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Subcontractor Report

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

**Phase 2, Development
Concept Stage Report**

Volume 1: Summary Report

September 1990

**Prepared by the American Society of Heating,
Refrigerating, and Air-Conditioning Engineers, Inc.,
for Pacific Northwest Laboratory
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Concept Stage Report**

Volume 1: Summary Report

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Abstract

Since 1985, the Pacific Northwest Laboratory (PNL) has managed the Whole-Building Energy Design Targets project for the U.S. Department of Energy (DOE) Office of Building Technologies (formerly the Office of Buildings and Community Systems). The primary focus of the Targets project is to develop a flexible methodology for buildings industry use in setting energy performance guidelines for commercial buildings and for determining compliance with those guidelines. The project is being conducted as a two-phase effort. In Phase 1, Planning, the project team determined the research that was necessary for developing the Targets methodology. In the concept stage of Phase 2, Development, the 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 summary volume is the first. The three other volumes are

- Volume 2: Technical Concept Development Task Reports
- Volume 3: Workshop Summaries
- Volume 4: Software Concept Development Task Reports.

Together, these four volumes represent an early product of the Targets project Phase 2.

Project team members representing the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., the American Institute of Architects, and the Illuminating Engineering Society of North America performed the work reported herein during the period extending from late 1987 through early 1989. A draft of the final report on the subcontracted activities was submitted to PNL and DOE in February 1989. This first volume summarizes the work presented in detail in Volumes 2 through 4.

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1.0 Background

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 and for determining compliance with those 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.

1.1 Project Overview

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 target guidelines and determining compliance with them, rather than to determine numerical target values. 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 work of project team members representing the American Institute of Architects (AIA), the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), and the Illuminating Engineering Society of North America (IES) performed during the period extending from late 1987 through early 1989 is summarized in this volume of the concept stage Phase 2 report.

1.2 Project Goals and Objectives

To achieve the overall objective of encouraging the design of energy-efficient buildings, it has been necessary to define a series of specific goals and objectives.

The goal of the Targets project is to provide a methodology that will

- provide energy performance information pertinent to a specific design project; i.e., information that recognizes the constraints prescribed by function, site, cost, and the economic perspective of the owner

- provide this information at appropriate stages in the design process
- require minimal effort on the part of the user.

In addition, Targets methodology developed in this project is intended to

- make a positive contribution to the design process and not become an added burden
- be flexible enough to encourage and facilitate the development of innovative new commercial building designs.

1.3 Criteria for a Whole-Building Energy Design Targets Methodology

The criteria for defining a whole-building energy targets methodology are based on the series of desired target attributes outlined below. The criteria have been grouped into four categories that relate to the need to develop a methodology that provides a comprehensive target setting procedure, custom building-specific targets, and a means of guiding the design process and demonstrating compliance, and is acceptable to the buildings industry. The elements of each of these groups of criteria are discussed below.

1.3.1 Comprehensive Target Setting Methodology

The methodology must be comprehensive, capable of producing targets that

- are applicable to all commercial building types, to locations throughout the United States, and to the sources of energy used in these buildings
- are based on reasoned professional judgment and on analytical procedures that are technically and economically sound and defensible
- provide useful information to users about energy-related costs relative to market-based decisions that are free from any artificial bias with respect to different energy sources
- are achievable and advantageous to both designer and client - The target levels set must not be so stringent that only a few highly skilled experts can achieve them and still maintain acceptable levels of comfort and amenity.

1.3.2 Custom Building-Specific Targets

The Targets procedure must be structured so that building designers can generate targets appropriate to the constraints and requirements of a specific building design. These custom targets must provide

- a target that will reflect levels of building internal loads, hours and patterns of occupancy, and site and other design constraints
- a procedure that incorporates economic considerations as an integral part of the development of the targets - Energy cost and building cost factors should be incorporated into the basic methodology for establishing targets, so that the targets reflect a balance of energy and economic considerations. The targets must be economically beneficial for building owners and operators.

- multiple target levels that illustrate the range of energy efficiency that may be achieved as designers (and their clients) are willing to consider a wider selection of technologies and investment perspectives - Defining boundaries in this way provides owners and designers an opportunity to consider the consequence of different energy conservation priorities and economic perspectives.

1.3.3 Design Guidance and Compliance

It is essential that the Targets methodology encourage the appropriate design of energy-conserving buildings. Setting a target does not, by itself, achieve this goal, and may, in fact, lead to building designs that are deficient in other crucial areas. To be complete, the proposed methodology must

- provide guidance during the design process - A procedure that is based only on a final check of compliance will not be efficient in affecting the design process. The proposed methodology must be able to provide information on the energy impact of design decisions throughout the design process.
- provide a means of determining if a proposed design will meet the defined target - If a means of demonstrating compliance is not provided, consistency between target levels design performance could not be ensured and the targets would have little meaning.

1.3.4 Buildings Industry Acceptance

The target formats and procedures must be acceptable to the major organizations of design professionals, building owners, and building operators. They must

- be simple enough to be readily understood and used by building owners, operators, and developers, as well as members of the design team.
- provide designers with beneficial information during the design process and be useful to each discipline involved in decisions affecting building design energy performance. They should also be educational for the user, illustrating the energy consequences of selecting particular design or construction practices.
- provide a means of easily accommodating future changes in building technologies, energy costs, and building costs.

1.4 Use of the Targets Methodology

The Targets methodology will have two primary applications: 1) voluntary use to provide guidance for the design of energy-efficient and cost-effective buildings and 2) in the development and implementation of building energy standards and codes. Within each of these applications, the methodology will be used in two modes: to set building energy targets and to evaluate a proposed design. The overall relationship of these applications and modes of use is shown in Figure 1.1.

1.4.1 Modes of Use

Target Setting Mode

The objectives of the target setting mode of use are

Figure 1.1. Targets Methodology Applications and Modes of Use

- to provide goals that encourage the development of energy-efficient commercial buildings during design
- to provide a final whole-building energy target based on the design criteria, constraints, and economic perspective arrived at through the design process.

The overall Targets model must operate quickly to be effective in the target setting environment. Speed is required to accommodate the potentially large number of iterations required to balance energy, cost, and economic considerations as targets are set. The level of detail required in the input, in the analysis, and in the output may be somewhat less in this mode than in the design analysis/evaluation mode. However, the same input, analysis, and output modules must be used in both modes of operation to provide a consistent comparison of targets and design evaluation results.

Design Analysis/Evaluation Mode

The objectives of the design analysis/evaluation mode of use are

- to provide design professionals with a method of quickly analyzing the energy consequence of decisions made during the design process
- to provide a means of measuring progress toward meeting the design target
- to provide a final whole-building evaluation of the building design's energy efficiency and cost-effectiveness.

The Targets model may have to analyze a broader range of design options in the design analysis/evaluation mode than in the target setting mode. Additional capabilities will be needed to accommodate analysis of features such as ventilation. External procedures and analysis modules must be consistent with those used to set the target.

The specific objectives in the use of the Targets methodology for target setting and in design analysis/evaluation are different in the voluntary application than they are in standards and codes applications. However, the same set of simulation and analysis tools, and the same procedures are used in both applications. Neither application will be complete without both the target setting and the design analysis/evaluation elements being functional.

1.4.2 Applications

Voluntary Application

In voluntary applications, the use of the Targets methodology will be motivated by a designer's (or an owner's) interest in designing an energy-efficient and cost-effective building. To serve this set of users, the energy model must be flexible, easy to use, and provide a quick response to the "what if" questions a designer (or, again, an owner) might pose. In this application, the Targets methodology must provide information of sufficient value, easily enough that the designer will choose to use it.

In the voluntary application, the Targets methodology will serve two important roles. They are

- setting a design target - to define a performance level that will serve as a goal during the design process
- design analysis/evaluation - to provide pertinent information on the impact of design decisions on the energy efficiency of the building at the several points in the design process where those decisions are made, and to facilitate a final evaluation of the simulated energy performance of the building design.

The steps in this process are illustrated in Figure 1.2. It should be noted that there are several points in the design process at which targets might be set to provide guidance and the design evaluated to check progress toward meeting the target. The user input to the target setting mode is limited to those items that constrain the design, while the input to the design analysis/evaluation process is open. The input to both the target setting and the design analysis/evaluation modes may change as more information is available to define design constraints and desired design characteristics. Therefore, several stages of target setting and design analysis/evaluation are shown in Figure 1.2.

Standards and Codes Application

The Targets methodology will also be applied in the development of building energy standards and codes. In this application, the Targets methodology 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). Second, the methodology might be used by a governmental entity, or by a corporate or institutional owner, to set targets and demonstrate compliance 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 methodology 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. Third, the methodology may be used in the development or revision of prescriptive or component performance types of codes.

Figure 1.3 illustrates the application of the Targets methodology in the first two of these standards and codes applications. It should be noted that these applications are very similar in form to that in the voluntary case.

Although it is not the function of this project to develop specific standards and codes, it is understood that DOE intends to use the Targets methodology to develop specific codes and standards for federal buildings. In such a case, the target setting mode along with a fixed set of clearly defined building design constraints would be used to define targets for specific federal buildings. The design analysis/evaluation mode would then be used to determine if a particular building design meets its specific target.

ARCHITECTURAL DESIGN PROCESS

Figure 1.2. Voluntary Application of the Targets Methodology

Figure 1.3. Standards and Codes Application of the Targets Methodology

2.0 Approach

2.1 Project Organization

The development of the Targets methodology is being funded by the U.S. Department of Energy through the Pacific Northwest Laboratory (PNL). The ASHRAE, AIA, and IES have assembled a management and technical team to direct this development. The project is being managed by a core team consisting of members selected by ASHRAE, AIA, and IES and representatives from PNL. Members of the core team and a number of additional PNL staff are also directly involved in various aspects of the research and development process. Consultants with specific expertise have also been engaged to provide review and to undertake specific research and development tasks. The individuals participating in the concept stage of the project are acknowledged in Section 7 of this report.

