL COMPONENTS

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

	Replacements to Capital Component			
	1	2	3	4
Year of Replacement (or 'NA')	—	—	—	—
(from occupancy year e.g. '2')				
Init Cost of Replacement (Unadjusted)	—	—	—	—
Percent Subject to Sales Tax	—	—	—	—
Expected Replacement Life (years)	—	—	—	—
Depr Salv Val Factor (% of repl cost)	—	—	—	—
Depreciation Life (years)	—	—	—	—
Resale Value (% of replacement cost)	—	—	—	—
Property Tax Assessment Factor (%)	—	—	—	—

DEPRECIATION

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

Year	Year	Year	Year	Year
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

MORTGAGE LOAN

	Constt Loan	Permanent Loans			
		1	2	3	4
% of Total Cost Borrowed (or 'NA')	—	—	—	—	—
Loan Type Code	—	—	—	—	—
1=fully amortized (equal payments)					
2=interest only (principal at end)					
3=interest and principal at end					
Annual Interest Rate (%)	—	—	—	—	—
Life of Loan (years)	—	—	—	—	—
Number of Payments per Year	—	—	—	—	—
Points Paid (% of loan amount)	—	—	—	—	—

I	Misc Elect	Electric equipment name (or 'NA')	_____	_____
	Misc Elect	Installed watts/ft ²	_____	_____
	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	_____	_____
J	Misc Elect	Monthly Diversity Factor Table Number	_____	_____
	Misc Sens	Load source name (or 'NA')	_____	_____
	Misc Sens	Installed BTUE/ft ²	_____	_____
	Misc Sens	(times) Percent of zone area	_____	_____
	Misc Sens	(or) Total installed BTUE	_____	_____
	Misc Sens	Hooded (Y/N)	_____	_____
	Misc Sens	Diversity Factor Occupied	_____	_____
K	Misc Sens	Diversity Factor Unoccupied	_____	_____
	Misc Sens	Monthly Diversity Factor Table Number	_____	_____
	Misc Latent	Load source name (or 'NA')	_____	_____
	Misc	Installed BTUE/ft ²	_____	_____
	Misc	(times) Percent of zone area	_____	_____
	Misc	(or) Total installed BTUE	_____	_____
	Misc	Hooded (Y/N)	_____	_____
	Misc	Diversity Factor Occupied	_____	_____
	Misc	Diversity Factor Unoccupied	_____	_____
	Misc	Monthly Diversity Factor Table Number	_____	_____
	Misc		_____	_____

Exhibit L

Structure for Building Categories, Types, and Subtypes

COMMERCIAL BUILDING	BUILDING TYPE	BUILDING SUBTYPE
OFFICES	HIGH RISE MID RISE LOW RISE	HIGH QUALITY NORMAL QUALITY COMPETITIVE LEVEL GOVERNMENT OFFICE MEDICAL OFFICE RADIOLOGICAL OFFICE DENTAL OFFICE LAW OFFICE OPHTHALMOLOGICAL OFFICES
HOTEL/ MOTEL	HIGH RISE MIDRISE LOWRISE	MULTIFUNCTION CONFERENCE STRIP
RETAIL	REGIONAL SHOPS RETAIL SHOPS	RETAIL SHOP WOMEN'S WEAR MEN'S WEAR BOOK SHOP GIFT SHOP JEWELRY SHOP BARBER SHOP TAILOR AND CLEANER BEAUTY SHOP SHOE REPAIR SHOP FLORIST SHOP DRUG STORES LIQUOR STORE SHOE STORE
	SUPERMARKET	
	BANK	
	RESTAURANT EATING PLACE	CAFETERIA LARGE SMALL FAST FOOD KITCHEN

COMMERCIAL BUILDING (contd)	BUILDING TYPE	BUILDING SUBTYPE
	AUTOMOTIVE	AUTOMOTIVE SERVICE STATION AUTOMOTIVE DEALER CTR. TRUCK DEALER AND SERVICE FACILITY
	COMMUNICATIONS	RADIO STATIONS TV STATION
	LABORATORY	COMPUTER (EDP) FACILITY PHOTOGRAPHIC LAB ANIMAL RESEARCH ELECTRONIC BIOLOGICAL CHEMICAL TOXICOLOGY
	FUNERAL HOME	
EDUCATIONAL	NURSERY CHILD CARE	
	ELEMENTARY SECONDARY	ADMINISTRATIVE LONG-RANGE RESOURCE CTR. CLASSROOM MULTIPURPOSE FAC. LANGUAGE LAB. SCIENCE FACILITY ARTS MUSIC INDUS. & VOCAT. FACIL. HOME ARTS FOOD SERVICE PHYS. ED. AUDITORIUM GUIDANCE

COMMERCIAL BUILDING (contd)	BUILDING TYPE	BUILDING SUBTYPE
EDUCATIONAL (Contd)	COLLEGE UNIVERSITY	CLASSROOM LECTURE ROOM GYMNASIUM PHYS ED/SPTS FACIL. FIELD HOUSE DORMITORY LIBRARY, ACADEMIC, & RESEARCH STUDENT UNION COMPUTATION CENTER COMMUNICATION CENTERS REGIONAL EDUCATION CTR. RESOURCE FACILITY (LIBRARY) LARGE GROUP FACILITY AUDIOVISUAL THEATER ARTS LABORATORY TEACHING STATION
RESIDENTIAL	HIGH RISE APART. MIDRISE APART. LOWRISE APART.	HIGH QUALITY NORMAL QUALITY COMPETTIVE LEVEL GROUP SENIOR CITIZEN ELDERLY HANDICAPPED
CULTURAL	MUSEUM LIBRARY MUSIC FACILITY	SMALL MUSEUM COMMUNITY THEATER
HEALTH	HOSPITAL REHAB. CTR. MENTAL HEALTH CTR. NURSING HOME CHILD HEALTH STA. MEDICAL SCHOOL DENTAL SCHOOL NURSING SCHOOL YOUTH TREATMENT CTR.	SURGICAL SUITE NURSERY PEDIATRIC NURSING UNIT DIAGNOSTIC X-RAY SUITE PHARMACY TELETHERAPY UNIT ELECTROLYSIS

COMMERCIAL BUILDING (contd)	BUILDING TYPE	BUILDING SUBTYPE
HEALTH (contd)	MULTIPHASIC HEALTH SCREENING CTR.	ENCEPHALOGRAPHIC SUITE PHYS. THERAPY DEPT. OCCUPATIONAL THERAPY LABORATORY LABOR-DELIVERY SUITE RADIOISOTOPE FACILITY OUT-PATIENT ACTIVITY EMERGENCY ACTIVITY EDP. UNIT
RELIGIOUS	CHURCHES GENERAL	CHURCH, LUTHERAN CHURCH, UNITED METHODIST TEMPLE AND SYNAGOGUE CHAPEL CHURCH SCHOOL
GOVERNMENTAL AND PUBLIC	CITY AND TOWN HALL COURTHOUSE FIRE STATION FIREHOUSE POLICE STATION POLICE FACILITY JAIL AND PRISON INCINERATOR PLANT YMCA BUILDING YWCA BUILDING BOY'S CLUB RECREATION CTR. NEIGHBORHOOD SERVICE CTR. EMBASSIE POST OFFICE	SMALL BRANCH LARGE BRANCH MAIN POST OFFICE LG. MAIN POST OFFICE VEHICLE MAINT FAC. BULK MAIL CENTER

COMMERCIAL BUILDING (contd)	BUILDING TYPE	BUILDING SUBTYPE
TRANSPORTATION	AIRPORT & TERMINAL AIR CARGO FACILITY AIR CARGO FACILITY SEA-PLANE TERMINAL BUS TERMINAL TRUCK TERMINAL	AIRPORT SERVICE EQUIPMENT BLDG. AIRCRAFT FIRE AND RESCUE STATION
INDUSTRIAL	INDUSTRIAL PARKS INDUSTRIAL PLANT RESEARCH LAB. WAREHOUSE	INDUSTRIAL BLDGS GENERAL
RECREATION AND ENTERTAINMENT	MOVIE THEATER BOWLING ALLEY BOWLING ALLEY WITH BILLIARD ROOM SPORTS ARENA	BASKETBALL (AAU) BASKETBALL (NCAA) ONE-WALL HANDBALL THREE- AND FOUR-WALL HANDBALL ICE HOCKEY PADDLE TENNIS TENNIS HANDICAPPED SEATING 500-SEAT MOVIE THEATER SWIMMING POOL LOCKER ROOM BATH HOUSE GYMNASIUM INDOOR TENNIS BLDG. GOLF COURSE AND CLUBHOUSE RIFLE AND PISTOL RANGE
MISCELLANEOUS	ANIMAL FACILITY LAB. GREENHOUSE HORSE BARN HORSE STABLE RIDING SCHOOL KENNEL NATURE CENTER	

Exhibit L-1

Thermal Functions

(From ASEAM 2-1, Quick Zone Routine)

1. ASSEMBLY RM.
2. AUDITORIUM
3. AUTO. REP. WKRM.
4. BARS
5. BEDROOM
6. CAFETERIA/DINING RM.
7. CLASSROOM
8. COIN LAUNDRY
9. COMMERC. LAUNDRY
10. COMMON RM, LOUNGE
11. COMPUTER RM.
12. CONFERENCE
13. CRAFT & VOCAT TRNG
14. DOCTOR CONSULT
15. DRAFTING, ART
16. GENL. OFFICE
17. GYMNASIUM
18. KITCHEN/COOKING
19. LABORATORY
20. LIBRARY
21. LIVING (SUITES)
22. LOBBY
23. LOCKER ROOM/SHOWER
24. MEAT PROC. RM.
25. MECH/ELECT RM.
26. MULTIFAM. KIT., BATH
27. MULTIFAM. LVG. BR.
28. MULTIPLE USE RM.
29. MUSIC RM.
30. PLAYING FLOOR
31. REPAIR SHOP
32. SALES AREA
33. SHIPPNG./RECEIVG.
34. SNGL. FAM. RES.
35. SPECTATOR AREA
36. STAGE
37. STORAGE/STOCK RM.
38. UTILITY RM.
39. WAITING RM.
40. WAREHOUSE

M

DATA DESCRIBING ROOM :

ROOM NAME OR NUMBER
APPROXIMATE ROOM LENGTH (FT)
APPROXIMATE ROOM WIDTH (FT)
AVERAGE ROOM HEIGHT (FT)
WORK PLANE HEIGHT (FT)
ACTUAL FLOOR AREA (SQ FT)
CEILING REFLECTANCE (%)
WALL REFLECTANCE (%)
FLOOR REFLECTANCE (%)
CLEANLINESS OF ROOM (1-5)
CLEANING CYCLE (# OF MONTHS)
TASK CRITERIA
IMPORTANCE OF COLOR

FIXTURE TYPE
STEM LENGTH (FT)
NUMBER OF FIXTURES

DESIRED LIGHT LEVEL (FC)

N

* - 80/20

1 Public Draft Review of
ASHRAE/IES Proposed Standard 90.1P
September 29, 1987

Table 6-7a

Base UPD (P_b) for Area/Activity
Common Activity Areas

Area/Activity	P_b W/ft ²	Note	Area/Activity	P_b W/ft ²	Note
<u>Office Category 1</u>					
* Auditorium -----	1.6	a	Enclosed offices, all open plan offices		
* Corridor -----	0.8	b	without partitions or with partitions*		
* Classroom/Lecture Hall -----	2.0		lower than 4.5 ft. below the ceiling.		
* Elec/Mech Equipment Room					
General -----	0.7	b	* Reading, Typing and Filing --	1.8	d
Control Rooms -----	1.5	b	Drafting -----	2.6	d
			Accounting -----	2.1	d
<u>Office Category 2</u>					
* Food Service			Open plan offices 900 square feet or		
Fast Food/Cafeteria -----	1.3		larger with partitions* 3.5 to 4.5		
Leisure Dining -----	2.5	c	feet below the ceiling.		
Bar/Lounge -----	2.5	c			
Kitchen -----	1.4		Offices less than 900 square feet		
			shall use category 1.		
Recreation/Lounge -----	0.7		* Reading, Typing and Filing --	1.9	b
Stair			Drafting -----	2.9	b
* Active Traffic -----	0.6		Accounting -----	2.4	b
* Emergency Exit -----	0.4				
<u>Office Category 3</u>					
* Toilet & Washroom -----	0.8		Open plan offices 900 square feet or		
* Garage			larger with partitions* higher than		
Auto & Pedestrian Circula. -----	0.3		3.5 feet below the ceiling. Offices		
Parking Area -----	0.2		less than 900 square feet shall use		
			category 1.		
Laboratory -----	2.3		* Reading, Typing and Filing --	2.2	b
			Drafting -----	3.4	b
			Accounting -----	2.7	b

*Not less than 90% of all work stations shall
be individually enclosed with partitions of
at least the height described.

Third Public Draft Review of
ANSI/ASHRAE/IES Proposed Standard 90.1P
September 29, 1987

Table 6-7a (continued)

Base UPD (P_b) for Area/Activity
Common Activity Areas

Area/Activity	P_b W/ft ²	Note	Area/Activity	P_b W/ft ²	Note
Library			Common Activity Areas		
Audio Visual -----	1.1		* Conference/Meeting Room -----	1.8	a
* Stack Area -----	1.5		Computer/Office Equipment ---	2.1	
Card File & Cataloging ----	1.6		Filing, Inactive -----	1.0	
* Reading Area -----	1.9		Mail Room -----	1.8	
Lobby (General)			Shop (Non-Industrial)		
* Reception & Waiting -----	1.0		Machinery -----	2.5	
* Elevator Lobbies -----	0.8		Electrical/Electronic-----	2.5	
Atrium (Multi-Story)			Painting -----	1.6	
First 3 Floors -----	0.7		Carpentry -----	2.3	
Each Additional Floor ----	0.2		Welding -----	1.2	
* Locker Room & Shower -----	0.8		Storage & Warehouse		
			Inactive Storage -----	0.3	
			Active Storage, Bulky -----	0.3	
			Active Storage, Fine -----	1.0	
			Material Handling -----	1.0	
			Unlisted Space -----	0.2	

Table 6-7b

Base UPD (P_b) for Area/Activity
Specific Buildings

Area/Activity	P_b W/ft ²	Note	Area/Activity	P_b W/ft ²	Note
Airport, Bus and Rail Station			Hotel/Conference Center		
Baggage Area -----	1.0		Banquet Room/Multipurpose --	2.4	a
Concourse/Main Thruway ----	0.9		Bathroom/Powder Room -----	1.2	
Ticket Counter -----	2.5		* Guest Room -----	1.4	
Waiting & Lounge Area -----	1.2	cas. *	* Public Area -----	1.2	
			Exhibition Hall -----	2.6	
Bank			Conference/Meeting -----	1.8	a
Customer Area -----	1.1		* Lobby -----	1.9	
Banking Activity Area -----	2.8		* Reception Desk -----	2.4	
Barber & Beauty Parlor -----			2.0		
Church, Synagogue, Chapel			* Laundry -----		
* Worship/Congregational ----	2.5		* Washing -----	0.9	
Preaching & Sermon/Choir --	2.7		Ironing & Sorting -----	1.3	
Dormitory			Museum & Gallery		
* Bedroom -----	1.1		General Exhibition -----	1.9	
Bedroom with Study -----	1.4		Inspection/Restoration -----	3.9	
Study Hall -----	1.8		Storage (Artifacts)		
Fire & Police Department			Inactive -----	0.6	
Fire Engine Room -----	0.7		Active -----	0.7	
Jail Cell -----	0.8		Post Office		
* Hospital/Nursing Home			Lobby -----	1.1	
Corridor -----	1.3	b	Sorting & Mailing -----	2.1	
Dental Suite/Exam/Treat ---	1.6		Service Station/Auto Repair		
Emergency -----	2.3		1.0		
Y Laboratory -----	1.9		Theater		
Lounge/Waiting Room -----	0.9		Performance Arts -----	1.5	
Medical Supplies -----	2.4		Motion Picture -----	1.0	
Nursery -----	2.0		Lobby -----	1.5	
Nurse Station -----	2.1		Retail Establishments		
Occu. /Physical Therapy ---	1.6		(Merchandising & Circulation Area)		
Patient Room -----	1.4		Applicable to all lighting, including		
Pharmacy -----	1.7		accent and display lighting, installed		
Radiology -----	2.1		in merchandising and circulation areas		
Surgical & O.B. Suites			Type A -----	5.6	e
General Area -----	2.1		Type B -----	3.2	e
Operating Room -----	7.0		Type C -----	3.3	e
Recovery -----	2.3		Type D -----	3.1	e
			Type E -----	2.8	e
			Mall Concourse -----	1.4	
			Retail Support Areas		
			Tailoring -----	2.1	
			Dressing/Fitting Rooms -	1.4	
			Type F -----	2.7	e

Table 6-7c

Base UPD (P_b) for Area/Activity
Indoor Athletic Areas^f

Area/Activity	P_b	Note
Seating Area, All Sports ---	0.4	

Notes for Table 6-7:

- A 1.5 adjustment factor is applicable for multi-functional spaces.
- Area Factor of 1.0 shall be used for these spaces.
- Base UPD includes lighting power required for clean-up purpose.
- Area Factor shall not exceed 1.55.
- See Section 3 Definitions for classification of Retail Establishments.
- Area Factor of 1.0 shall be used for all indoor athletic spaces.