2.2 Project Phasing

The Targets project is being conducted in two phases: Phase 1, Planning, and Phase 2, Development. Phase 1 was completed in 1987 and is documented in a two-volume report, *Development of Whole-Building Energy Design Targets for Commercial Buildings - Phase 1 Planning* (Crawley et al. 1987a,b).

The Phase 1 report presents the research effort to plan an approach for a methodology for setting whole-building targets. In Phase 2, the objective is to develop in detail the methodology identified in Phase 1. This report presents a summary of the results of the Phase 2 concept stage work.

3.0 Results

The concept stage work has been a critical step in the development of the Targets methodology. This effort has provided a blueprint for the development, implementation, testing, review and application processes to follow. In this stage, the Targets concept was defined in detail. Overall project goals and objectives were refined, and specific objectives were defined for each element of the methodology. Carefully defined data taxonomies were also developed for each element.

The refined project goals and objectives and the definitions of the specific objectives of each element of the Targets methodology were presented in Section 1 of this report. The results reported here cover the primary effort in this stage of the project, which was to define the detailed structure for the overall Targets model and for each of its elements. The objective of this task was to define appropriate structures for

- the overall Targets model
- the user interface module
- the input module
- the characteristics development module
- the set selection module
- the energy module
- the building cost module
- the energy cost module
- the economics module.

In the concept stage, the overall structure of the Targets model was defined. Structures were also defined for each of the modules. However, the level of detail developed differs from one module to another. The concept of the user interface has been clearly defined, but the structure at the software programming level has not yet been developed. This holds true, to some extent, for the input, characteristics development, and set selection modules. In the case of the energy module, criteria have been defined and a public domain energy simulation tool has been selected for use in the development stage of the work. The energy model selected will, however, require a number of modifications before it will meet Targets methodology needs. Conceptual structures for the energy cost and economic analysis modules have been defined, and specific existing models have been selected for development purposes. Like the energy model, the energy cost and economic models selected will need to be modified to meet Targets methodology requirements. A conceptual structure has been proposed for the building cost module. However, there are no public-domain building cost models from which to begin, and this module will have to be developed within the project. This will require a considerable effort, and there is some concern as to whether it is feasible. If the time and resources are not available to develop this module, a somewhat less ambitious Targets methodology may have to be considered, one based on energy and energy cost that did not require definition of the specific cost impacts of individual design decisions.

The results of the concept stage work are summarized in the sections that follow. More complete descriptions of the results in each of the major task areas are contained in Volumes 2 and 4 of this report.

3.1 Targets Methodology Structure

The objective of this activity has been to define both the overall structure of the Targets model and the detailed structures for each of its elements. As such, this activity has been the major challenge of the

concept stage; it is the largest activity within this stage of the work and has consumed the bulk of project resources. Alternative structures for several elements of the Targets methodology have been evaluated.

Because of its size and complexity, this activity has been divided into several parts, with separate (often overlapping) teams accomplishing the technical work for each part. During the first part of the concept stage, the project core team examined alternative approaches for the overall structure and for each element of the Targets model. Only after a lengthy examination of the issues were specific approaches selected, consultants engaged, or detailed development initiated.

In the case of both the energy module and the building cost module, the project team was particularly anxious that appropriate development approaches be defined. Thus, panels of experts were convened for 2-day review meetings in each of these two subject areas. The input from the experts at these workshop meetings provided a valuable basis for selecting development directions for both energy and building cost elements of the Targets model. These workshops are summarized in Volume 3 of this report.

The following subsections describe work accomplished in each of the major technical areas of the methodology.

3.1.1 Overall Structure of the Targets Model

The Targets model is an integrated structure consisting of five elements: the user interface; the characteristics development module; the set selection control module; and the energy, building cost, economic analysis, and energy cost modules. This structure is shown in Figure 3.1, which indicates the interactions between these five elements and various database and project files. The project files, shown on the left, are unique to a specific project. The database files, shown on the right, contain data that are to be available for all project analyses. The user interface is the entry point into the model, and it, along with the input module and characteristics development procedure, provides the control logic for the process.

Initial user data entry is accomplished through the user interface. The effectiveness of the user interface in facilitating initial data entry is critical to the project, and the development of this module will be one of the primary tasks of the development stage of this work. Data entry through the user interface will provide a complete definition of the intended function of the building project and those factors that will constrain the design process and drive the analysis procedures. Input describes location, site constraints, the intended function of the building and the space within the building, operating hours and patterns of occupancy, anticipated internal load levels, and any other factors (e.g., quality, amenity, comfort) that may constrain the design. The user will also input data to define energy cost and building cost criteria to balance energy and economic considerations. Users may also choose to consider multiple solutions to determine the range of energy efficiency that may be achieved under different assumptions about client perspectives on energy and project quality, and the client's willingness to consider the use of innovative technologies.

Once initial data entry has been completed, the input module prepares data for the other modules and passes program control to the analysis control and search routines in the set selection module. These modules carry out a variety of analysis functions, depending on the mode of use and/or the request of the user. The analysis control module directs the sequence of the analyses conducted by the various elements of the Targets model. It also directs the execution of individual modules: energy, energy cost, building cost, and economic analysis modules. In some modes of operation, the output from these modules will be processed back through the analysis control module and used to define additional analyses that may need to be performed to define the target or complete the design analysis/evaluation.

Figure 3.1. The Overall Targets Model

A key element of this data entry, and the set selection process that follows, is the specification of the factors that define the characteristics of the individual spaces, the lighting and thermal zones, and the building as a whole. This occurs in the characteristics development module. The specific description of a building's characteristics is composed of input factors that range from the specification of the function of a space and its geometric layout to such elements as the dry bulb temperature and relative humidity required to maintain thermal comfort and the illumination levels required to maintain visual comfort and to provide a productive environment within a space.

The need to define a target or conduct a design analysis/evaluation in a reasonable time sets some limits on the number of factors that may be considered. The space function concept was developed in Phase 1 of the Targets project to minimize the effort of identifying and classifying the pertinent factors. Specific sets of factors, predominantly associated with thermal and lighting requirements, are identified for each space function (such as classroom or conference room). These factors are referred to as characteristics. The characteristics may be specified directly by user input, taken from a consensus database, derived from several other factors, or, in some cases, derived from whole-building specifications. Characteristics represent the basic input that will ultimately define building components, energy use, and building and energy costs (by virtue of their interactions in the energy and cost modules). Space function characteristics will be aggregated to define the characteristics of thermal or lighting zones and ultimately to define the characteristics of the whole building.

As an example of how the space, zone, or building characteristics may be defined, consider a set of factors relating to details such as the color and distribution of light sources appropriate for specific space functions. The factors initially defined might be combined, along with other parameters related to aspects of the operations of light sources, into a characteristic called a source/ballast factor. This characteristic would have a range of values and an associated range of costs. One value for this characteristic would be initially selected by the analysis controller and combined with discrete values for other related and unrelated characteristics, which together comprise a characteristic set.

A characteristics set fully describes one of the possible options for the energy characteristics of the building. Design criteria and default values are translated, or developed into characteristics by the characteristics development module. In the target setting mode, this set will be the first considered in an iterative process of search and analysis, in order to find a set that achieves the objectives of the design in terms of function, acceptable energy use, and, for example, the lowest energy-related owning and operating costs (EROOC). In the design analysis/evaluation mode, the characteristics set would be defined by the user's preferred design specifications. This set will be analyzed directly by the energy, energy cost, building cost, and economic analysis modules. The results will then be compared with the target values. The search routine module is an important element in this process. It is used to select alternative combinations of a building's physical and cost characteristics and to identify and select those combinations of characteristics that would define a cost-effective, custom target for a specific building.

The characteristics sets are used to drive the analyses of energy, energy cost, building cost, and economics. In the target setting mode, the results of these analyses are evaluated, new characteristics sets defined, and the analyses repeated until the building project objectives are achieved at acceptable levels of energy use and cost. At this point, the target is set. In the design analysis/evaluation mode, a user-defined characteristics set is used to drive the analysis modules and determine if building performance meets the target and if the energy use, energy cost, building cost, and economic analysis results are acceptable to the client. This will be an interactive and, most likely, iterative process.

The results of the concept stage efforts to define the structure and characteristics of each of the Targets modules are described briefly in the following sections. More complete discussions are contained in the task reports presented in Volumes 2 and 4.

3.1.2 User Interface Module

The primary objective of the user interface is to simplify the use of the Targets methodology. In this pivotal role, substantial effort has been, and must continue to be, invested in its development. The success of the user interface in providing an easy-to-use, interactive input and output mechanism will largely determine the success of the entire Targets methodology. The user interface will also be an important tool for demonstrating many targets concepts during the development process, before the Targets methodology has been completed.

The user interface must allow the user to select options and to direct the flow of activities throughout the entire Targets methodology. It must provide a consistent and transparent connection between the user and the several different analysis modules of the Targets model. A user must be able to generate or modify inputs to each of the Target modules, run an analysis, and call up and review results from within the user interface module. The user interface is thus the focal point for the host of interface and integration issues that must be resolved if the Targets methodology is to succeed. Addressing and resolving these issues is difficult. Therefore, the development of a conceptual definition of the user interface structure has been a major effort in the present stage of this work. It can be expected that the user interface will require considerable attention during the development stage as well.

User Interface Concepts and Attributes

A number of the attributes that a successful user interface must have were defined early in this stage of the project. These desired attributes have guided the conceptual development of the user interface structure. The first and foremost requirement is that the user interface be easy to use. In addition, it should be highly graphical, accommodate different user skill levels, have extensive context-sensitive defaults, have default values and use options that can be modified (customized) by the user.

The structure of the user interface was developed in parallel with a series of "demonstration screens" that illustrate the user interface concept proposed for the Targets model. At this point, some portions of the user interface structure are more complete than others. A number of the demonstration screens will be used here to illustrate the basic concepts that have been developed. A more complete description of the proposed user interface is contained in Volume 4 of this report.

Two example buildings have been used in the development process. A small office building example has been used to explore how the user interface would work with a relatively uncomplicated project. A large, more complex building (a multifunction conference hotel complex) has also been used to test a number of the concepts developed. Using the complex building forced the development process to grapple with a number of difficult input and output problems that would have been missed if only the simple building example had been used.

Three user interface products were developed during this stage of the project:

- a proposed structure for the user interface
- three sets of user interface display screens that illustrate user options and show inputs to and outputs from the Targets model
- examples of several screen presentation formats that were examined, and examples of the format recommended for demonstration purposes.

The user interface must be easy to use. To accomplish this, it must have a clearly defined structure. The structure proposed is based on a data classification scheme (taxonomy) that can be used throughout the analysis modules as well. This taxonomy provides a logical structure for sequencing the operations and elements of the Targets model within the context of the user interface. Extensive coordination has been done to make sure that the user interface taxonomy is consistent with those being developed for organizing the building physical characteristics data (used in the energy simulation module) and the building cost data.

In each case, draft materials from these other work elements have been used to coordinate the development of a single, integrated logical data structure for the user interface, building characteristics, and building costs.

User Interface Operations. Three sets of computer screen displays that demonstrate the use of the user interface were developed. All three address the voluntary building design application of the Targets methodology. The first two address the target setting mode, while the third addresses the design analysis/evaluation mode. The three sets of screen displays are as follows:

- **Target Setting Mode for a Small Office Building** - This display sequence demonstrates how the Targets model can be used to set a target for a building design with very little input, through the extensive use of default options, systems, and data values. It also provides an example of a fairly complete use sequence of proposed user interface features.
- **Target Setting Mode for the Optima Building** - This display sequence illustrates some of the features that can be used to customize input data and to address subtleties that can be involved in setting a target for a large, complex, multifunction building.
- **Design Analysis/Evaluation Mode for the Optima Building (partial)** - The third display sequence illustrates some of the options available for specifying building design features during a design analysis use. Two separate sequences are shown, one for the specification of a fenestration system and another for the specification of a lighting system. This is not considered a complete design analysis sequence, but it does demonstrate a number of important proposed capabilities.

A few of the screen displays are presented here to provide a quick means of illustrating a number of important user interface concepts. The user interface attributes illustrated are

- the use of a graphic interface
- the use of defaults to minimize input requirements
- the ability to customize the defaults
- the ease with which the user interface can be used.

In these discussions, numerous related concepts are also touched upon.

Graphic Interface

The user interface is intended to be primarily graphic, both for input and output. However, the graphic emphasis will not be at the expense of standard text entry, which will also be available as an option. The graphic emphasis has a strong advantage: it is easier to grasp than extensive text and numbers.

Several types of graphic displays are proposed for the user interface: menus, input and output graphics (including patterns for handling building geometry and zoning), and icons. The graphic interface

will be easiest to use with a mouse or similar pointing device. Further, the authors anticipate that the user interface for the Targets model will be able to be linked with one or more computer aided design and drafting (CADD) systems in the future. Such links will greatly increase the graphics capabilities of the Targets model.

Menus. Figure 3.2 shows a sample display screen containing the proposed summary output from the Targets model. As illustrated, the user interface screen is divided into four major areas:

- **TREE menu** - The TREE menu in the upper half of the menu bar on the left of the screen indicates the user's current position within the Targets model. The number of line items in the menu indicates the number of layers down in the hierarchy. The label on each line records the option chosen at each higher level to get to this point in the model (the EXECUTIVE level is the highest level in the model).
- **OPTIONS menu** - This menu section lists the current options available to the user. Note that the SUMMARY output option has been selected, and the summary output information is being displayed in the window to the right in response to the selection.
- **FILES menu** - This menu will display current files in use by the model (e.g., project data files, cost files). This part of the screen has not yet been detailed in any of the demonstration screens.

Figure 3.2. Summary Output Display Screen

- **Active Window Area** - In addition to the TREE and OPTION menus, the active window area can be devoted to additional menus, a compact means of providing many options to a user. This area of the screen presents current graphics, input options, or output displays, depending upon the current location within the Targets model. If the screen is blank, it means that the user needs to make a selection from the current OPTIONS menu. The user can interact with the window area of the screen in several ways.

Input/Output Graphic Display. Figure 3.2 is also a good display screen to use as a first example of input/output display, as it contains the proposed summary output from a typical use of the Targets model. In this case, the output shown describes an energy target as a result of using the target setting mode of the methodology. This can be done very early in a building design process, for example, at the beginning of the conceptual (or schematic) design stage. The data shown represent a target for a specific building design, based primarily on location, space function mix, and building geometry. The target results do not reflect the specific materials and energy systems of the actual design under consideration.

This proposed screen of Target model results is to present concepts only. For example, the screen presented shows only one solution to represent a target. However, a target might also be defined by a set of solutions. In this case, the screen might show multiple solutions for each bar, where the set of solutions forms a target range for the building design situation. The precise formulation of the target output will be determined in later stages of Targets methodology development.

The screen display contains considerable information about the intended products and formats of the overall outputs of the Targets model. From left to right in Figure 3.2, the screen display indicates the following:

- **loads, energy, and energy costs (bars 1-5)** - The first five bars on the left indicate how perceptions of relative importance of various building energy end uses can change, depending upon whether one is looking at loads, energy, or energy costs. In the example, for discussion purposes it is assumed that heating is done by gas or oil and that all other end uses are served by electricity.

Starting at the left, from a *loads* perspective (bar 1), heating, cooling, and lighting appear to be of equal importance. However, from an *energy* perspective (bar 2), because of the lower on-site conversion efficiency of typical heating equipment compared with cooling, heating appears to be more important.

Then, from an *energy cost* perspective (bar 3), the relative importance of heating and cooling appear to reverse, with cooling now appearing more important than heating, due to the higher cost of electricity compared with gas or oil. This last trend becomes even more pronounced from a *total energy cost* perspective (bar 5) that includes demand charges on electricity.

- **building costs (bar 6)** - This bar displays the magnitude of construction cost for the building.^(a) A breakdown of costs into energy-related systems is not shown, but this can be done much like the energy end-use breakdown (bar 2) or the total energy cost breakdown (bar 5).

(a) For details of the proposed approach to building costing, see Volume 2, Section 7, "Building Cost Module."

- economic objective function (bar 7) - This bar displays the magnitude of the result of the economic analysis, using one of several different economic objectives that a user may choose.^(a) The value for this bar is developed in the characteristics development module of the Targets model.^(b) The results from the total energy costs and from the building costs are inputs to the economic analysis.

Only annual energy costs are displayed. However, monthly energy costs (related to monthly demand charges) or even diurnal energy cost patterns (related to time-of-day rates) may be required as inputs to properly assess the economic function.

From a cost-effectiveness perspective, the value of this bar defines the energy cost target for the proposed building design.

A user can also choose to display these data as a table of numbers instead of bar graphs. Because all data shown on this and subsequent output displays are hypothetical, units have not been indicated in the vertical dimension of the graph.

Figure 3.3 shows comparative results for two buildings. It is similar to Figure 3.2, except that it shows output for the target of a specific building, established in the target setting mode of operation, compared

Figure 3.3. Output Display for Two Buildings

- (a) See Volume 2, Section 9, "Economic Analysis Module," for details of the alternative economic objective functions being considered for use in the Targets model.
- (b) This module is described in Volume 2, Section 3, "Characteristics Development Module."

with results for an actual design solution for that same building, established in the design analysis/evaluation mode. This ability to provide such comparative data is an important proposed output feature of the Targets model.

Another type of comparison possible in the design analysis/evaluation mode is shown in Figure 3.4. A user may want to do parametric analyses of several features of the building design (e.g., window area versus shading coefficient), and to compare loads, energy, energy cost results, or other parameters. This is a potentially powerful feature of the Targets model. Figure 3.4 shows a hypothetical set of outputs from such parametric analysis, in which the sets of results from analyses of multiple options (simulation runs) are displayed as points on surfaces.

An example of using the active window area to provide menu and status information is the SUMMARY screen shown in Figure 3.5. Typically, the available actions are obvious from the presentation within the active window area. This screen provides a status report of currently active options and default values for each module of the Targets model. This feature is important because default values are available for building features and costs, for analysis modules selected, and for the level of detail of analysis and outputs.

Figure 3.5 shows currently active choices for the four analysis modules that are used within the target setting mode and the level of detail selected for the use of each module. It also shows databases to be used with relevant modules. Such summary screens are intended to enable a user to quickly review which options and defaults are active and to quickly modify the options and defaults. Summary screens are proposed to be used many places within the user interface. This can be seen from a review of the proposed user interface structure, which is discussed in detail in Volume 4.

Figure 3.4. Parametric Analysis Output

TARGETS MODEL		ANALYSE SUMMARY	
TREE EXECUTIVE TARGET MODE TARGET SETTING ANALYSES		ENERGY MODEL: DOE 2.1 D TIME PERIOD: FULL 8760 HOURS COMPACTED - MEDIUM COMPACTED - SHORT	
		FORMAT: TRY LOCATION: WASHINGTON, DC	
		ENERGY COST MODEL: DOE 2.1 D DATABASE: STANDARD DEMAND - DC	
		BUILDING COST MODEL: SUMMARY DETAILED	
		DATA BASES: MEANS DOOGE SUPPLEMENTARY	
		ECONOMICS OBJECTIVE: ERGOC MODEL: ANSI STANDARD	
OPTIONS: SUMMARY ENERGY ENERGY COST BUILDING COST ECONOMICS HELP			
FILES:			

Figure 3.5. Active Choices for the User Interface Input

Figures 3.6 through 3.8 provide several examples of how building geometry, zoning, and the definition of space functions might be addressed. These figures are primarily displays of building floor plans. Defining information on building configuration and function is one of the most challenging parts of the user interface development.