* Gymnasium
General Exercising &
Recreation Only ----- 1.0

Swimming
Recreational ----- 0.9
Exhibition ----- 1.5
Under Water ----- 1.0

Tennis
Recreational (Class III) - 1.3
Club/College (Class II) -- 1.9
Professional (Class I) --- 2.6

S1

S3

BANKS

OCCUPANCY

LIGHTING & RECEPTACLES

HOT WATER

Table 13-3
Building Schedule Percentage Multipliers

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ASSEMBLY OCCUPANCY	WEEKDAY:	0	0	0	0	0	0	0	0	20	20	20	60	60	60	60	60	60	60	20	20	20	20	10	0
	SATURDAY:	0	0	0	0	0	0	0	0	20	20	20	60	60	60	60	60	60	60	60	60	60	60	10	0
	SUNDAY:	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20	0
ASSEMBLY LIGHTING & RECEPTACLE	WEEKDAY:	0	0	0	0	0	0	40	40	40	75	75	75	75	75	75	75	75	75	75	75	75	25	0	0
	SATURDAY:	0	0	0	0	0	0	0	30	30	50	50	50	50	50	50	50	50	50	50	50	50	50	0	0
	SUNDAY:	0	0	0	0	0	0	0	30	30	30	30	30	30	65	65	65	65	65	65	65	65	65	0	0
ASSEMBLY HVAC	WEEKDAY:	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
	SATURDAY:	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
	SUNDAY:	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
ASSEMBLY SWH	WEEKDAY:	0	0	0	0	0	0	0	0	5	5	35	5	5	5	5	5	5	0	0	0	0	0	0	0
	SATURDAY:	0	0	0	0	0	0	0	0	5	5	20	0	0	0	0	0	0	0	65	30	0	0	0	0
	SUNDAY:	0	0	0	0	0	0	0	0	5	5	10	0	0	0	0	0	0	0	65	30	0	0	0	0
OFFICE OCCUPANCY	WEEKDAY:	0	0	0	0	0	0	10	20	95	95	45	45	95	95	95	95	95	30	10	10	10	0	0	0
	SATURDAY:	0	0	0	0	0	0	10	10	30	30	30	30	10	10	10	10	10	0	0	0	0	0	0	0
	SUNDAY:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OFFICE LIGHTING RECEPTACLE	WEEKDAY:	0	0	0	0	0	0	10	30	90	90	90	90	15	15	15	15	15	50	30	30	20	20	0	0
	SATURDAY:	0	0	0	0	0	0	10	10	30	30	30	30	15	15	15	15	15	0	0	0	0	0	0	0
	SUNDAY:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OFFICE HVAC	WEEKDAY:	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF
	SATURDAY:	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
	SUNDAY:	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
OFFICE SWH	WEEKDAY:	0	0	0	0	0	0	15	30	35	35	45	55	50	30	30	40	20	20	10	15	5	0	0	0
	SATURDAY:	0	0	0	0	0	0	10	10	20	15	20	15	15	10	10	10	0	0	0	0	0	0	0	0
	SUNDAY:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

T

TEMPERATURE, HUMIDITY, AND VENTILATION PARAMETERS

	a. MIN	b. TYP	c. MAX
OCCUPIED			
UNOCCUPIED			

V

W

- X

$$G \equiv \text{ALSO } \alpha \in \mathcal{C}$$

- Y

Z

- $$A \equiv B \equiv C \equiv D$$

- B.45

W1

u-name = EXTERIOR-WALL or E-W (or ROOF) (User Worksheet)

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
CONSTRUCTION	CONS	= _____	U-name or Code-word	*	-	-
GND-REFLECTANCE	G-R	= _____	fraction	0.2	0.	1.
SKY-FORM-FACTOR	S-F-F	= _____	fraction	**	0.	1.
GND-FORM-FACTOR	G-F-F	= _____	fraction	**	0.	1.
INF-COEF	I-C	= _____	number	0.	0.	160.
SHADING-DIVISION	S-D	= _____	integer	10	1	40
MULIPLIER	M	= _____	number	1.	0.	99.
X	-	= _____	ft	0.	-	-
Y	-	= _____	ft	0.	-	-
Z	-	= _____	ft	0.	-	-
HEIGHT	H	= _____	ft	*	0.	2000.
WIDTH	W	= _____	ft	*	0.	2000.
AZIMUTH	AZ	= _____	degrees	0.	-360.	360.
TILT	-	= _____	degrees	90.	0.	180.
LOCATION	LOC	= _____	code-word	***	-	-

The following keyword may be used if the user elects to use Custom Weighting Factors.

SOLAR-FRACTION S-F = _____ fraction Note a 0. 1.

W2

INTERIOR PARTITIONS INPUT FORM

- Adjacencies
- Area
- Mass
- Reflectance

Z1

*****
Window Configuration:

Layer (out->in)	IR Trans.	Emissivity		Solar				Gap
		out	in	Trans.	Reflec	(%)	Width(in)	Gas
1	.00	.84	.84	49	.07	50		
2	.00	.84	.84	49	.07	50	50	air

Environmental Conditions: ASHRAE Std Summer

Window Performance Results:

U-Value	Shading	Total Solar	Heat Flux
BTU/hr-ft ² -F (W/m ² -C)	Coeff.	Trans.	(BTU/hr-ft ² -out->in)
62 (3.50)	.819	341	79.66

Layer Temp. (out->in (F))= 115.9731000 111.5240000
(To continue type "<cr>")

_____ = GLASS-TYPE or G-T (User Worksheet)

U-name*

Keyword	Abbrev.	User Input	Input - Desc. -	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
PANES	P	= _____	integer	1	1	3
GLASS-TYPE-CODE	G-T-C	= _____	code- number	**	1	11
SHADING-COEF	S-C	= _____	fraction	**	0.	1.
GLASS-CONDUCTANCE	G-C	= _____	Btu/hr- ft ² -°F	***	0.	10.

* Mandatory entry, if GLASS-TYPE is specified.

** Either entry is mandatory. There are no default values.

*** See Table III.1 for default values.

Z3

_____ = WINDOW or WI (User Worksheet)

Keyword	Abbrev.	User Input	Input Desc.	Default	Range	
					Min.	Max.
LIKE	-	= _____	U-name	-	-	-
GLASS-TYPE	G-T	= _____	U-name	*	-	-
CONDUCT-SCHEDULE	C-SCH	= _____	U-name	***	-	-
SHADING-SCHEDULE	S-SCH	= _____	U-name	***	-	-
SHADING-DIVISION	S-D	= _____	integer	10	1	40.
SKY-FORM-FACTOR	S-F-F	= _____	fraction	**	0.	1.
GND-FORM-FACTOR	G-F-F	= _____	fraction	**	0.	1.
INF-COEF	I-C	= _____	number	0.	0.	160.
MULTIPLIER	M	= _____	number	1.	0.	99.
X	-	= _____	ft	0.	-	-
Y	-	= _____	ft	0.	-	-
SETBACK	SETB	= _____	ft	0.	0.	10.
HEIGHT	H	= _____	ft	*	0.	40.
WIDTH	W	= _____	ft	*	0.	1000.

* Mandatory entry, if WINDOW is specified.

** Program uses the value provided for the exterior wall.

***The schedule values will default to one for all 24 hours.

AA

CRITERIA FOR HVAC SYSTEMS SELECTION

<u>Type of Input</u>	<u>Specific Criteria</u>	<u>Assigned Relative Weight (0, 1, or 2)</u>
Comfort Criteria	Degree of Temperature Control	_____
	Air Quality - Cleanliness	_____
	Air Quality - Odor Control	_____
	Outside Air Ventilation Rate	_____
	Space Temperature "Float"	_____
	Air Motion	_____
	Percentage of RH Control, Winter	_____
	Percentage of RH Control, Summer	_____
	Noise Levels	_____
	Mean Radiant Surface Temperature	_____
Economic Criteria	First Cost	_____
	Cooling Energy Costs	_____
	Heating Energy Costs	_____
	Power Costs (Fans, Pumps)	_____
	Equipment Space Requirements	_____
	Duct Distribution Shaft Floor Area Requirements	_____
	Operating Staff Labor Costs	_____
	Housekeeping Staff Labor Costs	_____
	Equipment Depreciation Costs	_____
Application Criteria	System Flexibility (For Same Space Function but Different Layout)	_____
	System Adaptability (For New Space Function and Layout)	_____
	Primary Fuel Flexibility	_____

CRITERIA FOR HVAC SYSTEMS SELECTION

<u>Type of Input</u>	<u>Specific Criteria</u>	<u>Assigned Relative Weight (0, 1, or 2)</u>
	System Durability/Reliability	_____
	System Income Potential	_____
	Ease of Submetering	_____
	Aesthetics	_____

EXHIBIT BB **CRITERIA FOR LIGHTING SYSTEMS SELECTION**

For each space-function:

<u>Type of Input</u>	<u>Specific Criteria</u>	<u>Assigned Relative Weight (0, 1, or 2)</u>
Comfort Criteria:	Glare Control (direct/reflected) - Luminance Contrast - Ambient distribution - Task distribution - Wall distribution - Window Glare Control - Task difficulty - Task size/contrast - Task duration - Visual acuity/viewer characteristics - Visibility, contrast rendition - Source distribution - Source color rendering - Source color temperature - Reflector control of source - Color balance, adjacent sources - Visual order, orientation - Visual stimulation, variety - Lamp/ballast flicker - Control suitability - Acceptability of controls - Noise of ballasts,lamps,controls - Adjustment, targeting capability	
Economic Criteria:	First cost of equipment/installation - First cost of controls/installation - Lighting energy costs - Cost of relamping - Cost of cleaning fixture and space - Cost of ballast/lens/parts replacement - Cost of fixture replacement - Equipment Depreciation costs - Operating Staff labor costs - Maintenance staff labor costs	

For each space-function:

<u>Type of Input</u>	<u>Specific Criteria</u>	Assigned Relative Weight (0, 1, or 2)
Application Criteria:	Number of lamp types or sizes required Number of lamps per fixture Number of fixtures per room (identical rooms) Life of lamps/ relamping difficulty Lumen depreciation curves Color degradation over time or controls Cleanliness of luminaire design Cleanliness of space Vandal resistant Ambient operating temperature (air return) Idiot-proof lamping, targeting, controls, flex. Flexibility of tasks, personnel Appropriateness to space function Appropriateness to task Appropriateness to architectural design Perceptual imagery	

CC

CRITERIA FOR ROOF SELECTION

<u>Type of Input</u>	<u>Specific Criteria</u>	<u>Assigned Relative Weight (0, 1, or 2)</u>
Application Criteria	Design Life	_____
	Maintainability	_____
	Tapered Insulation	_____
	Acoustic Isolation	_____
	Impact Resistance	_____
	Wind Uplift Resistance	_____
	Light Weight	_____
	Fire Resistance	_____
	Moisture Migration Resistance	_____
Economic Criteria	First Cost	_____
	Maintenance Cost	_____

DD

CRITERIA FOR CEILING PLENUM SELECTION

<u>Type of Input</u>	<u>Specific Criteria</u>	<u>Assigned Relative Weight (0, 1, or 2)</u>
Application Criteria	Fire Resistance	_____
	Acoustic Absorptance	_____
	Incorporation of Light Fixtures	_____
	Access to Plenum Space	_____
	IAQ Considerations	_____
	Space Shape Flexibility	_____
	Ceiling Shape Flexibility	_____
	Adaptability to Space Change	_____
Economic Criteria	Resistance to Staining and Dirtying	_____
	First Cost	_____
	Maintenance Cost	_____
	Story Height Cost Penalty	_____

EE

CRITERIA FOR OPAQUE WALL SELECTION

<u>Type of Input</u>	<u>Specific Criteria</u>	<u>Assigned Relative Weight (0, 1, or 2)</u>
Application Criteria	Fire Resistance	_____
	Impact Resistance	_____
	Water Resistance	_____
	Acoustic Isolation	_____
	Finish Durability	_____
	Load Bearing Capability	_____
	Stiffness	_____
	Light Weight	_____
	Vermin Resistance	_____
	Corrosion Resistance	_____
	Moisture Migration Resistance	_____
	Maintainability	_____
	Ease of Creating Shapes	_____
Economic Criteria	Initial Cost	_____
	Maintenance Cost	_____
	Cost of Wall Thickness	_____
Comfort Criteria	Surface Temperature Control	_____
	Leakage/Draft Control	_____
	Acoustic Properties	_____

GG

8.	AVAILABLE HVAC DISTRIBUTION SYSTEMS	IV.10
1.	General Discussion of Systems	IV.10
2.	List of Available Systems and Options	IV.10
3.	Explanation of System Options	IV.15
4.	System Descriptions	IV.17
a.	Summation of LOADS to PLANT (SUM)	IV.17
b.	Single-Zone Fan System with Optional Subzone Reheat (SZRH)	IV.19
c.	Multizone Fan System (MZS)	IV.23
d.	Dual-Duct Fan System (DDS)	IV.28
e.	Ceiling Induction System (SZCI)	IV.33
f.	Unit Heater (UHT)	IV.38
g.	Unit Ventilator (UVT)	IV.40
h.	Floor Panel Heating System (FPH)	IV.43
i.	Two-Pipe Fan Coil System (TPFC)	IV.45
j.	Four-Pipe Fan Coil System (FPFC)	IV.49
k.	Two-Pipe Induction Unit System (TPIU)	IV.52
l.	Four-Pipe Induction Unit System (FPIU)	IV.57
m.	Variable-Volume Fan System w/Optional Reheat (VAVS)	IV.62
n.	Constant-Volume Reheat Fan System (RHFS)	IV.67
o.	Unitary Hydronic Heat Pump System (HP)	IV.71
p.	Heating and Ventilating System (HVSYS)	IV.75
q.	Ceiling Bypass Variable-Volume System (CBVAV)	IV.78
r.	Residential System (RESYS)	IV.82
s.	Packaged Single Zone Air Conditioner with Heating and Subzone Reheating Options (PSZ)	IV.87
t.	Packaged Multizone Fan System (PMZS)	IV.91
u.	Packaged Variable-Air-Volume System (PVAVS)	IV.95
v.	Package Terminal Air Conditioner (PTAC)	IV.100

Appendix C

Basic Input Linkages/Sample Taxonomy Input Sets

BUILDING CHARACTERISTIC SET TAXONOMY
19 JULY 1988

B. Occupancy

1. Occupant density
2. Age distribution [lighting]
3. Load (per person)
  - a. sensible
  - b. latent
4. Diversity factors
  - a. occupied
  - b. unoccupied
  - c. table #

C. Internal gains

1. lighting
2. lighting mass factors (see exhibit P: ASHRAE a & b Coeffs.)
3. miscellaneous electric (see exhibit I: ASEAM loads input forms)
4. miscellaneous sensible (see exhibit J: ASEAM loads input forms)
5. miscellaneous latent (see exhibit K)

VI. COMFORT CRITERIA

A. Temperature

1. Cooling
  - a. Air (see exhibit T)
  - b. Surface (see exhibit T)
2. Heating
  - a. Air (see exhibit T)
  - b. Surface (see exhibit T)

B. Humidity

1. Cooling (see exhibit T)
2. Heating (see exhibit T)
3. Special Requirements (see exhibit T)

C. Ventilation

1. Cooling (see exhibit T)
2. Heating (see exhibit T)
3. Special Requirements [labs, kitchens...] (see exhibit T)

D. Lighting

1. Desired footcandles
2. Color Rendition Index (CRI)
3. Color temperature

E. Acoustic properties

VII. BUILDING ENVELOPE

A. Roof/Ceiling

1. Basic information
  - a. Area
  - b. Slope & slope orientation
2. Selection criteria (see exhibits CC and DD)
3. Input library (see exhibit U: ASHRAE Design Heat Trans. Coeff.)
4. Input form (see exhibit V)

B. Walls (opaque)

1. Basic information
  - a. Area
  - b. Orientation
  - c. Tilt

TARGET SETTING

BUILDING CHARACTERISTIC SET TAXONOMY

I. MODE OF USE

- A. Target setting
- B. Design analysis
- C. Final evaluation
- D. Research and development

II. LEVEL

- A. Lighting Function (see exhibit L and N: ASHRAE Std. 90.1P)
- B. Thermal Function (see exhibit L and L1: ASEAM2)
- C. Subtype (see exhibit L)
- D. Type (see exhibit L)
- E. Category (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client
  - 4. Location
  - 5. Description
- B. Climate location
- C. Energy model
- D. Economic parameters
  - 1. Energy cost information
  - 2. Building cost information
  - 3. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

IV. BASIC CHARACTERISTICS

- A. Size (numeric)
- B. Configuration
  - 1. Building shape (graphic)
  - 2. Number of floors (graphic/numeric)
  - 3. Height changes of 1 story or more (graphic)
  - 4. Internal adjacencies (graphic/numeric)
    - a. percent of perimeter adjacent to other spaces with which a high temperature difference exists.
    - b. percent of perimeter that is at exterior wall
  - 5. Partitioning (open/closed offices, partition height,...)
(graphic/numeric)
- C. Orientation (graphic)
- D. Site adjacencies (numeric/graphic)

V. FUNCTIONAL PARAMETERS

- A. Occupancy
  - 1. Occupant density
  - 2. Load (per person)
    - a. sensible
    - b. latent

- 3. Special requirements
  - a. age distribution [lighting, thermal,...]
  - b. handicap requirements
- B. Internal gains
  - 1. Receptacles
  - 2. Priority (process and other)
    - a. sensible
    - b. latent
  - 3. Miscellaneous
    - a. sensible
    - b. latent
  - 4. Vertical transportation
- C. Schedules: select/modify (see exhibits S1 & S2:
  - ENERGY program input forms,
  - exhibit S3: DOE2 schedule library, and
  - exhibit S4: ASHRAE 90.1 schedule library
- 1. Occupancy
- 2. HVAC
- 3. Lighting
- 4. Equipment
- 5. DHW
- 6. Vertical transportation
- 7. Miscellaneous