Figure 3.6 shows a menu of typical building shapes from which the user can choose. In Figure 3.6, the T shape has been selected. The user can "drag" each edge of the shape chosen to alter the dimensions of the T; specify number of floors of this shape; or rotate the entire building or selected floors to a new orientation. From a user-convenience point of view, the importance of this type of concept is that many typical building geometries can be modified (which is easy) rather than generated from scratch by user input (which is more difficult and time-consuming). Although Figure 3.6 shows several different building configurations without regard to space functions, it is anticipated that the options available for selection will change. Thus, the typical building configurations that can be chosen will be context-sensitive. That is, different menus of building shapes could be presented, depending upon the type of building functions being considered.

Figure 3.7 shows several possible alternative thermal zoning arrangements for a floor of the T-shaped building. This thermal zoning feature will be particularly useful early in the design process. The user can choose from among several different possible thermal zoning situations to quickly provide input for an initial estimate of a target. The user can then alter the definition of the zone as the design progresses. Changes can be made by dragging zone boundaries, much like altering the floor plan dimensions selected in Figure 3.6.

Figure 3.6. Typical Building Shapes

Figure 3.7. Thermal Zone Arrangements

Figure 3.8. Assignment of Function to Thermal Zones

Use of Defaults

Figure 3.8 illustrates the underlying philosophy of the Targets methodology--the use of space functions as the basis of organizing data for analysis. A list of space functions is shown under the OPTIONS menu, from which the user may choose a space function name to assign to each thermal zone on the floor plan. The list of space functions in the menu will be context-sensitive; that is, the items in the list depend upon previous selections made by the user.^(a) Assigning a space function to a specific space brings in a set of default data. The data in this set can range from specifications for comfort criteria, to schedules, to system parameters (e.g., for the envelope, lighting, HVAC systems). The data in this default set can then be used in the energy and cost analysis modules, or the data can be modified (or customized) as needed.

The series of choices illustrated in Figures 3.6 through 3.8 represents the selection of large amounts of data. In the extreme limit, the process described would permit a virtually "data-free" use of the Targets model, in which the user could define analysis parameters simply by making choices among available

(a) A building's target will be based upon space function characteristics, not upon building types. For example, in screen display sequences, the user is asked to designate the building category, type, and subtype. This is not so that a target generated will be related to the building type selected. Rather, the building type choice simply provides a means for presenting to the user the most appropriate context-sensitive choices and defaults for building configuration, zoning options, and space function alternatives.

options. The success of this proposed approach will depend primarily upon two features: 1) the robustness and appropriateness of the choices available at each step of the process; and 2) the quality of the default data assigned to the choices made. It is intended that both of these features will be created through an in-depth, consensus-based development process involving knowledgeable people throughout the buildings community.^(a)

A similar example involving a more complex building is discussed in Volume 4 of this report. The more complex example has been useful, in that handling a higher level of geometric complexity has pointed out the complexity of the overall process and assisted in refining the proposed concept.

The displays shown in Figures 3.2 through 3.4 are proposed as the "default" level outputs from the Targets model. A user can, if desired, request progressively more detailed output to the limits of displaying all the data stored for the analysis. This feature is considered important because it permits default output to be simple, yet allows a user to interactively explore details if necessary. Such exploration is often necessary for troubleshooting, for research purposes, or simply to determine the basis of the summary results. Several figures in the task report in Volume 4 provide examples of how such output detail might be accessed in layers. The examples are for the energy simulation outputs, but the same concepts apply to other elements of the output (building cost, energy cost, and so on). The screens developed to date in the concept stage for this feature only scratch the surface of the potentials for this output facility.

Use of Icons

In desktop computing environments, icons have become a widely used means of referencing objects and classes of objects.^(b) Icons are also very useful for identifying user decision options. Icons are also excellent options for referencing building elements, because buildings are conveniently described via nested sets and subsets of objects (e.g., envelope, wall, fenestration, glazing, framing, shading devices). CADD systems typically have object-oriented structures that make extensive use of icons to reference objects.

Figures 3.9 and 3.10 show two steps in a process of selecting a lighting system and for choosing specific characteristics. These two screens are extracted from the sequence contained in Volume 4, Appendix C. The sequence illustrates selecting and defining the characteristics for a lighting system during the design analysis/evaluation mode analysis of the hypothetical Optima Building.

Figure 3.9 shows icons (and names) for 10 general fluorescent lighting fixture categories. The Wallslot or Wallwash option has been selected by moving the arrow cursor to the icon and selecting it via mouse or keyboard. This is indicated both by the shaded highlight over this icon and by the cursor arrow pointing at the icon. A user wishing to select a different option could simply move the cursor to another icon and select it instead.

An important feature of these icons is that they are not just pictures but are pointers either to other sets of objects or to sets of data that describe the physical features of the selected item. Thus, in choosing an icon, the user is also choosing data that will be automatically assigned for use by the various analysis

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- (a) Still, no matter how good the thinking imbedded in the defaults, users must be able to access, review, and modify both choices and defaults to suit their specific needs.
 - (b) Starting in sequence with the Xerox Star™ project, then the Apple Macintosh™ and Microsoft Windows™, icons have become increasingly widespread as increasing display screen resolutions have permitted widespread use of graphic interface displays.

Figure 3.9. The Use of Icons

Figure 3.10. Icons to Illustrate Option Details

modules of the Targets model (e.g., an energy simulation model or a building cost model). The example shown is in the context of an analysis of a building being designed, and the user is specifying the characteristics of a desired lighting system. In the example, the selection of the Wallslot or Wallwash fixture provides a pointer to three different types of such fixtures.

During the target setting mode of use of the Targets model, the user will not need to specify systems to be used. Default systems and parameters will be defined for typical space function choices. Thus, when a user defines a particular floor area to be a space function of "open office with low partitions," a set of building systems and/or system physical and cost parameters is automatically chosen by the Targets model. In a voluntary mode of using the Targets model, a user may be able to examine and select or modify some, or all, of the defaults selected.

Figure 3.10 occurs somewhat later in the script sequence. It is one of several screens allowing the user to select among optional parameters for the fixture type selected. In this case, a three-level time clock switching control has been selected from among the control options indicated by the icons. The OPTIONS menu at the left is not intended to be complete, but indicates that different types of lighting fixtures could be selected (fluorescent has been highlighted). If another type were selected, then a different array of icons would appear, indicating a different set of options.

Ease of Use

The preceding discussion indicates that availability of default data is critical to ease of use. As indicated, the intent of the proposed user interface approach is to provide defaults for virtually all inputs, allowing, in the limit, a data-free user environment for the first pass through the Targets model on a given building project. This includes defaults for most user inputs beyond the initial specification of design objectives and design constraints, for building configuration, for analysis specifications, for output formats, and so on. The sequence of Figures 3.5 through 3.7 and Figures 3.9 and 3.10 exemplifies how the user interface provides access to large amounts default data that can be used, or modified, with a minimum of user input. The default data files are therefore critical to the success of the user interface.

The consensus-based default files provided with the Targets model are expected to be "read-only" files. However, a user can copy and edit these files to generate a new set of "customized" default files that reflect the specifics of the user's building design practice or an owner's specifications. The user can then save these data and configure the Targets model system to automatically use the customized default files instead of the files originally provided.^(a) This is considered a powerful feature of the proposed user interface method.

The concept of customized defaults can be extended from data and options to also include the criteria that establish energy targets within the proposed Targets model. The criteria that will establish targets levels will consist of sets of available input data defaults and sets of constraints on the operation of the targets optimization routines in the target setting and the design analysis/evaluation modes. A set of defaults and constraints will define a target version X that can then be customized to a specific building by its application to the building's data; customized defaults and constraints can be generated and stored in user-specified files much like other default data. These files then become the source of custom target versions that are then available for use with the model.

(a) It may be necessary to set some limits on modifications to certain defaults that are to be used in the target setting mode. Such limits may be especially necessary within codes and standards applications of the Targets model.

To provide an example of how this might work, assume that when the Targets model is completed, it is well received, and a number of organizations develop custom target levels for use with it. Consider the following scenario:

- ASHRAE, IES, and AIA collaborate to develop a new version, A, of a whole-building energy performance path as part of a consensus energy standard (say, a future revised version of Standard 90.1-1989). The procedures would be as follows:
 - The specifications of this "standard path" would be described via sets of data defaults and constraints on the operation of the Targets model in the target setting mode.
 - These defaults and constraints would be contained in computer-stored files available to the Targets model.
 - Then, if a user wanted to generate a custom target for the building that reflected the ASHRAE/IES/AIA criteria, the user would access the ASHRAE/IES/AIA Version A target files when using the Targets model.
- Several federal agencies (e.g., the U.S. Department of Energy, U.S. Army Corps of Engineers, U.S. Postal Service, or General Services Administration) define target versions (B, C, D, E) by specifying sets of defaults and constraints that apply to the design of their buildings. These could also be installed as files in the Targets model. Then, for example, a future user designing a post office would access the postal service version target files when using the Targets model.
- Likewise, large corporations with an active building design program might define target objectives for buildings to be designed for them by developing their own versions of target files for use with the Targets model. A user could then access versions of target files for, say, General Computers, or United Insurance.
- Building design firms could also create, store, and use their own versions of target files of defaults and constraints that together define the objective of energy practice for each firm.

In a sense, all of the above organizations are "users" of the Targets model. Each organization uses the methodology to establish general versions of default and constraint files that define targets. These general target-defining files can then be applied to specific building design situations within the organization to provide custom targets reflecting the specific economic and design criteria and constraints. Some organizations may wish to further tailor the behavior of the Targets model by specifying certain specific building types and characteristics. For example, the postal service might define about six building types that describe its typical building stock and, consequently, have six versions of customized target files.

The graphic interface will be especially useful for learning to use the model. However, text modes of data entry are often faster for very experienced users (e.g., an experienced Lotus 1-2-3™ user will often hit a series of well-known keystrokes for commands without ever looking at the program's menu structure on the screen.) Likewise, an experienced energy simulation tool user may be much more comfortable with tables of numbers than with bar charts. The user interface will permit rapid moving among various use options, to provide for such differences in skill level and preference.