VI. COMFORT CRITERIA

- A. Temperature
  - 1. Cooling
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
  - 2. Heating
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
- B. Humidity
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements (see exhibit T)
- C. Air movement
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...] (see exhibit T)
- D. Fresh air
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...] (see exhibit T)
- E. Visual
  - 1. Desired footcandles
  - 2. Quality factors (see exhibit BB)
  - 3. Special requirements
- F. Acoustic (HVAC, ballast, etc...) (see exhibits AA through EE)

VII. BUILDING SYSTEMS

A. Envelope

1. Roof/Ceiling

- a. Basic information
  - (1) Area
  - (2) Slope & slope orientation
- b. Selection criteria (see exhibits CC and DD)
- c. Input library (exhibit U: ASHRAE Des. Heat Trans. Coeff.)
- d. Input form (see exhibit V)

2. Walls (opaque)

- a. Basic information
  - (1) Area
  - (2) Orientation
  - (3) Tilt
- b. Selection criteria (see exhibit EE)
- c. Input library (exhibits R1: ASHRAE Wall Const. Group Desc. and R2: ASHRAE Design Heat Trans. Coeff.)
- d. Input form (see exhibit W & W1: DOE2 Input Form)

3. Floor

- a. Basic information
  - (1) Area
- b. Selection criteria (see exhibit DD)
- c. Input library
- d. Input form (see exhibit X)

4. Doors (exterior)

- a. Basic information
  - (1) Area
  - (2) Orientation
- b. Selection criteria
- c. Input library
- d. Input form (see exhibit Y)

5. Fenestration

- a. Basic information
  - (1) Area
- b. Selection criteria
- c. Input library
- d. Input form (see exhibit Z)

6. Infiltration

- a. Occupied air change rate
- b. Unoccupied air change rate

B. Interior sub-divisions

1. Floor/Ceiling

- a. Basic information
  - (1) Area
- b. Selection criteria (see exhibit DD)
- c. Input library
- d. Input form (see exhibit X)

2. Partitions

- a. Basic information
- b. Selection criteria
- c. Input library
- d. Input form (see exhibit W2)

C. Lighting

1. Selection rules
2. Criteria (see exhibit BB)
3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
4. Input forms (see exhibit B: ASEAM loads input forms, and exhibit B1: DOE2 Input form)
5. Daylighting
  - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
  - b. Daylighting controls (see exhibit D: ASEAM loads input forms)

D. HVAC

1. Selection rules (see exhibit Q: ASHRAE TC 9.1)
2. Criteria (see exhibit AA)
3. Typical systems library (see exhibit GG: DOE2 list)
4. Input forms
  - a. Systems (see exhibit E: ASEAM systems input forms, and exhibit E2: DOE2 Input form)
  - b. Plants (see exhibit F: ASEAM plants input forms, and exhibit F1: DOE2 Input form)

E. Service water heating

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

F. Power

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

G. Vertical transportation

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

DESIGN ANALYSIS - LEVEL 1

BUILDING CHARACTERISTIC SET TAXONOMY

I. MODE OF USE

- A. Target setting
- B. Design analysis
- C. Final evaluation
- D. Research and development

II. LEVEL

- A. Lighting Function (see exhibit L and N: ASHRAE Std. 90.1P)
- B. Thermal Function (see exhibit L and L1: ASEAM2)
- C. Subtype (see exhibit L)
- D. Type (see exhibit L)
- E. Category (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client
  - 4. Location
  - 5. Description
- B. Climate location
- C. Energy model
- D. Economic parameters
  - 1. Energy cost information
  - 2. Building cost information
  - 3. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

IV. BASIC CHARACTERISTICS

- A. Size (numeric)
- B. Configuration
  - 1. Building shape (graphic)
  - 2. Number of floors (graphic/numeric)
  - 3. Height changes of 1 story or more (graphic)
  - 4. Internal adjacencies (graphic/numeric)
    - a. percent of perimeter adjacent to other spaces with which a high temperature difference exists.
    - b. percent of perimeter that is at exterior wall
  - 5. Partitioning (open/closed offices, partition height,...)
(graphic/numeric)
- C. Orientation (graphic)
- D. Site adjacencies (numeric/graphic)

V. FUNCTIONAL PARAMETERS

- A. Occupancy
  - 1. Occupant density
  - 2. Load (per person)
    - a. sensible
    - b. latent

- 3. Special requirements
  - a. age distribution [lighting, thermal,...]
  - b. handicap requirements
- B. Internal gains
  - 1. Receptacles
  - 2. Priority (process and other)
    - a. sensible
    - b. latent
  - 3. Miscellaneous
    - a. sensible
    - b. latent
  - 4. Vertical transportation
- C. Schedules: select/modify (see exhibits S1 & S2:
ENERGY program input forms,
exhibit S3: DOE2 schedule library, and
exhibit S4: ASHRAE 90.1 schedule library)
  - 1. Occupancy
  - 2. HVAC
  - 3. Lighting
  - 4. Equipment
  - 5. DHW
  - 6. Vertical transportation
  - 7. Miscellaneous

VI. COMFORT CRITERIA

- A. Temperature
  - 1. Cooling
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
  - 2. Heating
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
- B. Humidity
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements (see exhibit T)
- C. Air movement
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...](see exhibit T)
- D. Fresh air
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...](see exhibit T)
- E. Visual
  - 1. Desired footcandles
  - 2. Quality factors (see exhibit BB)
  - 3. Special requirements
- F. Acoustic (HVAC, ballast, etc...) (see exhibits AA through EE)

VII. BUILDING SYSTEMS

A. Envelope

1. Roof/Ceiling
    - a. Basic information
      - (1) Area
      - (2) Slope & slope orientation
    - b. Selection criteria (see exhibits CC and DD)
    - c. Input library (exhibit U: ASHRAE Des. Heat Trans. Coeff.)
    - d. Input form (see exhibit V)
  2. Walls (opaque)
    - a. Basic information
      - (1) Area
      - (2) Orientation
      - (3) Tilt
    - b. Selection criteria (see exhibit EE)
    - c. Input library (exhibits R1: ASHRAE Wall Const. Group Desc. and R2: ASHRAE Design Heat Trans. Coeff.)
    - d. Input form (see exhibit W & W1: DOE2 Input Form)
  3. Floor
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  4. Doors (exterior)
    - a. Basic information
      - (1) Area
      - (2) Orientation
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit Y)
  5. Fenestration
    - a. Basic information
      - (1) Area
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit Z)
  6. Infiltration
    - a. Occupied air change rate
    - b. Unoccupied air change rate
3. Interior sub-divisions
1. Floor/Ceiling
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  2. Partitions
    - a. Basic information
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit W2)

- C. Lighting
  - 1. Selection rules
  - 2. Criteria (see exhibit BB)
  - 3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
  - 4. Input forms (see exhibit B: ASEAM loads input forms, and exhibit B1: DOE2 Input form)
  - 5. Daylighting
    - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
    - b. Daylighting controls (see exhibit D: ASEAM loads input forms)
- D. HVAC
  - 1. Selection rules (see exhibit Q: ASHRAE TC 9.1)
  - 2. Criteria (see exhibit AA)
  - 3. Typical systems library (see exhibit GG: DOE2 list)
  - 4. Input forms
    - a. Systems (see exhibit E: ASEAM systems input forms, and exhibit E2: DOE2 Input form)
    - b. Plants (see exhibit F: ASEAM plants input forms, and exhibit F1: DOE2 Input form)
- E. Service water heating
  - 1. Selection rules
  - 2. Criteria
  - 3. Typical systems library
  - 4. Input forms
- F. Power
  - 1. Selection rules
  - 2. Criteria
  - 3. Typical systems library
  - 4. Input forms
- G. Vertical transportation
  - 1. Selection rules
  - 2. Criteria
  - 3. Typical systems library
  - 4. Input forms

T

TEMPERATURE, HUMIDITY, AND VENTILATION PARAMETERS

	a. MIN	b. TYP	c. MAX
OCCUPIED		X	
UNOCCUPIED		X	

INPUT FORMS for Building Envelope

V

1. ROOF/CEILING ----- INPUT FORM

- 1.1. U-value
- 1.2. Mass
- 1.3. Color
- 1.4. Reflectivity (interior surfaces)
- 1.5. Plenum
- 1.6. Assembly
- 1.7. Type

W

2. Walls (opaque) ----- INPUT FORM

- 2.1. U-value
- 2.2. Mass
- 2.3. Color
- 2.4. Reflectivity (interior surfaces)
- 2.5. Plenum
- 2.6. Assembly [where mass occurs]
- 2.7. Type

X

3. Floor/ceiling ----- INPUT FORM

- 3.1. U-value
- 3.2. Mass
- 3.3. Finish
- 3.4. Reflectance
- 3.5. Type
- 3.6. Assembly
- 3.7. Plenum

Y

4. Doors ----- INPUT FORM

- 4.1. U-value
- 4.2. Color
- 4.3. Type
- 4.4. Assembly
- 4.5. Vestibule
- 4.6. Infiltration factor

Z

5. FENESTRATION ----- INPUT FORM

- 5.1. Glazing
  - 5.1.1. Wall window ratio
  - 5.1.2. U-value
  - 5.1.3. Emittance (surface #)
  - 5.1.4. Reflectivity
  - 5.1.5. Type
  - 5.1.6. Shading Coefficient
  - 5.1.7. Visible transmittance
- 5.2. Window specifics
  - 5.2.1. Orientation
  - 5.2.2. Tilt
  - 5.2.3. Window vertical placement
  - 5.2.4. Assembly [where tint is]
    - 5.2.4.1. frame
  - 5.2.5. Infiltration factor
  - 5.2.6. Shading devices
    - 5.2.6.1. external (see exhibit A: ASEAM loads input form)
    - 5.2.6.2. internal (see exhibit O: ASHRAE S.C. - internal)
  - 5.2.7. Shading management
  - 5.2.8. Ground reflectivity

DESIGN ANALYSIS - LEVEL 2

BUILDING CHARACTERISTIC SET TAXONOMY

I. MODE OF USE

- A. Target setting
- B. Design analysis
- C. Final evaluation
- D. Research and development

II. LEVEL

- A. Lighting Function (see exhibit L and N: ASHRAE Sto. 90.1P)
- B. Thermal Function (see exhibit L and L1: ASEAM2)
- C. Subtype (see exhibit L)
- D. Type (see exhibit L)
- E. Category (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client
  - 4. Location
  - 5. Description
- B. Climate location
- C. Energy model
- D. Economic parameters
  - 1. Energy cost information
  - 2. Building cost information
  - 3. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

IV. BASIC CHARACTERISTICS

- A. Size (numeric)
- B. Configuration
  - 1. Building shape (graphic)
  - 2. Number of floors (graphic/numeric)
  - 3. Height changes of 1 story or more (graphic)
  - 4. Internal adjacencies (graphic/numeric)
    - a. percent of perimeter adjacent to other spaces with which a high temperature difference exists.
    - b. percent of perimeter that is at exterior wall
  - 5. Partitioning (open/closed offices, partition height,...)
(graphic/numeric)
- C. Orientation (graphic)
- D. Site adjacencies (numeric/graphic)

V. FUNCTIONAL PARAMETERS

- A. Occupancy
  - 1. Occupant density
  - 2. Load (per person)
    - a. sensible
    - b. latent

- 3. Special requirements
  - a. age distribution [lighting, thermal,...]
  - b. handicap requirements
- B. Internal gains
  - 1. Receptacles
  - 2. Priority (process and other)
    - a. sensible
    - b. latent
  - 3. Miscellaneous
    - a. sensible
    - b. latent
  - 4. Vertical transportation
- C. Schedules: select/modify (see exhibits S1 & S2:
  - ENERGY program input forms,
  - exhibit S3: DOE2 schedule library, and
  - exhibit S4: ASHRAE 90.1 schedule library
- 1. Occupancy
- 2. HVAC
- 3. Lighting
- 4. Equipment
- 5. DHW
- 6. Vertical transportation
- 7. Miscellaneous

VI. COMFORT CRITERIA

- A. Temperature
  - 1. Cooling
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
  - 2. Heating
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
- B. Humidity
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements (see exhibit T)
- C. Air movement
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...] (see exhibit T)
- D. Fresh air
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...] (see exhibit T)
- E. Visual
  - 1. Desired footcandles
  - 2. Quality factors (see exhibit BB)
  - 3. Special requirements
- F. Acoustic (HVAC, ballast, etc...) (see exhibits AA through EE)

VII. BUILDING SYSTEMS

A. Envelope

1. Roof/Ceiling
    - a. Basic information
      - (1) Area
      - (2) Slope & slope orientation
    - b. Selection criteria (see exhibits CC and DD)
    - c. Input library (exhibit U: ASHRAE Des. Heat Trans. Coeff.)
    - d. Input form (see exhibit V)
  2. Walls (opaque)
    - a. Basic information
      - (1) Area
      - (2) Orientation
      - (3) Tilt
    - b. Selection criteria (see exhibit EE)
    - c. Input library (exhibits R1: ASHRAE Wall Const. Group Desc. and R2: ASHRAE Design Heat Trans. Coeff.)
    - d. Input form (see exhibit W & W1: DOE2 Input Form)
  3. Floor
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  4. Doors (exterior)
    - a. Basic information
      - (1) Area
      - (2) Orientation
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit Y)
  5. Fenestration
    - a. Basic information
      - (i) Area
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit Z)
  6. Infiltration
    - a. Occupied air change rate
    - b. Unoccupied air change rate
- B. Interior sub-divisions
1. Floor/Ceiling
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  2. Partitions
    - a. Basic information
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit W2)

C. Lighting

1. Selection rules
2. Criteria (see exhibit BB)
3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
4. Input forms (see exhibit B: ASEAM loads input forms, and exhibit B1: DOE2 Input form)
5. Daylighting
  - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
  - b. Daylighting controls (see exhibit D: ASEAM loads input forms)

D. HVAC

1. Selection rules (see exhibit Q: ASHRAE TC 9.1)
2. Criteria (see exhibit AA)
3. Typical systems library (see exhibit GG: DOE2 list)
4. Input forms
  - a. Systems (see exhibit E: ASEAM systems input forms, and exhibit EZ: DOE2 Input form)
  - b. Plants (see exhibit F: ASEAM plants input forms, and exhibit F1: DOE2 Input form)

E. Service water heating

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

F. Power

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

G. Vertical transportation

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

T

TEMPERATURE, HUMIDITY, AND VENTILATION PARAMETERS

	a. MIN	D. TYP	c. MAX
OCCUPIED		X	
UNOCCUPIED		X	

RESEARCH & DEVELOPMENT

BUILDING CHARACTERISTIC SET TAXONOMY

I. MODE OF USE

- A. Target setting
- B. Design analysis
- C. Final evaluation
- D. Research and development

II. LEVEL

- A. Lighting Function (see exhibit L and N: ASHRAE Std. 90.1P)
- B. Thermal Function (see exhibit L and L1: ASEAM2)
- C. Subtype (see exhibit L)
- D. Type (see exhibit L)
- E. Category (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client
  - 4. Location
  - 5. Description
- B. Climate location
- C. Energy model
- D. Economic parameters
  - 1. Energy cost information
  - 2. Building cost information
  - 3. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

IV. BASIC CHARACTERISTICS

- A. Size (numeric)
- B. Configuration
  - 1. Building shape (graphic)
  - 2. Number of floors (graphic/numeric)
  - 3. Height changes of 1 story or more (graphic)
  - 4. Internal adjacencies (graphic/numeric)
    - a. percent of perimeter adjacent to other spaces with which a high temperature difference exists.
    - b. percent of perimeter that is at exterior wall
  - 5. Partitioning (open/closed offices, partition height,...)
(graphic/numeric)
- C. Orientation (graphic)
- D. Site adjacencies (numeric/graphic)

V. FUNCTIONAL PARAMETERS

- A. Occupancy
  - 1. Occupant density
  - 2. Load (per person)
    - a. sensible
    - b. latent

- 3. Special requirements
  - a. age distribution [lighting, thermal,...]
  - b. handicap requirements
- B. Internal gains
  - 1. Receptacles
  - 2. Priority (process and other)
    - a. sensible
    - b. latent
  - 3. Miscellaneous
    - a. sensible
    - b. latent
  - 4. Vertical transportation
- C. Schedules: select/modify (see exhibits S1 & S2:
  - ENERGY program input forms,
  - exhibit S3: DOE2 schedule library, and
  - exhibit S4: ASHRAE 90.1 schedule library
- 1. Occupancy
- 2. HVAC
- 3. Lighting
- 4. Equipment
- 5. DHW
- 6. Vertical transportation
- 7. Miscellaneous

VI. COMFORT CRITERIA

- A. Temperature
  - 1. Cooling
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
  - 2. Heating
    - a. Sensible (see exhibit T)
    - b. Mean radiant temperature (MRT) (see exhibit T)
- B. Humidity
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements (see exhibit T)
- C. Air movement
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...] (see exhibit T)
- D. Fresh air
  - 1. Cooling (see exhibit T)
  - 2. Heating (see exhibit T)
  - 3. Special Requirements [labs, kitchens...] (see exhibit T)
- E. Visual
  - 1. Desired footcandles
  - 2. Quality factors (see exhibit BB)
  - 3. Special requirements
- F. Acoustic (HVAC, ballast, etc...) (see exhibits AA through EE)