Ease of use is the overriding objective of the user interface. All of the above concepts have been developed to address this objective in one way or another. In summary, a few key concepts are repeated for emphasis:

- The user interface will be structured to allow the Targets model to be as data-free as possible, so that it can be used with very little time spent during early stages of the design process. The proposed means of doing this is to keep required inputs to an absolute minimum through the extensive use of context-sensitive defaults.
- Another approach is to "hide" input data until a user wishes to view or change it. The intent here is to make each part of the model appear simple, until the user needs to use the depth of data available. It is important that users be able to control data input options, design options, and data output options.

Actually achieving ease of use of the user interface will be a major challenge in the next stages of development.

3.1.3 Input and Characteristics Development Modules

One of the primary objectives of the work performed in this stage of the project was to develop a viable framework or conceptual classification system to organize the data used throughout the Targets methodology. This taxonomy was to be broad enough to include not only input data related to the energy simulation module, but to be applicable from the user interface through the characteristics development and building costs modules. The second objective was to define all the steps within the methodology required to move from raw input data to sets of characteristics appropriate for use by the control functions or search routines for analysis. Finally, and no less important than the first two objectives, an adequate way of dealing with qualitative issues relating to design, which are frequently difficult to quantify, needed to be addressed.

The first two modules used within the Targets model are the input module and the characteristics development module. These modules are described in detail in Volume 2. The input module will be described here very briefly. Input procedures are inherently tied to issues pertaining to the user interface and have been described more completely in Section 3.1.2. The characteristics development module will be discussed more fully here. This module handles a variety of activities that are required after the initial entry of project data for a specific building and before using the analysis control and search routine modules to select the set of characteristics on which the target will be based.

Input Module

The type and extent of the data that must be entered to begin an analysis may differ, depending on whether the user wishes to use the target setting or the design analysis/evaluation mode. The level of detail, or degree of accuracy, of the input data will also depend on the point in the design process at which the Targets model is being used. An extensive library of defaults planned for the input module will enable the user to use the methodology even during the architectural programming phase. There will, of course, be a minimum amount of input required to use the model. This minimum corresponds to a theoretical point at which a building description becomes that of a specific building, appropriate for establishing customized targets, instead of a general reference building.

Characteristics Development Module

This module serves the function of bridging between user input and the control of the analysis procedures within the Targets model. In particular, the many factors compiled by user input and default databases must be manipulated into a grouping of characteristics, each set of which forms a description of a building's energy-related design, so that the sets can be ranked by cost-effectiveness (during the target setting mode), or analyzed (during the design analysis/evaluation mode).

The following group of functions, not necessarily related, comprise the characteristics development module:

- the consolidation/summation function, which handles the input and database information relevant to the specific project
- the characteristics development algorithms, which translate input and default factors into characteristics to be analyzed or optimized
- the verification and evaluation function that identifies and resolves inconsistencies between input data and data generated by the characteristics development algorithms
- the qualitative aspects and priority energy use function that maintains criteria set to ensure specified levels of comfort and amenity
- the path function that directs the passage of data through the module
- the preselection or screening functions used to eliminate options and narrow boundaries for the sets of characteristics to be optimized, based to some agreed-upon rule-based algorithms.

Realistic and acceptable targets must address the priorities of the owners, or developers, in investing in a building project; the objectives of the design team; and the needs for occupant comfort, well-being, and productivity. These concerns relate to both the cost and benefit sides of economic and energy use calculations. However, they are often difficult to quantify, and sometimes difficult to define, even by consensus. One objective of the concept stage has been to examine this problem, identify specific issues, and explore some options for dealing with quality-related criteria in the Targets methodology. However, a specific methodology was not developed during the concept stage.

Taxonomy

The Targets taxonomy is a logical structuring of information which provides a framework for input data, integral databases (e.g., cost, weather, schedules, comfort criteria), generated data, and graphic interface data utilized by the all the modules in the Targets model. It 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 model might be used.

Three separate taxonomies were developed during the concept stage work: one for the user interface, one for the characteristic development module, and one for the building cost module. These taxonomies were then combined to provide one uniform procedure for classification throughout the Targets methodology. This overall Targets taxonomy is discussed briefly below and in detail in the task reports documented in Volume 2.

Organizational Units: Levels of Hierarchy. The primary level at which the Targets model addresses a building is at the space function level. There are specific sets of thermal and lighting requirements associated with each space function that lead to the definition of space characteristics, a thermal or lighting zone, or a building. These characteristics are the inputs to the Targets model's analysis modules. 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. Thermal function focuses on the characteristics traditionally addressed in thermal energy and peak load analyses, while lighting function may include more detail, such as practical partition height or requirements for an individual visual task.

A building category-type-subtype hierarchy is also used to carry information and describe characteristics at a whole-building level. These data are provided to permit quick identification of many different types of building configurations, costs, schedules, and thermal zoning layouts for the initial input and to speed up user/model interaction. The selection of a building's category, type, or subtype in an analysis does not constitute sufficient or even necessary information for actually generating the custom targets. The custom targets are based, for the most part, on decisions made at the space function level. At the thermal and lighting space function level, the building is broken down to an individual space, or group of similar spaces, to generate the custom targets. The space function analysis results may then be combined into zones, floors, or buildings.

The initial data input contains the following:

- project description
- basic project information
- geometry
- functional parameters
- building systems.

Basic Input Linkages. In the appendixes to Volume 2, linkages are drawn to show basic connections within the taxonomy and exhibits. These are based on relationships that will allow the program 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 whether user inputs create an energy-efficient combination. Later, in the characteristics development module, higher-level linkages would bring energy-related technologies and design strategies into play, to reveal inconsistencies or to recommend specific design options.

Minimum Inputs Required. A building's target cannot be generated based on a designation of building type, such as office building, retail mall, or school. The entire methodology uses the space function (e.g., conference room, hotel guest room, cafeteria server) as the core unit, in order to achieve the goal of truly customized targets. This approach also avoids oversimplifications based on typical buildings of a particular building type.

At the very least, the user must describe or make assumptions about a number of aspects of a project's programmatic requirements, in order to generate a target during the target setting mode. Slightly more input is required as a minimum during the design analysis/evaluation mode, as the following list indicates.

<u>Target Setting Mode</u>	<u>Design Analysis/Evaluation Mode</u>
Location	Location
Orientation	Orientation
Basic exterior geometry	Basic exterior geometry
Space functions	Space functions
Basic interior geometry	Basic interior geometry
Schedules	Schedules
	Envelope construction (including fenestration)
	Lighting system identification
	HVAC system and controls identification

Note that more input may be entered, if known, but any less input ceases to describe an actual, specific building program or design. The intent of the Targets methodology is to establish custom energy targets for specific buildings. Minimum input requirements are discussed further in Section 4 under the topic of Issues. Extensive use of default options for ease of input is discussed under User Interface.

Default Data. The Targets model is dependent on a large system of databases and defaults that serve a variety of functions. These functions include

- objective databases containing weather data necessary for the operation of the energy analysis module
- databases related to comfort and function of visual and thermal environment, based typically on space functions, which are necessary to provide a consistency between buildings, and to preserve the quality of the environment for the occupants - The information in these databases will be a combination of first principles criteria and professional judgment.
- defaults related to costs and building design strategies or technologies defined in much the same way as consensus-based space function data
- a system of default databases and internal user interface rules to allow the user to move quickly and effortlessly through a very complex system - It is necessary to change only a few items, when desired, while leaving most values at their default settings.

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

The databases are the locations within the Targets model 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 minimum acceptable quality at one end and energy conserving aims at the other.

Technologies/Design Strategies (TDS) List. A basic list of energy-related technologies and design strategies (TDS) is located in Appendix E of Volume 2, which covers reasonable options, organized by area of impact. Options for improving building energy performance will most likely be identified and compared on the basis of energy and cost analyses. These comparisons may arise from both target setting and building design analysis/evaluation.

3.1.4 Analysis Control Module

This module will manage a variety of analysis functions depending on the mode of use and/or the request of the user. It will also control the flow of information between the analyses conducted by the various modules within the Targets model. During a building design process, its functions will 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 of the final design.

The analysis control module will perform a master control function for the analysis modules. This master control function will involve directing the execution of the energy simulation module(s), 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 processed back through the analysis control module and used to define any additional analyses that need to be performed. The analysis control module may also need to perform additional tasks during the development stage of the project for the validation of the Targets model.

3.1.5 Search Routine Module

This module will evaluate alternative combinations of a building's physical and cost characteristics, and will identify and select those combinations of characteristics that define cost-effective, custom targets for building designs. The selection of search techniques is an important step in the definition of the Targets methodology. The search routines are needed to identify energy-efficient and cost-effective design solutions. They will be used to identify one or more sets of building features--both physical and cost characteristics--that together define an economically sound energy target for a building design. In the target setting mode of operation, as an example, the search routine may select features based on their performance as measured by, for example, the total energy-related owning and operating costs (EROOC).

Steps in a Search Process

Within the context defined here, conducting a search is envisioned as a four-step process:

1. **Pre-Selection** - The purpose of this step is to perform the initial screening of characteristics and to weed out those that are clearly inappropriate. This screening process will depend in large part on the content of consensus databases.
2. **Select First Set and Run Initial Analysis** - This step has two purposes. It establishes 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, in order to save computation time. It also finds a starting point for a search routine that evaluates the extremes (best possible conditions for given characteristic) in order to rule out options that are clearly not viable, even under those ideal conditions.
3. **Select Subsequent Sets** - The purpose of this step is to move toward a solution to the search in the most efficient way, i.e., requiring the smallest number of iterations through sequentially selected sets to meet the criteria.

4. **Use Historic Information to Refine the Selection Process** - The purpose of this step is to use data generated from previous analyses (Step 2 or Step 3) to influence the direction of characteristic values to be used for subsequent sets, as well as to modify or verify information employed for procedures, and for search related data sources (such as libraries or modules).

Use of historical information is also an effective way to conduct a check on the reasonableness of the solution obtained.