VII. BUILDING SYSTEMS

A. Envelope

1. Roof/Ceiling
    - a. Basic information
      - (1) Area
      - (2) Slope & slope orientation
    - b. Selection criteria (see exhibits CC and DD)
    - c. Input library (exhibit U: ASHRAE Des. Heat Trans. Coeff.)
    - d. Input form (see exhibit V)
  2. Walls (opaque)
    - a. Basic information
      - (1) Area
      - (2) Orientation
      - (3) Tilt
    - b. Selection criteria (see exhibit EE)
    - c. Input library (exhibits R1: ASHRAE Wall Const. Group Desc. and R2: ASHRAE Design Heat Trans. Coeff.)
    - d. Input form (see exhibit W & W1: DOE2 Input Form)
  3. Floor
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  4. Doors (exterior)
    - a. Basic information
      - (1) Area
      - (2) Orientation
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit Y)
  5. Fenestration
    - a. Basic information
      - (1) Area
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit Z)
  6. Infiltration
    - a. Occupied air change rate
    - b. Unoccupied air change rate
- B. Interior sub-divisions
1. Floor/Ceiling
    - a. Basic information
      - (1) Area
    - b. Selection criteria (see exhibit DD)
    - c. Input library
    - d. Input form (see exhibit X)
  2. Partitions
    - a. Basic information
    - b. Selection criteria
    - c. Input library
    - d. Input form (see exhibit W2)

C. Lighting

1. Selection rules
2. Criteria (see exhibit BB)
3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
4. Input forms (see exhibit B: ASEAM loads input forms, and exhibit B1: DOE2 Input form)
5. Daylighting
  - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
  - b. Daylighting controls (see exhibit D: ASEAM loads input forms)

D. HVAC

1. Selection rules (see exhibit Q: ASHRAE TC 9.1)
2. Criteria (see exhibit AA)
3. Typical systems library (see exhibit GG: DOE2 list)
4. Input forms
  - a. Systems (see exhibit E: ASEAM systems input forms, and exhibit E2: DOE2 Input form)
  - b. Plants (see exhibit F: ASEAM plants input forms, and exhibit F1: DOE2 Input form)

E. Service water heating

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

F. Power

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

G. Vertical transportation

1. Selection rules
2. Criteria
3. Typical systems library
4. Input forms

Appendix D

Sample Test Application of the Taxonomy and Exhibits

ZONE - WEST 1

TARGETS OUTLINE

I. MODE OF USE

- A. Target setting
- B. Design evaluation
- C. Design analysis
- D. Research and development

II. LEVEL

- A. Lighting Function (3B)
- B. Thermal Function (3A)
- C. Subtype (2) (see exhibit L)
- D. Type ~~OFFICE, GENERAL~~ (1B) (see exhibit L)
- E. Category ~~COMMERCIAL~~ (1A) (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client WISCONSIN POWER & LIGHT
  - 4. Location MADISON, WI.
  - 5. Description
- B. Energy model
- C. Energy cost information

IV. BASIC BUILDING CHARACTERISTICS

- A. Climate zone
- B. Latitude 43
- C. Size
- D. Configuration
- E. Orientation
- F. Adjacency
  - 1. site
  - 2. internal
- G. Structure
- H. Floor
- I. Partitioning
- J. Infiltration 2566 C CFM
  - 1. Occupied air change rate
  - 2. Unoccupied air change rate

V. BUILDING ENVELOPE

- A. Roof/Ceiling
  - 1. Basic information
    - a. Area 5251
    - b. Slope & slope orientation
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- B. Walls (opaque)
  - 1. Basic information
    - a. Area 2523

- b. Orientation
    - c. Tilt
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- C. Floor/Ceiling
  - 1. Basic information
    - a. Area
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- D. Doors (exterior)
  - 1. Basic information
    - a. Area
    - b. Orientation
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- E. Fenestration
  - 1. Basic information
    - a. Area
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form

13756.0

VI. FUNCTIONAL PARAMETERS

A. Schedules: select/modify

- 1. Occupancy   1
- 2. HVAC   HTG 6
- 3. Lighting   LTG 5
- 4. Equipment
- 5. DHW   1
- 6. Miscellaneous

B. OCCUPANCY

- 1. Occupant density   5 DAYS/WEEK
- 2. Age distribution [lighting]   NO. OF PEOPLE - 52
- 3. Load (per person)
  - a. sensible   GAIN 255.0
  - b. latent   GAIN 255.0
- 4. Diversity factors
  - a. occupied
  - b. unoccupied
  - c. table #

C. Internal gains

- 1. lighting
- 2. lighting mass factors
- 3. miscellaneous electric (see exhibit I: ASEAM loads input forms)
- 4. miscellaneous sensible (see exhibit J: ASEAM loads input forms) 10317
- 5. miscellaneous latent (see exhibit K)

VII. COMFORT/PRODUCTIVITY CRITERIA

A. Temperature

1. Cooling
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MIN
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
  2. Heating
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
8. Humidity
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX

- C. Ventilation *CFM 260.0*
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements [laboratories, kitchens...]
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
- D. Lighting
1. Desired footcandles *50.0*
  2. Color Rendition Index (CRI)
  3. Color temperature

VIII. Systems

- A. Lighting
1. Selection rules
  2. Criteria
  3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
  4. Input forms (see exhibit B: ASEAM loads input forms)
  5. Daylighting
    - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
    - b. Daylighting controls (see exhibit D: ASEAM loads input forms)
- B. HVAC
1. Selection rules
  2. Criteria
  3. Typical systems library
  4. Input forms
    - a. Systems (see exhibit E: ASEAM systems input forms)
    - b. Plants (see exhibit F: ASEAM plants input forms)
- C. Service water heater
1. Selection rules	DHW FUEL COST	5.50	\$/MM BTU
2. Criteria	DHW COMBUSTION		
3. Typical systems library	EFFICIENCY	0.75	
4. Input forms	DHW PEAK LOAD	53300	BTU/H

IX. ECONOMIC PARAMETERS

- A. FBLCC (see exhibit G: ASEAM FBLCC input forms)
- B. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

INPUT FORMS for Building Envelope

1. ROOF/CEILING ----- INPUT FORM

- 1.1. U-value 0.077
- 1.2. Mass
- 1.3. Color
- 1.4. Reflectivity (interior surfaces)
- 1.5. Plenum
- 1.6. Assembly
- 1.7. Type

2. Walls (opaque) ----- INPUT FORM

- 2.1. U-value 0.067
- 2.2. Mass
- 2.3. Color
- 2.4. Reflectivity (interior surfaces)
- 2.5. Plenum
- 2.6. Assembly [where mass occurs]
- 2.7. Type

3. Floor/ceiling ----- INPUT FORM

- 3.1. U-value
- 3.2. Mass 55024.0
- 3.3. Finish
- 3.4. Reflectance
- 3.5. Type
- 3.6. Assembly
- 3.7. Plenum

PERIMETER

291.0

4. Doors ----- INPUT FORM

- 4.1. U-value
- 4.2. Color
- 4.3. Type
- 4.4. Assembly
- 4.5. Vestibule
- 4.6. Infiltration factor

5. FENESTRATION ----- INPUT FORM

5.1. Glazing

- 5.1.1. Wall window ratio 1:2.17
- 5.1.2. U-value 0.50
- 5.1.3. Emittance (surface #)
- 5.1.4. Reflectivity
- 5.1.5. Type
- 5.1.6. Shading Coefficient 0.62
- 5.1.7. Visible transmittance 0.80

5.2. Window specifics

- 5.2.1. Orientation
- 5.2.2. Tilt
- 5.2.3. Window vertical placement
- 5.2.4. Assembly [where tint is]
  - 5.2.4.1. frame
- 5.2.5. Infiltration factor
- 5.2.6. Shading devices
  - 5.2.6.1. external (see exhibit A: ASEAM loads input form)
  - 5.2.6.2. internal
- 5.2.7. Shading management
- 5.2.8. Ground reflectivity 0.06

A	Shading	Window Model Name (or 'NA')	ZONE-WEST 1	2	5	
	Shading	Window Width		12	64	
	Shading	Window Height		4	4	
	Shading	Overhang Depth		60	12	
	Shading	Top of Window to Overhang		1	1	
	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		64		
	Shading	Left fin extension above top of window		1		
	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			12	
	Shading	Right fin extension above top of window			1	
	Shading	Dist from right edge of window to right fin				
	Shading	Dist from right fin bottom to bottom of window				
		Orientation		SE	SW	CON'T
3	Lighting	Function name (or 'NA')				
	Lighting	Average function area (ft ²)				
	Lighting	Installed watts/ft ²				
	Lighting	(times) Percent of function area				
	Lighting	(or) Total installed watts	24760			
	Lighting	Daylighting (Y/N)	-	-	-	-
	Lighting	Controllite 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 #				
C	Daylighting	Function name (or 'NA')				
	Daylighting	Window orientation (N,NW,etc)				
	Daylighting	Ground reflectance (%)				
	Daylighting	Typical room window area (ft ²)				
	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'in or 'S'tep)				
D	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				

ZONE - WEST 1

A,

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

1	2	3	6
<u>511</u>	<u>43</u>	<u>101</u>	<u>20</u>
<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>
<u>NE</u>	<u>E</u>	<u>SW</u>	<u>S</u>

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

<u> </u>	<u> </u>	<u> </u>	<u> </u>
<u> </u>	<u> </u>	<u> </u>	<u> </u>
<u> </u>	<u> </u>	<u> </u>	<u> </u>
<u> </u>	<u> </u>	<u> </u>	<u> </u>

ZONE - WEST 2

TARGETS OUTLINE

I. MODE OF USE

- A. Target setting
- B. Design evaluation
- C. Design analysis
- D. Research and development

II. LEVEL

- A. Lighting Function (38)
- B. Thermal Function (3A)
- C. Subtype (2) (see exhibit L)
- D. Type ~~OFFICE, GENERAL~~ (1B) (see exhibit L)
- E. Category ~~COMMERCIAL~~ (1A) (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client WISCONSIN POWER & LIGHT
  - 4. Location MADISON, WIS.
  - 5. Description
- B. Energy model
- C. Energy cost information

IV. BASIC BUILDING CHARACTERISTICS

- A. Climate zone
- B. Latitude 43
- C. Size
- D. Configuration
- E. Orientation
- F. Adjacency
  - 1. site
  - 2. internal
- G. Structure
- H. Floor
- I. Partitioning
- J. Infiltration 1695.0 CFM
  - 1. Occupied air change rate
  - 2. Unoccupied air change rate

V. BUILDING ENVELOPE

- A. Roof/Ceiling
  - 1. Basic information
    - a. Area 6488.0
    - b. Slope & slope orientation
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- B. Walls (opaque)
  - 1. Basic information
    - a. Area 3325.0

- b. Orientation
    - c. Tilt
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form

C. Floor/Ceiling

- 1. Basic information
  - a. Area
- 2. Selection criteria
- 3. Input library
- 4. Input form

8114.0

D. Doors (exterior)

- 1. Basic information
  - a. Area
  - b. Orientation
- 2. Selection criteria
- 3. Input library
- 4. Input form

E. Fenestration

- 1. Basic information
  - a. Area
- 2. Selection criteria
- 3. Input library
- 4. Input form

1724.0

VI. FUNCTIONAL PARAMETERS

A. Schedules: select/modify

- 1. Occupancy — 1
- 2. HVAC — FIG 6
- 3. Lighting — LTG 5
- 4. Equipment
- 5. DHW — 1
- 6. Miscellaneous

B. OCCUPANCY

- 1. Occupant density 5 DAYS/WEEK
- 2. Age distribution [lighting] NO. OF PEOPLE - 31
- 3. Load (per person)
  - a. sensible GAIN 255.0
  - b. latent GAIN 255.0
- 4. Diversity factors
  - a. occupied
  - b. unoccupied
  - c. table #

C. Internal gains

- 1. lighting
- 2. lighting mass factors
- 3. miscellaneous electric (see exhibit I: ASEAM loads input forms)
- 4. miscellaneous sensible (see exhibit J: ASEAM loads input forms) 6085.0
- 5. miscellaneous latent (see exhibit K)

VII. COMFORT/PRODUCTIVITY CRITERIA

A. Temperature

1. Cooling
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MIN
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
  2. Heating
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
- B. Humidity
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX

- C. Ventilation CFM 1350
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements [laboratories, kitchens...]
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
- D. Lighting
1. Desired footcandles 50 C
  2. Color Rendition Index (CRI)
  3. Color temperature

VIII. Systems

- A. Lighting
1. Selection rules
  2. Criteria
  3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
  4. Input forms (see exhibit B: ASEAM loads input forms)
  5. Daylighting
    - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
    - b. Daylighting controls (see exhibit D: ASEAM loads input forms)
- B. HVAC
1. Selection rules
  2. Criteria
  3. Typical systems library
  4. Input forms
    - a. Systems (see exhibit E: ASEAM systems input forms)
    - b. Plants (see exhibit F: ASEAM plants input forms)
- C. Service water heater
1. Selection rules	DHW FUEL COST	5.50	\$/MMBTU
2. Criteria	DHW COMBUSTION		
	EFFICIENCY	0.75	
3. Typical systems library	DHW PEAK LOAD	53300	BTU/H
4. Input forms			

IX. ECONOMIC PARAMETERS

- A. FBLCC (see exhibit G: ASEAM FBLCC input forms)
- B. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

INPUT FORMS for Building Envelope

1. ROOF/CEILING ----- INPUT FORM

- 1.1. U-value 0.077
- 1.2. Mass
- 1.3. Color
- 1.4. Reflectivity (interior surfaces)
- 1.5. Plenum
- 1.6. Assembly
- 1.7. Type

2. Walls (opaque) ----- INPUT FORM

- 2.1. U-value 0.067
- 2.2. Mass
- 2.3. Color
- 2.4. Reflectivity (interior surfaces)
- 2.5. Plenum
- 2.6. Assembly [where mass occurs]
- 2.7. Type

3. Floor/ceiling ----- INPUT FORM

- 3.1. U-value
- 3.2. Mass 32456.0
- 3.3. Finish
- 3.4. Reflectance
- 3.5. Type
- 3.6. Assembly
- 3.7. Plenum
- PERIMETER 0.0

4. Doors ----- INPUT FORM

- 4.1. U-value
- 4.2. Color
- 4.3. Type
- 4.4. Assembly
- 4.5. Vestibule
- 4.6. Infiltration factor

5. FENESTRATION ----- INPUT FORM

- 5.1. Glazing
  - 5.1.1. Wall window ratio 1:1.93
  - 5.1.2. U-value 0.50
  - 5.1.3. Emittance (surface #)
  - 5.1.4. Reflectivity
  - 5.1.5. Type
  - 5.1.6. Shading Coefficient 0.62
  - 5.1.7. Visible transmittance 0.60
- 5.2. Window specifics
  - 5.2.1. Orientation
  - 5.2.2. Tilt
  - 5.2.3. Window vertical placement
  - 5.2.4. Assembly [where tint is]
    - 5.2.4.1. frame
  - 5.2.5. Infiltration factor
  - 5.2.6. Shading devices
    - 5.2.6.1. external (see exhibit A: ASEAM loads input form)
    - 5.2.6.2. internal
  - 5.2.7. Shading management
  - 5.2.8. Ground reflectivity 0.06

A	Shading	Window Model Name (or 'NA')	ZONE-WEST2			
	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				

CON'T

	Lighting	Function name (or 'NA')				
	Lighting	Average function area (ft ²)				
	Lighting	Installed watts/ft ²				
	Lighting	(times) Percent of function area				
	Lighting	(or) Total installed watts	146050			
	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 (ft ²)				
	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'in 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				

ZONE - WEST 2

A,

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

1	2	3	4
<u>144</u>	<u>76</u>	<u>51</u>	<u>43</u>
<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>
<u>SW</u>	<u>NW</u>	<u>NE</u>	<u>E</u>

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

5	6	7	8
<u>20</u>	<u>16</u>	<u>26</u>	<u>55</u>
<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>
<u>S</u>	<u>NE</u>	<u>NW</u>	<u>SW</u>

ZONE - EAST 1

TARGETS OUTLINE

I. MODE OF USE

- A. Target setting
- B. Design evaluation
- C. Design analysis
- D. Research and development

II. LEVEL

- A. Lighting Function (3B)
- B. Thermal Function (3A)
- C. Subtype (2) (see exhibit L)
- D. Type *OFFICE, GENERAL* (1B) (see exhibit L)
- E. Category *COMMERCIAL* (1A) (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client *WISCONSIN POWER & LIGHT*
  - 4. Location *MADISON, WI.*
  - 5. Description
- B. Energy model
- C. Energy cost information

IV. BASIC BUILDING CHARACTERISTICS

- A. Climate zone
- B. Latitude *43*
- C. Size
- D. Configuration
- E. Orientation
- F. Adjacency
  - 1. site
  - 2. internal
- G. Structure
- H. Floor
- I. Partitioning
- J. Infiltration *4096.0 CFM*
  - 1. Occupied air change rate
  - 2. Unoccupied air change rate

V. BUILDING ENVELOPE

- A. Roof/Ceiling
  - 1. Basic information
    - a. Area *5920.0*
    - b. Slope & slope orientation
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- B. Walls (opaque)
  - 1. Basic information
    - a. Area *3988.0*

- b. Orientation
    - c. Tilt
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form

C. Floor/Ceiling

- 1. Basic information
  - a. Area
- 2. Selection criteria
- 3. Input library
- 4. Input form

19661.0

D. Doors (exterior)

- 1. Basic information
  - a. Area
  - b. Orientation
- 2. Selection criteria
- 3. Input library
- 4. Input form

E. Fenestration

- 1. Basic information
  - a. Area
- 2. Selection criteria
- 3. Input library
- 4. Input form

1906.0

VI. FUNCTIONAL PARAMETERS

A. Schedules: select/modify

- 1. Occupancy _____ 1
- 2. HVAC _____ HTG 6
- 3. Lighting _____ LTG 5
- 4. Equipment
- 5. DHW _____ 1
- 6. Miscellaneous