Evaluation Criteria for Identifying Search Routine Alternatives

The following criteria have been developed for evaluating the suitability of alternative search methods for use in the Targets methodology:

- **accuracy** - The ability of the search routines used to produce accurate (and consistent) results must be determined. The selected routines may not be the most accurate available as speed is also important. However, their relative accuracy must be determined by comparison with the most accurate procedures applicable to the problem.
- **versatility and adaptability** - The procedure needs to work well over a wide range of variables. It is desirable that the search routines used be highly versatile and/or easily adaptable to future changes.
- **reliability** - This criterion has three parts:
 - **stability of the search** - The search routines on the whole must be stable and reliable; they must not terminate execution unexpectedly with a final result far from an optimum.
 - **replicability of results**
 - **sensitivity** - The sensitivity of the result to changes in costs and future costs can be very important, and is mathematically different from reliability.
- **execution speed** - At least one of the search routines selected needs to be fast enough for inclusion in a responsive, interactive tool. It would also be desirable to offer users the option of choosing either a fast or an accurate procedure or operating mode, depending on their specific analysis need (i.e., speed or accuracy).
- **hardware requirements** - The selected search routines need to operate within the desktop environment with reasonable disk storage and central processing unit memory requirements.
- **reasonable cost** - Initial development of the search routines and any required updating must be achievable within reasonable time and cost constraints. They should not exceed 10% to 15% of development stage resources.
- **public domain** - The search routines and software routines must be in the public domain.
- **understandable methods** - It is essential that the search routines be understandable from an engineering perspective.

Alternative Approaches

The following list indicates several categories of search routines that might be utilized in the targets selection procedure. Any of these options could be used within the Targets methodology for defining a set of characteristics that reasonably achieves the design objectives. The available approaches could also be used in concert with other methods. It is obviously not possible to describe all of the possible combinations of methods and their variants. What follows is therefore a somewhat artificial categorization of available approaches. The intention has been to describe the major possible directions. It is important to recognize that, in all likelihood, the most effective procedure will employ a number of these approaches in some combination. The categories are

- rule-based
- artificial intelligence
- iteration
- customized.

Data Sources

The selection of a data source is secondary to the search approaches outlined above. Any of the data sources listed below could be used with any of the approaches listed above. Data sources include

- libraries of search results
- libraries of energy response data
- models of search results
- response-surface models.

Evaluation of Methods and Sources

The authors feel that the best approach to defining search routines for set selection will most likely be a combination method, utilizing rule-based pre-selection, 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 then define the first set and determine the direction to move for subsequent sets by identifying approximate areas of potential characteristics. Next, user input economic parameters, including energy costs, would be examined. Fine tuning would use direct search methods to determine acceptable values considering both global and local variations in energy use and cost. The energy and cost modules would be used determine the acceptability of the results obtained during this fine tuning. These results would also be used to update the databases and recursively improve the customized search algorithms.

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 work, the authors feel that the use of energy response libraries would prove a better data source for the Targets model than response-surface models. It was felt that there was a greater likelihood that the libraries could be developed successfully and that they would prove more beneficial, given the resources available for development and maintenance. This is discussed in detail in Volume 2.

3.1.6 Energy Module

The Targets methodology defined in this project will require an effective, time-efficient, and accurate 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 methodology, and it must operate efficiently as a part of iterative, cost and economic analyses. It must also accomplish these tasks on an affordable desktop computer.

Determining which existing building energy simulation model might best be adapted to meet these criteria was one major objective of the concept stage. After considerable effort, including a 2-day meeting with a group of building energy simulation experts, the project team concluded 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 current microcomputers, 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 between space loads, systems, and equipment that must be considered if one is to develop a truly energy-efficient building design. However, it is also evident that it is not possible to develop an entirely new approach within the budget limitations of this project. Therefore one, or more, of the existing tools must be selected and modified to the extent required to meet project needs.

During the concept stage, a two-pronged approach was used to select a building energy simulation tool to use in the Targets energy module. The project team first developed a definition of those energy module attributes that would be required to meet the Targets methodology objectives. The development of this definition required extensive effort, both in Phase 1 and early in the concept stage work. Next, a number of alternative approaches were formulated and the team then sought the review and advice of a group of energy simulation experts. This group of experts met in March 1988 to review the energy module requirements and the proposed alternative energy module approaches and to provide advice.

Four criteria were identified for judging energy module performance: time, flexibility, consistency, and accuracy. Unfortunately, these criteria are often in conflict. In general, 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 data entry time. The challenge has been to try to find the balance between these criteria by defining and evaluating the following general and specific sets of requirements. Both the development and evaluation involved the Targets team, project consultants, and those attending the building energy simulation experts meeting.

General Energy Module Requirements

The following general requirements were defined as criteria. The energy module must

- be easily integrated into the overall Targets methodology
- be capable of providing both a full detailed analysis and an abbreviated, or compact, analysis
- be capable of providing distinct output of space loads (including the effects of variable space temperatures), system loads, and equipment (plant) energy use
- be sufficiently modular that the space loads, systems loads, and equipment energy use modules can be run separately as well as a unit

- contain systems and equipment modules that have the capability of building HVAC systems from selected components, rather than being tied to fixed system descriptions
- 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.
- 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 has to provide useful intermediate results at a high enough rate that the user does not lose interest while the calculations proceed. These intermediate outputs must 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. They are considered in detail in Volumes 2 and 3 of this report.

The Selected Energy Module

Based on the above requirements, advice of project consultants, recommendations from the energy simulation experts meeting, and the input requirements of other modules within the Targets model, the project team came to the following conclusions:

1. A single, consistent energy analysis procedure should be used throughout the Targets model.
2. A public domain program should be selected as the starting point for developing the energy module. A single module, to be part of the Targets model package, should be developed first. Hooks for external energy models, including private sector programs, should be developed as part of the Targets project.
3. The energy module should use a compact hourly analysis as the primary mode of operation, with an option for a full 8760-hour analysis at the user's discretion. Regression-based procedures should be used only in a secondary role, if used at all.
4. The selected procedure should have the capability of providing hourly output for a single day, or short series of days, as well as seasonal and annual summary output.

It has been recognized from the beginning that the perfect analysis tool did not exist. However, it was also clear that, because of limited project resources, an existing simulation tool had to be chosen. It was also clear that it had to be one of the public domain tools if there were to be any possibility of modifying the program to better suit project needs.

After careful consideration of the specific criteria and the recommendations discussed above and in Volume 2 and 3, DOE-2.1D was selected as the starting point for the development of the initial Targets energy module. This decision was made reluctantly, and only after extended discussion. A faster, more flexible, and more complete energy analysis tool would have been preferred.

DOE-2.1D was selected with the understanding that it needs to be modified to more fully meet the Targets methodology needs. This work should begin as soon as possible. These modifications will require considerable time and effort during the development stage of the work.

Modifications Needed to DOE-2.1D for Its Use Within the Targets Methodology

Once the energy module criteria had been defined and DOE-2.1D had been selected as the basis of the Targets model energy module, the project team's attention turned to defining future work in two areas: modification of DOE-2.1D and development of the compact analysis approach. It has been concluded that the following actions should be taken in the development stage of the project to adapt DOE-2.1D to the needs of the Targets methodology:

1. Develop an interface between the user interface and DOE-2.1D to provide the information necessary to run the energy analysis. This interface is necessary if the project is to succeed. Requiring the user to deal with the DOE-2.1D input directly would limit the usefulness of the Targets methodology.
2. Modify DOE-2.1D to provide hourly loads output that includes the effects of variable space temperature. This is necessary, as real hourly load and energy use data are essential for both design analysis/evaluation and the cost and economic analysis modules.
3. Evaluate DOE-2.1D systems and equipment algorithms and modify them as necessary to provide for more flexibility in defining systems. The systems and equipment modules must provide options for selecting individual system, control, and equipment components. The predefined sets of systems and equipment components in DOE-2.1C do not provide an adequate range of selection.
4. Convert DOE-2.1D for operation on a desktop computer. Develop a desktop computer version of DOE-2.1D that is in the public domain and can be modified for Targets methodology use.
5. Provide options for limiting the periods of analysis and to use simplifying assumptions at those points in the design process where speed is more important than precision.
6. Develop any new output routines that may be needed to provide the necessary hourly load, energy use, and system property data. This may require the development of a means of interfacing with database and graphics programs (or subroutines) to provide user-friendly output.

A meeting at Lawrence Berkeley Laboratory indicated that items 2 through 6 were possible and could, for the most part, be accomplished within a reasonable time period. Each of these modifications and recommendations from the DOE-2 development staff for completing them are discussed further in the energy module task report contained in Volume 2 of this report. Item 1, the interface with the Targets model user interface, will be more difficult, but is critical to the overall success of the Targets project.

3.1.7 Building Cost Module

The building cost module is a major component of the overall Targets methodology. Comparative building cost data must be available within the Targets model in order to make economic comparisons among alternative energy design strategies. These comparisons are one of the criteria for selecting the characteristics upon which the targets are based.

The starting point for the development of the building cost module differs from that for the energy module. A ready-made, public domain building cost model that will meet the needs of the Targets methodology does not exist. Available building cost models do not adequately handle cost estimating of energy-related building assemblies and systems. Thus, a model must be developed from scratch, or a major overhaul of a public domain cost model written for other purposes must be undertaken. Either option is a

major task. Consequently, the development of a proper building cost module for the Targets methodology will probably require a significant portion of project resources available during the development stage of the project.

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 and to permit economic comparisons to be made among the strategies. To accomplish this overall objective, the building cost module is expected to have two main functions: 1) accessing and manipulating cost information contained in existing databases and 2) evaluating costs of building components involved in alternative design strategies.

In the Phase 1 report, it was stated that the major effort to develop the building cost module would be required "to build or manipulate a data base of building construction costs to yield arithmetic expressions relating to the energy performance of building components to component costs" (Crawley et al. 1987b). In the concept stage, this basic approach remains unchanged and the major effort has been to develop this conceptual approach in further detail.