B. OCCUPANCY

- 1. Occupant density 5 DAYS/WEEK
- 2. Age distribution [lighting] NO. OF PEOPLE - 74
- 3. Load (per person)
  - a. sensible GAIN 255.0
  - b. latent GAIN 255.0
- 4. Diversity factors
  - a. occupied
  - b. unoccupied
  - c. table #

C. Internal gains

- 1. lighting
- 2. lighting mass factors
- 3. miscellaneous electric (see exhibit I: ASEAM loads input forms)
- 4. miscellaneous sensible (see exhibit J: ASEAM loads input forms) 14746.0
- 5. miscellaneous latent (see exhibit K)

VII. COMFORT/PRODUCTIVITY CRITERIA

A. Temperature

- 1. Cooling
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MIN
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
  - 2. Heating
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
- B. Humidity
- 1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  - 2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  - 3. Special Requirements
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX

- C. Ventilation CFM 370.0
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements [laboratories, kitchens...]
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
- D. Lighting
1. Desired footcandles 50.0
  2. Color Rendition Index (CRI)
  3. Color temperature

VIII. Systems

- A. Lighting
1. Selection rules
  2. Criteria
  3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
  4. Input forms (see exhibit B: ASEAM loads input forms)
  5. Daylighting
    - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
    - b. Daylighting controls (see exhibit D: ASEAM loads input forms)
- B. HVAC
1. Selection rules
  2. Criteria
  3. Typical systems library
  4. Input forms
    - a. Systems (see exhibit E: ASEAM systems input forms)
    - b. Plants (see exhibit F: ASEAM plants input forms)
- C. Service water heater
1. Selection rules	DHW FUEL COST	5.50	\$/MMBTU
2. Criteria	DHW COMBUSTION		
	EFFICIENCY	0.75	
3. Typical systems library	DHW PEAK LOAD	53300.0	BTU/H
4. Input forms			

IX. ECONOMIC PARAMETERS

- A. FBLCC (see exhibit G: ASEAM FBLCC input forms)
- B. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

INPUT FORMS for Building Envelope

1. ROOF/CEILING ----- INPUT FORM

- 1.1. U-value 0.077
- 1.2. Mass
- 1.3. Color
- 1.4. Reflectivity (interior surfaces)
- 1.5. Plenum
- 1.6. Assembly
- 1.7. Type

2. Walls (opaque) ----- INPUT FORM

- 2.1. U-value 0.067
- 2.2. Mass
- 2.3. Color
- 2.4. Reflectivity (interior surfaces)
- 2.5. Plenum
- 2.6. Assembly [where mass occurs]
- 2.7. Type

3. Floor/ceiling ----- INPUT FORM

- 3.1. U-value
- 3.2. Mass 78644.0
- 3.3. Finish
- 3.4. Reflectance
- 3.5. Type
- 3.6. Assembly
- 3.7. Plenum

PERIMETER

531.0

4. Doors ----- INPUT FORM

- 4.1. U-value
- 4.2. Color
- 4.3. Type
- 4.4. Assembly
- 4.5. Vestibule
- 4.6. Infiltration factor

5. FENESTRATION ----- INPUT FORM

- 5.1. Glazing
  - 5.1.1. Wall window ratio 1:2.09
  - 5.1.2. U-value 0.50
  - 5.1.3. Emittance (surface #)
  - 5.1.4. Reflectivity
  - 5.1.5. Type
  - 5.1.6. Shading Coefficient 0.82
  - 5.1.7. Visible transmittance 0.80
- 5.2. Window specifics
  - 5.2.1. Orientation
  - 5.2.2. Tilt
  - 5.2.3. Window vertical placement
  - 5.2.4. Assembly [where tint is]
    - 5.2.4.1. frame
  - 5.2.5. Infiltration factor
  - 5.2.6. Shading devices
    - 5.2.6.1. external (see exhibit A: ASEAM loads input form)
    - 5.2.6.2. internal
  - 5.2.7. Shading management
  - 5.2.8. Ground reflectivity 0.06

		ZONE - EAST 1		
		6	7	8
A	Shading	Window Model Name (or 'NA')		
	Shading	Window Width	19	19
	Shading	Window Height	4	7
	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		10
	Shading	Left fin extension above top of window		6
	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	10	
	Shading	Right fin extension above top of window	6	
	Shading	Dist from right edge of window to right fin		
Shading	Dist from right fin bottom to bottom of window			
Orientation		5	5	5
CCN'T				
3	Lighting	Function name (or 'NA')		
	Lighting	Average function area (ft ²)		
	Lighting	Installed watts/ft ²		
	Lighting	(times) Percent of function area		
	Lighting	(or) Total installed watts	353900	
	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 #			
C	Daylighting	Function name (or 'NA')		
	Daylighting	Window orientation (N,NW,etc)		
	Daylighting	Ground reflectance (%)		
	Daylighting	Typical room window area (ft ²)		
	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'in or 'S'tep)		
	D	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			

ZONE - EAST 1

A₁

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

1	2	3	4
<u>149</u>	<u>101</u>	<u>151</u>	<u>10</u>
<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>
<u>N</u>	<u>E</u>	<u>S</u>	<u>W</u>

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

5			
<u>10</u>	<u> </u>	<u> </u>	<u> </u>
<u>4</u>	<u> </u>	<u> </u>	<u> </u>
<u>E</u>	<u> </u>	<u> </u>	<u> </u>

ZONE - EAST 2

TARGETS OUTLINE

I. MODE OF USE

- A. Target setting
- B. Design evaluation
- C. Design analysis
- D. Research and development

II. LEVEL

- A. Lighting Function (3B)
- B. Thermal Function (3A)
- C. Subtype (2) (see exhibit L)
- D. Type *OFFICE, GENERAL* (1B) (see exhibit L)
- E. Category *COMMERCIAL* (1A) (see exhibit L)

III. PROJECT INFORMATION

- A. Report information
  - 1. Project name
  - 2. Project number
  - 3. Client *WISCONSIN POWER & LIGHT*
  - 4. Location *MADISON, WI.*
  - 5. Description
- B. Energy model
- C. Energy cost information

IV. BASIC BUILDING CHARACTERISTICS

- A. Climate zone
- B. Latitude *43*
- C. Size
- D. Configuration
- E. Orientation
- F. Adjacency
  - 1. site
  - 2. internal
- G. Structure
- H. Floor
- I. Partitioning
- J. Infiltration *2396-C CPM*
  - 1. Occupied air change rate
  - 2. Unoccupied air change rate

V. BUILDING ENVELOPE

- A. Roof/Ceiling
  - 1. Basic information
    - a. Area *13300.0*
    - b. Slope & slope orientation
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- B. Walls (opaque)
  - 1. Basic information
    - a. Area *4962*

- b. Orientation
    - c. Tilt
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- C. Floor/Ceiling
  - 1. Basic information
    - a. Area 11495.0
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- D. Doors (exterior)
  - 1. Basic information
    - a. Area
    - b. Orientation
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form
- E. Fenestration
  - 1. Basic information
    - a. Area 2776.0
  - 2. Selection criteria
  - 3. Input library
  - 4. Input form

VI. FUNCTIONAL PARAMETERS

- A. Schedules: select/modify
  - 1. Occupancy — 1
  - 2. HVAC — HTG 6
  - 3. Lighting — LTG 5
  - 4. Equipment
  - 5. DHW — 1
  - 6. Miscellaneous
- B. OCCUPANCY 5 DAYS/WEEK
NO. OF PEOPLE - 42
  - 1. Occupant density
  - 2. Age distribution [lighting]
  - 3. Load (per person)
    - a. sensible GAIN 255.0
    - b. latent GAIN 255.0
  - 4. Diversity factors
    - a. occupied
    - b. unoccupied
    - c. table #
- C. Internal gains
  - 1. lighting
  - 2. lighting mass factors
  - 3. miscellaneous electric (see exhibit I: ASEAM loads input forms)
  - 4. miscellaneous sensible (see exhibit J: ASEAM loads input forms) 8624.0
  - 5. miscellaneous latent (see exhibit K)

VII. COMFORT/PRODUCTIVITY CRITERIA

- A. Temperature

1. Cooling
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MIN
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
  2. Heating
    - a. Air
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
    - b. Surface
      - (1) occupied MIN
      - (2) occupied TYP
      - (3) occupied MAX
      - (4) unoccupied MIN
      - (5) unoccupied TYP
      - (6) unoccupied MAX
- B. Humidity
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX

- C. Ventilation *CFM 2150*
1. Cooling
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  2. Heating
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
  3. Special Requirements [laboratories, kitchens...]
    - a. occupied MIN
    - b. occupied TYP
    - c. occupied MAX
    - d. unoccupied MIN
    - e. unoccupied TYP
    - f. unoccupied MAX
- D. Lighting
1. Desired footcandles *50.0*
  2. Color Rendition Index (CRI)
  3. Color temperature

VIII. Systems

- A. Lighting
1. Selection rules
  2. Criteria
  3. Typical systems library (see exhibit M: LIGHTING PROGRAM forms)
  4. Input forms (see exhibit B: ASEAM loads input forms)
  5. Daylighting
    - a. Daylighting parameters (see exhibit C: ASEAM loads input forms)
    - b. Daylighting controls (see exhibit D: ASEAM loads input forms)
- B. HVAC
1. Selection rules
  2. Criteria
  3. Typical systems library
  4. Input forms
    - a. Systems (see exhibit E: ASEAM systems input forms)
    - b. Plants (see exhibit F: ASEAM plants input forms)
- C. Service water heater
1. Selection rules	DHW FUEL COST	5.50	\$/MMBTU
2. Criteria	DHW COMBUSTION		
	EFFICIENCY	0.75	
3. Typical systems library	DHW PEAK LOAD	53300	BTU/H
4. Input forms			

IX. ECONOMIC PARAMETERS

- A. FBLCC (see exhibit G: ASEAM FBLCC input forms)
- B. NBSLCC (see exhibit H: ASEAM NBSLCC input forms)

INPUT FORMS for Building Envelope

1. ROOF/CEILING ----- INPUT FORM
  - 1.1. U-value *0.077*
  - 1.2. Mass
  - 1.3. Color
  - 1.4. Reflectivity (interior surfaces)
  - 1.5. Plenum
  - 1.6. Assembly
  - 1.7. Type
2. Walls (opaque) ----- INPUT FORM
  - 2.1. U-value *0.067*
  - 2.2. Mass
  - 2.3. Color
  - 2.4. Reflectivity (interior surfaces)
  - 2.5. Plenum
  - 2.6. Assembly [where mass occurs]
  - 2.7. Type
3. Floor/ceiling ----- INPUT FORM
  - 3.1. U-value
  - 3.2. Mass *45992.0*
  - 3.3. Finish
  - 3.4. Reflectance
  - 3.5. Type
  - 3.6. Assembly
  - 3.7. Plenum

PERIMETER *00*
4. Doors ----- INPUT FORM
  - 4.1. U-value
  - 4.2. Color
  - 4.3. Type
  - 4.4. Assembly
  - 4.5. Vestibule
  - 4.6. Infiltration factor
5. FENESTRATION ----- INPUT FORM
  - 5.1. Glazing
    - 5.1.1. Wall window ratio *1:1.79*
    - 5.1.2. U-value *0.50*
    - 5.1.3. Emittance (surface #)
    - 5.1.4. Reflectivity
    - 5.1.5. Type
    - 5.1.6. Shading Coefficient *0.82*
    - 5.1.7. Visible transmittance *0.80*
  - 5.2. Window specifics
    - 5.2.1. Orientation
    - 5.2.2. Tilt
    - 5.2.3. Window vertical placement
    - 5.2.4. Assembly [where tint is]
      - 5.2.4.1. frame
    - 5.2.5. Infiltration factor
    - 5.2.6. Shading devices
      - 5.2.6.1. external (see exhibit A: ASEAM loads input form)
      - 5.2.6.2. internal
    - 5.2.7. Shading management
    - 5.2.8. Ground reflectivity *0.06*

4 Shading	Window Model Name (or 'NA')	ZONE-EAST 2			
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				

CCN^{TT}

Lighting	Function name (or 'NA')				
Lighting	Average function area (ft ²)				
Lighting	Installed watts/ft ²				
Lighting	(times) Percent of function area				
Lighting	(or) Total installed watts	206960			
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 (ft ²)				
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'in 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				

ZONE - EAST 2

A₁

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

1
175
4
N

2
76
4
E

3
175
4
S

4
23
4
NE

WITHOUT
SHADING

Window Model Name (or 'NA')
Window Width
Window Height
Orientation

5
89
4
N

6
52
4
E

7
104
4
S

ZONE- WEST 1 / EAST 1 / WEST 2 / EAST 2

ASEX2 PLANT INPUT FORMS (ABBREVIATED)

(F)

Fuel Type	Energy Units	Unit Cost \$ / Unit	Conversion Factors (BTU/Unit)	Site	Source
Electricity	KWH	0.03			
Natural Gas	Therms	5.50 \$/MMBTU			
#2 Oil	Gallons				
#4 Oil	Gallons				
#6 Oil	Gallons				
Dist Heating	MBTU	5.50 \$/MMBTU			
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 (1=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 (1=Boiler 2=Dist Heat)	_____	_____	
Design coefficient of performance	_____	_____	
Minimum part load ratio (% of capacity)	_____	_____	%
Number of absorption stages	_____	_____	
Load management/operation (1=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 (1=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 (1=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 (1=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
DEW Energy Source (0=None 1=Elec 2=Gas 3=Oil 4=Blr 5=Dist)	<u>2</u>	
(if oil) Oil Type (2 or 4 or 6)	_____	
(if gas) Annual pilot consumption	_____	therms
Domestic Hot Water Heating Capacity (blank=autosized)	_____	KBTUE
(if autosized) Peak hourly DEW usage	<u>PEAK LOAD 53300 BTU/H</u>	gal/hour
Average hourly DEW usage - occupied cycle	_____	gal/hour
Average hourly DEW 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	<u>75</u>	%
DHW losses - occupied cycle	_____	BTUE
DHW losses - unoccupied cycle	_____	BTUE
Boiler Energy Source (1=Elect 2=Nat Gas 3=Oil)	Type 1 _____	Type 2 _____
(if oil) Oil type (2 or 4 or 6)	_____	_____
(if gas) Annual pilot consumption	_____	therms
Boiler heating capacity (per boiler)	_____	KBTUE
(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	_____	%

DATA ECHO FOR PLANT INPUT FILE: WASH1WO.PID

ENERGY COSTS/CONVERSIONS

Fuel Type	Energy Units	Unit Cost	Conversion Factors (BTU/Unit)	
			Site	Source
Electricity	KWH	\$0.0750	3,413	11,600
Natural Gas	Therms	\$0.5400	100,000	100,000

MISCELLANEOUS ENERGY CONSUMPTION

CENTRIFUGAL CHILLER

Centrifugal Chiller Cooling Capacity	Type 1
Percent maximum load satisfied per chiller	: Autosized
Number of chillers of this capacity	: 120 %
Cooling Performance	: 1
Design coefficient of performance	: 3.0
Minimum unloading ratio (percent of capacity)	: 10 %
Minimum part load ratio (percent of capacity)	: 10 %
Load management/operating method	: As Needed
Chilled Water Parameters	
Chilled water temperature at maximum load	: 44 deg F
Chilled water temperature at minimum load	: 44 deg F
Chilled water flow rate	: Autosized
Chilled water pump KW	: Autosized

COOLING TOWER

Cooling Tower Heat Rejection Capacity	: Autosized
Percent of maximum heat rejection load satisfied	: 120 %
Tower Performance	
Number of tower cells	: Autosized
Fan KW per cell	: Autosized
Number of fan speeds	: 1
Approach temperature	: 10 deg F
Condenser Water Parameters	
Condenser water temperature at maximum load	: 95 deg F
Condenser water temperature at minimum load	: 85 deg F
Condenser water flow rate	: Autosized
Condenser water pump KW	: Autosized

DOMESTIC HOT WATER

Domestic Hot Water Energy Source	:	
Oil type	:	# 0
Domestic Hot Water Heating Capacity	:	Autosized
Peak hourly DHW usage	:	gal/hour
Average hourly DHW usage - occupied cycle	:	gal/hour
Average hourly DHW usage - unoccupied cycle	:	gal/hour
DHW Temperatures		
Domestic hot water supply temperature	:	deg F
DHW inlet temperature - design summer	:	deg F
DHW inlet temperature - design winter	:	deg F
Circulating Pumps		
Circulating pump KW - occupied cycle	:	KW
Circulating pump KW - unoccupied cycle	:	KW
Domestic Hot Water Efficiency and Losses		
Design DHW heating efficiency	:	%
DHW losses - occupied cycle	:	BTUH
DHW losses - unoccupied cycle	:	BTUH

BOILER

Boiler Energy Source	Type 1
Annual Pilot Consumption	: Natural Gas
	: 70 therms
Boiler Heating Capacity	
Boiler heating capacity (per boiler)	: Autosized
Percent maximum heating load satisfied (per boiler)	: 120 %
Number of boilers with this capacity	: 1
Load management/operating method	: As Needed
Boiler Performance	
Boiler efficiency method	: User Entered
Design boiler efficiency	: 75 %
Minimum part load ratio (percent of capacity)	: 25 %
Boiler Pumping and Losses	
Boiler pump KW	: Autosized
Boiler losses - percent of capacity	: 0 %
Boiler losses - percent of load	: 0 %

DATA ECHO FOR SYSTEMS INPUT FILE - WASH1WO.SID
SYSTEM TYPE - FAN COIL UNITS
SYSTEM LABEL - HVAC: Fan Cooling Unit/Centrifugal Chill