Three main activities have been completed during the concept stage. First, the project team formulated a basic proposed approach to the building cost module. Second, assistance and advice were sought from a group of building cost experts in a 2-day meeting. The feedback obtained from the cost experts attending was extremely valuable in determining a course of action for the building cost module conceptual development (see Volume 3). A major recommendation from that meeting involves the utilization of generalized "templates" to structure the access to, and manipulation of, cost databases. Third, based upon the input received from the experts, the approach to the building cost module was refined and detailed.

The main results produced from the concept stage work are

- criteria defined for the building cost module
- a proposed conceptual approach using a cost "template" structure
- a taxonomy for logically structuring and accessing the building cost module
- building cost examples, developed as vehicles for defining details of the template approach.

These results are summarized in the following paragraphs.

Criteria Established for the Building Cost Module

The building cost experts attending the building cost meeting were quite excited by the prospect of developing a building cost estimating package with the features proposed for the Targets model. They made a number of recommendations that they thought were important to proper operation of a building cost module within the Targets model:

1. 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 requires that
 - one or more databases of building costs be available within, or accessible from, the building cost module
 - expressions exist to convert cost data to cost estimates that relate to the specifics of the building, systems, components, design situation, and energy strategies involved

- multiple alternative cost estimates are available for comparing building assemblies, design strategies, or design technology tradeoffs.
2. The user should need to address only summary cost data and should not have to deal with cost estimating details, unless desired. This is especially important for cost estimating during the early conceptual and schematic design stages when a detailed description of each building system does not yet exist.
 3. If desired, a user must be able to review the full supporting cost data and calculation details, to provide confidence in the summary cost data normally presented.^(a) This includes an ability to review the constituent costs of building assemblies, design strategies, or design technologies, in incremental layers of increasing detail.
 4. Cost data must be "believable." The most acceptable form is historical project cost data that has been thoroughly reviewed by competent building cost estimators.
 5. Mechanisms/linkages should be provided to allow the user to access a preferred unit cost database, e.g., Means, Marshall-Swift, or a user's customized in-house cost database.
 6. The user must have full editing capabilities for all cost data and cost estimating methods, since many users will strongly desire to use their own tried and tested data and methods.
 7. A facility must be included to update all cost data, using either automated or semi-automated approaches.
 8. To prevent obsolescence, the user must have the capability to readily enter building cost data about new and innovative design strategies.
 9. The outputs should be formatted to clearly indicate that the results are very "soft" estimates, either by indicating a "reliability factor" for each cost item or by presenting the user with expected ranges of cost values (as opposed to a single dollar value).

Building Cost Module Applications

The building cost module will serve a distinct function within each of the two primary modes of use of the Targets model. In the target setting mode, the building cost module will be automatically accessed to establish the cost of alternative building energy design strategies selected by the analysis control module. A Targets model user will not be required to use the building cost module in the design analysis/evaluation mode (but can, if desired).

In the design analysis/evaluation mode of the Targets model, the building cost module has two purposes. First, a Targets user can compare the construction costs and economic impact of alternative energy-related design strategies for a building design or for a number of alternative 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.

(a) Note that precisely the same comment was made about the importance of providing full access to input/output details within the energy simulation model, for troubleshooting and for providing confidence in results. See Volume 3 for summaries of both expert groups' comments.

In the design analysis/evaluation mode, the Targets user has complete access to the building cost module data. New data can be added, or existing data sets modified, to reflect specific 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.

Existing Building Cost Databases and Estimating Methods

A survey of existing costing databases and cost estimating methods revealed that none provides the set of capabilities required for the Targets building cost module.

Cost Databases. Commercially available sources of cost data include F. W. Dodge, R. S. Means, National Price Service, and the Trade Service Corp. However, these cost databases do not provide the level of detail of cost information needed by the Targets methodology for most energy-related building materials, assemblies, and subsystems. Some proprietary in-house cost databases may have more detailed energy-related cost data than the commercially available databases, but their proprietary nature precludes public examination.

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. 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.

These existing building cost programs have been developed for the primary purpose of evaluating costs associated with constructing a building. None of these cost programs contains the set of specialized capabilities needed for the building cost module. There are other difficulties with the existing estimating programs. Some are written for mainframe computers and would need to be ported to a desktop computer

environment for Targets purposes. The use of commercial packages may also involve a purchase cost or licensing fee and provide only limited access to source code. Proprietary restrictions notwithstanding, the very high anticipated cost of developing a complete cost estimating method for Targets purposes is a strong incentive to explore the potential of modifying one or more of these proprietary programs for use within the Targets model.

Alternative Approaches for Developing a Targets Building Cost Module

The Targets team identified two alternatives that may best enable the basic building cost module criteria to be satisfied:

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

Each alternative has benefits and liabilities. Option 1 will specifically satisfy the Targets criteria, but will be very expensive. Option 2 is more limited in scope. It may restrict the Targets user, and while it will be less expensive than building a module from scratch, it will still be a major undertaking. A decision on which option to use has not been made at this time. Further evaluation of existing cost estimating programs, such as Costpro (which has an open architecture), is recommended. Such evaluations may indicate that pre- and post-processing capabilities can be developed to extend the utility of one or more of these packages to meet the Targets building cost module criteria. To date, most of the conceptual development has focused on the needs of Option 1. Only recently, the Targets team has felt that the time and cost of developing a cost module may in fact be prohibitive. Therefore, most of the discussion that follows focuses on developing a complete new building cost module for use with the Targets model.

Proposed Conceptual Structure for the Building Cost Module: A Hierarchical "Template" Approach

A conceptual approach for the building cost module has been developed that is based on a hierarchical structure of "templates." This concept was discussed at the building cost meeting held in Washington, D.C. (see Volume 3 for the meeting minutes) and has been developed in considerably more detail since the meeting. The proposed structure is modular to allow incremental development and future modification.

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 Targets building cost module. In a sense, the template structure acts as a "neutral" file format for organizing cost data that can be drawn from different sources.

Five key structural elements are used to develop a template. They are

1. cost data containing building material and labor costs and various adjustment factors
2. data rules to select and format specific cost data items - Functions as a preprocessor for the cost estimating calculations. Also contains 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.
4. **template rules** - A postprocessor for the cost equation calculation module, that 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** - A standardized format for the display of 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 layering of cost-related data in a hierarchical manner involves the separation of the large amount of cost data into small closely interrelated subsets of data. Generally, the user will be presented with relative total cost summaries of energy-related design strategies or technologies. In contrast, conventional databases are usually structured so that the user must search through lengthy lists of data before accessing the desired data value.

3.1.8 Energy Cost Module

Three products of the energy cost module task are summarized below. These products are discussed in detail in Volume 2.

Basic Requirements Identified for the Energy Cost Module

Basic requirements and criteria for the energy cost module were defined as follows:

- The algorithms should be in the public domain.
- The module should be able to utilize hourly energy results from a variety of public and private sector energy simulation programs as a direct input.
- The module should use actual local energy costs, rather than regional or national average costs.
- The module should address a wide variety of utility rate structures.
- The module outputs should reflect variations in annual, monthly, and diurnal energy costs (to address demand charges and time-of-day rates).

Selection of a Provisional Energy Cost Module

Based upon the above criteria, the energy cost module within DOE-2 was selected for use in the next stages of development of the Targets model. This selection is provisional, however, and the Targets project team will continue to seek to identify a better alternative.

Modifications Needed to DOE-2 Energy Cost Module

If the DOE-2.1D energy cost module is to be used, several modifications will need to be made to it to meet Targets methodology requirements. It must

- be extracted from DOE-2.1D and accessed as a separate module
- have the data input redesigned and coded to interface with the user interface and the energy module.
- have its algorithms refined and/or expanded to meet all of the detailed requirements of the Targets model operation.

Local Energy Costs

To minimize user input requirements, it is proposed that database files of local energy costs and cost structures be provided for use with the Targets model. The Gas Research Institute (GRI) has an annually updated national database of utility rate structures that is routinely maintained (e.g., Casazza, Schultz, and Associates, Inc. 1989). This should provide an excellent resource for developing sets of typical rate structures for use within the energy cost module.

The basic structure of the energy cost module has been defined in this stage of the project. The following steps are proposed for the next stages of development. The DOE-2 energy cost module should be adjusted to properly interface with the other major elements of the Targets model. The requirements list should be refined. A working prototype of the proposed energy cost module should be developed, tested, and thoroughly reviewed by a set of potential Targets users. Based upon feedback on this first prototype effort, the energy cost module should be extracted from DOE-2 and a file format developed to permit linking it with energy simulation tools other than DOE-2.1D. Sets of typical utility rate structures should be developed to access energy costs from one or more energy cost databases. The new features should be incorporated into a revised prototype, which will then be tested and reviewed by potential users. This would form a basis for final modifications. More detail is contained in the energy cost module task report in Volume 2.

3.1.9 Economic Analysis Module

One goal of the Targets methodology is to include economic considerations as an integral part of the target setting and design analysis/evaluation process. The economic analyses will have a central role in assessing cost-effectiveness of the targets. Output from the energy module, the energy cost module, and the building cost module will be used as input to the economic analysis module to derive estimates of economic benefits of alternative building design solutions.

The conceptual development of the economic analysis module has focused on the identification of

- possible owner economic objectives
- external measures to be imposed to assess economic performance
- issues related to owner economic perspectives, data needs, and default values.

However, the actual development of an economic analysis module has not been addressed, because calculations of economic benefits will occur within the analysis control and search routine modules of the Targets model,^(a) and because economic analysis models are already available in the public domain. It is expected that these can be adapted with minimal effort to the needs of the Targets model.

(a) Details of how these calculations might be performed are described in Volume 2 of this report.

Four products have been produced from the conceptual development effort:

- a list of basic requirements for the economic analyses
- identification of the types of economic objectives that the economic analyses should be able to address
- identification of economic indicators to be considered
- definition of approaches to economic perspectives and parameters.