ZONES ASSIGNED TO SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chill

Load Zone	Zone Label
1	WORKROOM FOR CATEGORY 3 FACILITY

HEATING PARAMETERS FOR SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chill

Heating plant type	: Boiler
Heating available below	: 055 deg F
Heating availability	: Oct through Apr
Design heating discharge temperature	: 85 deg F

COOLING PARAMETERS FOR SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chill

Cooling plant type	: Centrifugal
Outside temperature below which cooling is off	: -30 deg F
Cooling availability	: Mar through Nov
Design cooling coil discharge temperature	: 58 deg F

BASEBOARD PARAMETERS FOR SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chill

Baseboard plant type	: None

FAN PARAMETERS FOR SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chill

Total supply fan power required	: Defaulted
Supply fan temperature rise	: Defaulted
Occupied cycle fan control method	: On Continuously
Unoccupied cycle fan control method	: On Continuously

OUTSIDE AIR PARAMETERS FOR SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chi

Occupied Cycle	
Outside air damper control method	: Dry Bulb Economizer
Minimum percent outside air intake	: 10 %
Dry bulb switchover temperature	: 60 deg F

Unoccupied Cycle
Outside air damper control method : Dry Bulb Economizer
Minimum percent outside air intake : 10 %
Dry bulb switchover temperature : 60 deg F

ZONE AIR PARAMETERS FOR SYSTEM 1 - HVAC: Fan Cooling Unit/Centrifugal Chill

Zonal air volume method : Autosized
Percent of design default air flow : 100 %
Zonal fan power method : Autosized
Percent of design default fan KW : 100 %

Appendix E

Technologies/Design Strategies List and Triggers

Appendix E

Technologies/Design Strategies List and Triggers

Draft Categorization: Summary of Basic Approaches

A. Reduce Cooling Load

Conduction (walls, windows, roof, floor)
Solar Radiation (walls, windows, roof, floor)
Infiltration/Ventilation
Internal

B. Reduce Heating Load

Conduction (walls, windows, roof, floor)
Solar Radiation (walls, windows, roof, floor)
Infiltration/Ventilation
Internal

C. Time Shifting Loads/Resources

Radiation
    External (Solar)
    Internal
Ventilation
HVAC Systems

D. Reduce Lighting Energy

Design
Lamps
Ballasts
Luminaires
Operation
Maintenance
Daylighting
Controls

E. Maximize HVAC Performance

Cooling Plant
Heating Plant
Cooling Distribution
Heating Distribution
Controls

F. Reduce Demand Charges

Off Peak Cooling
Off Peak Heating
Daylighting
Controls

A. Details of Strategies/Technologies for Reducing Cooling Load

Conduction (walls, windows, roof, floor)

Configuration

- Reduce Surface Area to Volume Ratio
- Consider Below-Grade Location for Part(s) of the Building
- Consider Compact Configuration (Low Length/Width Aspect Ratio)
- Reduce Floor-to-Floor Dimension for More Compact Building
- Avoid Elevated Buildings, Overhanging Spaces, Parking Garages or

Intermediate Levels

Materials

- * - Increase R-Value of Roof
- * - Increase R-Value of Walls, Doors, and Window Frames
- Reduce Emissivity of Glazing
- * - Increase R-Value of Glazing
- Increase R-Value of Slab and Slab Perimeter (Vertical and Horizontal Insulation)
- Increase Roof Thermal Mass
- Increase Wall Thermal Mass
- Increase Interior Thermal Mass

Solar Radiation (walls, windows, roof, floor)

Configuration

- Reduce Surface Area to Volume Ratio
- Orient Building To Minimize Insolation
- * - Elongate E/W Axis to Reduce East and West Exposure
- Configure Building Exterior to Provide Self-Shading
- Provide Fixed External Shading Devices
- Provide Moveable External Shading Devices
- Use Double Roof with Ventilation Space in Between
- Use Smooth Surfaces

Site

- Reduce Paved Areas in Vicinity of Building
- Plant Deciduous Trees Adjacent to Building to Moderate Surface Temperatures
- Utilize Site Elements for Shading

---

* 80/20 OPTION (i.e. 80% of the cases are covered by 20% of the technologies/strategies)

A. Details of Strategies/Technologies for Reducing Cooling Load, contd

Materials

- * - Use Light Colors
- * - Use Glazing with Low Shading Coefficient (Tinted)
- * - Use Glazing with Low Shading Coefficient (Reflective)
- * - Use Glazing with Emissivity Configured for Cooling
- * - Use Radiant Barrier in Roof, Walls
- * - Provide Interior Shading Devices

Infiltration/Ventilation

Configuration

- * - Reduce Surface Area to Volume Ratio
- * - Minimize Wind Effects by Orienting Major Axis Into the Wind
- * - Site Near Existing Windbreaks
- * - Provide Vestibules for Entrances
- * - Locate Entrances on Downwind Side of Building
- * - Vertically Offset or Stagger Stairwells Elevator Shafts, Mechanical Shafts to Avoid Chimney Effect
- * - Reduce Building Height

Materials

- * - Provide Air/Vapor Barrier
- * - Seal All Vertical Shafts
- * - Use Low Leakage or Inoperable Windows
- * - Use Low Leakage Doors

Mechanical

- * - Use Cooling Reclamation on Exhaust

Internal

Configuration

- * - Increase Local Space Volume
- * - Isolate/Cluster Heat Gain Sources for Control of Gains

Materials

- * - Employ Efficient Lighting Strategies

B. Detailed Strategies/Technologies for Reducing Heating Load

Conduction (walls, windows, roof, floor)

Configuration

- Reduce Surface Area to Volume Ratio
- Consider Below-Grade Location for Part(s) of the Building
- Consider Compact Configuration (Low Length/Width Aspect Ratio)
- Reduce Floor-to-Floor Dimension for a More Compact Building
- Avoid Elevated Buildings, Large Overhangs, Parking Garages or Intermediate Levels

Materials

- * - Increase R-Value of Roof
- * - Increase R-Value of Walls, Doors, and Window Frames
- * - Increase Glazing R-Value
- Reduce Glazing Emissivity
- * - Increase R-Value of Slab and Slab Perimeter (Vertical and Horizontal Insulation)

Solar (walls, windows, roof, floor)

Configuration

- Increase Surface Area to Volume Ratio
- Orient Building To Maximize Insolation
- Elongate N/S Axis to Increase East and West Exposure
- Configure Building Exterior to Minimize Shelf-Shading

Site

- Minimize Site Shading

Materials

- Use Dark Colors
- Use Low Mass Walls, Floors, Roof (Daytime Occupancy)
- * - Use Glazing with High Shading Coefficient

Infiltration/Ventilation

Configuration

- Reduce Surface Area to Volume Ratio
- Minimize Wind Effects by Orienting Major Axis Into the Wind
- Site Near Existing Windbreaks
- Vertically Offset or Stagger Stairwells Elevator Shafts, Mechanical Shafts to Avoid Chimney Effect
- * - Provide Vestibules for Entrances

B. Detailed Strategies/Technologies for Reducing Heating Load, contd

- Locate Entrances on Downwind Side of Building
- Reduce Building Height

Materials

- Provide Air/Vapor Barrier
- Seal All Vertical Shafts

Mechanical

- Use Exhaust Heat Reclamation

Internal

Configuration

- Isolate/Cluster Heat Gain Sources for Control of Gains
- Locate Heat Gain Source Close to Areas Needing Heat Gain (cascading)
- Decrease Local Space Volume

C. Detailed Strategies/Technologies for Time Shifting Loads and Resources

Radiation

External (Solar)

- Increase Roof Thermal Mass
- Increase Wall Thermal Mass
- Increase Interior Thermal Mass

Internal

- Use Daytime Internal Gains to Charge Mass and Offset Night loads

Ventilation

- Increase Interior Thermal Mass to Utilize Night Ventilation

HVAC Systems

- Ice Storage, Chilled Water Storage, Hot Water Storage (Diurnal)
- Ground Water Aquifer, Ice Storage (Seasonal)

D. Detailed Strategies/Technologies for Reducing Lighting Energy

Design

Space Materials

- Higher reflectance surfaces (esp.walls/ceiling)
- Matte finishes
- Higher ceilings for better distribution
- Establish repainting/cleaning schedule to reduce light loss and reduce overdesign.

Space Layouts

- Larger spaces with lower room cavity ratio, i.e. reduce wall area to workplane area.
- Unobstructed open plan.
- Reduce height of partial-height partitions
- Reduce circulation space in open plan, or fix location. (so spill light can light circulation)
- Fix location of work stations (avoid lighting planned for all possible future conditions.)
- Fix orientation of all workers to one, or two directions
- Cluster workers of similar tasks, or time schedules, or visual characteristics.

Lighting techniques:

- Provide lower level ambient, supplemented by local task lighting
- Provide low level wash on ceiling and vertical surfaces. Utilize direct distribution for task lighting.
- Provide compensatory lighting at window wall and interior walls to balance daylight.
- Utilize transition zones to ease eye adaptation between spaces of different color or luminance.
- Reduce contrast between task brightness and space brightness and/or window brightness.
- Avoid uniform layouts, provide visual interest along with clear organization. - Avoid chaotic layouts.

Luminaires

- Consider luminaires with the highest efficiency and coefficient of utilization, once the desired distribution and glare control have been selected.
- Select best cleaning characteristics / maintenance characteristics
- Consider air return through fixtures
- Select appropriate fixture for each application. Avoid "building standard" repetition regardless of situation, or uniform layouts.
- Modify luminaires for output rather than introduce new lamps for specialized applications.
- Consider white painted parabolic louvers in small rooms and near walls, to combine space lighting and task lighting.
- Label luminaires for correct relamping.

D. Detailed Strategies/Technologies for Reducing Lighting Energy, contd

Sources

- Reduce the number of lamps on project for reasonable maintenance.
- Use improved color lamps for greater visibility per lumen.
- Select highest efficacy lamp, once color and distribution characteristics are met.
- Establish cost-effective group relamping to reduce maintenance factor and overdesign.
- Avoid low efficacy/long life lamps except where relamping is extremely difficult.
- Use higher efficacy sources for ambient lighting, and lower efficacy sources for "apparent light"
- Reduce use of low efficacy incandescent to those instances where the required color spectrum, control or distribution cannot be duplicated by other sources.
- Consider use of compact fluorescent and low wattage metal halide luminaires as substitution for incandescent luminaires

Ballasts

*

- Select reduced watts-loss ballasts
- Select best ballast factor for specific lamp/ballast combination
- Consider stepped level or dimmable ballasts

*

- Use electronic ballasts

Operation

*

- Provide controls to reduce output for different visual needs, and at different times of day related to occupancy.

*

- Manual Controls (Wall Switch or Dimmer)
- Occupancy Sensors
- Timer - Programmable from Space Being Controlled
- Three Level, Including Off, Stepped Control or Pre-Set Dimming
- Four Level, Including Off, Stepped Control or Pre-Set Dimming
- Automatic Continuous Dimming
- Lumen Maintenance

D. Detailed Strategies/Technologies for Reducing Lighting Energy

Daylighting

- Increase use of daylighting for ambient lighting of ceiling and walls rather than task lighting.
- Increase Glazing Area/ decrease opaque vertical area on window wall.
- Add Clerestories
- Add Roof Monitors
- Add Skylights
- Locate Windows Head Close to Ceiling
- Reduce glazing area below working plane height
- Avoid direct sun penetration in work areas
- Control Glare/heat with exterior overhangs
- Control Glare with Blinds/Drapes
- Control Glare with Shutters
- Control Glare with Aperture Placement and Configuration
- Use Light Shelves to Limit Direct Sunlight and Increase Penetration
- Use Glazing with High Visible Transmittance
- Use Light Colors on Interior walls, especially window wall.
- Use Automatic Dimming Controls
- Use Automatic Switching Controls
- Use Manual Switching
- Use Manual Dimming Controls

E. Detailed Strategies/Technologies for Maximizing HVAC Performance

Cooling Plant

Heating Plant

Air Distribution

- * - Minimize Outdoor Air According to Space Requirements
- * - Reduce Outdoor Air During Unoccupied Periods

Hydronic Distribution

Controls

F. Detailed Strategies/Technologies for Reducing Demand Charges

Off Peak Cooling

- Cool Interior Thermal Mass Using Night Flushing
- Use Chilled Water Tanks and Run Chillers at Coolest Diurnal

Off Peak Heating

Daylighting (Lighting Section)

Controls

- * - Include Economizer Cycle
- * - Utilize Setback Thermostat
- * - Use Anticipatory Controls

STRATEGIES/TECHNOLOGIES LIST
Basic Approaches

* - 80/20 Option

16 June 1988

DRAFT CATEGORIZATION:

Reduce Cooling Load

Reduce Heating Load

Time Shifting Loads/Resources

Reduce Lighting Energy

Maximize HVAC Performance

Reduce Demand Charges

Appendix F

Priority Energy

Appendix F

Priority Energy

How Will Priority (Discretionary) Energy Use Be Dealt with During Input and in the Selection Procedure?

How will the Targets methodology deal with energy intensive uses above that of typical uses described by consensus database? Priority or discretionary energy is the energy resulting from a characteristic, usage, or piece of equipment (above the range established by consensus for typical conditions) which is deemed by the owner to be essential for the effective operations of the owner's building or business. There are two aspects to priority energy inputs: operational loads (direct use of electricity, gas, hot water, etc.) and thermal loads (heat gain or loss as it affects heating and cooling loads).

Typical kinds of priority energy (in excess of that allowed) include

- equipment
- machinery
- computers
- lighting
- increased requirement for cooling/heating
- decreased requirement for controls
- specific orientation requirements
- increased window-to-wall ratios, etc.

In component system energy standards (such as Standard 90) there is no adequate methodology for considering all forms of priority energy in an equitable manner. Certain priority energy uses (process energy) have historically been exempt from energy limitations while others have been included. Under reasonably stringent targets these differences could be quite unfair.

This project offers the opportunity to view project-specific energy use in buildings in a new way, without overly impinging on the owner's right to use energy, while attempting to insure that all the energy in a building is used wisely.

The definition of "process energy" in Standard 90.1-1989 is as follows:

"Energy consumed in support of manufacturing, industrial, or commercial process, other than the maintenance of comfort and amenities for the occupants of a building."

This latter is a broad definition which could allow for a fairly wide definition range, but does not include all of the potential kinds of priority energy. In addition, the words "process energy" have too strong of a historical use, forcing a wider definition would be difficult. If processed energy is to be exempt from limitations within the Targets methodology, then the definition of what processed energy is, and is not would be very controversial and would lean heavily toward the traditional usage.

Goals:

1. Deal with priority energy for the Targets methodology in the voluntary mode, as a framework for standards and codes.

2. Consider all energy use in a building, so that targets and designs are realistic.
3. Give the owner some flexibility in using energy to achieve purposes for which the facility is being built and for which an investment is being made.
4. Encourage energy conservation of all energy use in a building.
5. Avoid making the model specific enough to deal with all contingencies at one extreme, or the other, avoid treating all above typical energy use as a special type or variance condition, this puts the decision of appropriateness on the code checker, the party least qualified to judge.
6. Provide a system that is equitable to all users of priority energy.

Examples Related to Priority Energy

I. Retailing: Priority Energy Use Examples

- A. Heidi's Housewares
Typical general merchandise store: typical range of R-values, occupancy, lighting (ambient and display), cooling load receptacle use, glazing transmission, W/W ratio, etc. No priority energy required.
- B. Fred's Fur Vault
Requires much cooler temperatures for store and vaults. Requires much higher light levels to accent the Black Lama minks.
- C. Connie's Computer Land
Requires increased receptacle load for operating computer. Associated increase in cooling load. Runs computers (video display) in window after normal hours of occupancy.
- D. Arnie's Antiques
Normal display lighting. Much higher occupancy for weekend auctions. Higher heat gain due to west facing location (glazing standard for mall).

II. Hotels: Priority Energy Use Examples

- A. Handy Hilton
Business primarily based on quiet ambience and convenient location. Typical hotel requirements. No priority energy requirements.
- B. At Your Service Hotel
Each room equipped with computerized robotic valet, which makes coffee, presses pants, shines shoes, and plays video games. Required additional power and cooling.
- C. Versailles Viscount
Located in ornate chateau, famous for extensive art collection in lobby, requiring additional display lighting.

D. Lakeview Lodge

West-facing site overlooking lake to West. Floor to ceiling, lightly tinted glazing. Solar overhangs ineffective after 3:00 p.m., summer. Vertical fins ruin view.

E. Edmonton Entertainment Palace Hotel

Lobby has carousel, electrically and gas generated rides for kids. High-density occupancy and activity level.

III. Offices: Priority Energy Use Examples

A. IBM Urban Towers

Four orientations, fairly obstructed, typical office requirements. No priority energy required.

B. Harborview

Unobstructed high rise on tip of Manhattan. Views East, South, West. Increased window/wall ratio to compete in tight real estate market.

C. Data Processing Plaza

Silicon Valley low rise, designed for potential use of 10 W/SF connected computer load, needed to make spec. building competitive in tight market.

D. Pioneer Publishers

Desk top publishing equipment, CAD, printers, photo studios, paint labs, special ventilation and cooling, within standard office building shell.

E. Acme Atrium

Extensively planted atrium. Increased energy for plant lighting supplement, waterfalls, special humidity control. Periodically used for Jazz Dance festivals, requiring excessive cooling for high occupancy density and activity.

In the examples above, Type A buildings fit comfortably within typical range, flexibility and latitude of consensus based assumptions built into target level and are encouraged by target level to design a building that utilizes that energy in an acceptable, energy conserving manner. In all other cases, the desired functioning of the building involves activities, equipment, processes, or market pressures that result in uses of energy above and beyond the definition of a typical building of that type. For the sake of discussion, the total energy impact of each of the various buildings should be assumed to be roughly equivalent.

The discussion of whether one building's need for Priority Energy is more "legitimate" than another's seems impossible to resolve in an equitable manner. Yet, the if traditional application of "processed energy" was used, one building's excess usage might be exempt and another limited.

Decision

Recommendation: Define priority energy in the broadest sense, and incorporate into Targets methodology with "compensation" factors described in Option 2c.

Possible Alternative Solutions:

Two options are suggested:

1. Exempt operational loads from Targets methodology.
  - a. Include thermal impact in loads calculation; do not include operational load in target setting, design analysis, or final evaluation mode.
2. Include total priority energy (operational and thermal loads) in Targets methodology.
  - a. Include thermal impact in all modes; add operational load to design analysis and final evaluation modes only.
  - b. Include operational load and thermal impact in all modes.
  - c. Include operational load and thermal impact in all modes with restrictive compensation required for process energy.

OPTION 1: Exempt priority "operational loads" from Targets methodology.
Include priority "thermal impact".

	TARGET SETTING	DESIGN	CHECK	
<u>target</u>	Priority thermal impact Typical consensus limited energy	Priority thermal impact Building Energy	Priority thermal impact Building Energy	must be equal or greater
	+	+	+	
	Priority Operat. Load	Priority Operat. Load	Priority Operat. Load	actual operational load could increase
	=	=	=	
<u>allowable energy use</u>	limited unlimited	unlt'd	unlimited	

Advantages

- Treated traditionally like process energy.
- Requires energy conserving design to deal with thermal impact of priority energy.

Disadvantages

- No control on operational load of priority energy.
- No limitations on total priority energy use - will likely be controlled by definition of what is "legitimate" priority energy for standards/codes, leading to inequity.

OPTION 2: Include both operational loads and thermal loads for priority energy in Targets methodology.

OPTION 2A: Include thermal impact in all modes; add operational load to design/check modes only

	TARGET SETTING	DESIGN	CHECK	
<u>target & allowable energy use</u>	Priority thermal impact	Priority thermal impact	Priority thermal impact	equal or greater than value used in target setting
	-----	-----	-----	
	Typical (consensus limited) energy	Bldg. energy	Bldg. energy	
		-----	-----	
		Priority operational loads	Priority operational loads	

Advantages

- Includes all energy in methodology.
- Requires energy conserving strategies to offset priority energy.

Disadvantages

- Can be extremely detrimental to businesses requiring priority energy. Too stringent.

OPTION 2B: Include operational loads and thermal impact in all modes.

	TARGET SETTING	DESIGN	CHECK	
<u>target & allowable energy use</u>	Priority thermal impact	Priority thermal impact	Priority thermal impact	must be equal or greater than target setting mode
	Priority operational load	Priority operational load	Priority operational load	
	Typical (consensus limited) energy	Building Energy	Building Energy	

Advantage

- Strategies in design deal with all energy uses in a building in an energy conserving and cost effective way.

Disadvantages

- "Target" becomes more of a definition of energy use than an energy conserving goal.
- No limitations are placed on total priority energy use.
- Will likely be controlled in standards/codes by definition of what is "legitimate" priority energy. Leads to inequity.

OPTION 2C: Include operational load and thermal impact in all modes with restrictive "compensation" for Process Energy.

	TARGET SETTING	DESIGN	CHECK	
Priority thermal impact	Priority thermal impact	Priority thermal impact	Priority thermal impact	must be equal or greater than original Priority Energy
Original operat'l loads	Adjusted priority operational loads	Priority operational loads	Priority operational loads	
	Typical (consensus limited) energy	Building Energy	Building Energy	

Advantages

- Methodology includes all energy use.
- Requires energy conserving strategies to offset priority energy.
- Does not limit priority energy, but adds additional "compensation" for excess use, requiring reasonable increase in cost or energy conserving strategies.
- Does not require definition or determination of legitimacy of priority energy.
- All excess energy is treated equally.

Disadvantages

- Requires determination of "reasonable compensation" factor.
- Places heavier compensation burden on energy intensive businesses versus energy light businesses.

OPTION 2C (cont):

Potential methods for compensation adjustment within target setting methodology:

- A. Adjust original input of operational energy with discounting factor, e.g., reduce operational load to 70% of actual (e.g., compensation factor = .70) in target setting mode. Include full thermal impact. Include 100% of both operational and thermal load in design/check mode.

(If no operational load is involved, e.g., if increased cooling load is due to solar penetration, or occupant density, etc., then thermal load should be decreased by a compensation factor (e.g., .9) in target setting mode only.)

- B. Reduce "costs" associated with priority energy so that energy conserving strategies will become more cost effective in selection procedure. This is based on assumption that owner should bear more of the (first?) cost of priority energy use.
- C. Adjust economic perspective for priority energy. Assumes owner must have a more "societal benefit" cost outlook in respect to priority energy use.

Appendix G

Search Variables, Ranges, Constraints, and Disaggregation

Appendix G

Search Variables, Ranges, Constraints, and Disaggregation

Introduction

It is expected that constraints and project parameters will narrow the decisions to be optimized from the tens of thousands made on a medium or large sized building to a more manageable number (50 to 10,000). The technologies/design strategies list in Appendix E of this volume is a good starting point for energy.

Configuration changes in the technologies/design strategies that would require plan adjustment are not included here, since two and three dimensional planning is an enormously difficult problem itself. Plan changes will probably not be a topic for the search routines, though configuration suggestions may certainly be available to the user outside the search efforts.

The list has been sequenced into design decisions in the Building Construction, HVAC, Lighting, and Daylighting areas.

A Note on Economic Issues

Technologies and design strategies for energy saving must be supplemented with a few other concepts for use in the search routines. Conducting searches for the energy-related owning and operating costs (EROOC) may include using the reverse of the listed strategies to reduce first cost (representing the effort and energy going into initial construction) in favor of increases in long-term energy use.

Evaluating EROOC may also include choosing equipment with better maintenance characteristics (for higher first cost) or increased maintenance requirements (for lower first cost). Even if two systems have the same energy costs but different maintenance characteristics, this issue cannot be totally ignored. In some economic environments, one or the other system BUT NOT BOTH may provide an adequate return.

List of Search Variables (Draft)

- **Building Construction**
  - Slab and Slab perimeter R-Value
  - Floor R-Value (above garages, crawl spaces, building indentations)
  - Wall R-Value
  - Wall Vapor Barrier
  - Wall Thermal Mass
  - Wall Doubled with Ventilation, or other radiant barrier
  - Wall color (light for cooling, dark for heating) (Walls may be treated differently for different orientations or may be handled together.)
  - Window Frame R-Value
  - Window infiltration rate (inoperable or weather-stripped)

- Door (and Door Frame) R-Value
- Door infiltration rate (weather-stripping)
- Door vestibules (affects planning and so may be omitted)
- Service Entrances Door R-Value
- Overhead Door R-Value

- Roof R-Value
- Roof Vapor Barrier
- Roof Thermal Mass
- Roof Doubled with Ventilation or other radiant barrier
- Roof Color (light for cooling, dark for heating)

- Window aperture
- Window location
- Glazing R-Value
- Glazing Shading Coefficient
- Glazing Emissivity
- Glazing Transmittance

- Window exterior shading devices (fixed or movable)
- Window interior shading devices (fixed or movable) (Windows may be treated differently for different orientations or may be handled together.)

- In single story and top floor situations:
  - Ceiling glazing aperture (0 to 100 percent)
  - Ceiling glazing configuration (clerestory, monitor, skylight)
  - Ceiling glazing R-Value, Shading Coefficient, Emissivity, Transmittance

- Deciduous Trees planted adjacent to building

- Vertical shaft sealing/offsetting (for infiltration and ventilation control)

- Interior thermal mass (configuration to shift heating/cooling loads and resources)

- HVAC Variables
  - HVAC heating plant (type and efficiency)
  - HVAC cooling plant (type and efficacy)
  - Cooling systems (energy sources)

  - Cooling/Heating Reclamation of exhaust (air)

  - HVAC Storage Systems (ice, chilled water, ground water, hot water storage)

  - Off peak Cooling (using interior thermal mass, chilled water)

  - Off peak heating

  - Heating/cooling distribution systems (hydronic, VAV, reheat)

- HVAC zoning strategy (ties in with zone controls and equipment location)
- HVAC zone sensing and controls (zone/programmed/tailored) (economizer cycles, setback thermostats, anticipatory controls)
- Fan room location(s) (may affect planning, and so may be outside of optimization. Fan room location can yield significant benefits in first and operating costs.)
- Fan efficiencies
- Duct insulation R-Value
- Pipe insulation R-Value
- Air distribution controls on outside air with time and occupancy.
- Air distribution controls (with space requirements/use/occupancy)
- Heating/Cooling/Ventilation Delivery
  - Delivery temperature
  - Air delivery speed
  - Diffuser sizing
  - Fan coil/reheat sizing
  - Localized (task) cooling/heating
  - Room controls (thermostat/setback thermostat)
- Cogeneration
- **Lighting (Variables Not Involved With Quality)**
  - Lighting Controls (daylighting)
  - Lighting Controls (lumen maintenance)
  - Lighting Controls (use/occupancy)
  - Lighting Ballasts (per source/wattage of lamp)
  - Lighting Supply Voltage
  - Other lighting decisions impact the lighting results, and so involve checking results against the lighting criteria. Essentially, lighting design is required to change other lighting decisions. Even choosing lower wattage lamps with higher efficiency fixtures requires checking that the photometric results are equivalent or acceptable.
- **Lighting Variables Related to Lighting Quality**
  - Fixture type
  - Specific fixture
  - Lamp source type
  - Specific lamp (size and watts)
  - Lamp color
  - Mounting height
  - Mounting position
  - Maintenance - spot relamp

- Maintenance - group relamp frequency
- Maintenance - room surface cleaning
- Heat removal strategy
- **Daylighting Variables**
  - Glazing Aperture (included in Building construction above)
  - Glazing Transmittance (included in Building Construction)
  - Glare Control Strategies
  - Lighting Controls for Daylighting (included in Lighting)
  - Exterior Reflectors (Light Shelves)
  - Interior Reflectors (Light Shelves)

Notes on Selected Search Variables, Ranges, and Constraints

Building Construction Variables - Comments

Change Floor-to-Floor Dimension for More or Less Compact Building: This is often difficult to justify, given that structural, mechanical equipment, lighting, and electrical costs tend to rise as the plenum space gets tighter and more complicated.

R-Value of Roof: The ASHRAE Handbook of Fundamentals (1967 ed. anyway) has hundreds of roof, wall, and floor constructions listed, with varying insulation thicknesses. For example, roof decks with insulation above the deck lists 0 to 3 inches of insulation in half-inch increments. Placing the insulation below the roof deck is another option, with different cost consequences. It is expected that pre-selection will narrow the roof R-Value choices to 3 to 20 choices.

R-Value of Walls: R values may or may not be easy to change, depending on the building and construction type. R-19 insulation in 2x6 studs may be easy for wood frame construction (and no more expensive than R-17 insulation), but different insulation technologies are used in block wall and steel stud and curtain wall construction. Some insulation technologies allow finer steps in R-Value than others, so some are more "continuous" than others in the optimization process. Pre-selection processes will have narrowed wall construction to 3 to 20 choices for the given building type. Walls to special or non-outside areas may be different variables (as walls, floors, or ceilings to garages). South walls may be handled differently, particularly in solar construction.

R-Value of Doors (or Door Frames): In wood frame construction, paneled, solid, and insulated metal doors might be options. Storm doors (metal or wood) are options, leading to 6 choices: In public buildings, vestibules or rotating doors will be common. Door and window frames may have with 1 to 5 choices presented for optimization (standard frames, insulated frames, insulated gasketed frames for the finish materials being used. Insulating bronze or stainless frames is more expensive than insulating aluminum frames.) R-Values for public entrance doors, service entrance doors, and overhead doors are each separate variables.

R-Value of Window Frames: As with doors, the costs and opportunities to change the R-Value of window frames may differ widely between materials (wood/aluminum/bronze/stainless steel/concrete/...) but will offer a limited number of choices (1 to 10) for a given material.

R-Value of Glazing: R-Values for glazing will tend to come in 3 (or 4) steps: single glazing, double glazing, and triple glazing. Storm windows are possible in residential construction. Costs will vary considerably between construction types.

Fixed External Shading Devices: Movable External Shading Devices: 1 to 10 candidates may be chosen by the pre-selection process. As usual, the first candidate is "do nothing".

HVAC Variables - Comments

HVAC Heating Plant: Energy sources can be electric, natural gas, oil, (bottled gas for rural residential construction). Systems can be (see X5 list). Once generic equipment is chosen, specific combinations of size and efficiency are available. Choosing the heating energy source and mechanism is not a trivial exercise in mechanical engineering but requires a number of choices. It will be tied in with the cooling system, it will affect the method of delivery of heating (and cooling) to individual spaces.

Heating and cooling system choices lead not just to equipment optimums but determine whole regions for the optimization algorithm to search for HVAC system optimums.

Cooling/Heating Reclamation on Exhaust: 1 to 10 systems. One system will always be "no reclamation". Reclamation efficiencies may range up to 60% efficient.

Heating/Cooling Distribution Systems: HVAC distribution systems are a core issue, and have big impact on the energy use of an HVAC system. Certain rules of thumb can be provided, but choosing distribution systems often involves detailed analysis by the practitioner. Distribution systems may be expected to cause many of the "ridges" between local optimums in HVAC system selection.

HVAC Zoning Strategy: Zoning strategies can improve (or degrade) the system's responsiveness to uneven loads, so smaller zones can improve energy use if zones are well chosen. Designing zones for HVAC systems is as hard as designing zone controls for lighting. It is not anticipated that zoning design could be well enough automated for zoning strategy to be a promising optimization variable.

Duct insulation R-Value: Pipe insulation R-Value: Each size of pipe or duct carrying each temperature of fluid through each type and temperature of space could be listed as a separate variable for optimization. It is expected that each decision will be made on the basis of energy lost through the insulation plus some percentage of extra insulation. No system factors (central unit size savings, fan energy savings from delivering less air at a lower or higher temperature) will be included in the disaggregated optimization. The pre-selection process will have determined the minimum insulation to prevent condensation or deaden sound, if such concerns are relevant.

Appendix H

Proposed Optimization Approach Based on Response-Surface Methods

Appendix H

Proposed Optimization Approach Based on Response-Surface Methods

Objective

The objective of this Appendix is to describe one proposed approach for the optimization portion of the Targets model. This Appendix includes some background on the optimization problem that we consider necessary in order to understand the proposed approach. It describes the rationale for viewing response-surface methods as a promising approach and describes the general process that the proposed approach would employ in conducting an optimization. The major functional elements of software capable of performing the process are described, and lastly, the tasks that would be required to implement such a procedure in the Targets model are described.

Background

The rationale for a response-surface approach to optimization in the Targets model builds logically on some basic concepts related to optimization in general and the Targets model optimization problem in particular. Some of these discussions may be repetitious of materials presented in the body of the report. The concepts are discussed here to provide a logical flow of ideas and because understanding these concepts is important in gaining an understanding of the proposed approach.

The Value of Equations for the Objective Function

Some optimization methods make use of information about the slopes of objective function curves or surfaces. This information is sometimes available in the form of derivatives of the objective function. For continuous variables, derivatives can indicate the direction that leads toward the optimum indicate or whether a surface is concave or convex. Under some circumstances, derivatives of the objective function can even be used to prove optimality. In contrast, so called direct-search methods, which depend on repeated discrete function evaluations, would require two function evaluations to establish the direction of slope at a given point and a third to establish whether the curve is concave or convex at that point.

Referring to the earlier building energy example, a direct search method would have no way of knowing that the R-10 to R-15 increment of insulation would be more productive than the R-20 to R-25 increment. It would need to establish this fact by repeated function evaluations. Other methods making use of equations describing the objective functions could bypass the consideration of many strategy sets using these higher insulation levels by using derivatives.

Dramatic improvements could be achieved in optimization performance if suitable equations describing the relationships between objective function and optimization parameters were available.

Feasibility of Generating Equations for the Objective Function

The envelope model in ASHRAE/IES Standard 90.1-1989 (ASHRAE 1989) is based on regression analysis of a large number of DOE-2 runs in which parameters similar to the Targets optimization variables were varied. In general this regression model performs adequately, providing results within 10% of DOE-2 results more than 90% of the time.

The R^2 values for the regressions are in the high 90s, and reasonably good performance has been observed on the average in terms of both the absolute and relative value of predictions resulting from changes. Some testing of the regression model was conducted at PNL focussing on reported problems of the model under certain conditions. That study concluded that "the model seems to perform reasonably well for most climates and ranges of building parameters."

The form of equations found in the Standard 90.1 regression model suggest that it is possible to get good approximations of optimization variable-objective function relationships without resort to high-order polynomial terms. The highest power term that occurs in the Standard 90 regression model for a variable related to our likely optimization parameters is a squared term. This is encouraging in that it suggests that approximation equations for the objective function can be cast in a form that is not very difficult to deal with expeditiously using available optimization algorithms.

Regression analysis can provide a method for developing approximations of energy model results. Evidence from previous work suggest that an approximation model with relatively simple mathematical form and acceptable performance could be developed. In fact, this is a well accepted approach in optimization and is used where actual function evaluations are time consuming and/or expensive to obtain.

Rationale for Recommending Response-Surface Methods

The optimization problem in the Targets model is computationally difficult enough that sophisticated approaches will be required. If the methods given consideration are limited to those that are uncomplicated or intuitively understandable to a particular group, the scope of the optimization may need to be limited. The issues related to selection of optimization methods are not predominately related to response time, but rather to scope: how many issues will the optimization be capable of dealing with.

The optimization procedure needs to have more information about the relationships between optimization variables and objective function than can be gained from direct function evaluations. If it does not have this information, the scope of the optimization will need to be quite limited.

A regression model is the most effective way to provide information about these relationships for the following reasons:

- It is concise.
- It is an expression of the strongest inference that can logically be made from precalculated energy data.
- It inherently contains the capability for sophisticated multidimensional interpolation.
- It can be structured to embody any disaggregation of the problem that is warranted.
- It can be structured to embody a first-principles understanding of energy use in buildings.
- It can deal with binary, discrete, and continuous variables.
- It can provide first- and second-order derivatives.
- It can execute quickly.

- It can be readily and incrementally updated: it, in effect, can learn from experience.
- It provides a platform on which a full range of optimization techniques can operate.
- It is well accepted as a method for addressing this kind of problem.
- It is a manageable task to create. We currently have the hardware and software tools to do this kind of development work very efficiently.
- It provides other potential benefits to the model unrelated to its role in optimization.

The use of function approximations and response-surface methods in optimization are not novel or particularly new. The strengths and limitations of these methods are well understood. Most text books on optimization contain some discussion of the use of approximations. One such text lists the following three criteria to determine which approximation techniques are likely to be competitive with alternative methods:

- function evaluations are expensive (or time-consuming)
- the same data can be used in several separate optimizations
- high-quality approximations are available.

The target optimization problem would appear to fit these criteria reasonably well.

An important aspect of approximation techniques is the successive updating of approximations. As was mentioned above, this gives the method the capability to, in effect, learn from previous function evaluations. This learning process can be made to work for parameters that were not included in the original approximation model as well as for those that were. Where a parameter being optimized was not included in the original model, the process reduces to a line search based on curve-fitting. It should be noted that this type of search generally will outperform heuristic searches, such as Fibonacci and the bisection search. Experience with the new parameter can be fed back into the approximation model to speed up future optimizations when this parameter is again employed. This, of course, is true for parameters that were included in the original model as well.

Inherent in the capability to update the approximation model will be the capability to perform regression analysis. This capability will enable the model to create a new set of approximations to work with any new energy model that might be set up to work with the Targets model. This would be done by providing an option within the model to create a new data set following the same experimental design that was used for the original set but using the new energy model rather than DOE-2. This obviously would take considerable time to execute, however, it would be an entirely automated process. This could effectively address compatibility issues related to the use of an optimization procedure based on response-surface methods with different energy models.

Elements of the Proposed Solution

The following three major program elements would be needed to implement an optimization procedure based on response-surface methods.

Approximation Model

The proposed approximation model would provide an estimate of the objective function based on a building description. The model would consist of arithmetic expression(s) whose independent variables would be characteristics of optimization variables (e.g., effective conductance and thermal efficiency) and whose dependent variable would be the objective function or components thereof.

The approximation model would use as independent variables important performance characteristics of the strategies and technologies that the Targets model optimization will be able to address. It is not critical that the approximation model include all performance characteristics of these options or that all possible future options be reflected in the development of the approximation model. However, the performance benefits of the approximation model would not be realized fully when dealing with optimization variables not effectively addressed by the model. As was mentioned above, the process would be reduced to a sophisticated direct search for options missing from the approximation model. Similarly, additional function evaluations would likely be required if the approximation model was inaccurate due to omission of important performance characteristics.

The required sophistication and complexity of the approximation model needs to be considered in the light of tradeoffs that may exist with other components of the Targets model. If the energy simulation module is very fast, sophistication and accuracy in the approximation model is less important than if each function evaluation is very time-consuming to obtain. If high order terms are used in the approximation model to obtain better accuracy, the optimization engine using these expressions will execute more slowly. A more accurate approximation model could actually slow down the optimization process as a whole relative to a simpler, less accurate approximation model. Both the scope and complexity of the approximation model need to be viewed in a flexible way during development.

As currently envisioned, the approximation model(s) would be generated by performing regression analysis using optimization variable descriptors as the independent variables and energy results from a set of simulations as dependent variables. Initial thinking has focused on an approximation model for the energy simulation module. If it proves necessary, the approach could be applied to the other components that make up the objective function, such as energy costs or economics.

Lessons learned in the development of the Standard 90.1 envelope model could be usefully applied to the task of developing the approximation model. While the two models have distinctly different applications, some important similarities do exist.

- Both are regression models generated using DOE-2 output.
- Both must be suitable for a range of climates and would require many of the same independent variables.

Important differences are seen as well.

- The approximation model would need to include HVAC performance, utility rates, and possibly other components making up energy-related owning and operating cost.
- Performance criteria should be different since one serves to define a standard for performance while the other serves to speed up a process of optimization.

Differences in emphasis that seem warranted based on experience with the Standard 90.1 envelope model are as follows:

- A major emphasis on an efficient experimental design for the approximation model. Recognition of linearities and situations where variables are independent may lead to significant efficiencies in generating the model.
- The approximation model will be given a stronger first-principles basis as reflected in the form of model expressions.
- The final approximation model would probably be generated using 8760-hour DOE-2 runs, although initial development work could be done using compact weather.

Appropriate Optimization Engines

The second major component of a response-surface approach would be the optimization engines (or optimization algorithms). It is probable that there will need to be more than one optimization engine for several reasons. The optimization problem will likely be disaggregated into several subproblems having differing forms which favor different algorithms. Different algorithms have different capabilities with respect to the various performance criteria, e.g., speed, effectiveness in finding global optimums. These various strengths may be useful in concert within a single optimization model to achieve the stated performance objectives.

The optimization engines will be selected to operate effectively given the way the problem is formulated mathematically in the approximation model. The selection process must necessarily follow the development work on the approximation model. The selection of optimization algorithms is recognized as a task requiring a high level of technical expertise and is one that we expect to be made primarily by the optimization consultant to the project.

Module Capable of Updating the Approximation Model

The third and final major component of an approach based on response-surface methods is the module that updates the approximation model based on actual function evaluations. The optimization engine will calculate an optimal set of strategies based on the approximation model. Once this strategy set has been simulated using the energy and energy cost modules, the approximation model will be updated to bring it into exact agreement with the simulation results. Performing these updates is the task of this component of the model.

In concept, the approximation model update module will attempt to force the approximation model to match exactly simulation results while contradicting as little of the information contained in the approximation model as possible. If approximation model relationships were envisioned as a gently curving surface, a single-function evaluation would enable the height of that surface to be updated. Two-function evaluations would enable the surface to be tilted, and a third collinear function evaluation would be required before the curvature of the surface could be adjusted.

The best way to adjust the coefficient in the approximation model can be defined statistically, and for this reason it will be necessary to include some limited regression capabilities within this module of the program. It may be more effective, under some circumstances, to constrain the way in which updates are performed. Rules effecting these constraints may need to be included within this module.

An important spin-off benefit of including the regression capability within this module is that it will allow the process of adapting the Targets model for use with alternative energy models to be automated. A routine within the module will be set up to run the simulations following the experimental design used to develop the approximation model. If an alternate energy model is selected for use, an approximation model customized for use with that program will be generated.

Description of the Proposed Optimization Process

The major steps involved with an approach based on response-surface methods are described below:

Step 1

Generate the First Strategy Set Using the Appropriate Optimization Engine(s). Based on the building description from the user (including energy prices, economic perspective, etc.) and a list of parameters to be optimized (within constraints), those parameters are optimized with respect to the approximation model. The optimization algorithm(s) used will depend on the nature of the relationships as represented by the form of the approximation model.

Step 2

Simulate the First Set. The model will run DOE-2 using the initial set. This produces actual results that can be compared with the estimated results from the approximation model. This is a first-estimate of the building's target. The final target may be lower or higher, although the objective function (i.e., EROOC) can only be equal to or lower than this value.

Step 3

Update the Approximation Model. The DOE-2 run based on the first-set produces results that can be compared to the estimate from the approximation model. This comparison can be done on a component by component basis. The approximation model is refined to bring it into exact agreement with the single set of DOE-2 results currently available, while preserving the generalizations about the response of parameters imbedded in the initial approximation model. This process of updating the approximation model could be done on the basis of rules based on statistics, or it could be done on the basis of experience with the process of updating the approximation model. The first update would probably involve adjusting the constant terms in the approximation model equations.

Step 4

Regenerate the Strategy Set Using the Same Optimization Engine(s). The optimization would be rerun as before (perhaps using the previous set as a starting point for the optimization engine), but this time using the refined approximation model. The second strategy set would probably be different from the initial set. If the second set is identical to the first, the optimization has stabilized and the program would skip ahead to Step 6.

Step 5

Simulate the Next Strategy Set. Run DOE-2 using the second set. If the objective function is lower with the second set, the corresponding target would be used to update the initial estimate of the building's target.

Step 6

Update the Approximation Model. The component results from the DOE-2 run would again be used to update the approximation model. If multiple interactive parameters were changed from the previous run, there would be multiple parameters that could be changed to bring the approximation model into strict agreement with the simulation results. Either experience or statistical principles will need to provide the rules for how these changes should be done. Subsequent runs will tend to correct any inaccuracies

resulting from attributing changes to the wrong parameter(s). In general, the process would tend to adjust the height of a curve before the slope and the slope before the form, thus preserving as much of the information imbedded in the original approximation model as possible, while fully respecting the results from actual DOE-2 runs.

Description of Proposed Development Stage Work

The major steps that would be required to design, implement, and test an optimization model based on response-surface methods for the Targets model are listed in the outline below.

.1. Analyze Problem Structure

1.1. List optimization variables and assign priorities

1.2. Analyze objective function

1.2.1. Make preliminary decisions on disaggregation of the problem

1.2.2. Develop an experimental design for...

1.2.3. Run energy model (and possibly other parts of models)

.2. Interpret results

2.1. Define any necessary additional runs

2.2. Define optimization approaches

2.3. Finalize decisions on disaggregation of the problem

.3. Determine structure of resultant problem(s)

3.1. Identify appropriate optimization approaches for each subproblem

3.2. Select appropriate optimization algorithms for each subproblem

.4. Define method for generating response-surface model(s)

4.1. Develop preliminary experimental design

4.2. Run energy model (and possibly other parts of models)

4.3. Perform regression analyses on the energy model results

4.4. Define final form and experimental design for model

.5. Develop response-surface model up-date methodology

- .6. Develop prototype
  - 6.1. Generate response-surface model
  - 6.2. Implement response-surface model up-date methodology
- .7. Test and fine-tune prototype
  - 7.1. Test selected approaches
  - 7.2. Complete testing and fine-tuning of prototype
- .8. Develop final model
  - 8.1. Make decision on alterations to prototype for final operational model
  - 8.2. Develop final model
- .9. Test final model

Reference

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. 1989. "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings." *ASHRAE/IES Standard 90.1-1989*. Atlanta, Georgia.

Appendix I

Issues Related to Execution Time

Appendix I

Issues Related to Execution Time

Combinatorial Nature of the Optimization Problem

Multivariable optimizations are difficult and often time-consuming to conduct because of the large number of possible sets of solutions. To illustrate, an optimization problem with 10 binary variables has 2^{10} or 1,024 possible outcomes. If evaluation of each of these combinations were necessary to determine the least-cost solution and if each evaluation involved running DOE-2 for 30 minutes, it would take roughly 3 weeks to complete the optimization. The calculation for this and two other examples are shown below:

10 Variables:	2^{10}	= 1,024 -> 3 weeks @ 30 min each
20 Variables:	2^{20}	= 1,000,000 -> 20 years @ 10 min each
30 Variables:	2^{30}	= 1,000,000,000 -> 2,000 years @ 1 min each

If overnight turnaround is required for the Targets Model (roughly 12 hours of execution time), each function evaluation takes 6 minutes, and all variables are binary, then the largest number of binary variables that could be solved for using an exhaustive search method would be 7, since $2^7 = 128$ and $128 * 6 = 768$ minutes = 12 hours and 48 minutes.

While the exact number of parameters to be optimized has not been set and the time each function evaluation will require is not precisely known, it is clear that the scope of the optimization would need to be curtailed if we were to insist that exhaustive search methods be employed, even if only in a validation mode. Furthermore, dramatically faster computers or simplified energy models would be only marginally beneficial in making greater scope possible. At 100-function-evaluations per second, the 30-binary-variable problem would still require 4 months to execute using an exhaustive search.

Speed of Function Evaluation

Some optimization methods make direct use of the equations that define the objective function. In the Targets methodology, the objective function will be defined by the building cost module, economic analysis module, and energy simulation module. Equations are not available for the actual objective function. The way that information about the actual objective function can be obtained is through repeated evaluations of the building cost, economic analysis, and energy simulation modules.

On current desktop computers, the execution time for the simulation of a ten-zone building using DOE-2 is on the order of 30 minutes. Efforts are underway to reduce this execution time, however, it appears unlikely that the time required to conduct each function evaluation can be reduced by more than one order of magnitude. If an order of magnitude reduction in execution time were achieved, the number of function evaluations that would be possible within a 12-hour execution time for generating a target would be 240. If full simulations were performed at current execution speeds, 24 function evaluations would be possible. Given these execution times, it appears that using methods based primarily on direct evaluation of the building cost, economic analysis, and energy simulation modules, would necessarily limit the number of variables that could be addressed by the optimization.

Effect of Disaggregation on Execution Time

The feasibility of solving an optimization problem, the time required to solve it, and the most appropriate methods for solving it are all a function of the nature of the relationships between variables and the objective function. In the example above, the 30-binary-variable optimization took 2,000 years to solve using an exhaustive search. If we discovered that the relationships actually consisted of 6 independent sub-problems of 5 variables each, then the 30 binary variable problem could be optimized in less than four hours using an exhaustive search. The math is shown below.

$$6 * 2^5 = 192 \rightarrow 3 \text{ hours and 12 minutes @ 1 min each}$$

By recognized ways that a large optimization problem can be disaggregated, the problem can be dramatically reduced in difficulty. There clearly are elements of the building energy optimization problem that can be disaggregated.

Impacts - Energy Simulation Module Run Time

The decision to use an hourly energy simulation model as the choice for the Targets model has major implications for the selection and use of optimization tools. The main issue is one of run time.

For example, the standard nonlinear or dynamic optimization routines generally involve from 500 to several thousand iterations for a "robust" solution to a single instance of a complex problem. A DOE-2 simulation of a reasonably simple building takes about 20 minutes to run on a VAX. For the number of iterations mentioned above, this translates to approximately one week execution per robust solution.

Such run time lengths may not preclude the use of such standard techniques during R&D (if the need to be sure of robustness is paramount). But, such run times are prohibitive for a building design situation. Thus, it is not considered feasible to base the optimization procedure (or at least its normally used execution mode) on methods relying exclusively on recursive execution of the energy simulation module.

ASEAM-2.1: The first step is to use a simpler energy simulation model (with a much shorter calculation time) for the initial examination of optimization alternatives and issues. One such tool available in the public domain is ASEAM-2.1. Since run time for ASEAM-2.1 on an MS DOS-compatible 386 is about 45 seconds, robust runs become approximately one day efforts, hence more amenable in an R&D setting. Using brute force nonlinear or dynamic programming methods appear to become feasible in an R&D setting, at least as one avenue of exploration. Also, ASEAM-2.1 has a built in parametric processor that would allow the generation of many alternative solution sets for use in test bed data libraries.

Distribution

No. of Copies

Offsite

- 12 DOE/Office of Scientific and
Technical Information

- 5 M. L. Bailey
U.S. Department of Energy
1000 Independence Avenue SW
Forrestal Building, CE-131 5E-098
Washington, DC 20585

J. J. Boulton
U.S. Department of Energy
1000 Independence Avenue SW
Forrestal Building, CE-131 5E-098
Washington, DC 20585

D. Anderson
Burt Hill Kosar Rittelmann Associates
1056 Thomas Jefferson Street
Washington, DC 20007

J. J. Deringer
The Deringer Group
1349 Addison Street
Berkeley, CA 94702

H. K. Diemer
David Mintz, Inc.
330 West 42nd Street
New York, NY 10036

C. Gardner
Puget Energy Services, Inc.
Suite E175
1750 112th Avenue
Bellevue, WA 98004

J. D. Hall
ICF Incorporated
Suite 700
409 12th Street SW
Washington, DC 20024

No. of Copies

G. A. Hauser
Gregg Hauser Consulting
P.O. Box 20657
Oakland, CA 94620-0657

J. Holton
Burt Hill Kosar Rittelmann Associates
1056 Thomas Jefferson Street
Washington, DC 20007

B. K. Johnson
State of New Mexico
Energy, Minerals, and Natural Resources
Department
Energy Conservation and Management
Division
525 Camino de los Marquez
Santa Fe, NM 87501

J. W. Jones
University of Texas at Austin
Engineering Teaching Center
26th & San Jacinto
Austin, TX 78712

J. E. Kaufman
Illuminating Engineering Society
of North America
Ninth Floor
345 East 47th Street
New York, NY 10017

H. N. McKay
Hayden McKay Lighting Design
Ninth Floor
31 West 21st Street
New York, NY 10010

W. W. Seaton
American Society of Heating, Refrigerating,
and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329

**No. of
Copies**

K. G. Sigel
Wolf & Company
P.O. Box 275
Pleasantville, NY 10570

Onsite

DOE Richland Operations Office

R. B. Goranson

**No. of
Copies**

18 Pacific Northwest Laboratory

P. K. Alley, K7-44
M. R. Brambley, K5-19 (5)
R. S. Briggs, K5-19
D. B. Crawley, K5-19
B. M. Johnson, K5-12
L. D. Kannberg, K5-12
T. J. Secrest, K5-12
G. L. Work, K2-51
Publishing Coordination
Technical Report Files (5)