Basic Requirements for the Economic Analysis Module

The following requirements have been identified for the economic analysis module:

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

Possible Owner Economic Objectives

Within the Targets methodology, economic analysis occurs primarily in the efforts to find the "best" ranges of solutions for a given objective.^(a) This section defines a set of formats for possible owner objectives to be included in the Targets methodology.

- EROOC - In Phase 1 of the project, based upon an examination of economic perspectives, the consideration of full energy-related owning and operating costs (EROOC) was identified as the most desirable economic objective to use. The use of EROOC has remained a primary objective of the concept stage of Phase 2.
- additional economic objectives - In Phase 2, an examination was made of what might constitute reasonable economic objectives of a building owner when using the Targets methodology in a voluntary mode. A number of additional economic objectives are seen to be needed as part of the Targets economic analysis to address building owner needs. Also, some owners may have energy objectives in addition to economic ones (e.g., public image) that emphasize energy

(a) For a discussion of the methods being considered for finding the "best" range of solutions, see Volume 2, Section 4, "Analysis Control Module."

conservation levels in addition to those levels justifiable purely on economic terms. In addition, some noneconomic objectives appear very useful for possible research and development uses of the Targets methodology.

Some statements of economic objective contain only partial economic data (building cost only, or energy cost only, or only energy use). The set of possible statements of economic objectives that have been identified is listed below.

Objectives That Consider Both Energy Cost and Building Costs:

1. *Minimize the energy-related owning and operating costs (EROOC) of the building to the owner.* This includes consideration of all energy-related costs of designing, constructing, and operating the building over an expected life of investment. Its main drawback is its complexity.
2. *Minimize the total life-cycle costs (LCC) of the building to the owner.* This alternative is very similar to the EROOC approach. The major difference is that in this approach all owning and operating costs are considered, not just those related to energy.
3. *Minimize energy cost, within an upper limit on construction cost.* Often, organizations (e.g., corporations, franchises, chain stores, government agencies) will set a not-to-exceed construction cost budget for a new building.
4. *Attain energy cost lower than a stated value, at lowest possible building construction cost.* This option is very similar to the previous one, but has a stronger emphasis on building construction costs.

Objectives That Consider Only Building Costs:

5. *Minimize energy consumption, with an upper limit on building construction cost.* This option is very similar to Option 3, except energy consumption is being minimized instead of energy cost, to address non-economic conservation objectives.
6. *Attain energy consumption lower than a stated value, at lowest possible building construction cost.* This option is very much like Option 4, but does not consider energy costs.

Objectives That Consider Only Energy Costs:

7. *Minimize energy cost.* This objective does not rely on tradeoffs between the first costs of construction and energy costs over time. However, minimizing energy cost does provide a way to balance energy consumption and demand effects.
8. *Attain energy cost lower than a stated value.* This option might be useful if an owner has a fix on desirable energy cost levels and good building cost data are not available.

Objectives That Consider Only Energy Consumption:

9. *Minimize energy consumption.* This is not an economic objective. However, this objective could be very useful to test the overall capabilities of the Targets methodology, including the impacts of the set of technologies being considered within the model and the technical limit to energy conservation that is attainable by the Targets methodology in a given location.

10. *Attain energy consumption lower than a stated value.* This is essentially the old BEPS approach (or California, etc.).

Since the EROOC (and LCC) method is the most complex and requires the most data elements, the other economic analysis methods can be viewed as subelements of the EROOC/LCC analysis methods. The only additions required are for adding rather simple procedures to calculate the various objectives and for providing user options for them. The Economic Analysis Task Report in Volume 2 describes the data requirements and discusses the situations in which the various economic perspectives might be useful to building owners.

In selecting economic objectives to use within the Targets model, the obvious choice is to develop the first option (EROOC) as the primary economic objective, and to provide all 10 economic objectives as choices available to a user in the voluntary use mode. Options 1 through 4 and Option 9 are the strongest candidates for inclusion as basic options within the Targets model, for reasons discussed in Volume 2. However, the other options may have uses in specific circumstances.

Economic objective choices become much more difficult if the Targets model is not developed to the complete extent that is proposed in this set of reports. For example, Volume 2 of this report contains a discussion of the expected high development cost to produce a viable building cost module. If it is not possible to develop such a model, or if an early version of the Targets model is to be produced without a building cost module, then economic objectives Options 1 through 6 above cannot be used. Each of them depends upon the ready access to building cost data in order to set a target. In this situation, only Options 7 through 10 are available as choices.

Economic Indicators

For many of the economic objective options just described, a number of alternative economic indicators or measurement indices may be used.^(a) 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.

Construction cost by itself is limited, for it does not consider energy expenditures, O&M costs, or replacement cost. 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.

(a) For a reference source for the material discussed in this section, see PNL-4870, *Recommendations for Energy Conservation Standards and Guidelines for New Commercial Buildings, Volume III: Description of the Testing Process*, Section 8, Pacific Northwest Laboratory, October 1983.

Present value (PV) and equivalent annuity (EA) are essentially the same. EA spreads PV into equal payments over the study period. These indices have two advantages: 1) they include all costs of concern 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.

Return-on-investment (ROI) and internal-rate-of-return (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 search routines to prevent the use of either ROI or IRR within these routines. This is expected to severely limit the use of ROI or IRR as the comparison metrics. However, it may be possible to use them as metrics in limited situations, perhaps after the analysis control module search routine has been used in several different circumstances, to compare the results of different runs of the search routine.

Owner Economic Perspectives and Parameters

The Targets methodology needs to provide flexibility in defining ownership economic perspectives and parameters to provide an ability to generate custom targets for specific building situations. Approaches to these factors are discussed in this section.

Owner Economic Perspectives. From previous studies,^(a) it appears that a minimum of four different types of owner economic perspectives will provide a reasonable range of options to imbed within the economic analysis. These 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, the choices of values for the study period, the discount rate, and the fuel escalation rates over time can strongly influence the outcomes of an 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 a user will have the ability to change these values and to create new sets of defaults for further use, the initial selections may not be 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 future scenarios. If the economic results point in the same direction for the boundary conditions as well as 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 are substantially different from those obtained using typical values for the parameters.

(a) In particular, see the study referenced in the previous footnote for both owner economic perspectives and economic parameters used.

3.2 Other Activities

3.2.1 Selection of Project Standard Software

This task has been primarily a PNL responsibility. The ASHRAE/AIA/IES team has provided input and review as requested. In this activity, the project standard software and procedures have been defined. These standards are required for the project to function smoothly and to ensure an efficient flow of work between the project participants. Standardized software products and services have simplified data transfer and communication between team members. This is important because interrelated work is being conducted at various locations.

Project standard software includes the following:

- communication software - cc:Mail as the standard communications package, with Kermit used when cc:Mail is not implementable
- word processing software - WordPerfect
- statistical software
- calculation software
- spreadsheet software - EXCEL
- graphics software - For interim development and demonstration purposes, a number of graphics software packages have been used. However, they are not considered "standards" for the project.

The selection of energy calculation procedures and associated software is not included in this activity, but rather in the energy module activity, described in Section 3.1.4.

3.2.2 Software Engineering

The size and complexity of the proposed Targets model indicated the need for using a structured procedure in designing the model, to ensure that a complete and correct system was achieved at the outset. Many Targets system design issues required resolution. Most issues could not be resolved until more analysis was done and the system began to evolve. The software engineering process is a design technique that allows the system to evolve while issues are being resolved, without having to return to the beginning of the design effort and start all over.

A key objective of the Targets model software development effort is to design a system that is cleaner and more maintainable by system developers. Because it is systematic, the software engineering approach can lead to a system that is easier to maintain. The approach uses a simple tree-like format that begins with a basic concept and gradually branches out to finer and finer levels of detail. At each level of detail, relevant issues are resolved and documentation is provided. Good documentation allows other programmers and users to quickly trace through the system to locate specific areas for modifications, which, in return, provides better maintainability.

During the concept stage, work progressed concurrently on the logical and physical steps in the software engineering process. The team created a structure diagram to graphically portray the main idea

and components of the Targets model and the basic flow of that system. From the structure diagram, the team then created a simple data flow diagram (Figure 3.11) to show the basic flow of the data throughout the system.

The project team then started the iteration process on the analysis phase by breaking down the main data flow diagram to show the proposed Targets model in greater detail. Again repeating the process, another level of detail was created by showing data flow for two of the modules with the Targets model.

The team also dealt with many user interface issues. It created a prototype of a Targets model user interface (see Volume 4, Appendixes A through C). The detailed design step will be approached next, in the development stage of the project.

Figure 3.11. Logical Data Flow Diagram for the Targets Model

4.0 Issues and Recommendations

During the concept stage, a number of important issues arose and were discussed at length. Some of the issues have been resolved while others have not. In preparing for the development stage, it is useful to summarize these issues and to discuss their resolution.

Specific recommendations are presented for those issues that have been fully resolved. For those issues that have not been resolved, the alternatives are presented and the authors' recommendations are stated. The issues and recommendations are grouped by task. Each issue is briefly stated, alternatives discussed, and recommendations presented. In instances where there was only one viable approach, only the recommendation is provided. More detailed descriptions of the issues are presented in individual task reports in Volumes 2 and 4.

4.1 User Interface

Many of the issues that have arisen as each separate module of the Targets model has been developed could be classified as user interface issues. Most of these issues will, however, be discussed in the context of the individual modules. Only those issues that fall exclusively into the user interface context will be discussed here.

Issue 1: Who will use the Targets model? What interests and capabilities should we assume the users will have? How should these assumptions influence the design of the user interface?

It is likely that the early users of the Targets model will be

- the more innovative building designers (irrespective of size of firm or of project)
- designers of larger, more complex projects
- managers and decision makers within public and private sector organizations responsible for the design and construction of multiple buildings
- the designers of federal buildings that are required to use the performance standard.

The design of the user interface will be important to each of these groups. But more than this, the effectiveness of the user interface will determine the size of the first three groups. It is clear that the Targets methodology must appeal to voluntary users if it is to have any real impact on the energy efficiency of the future building stock in the United States.

Recommendation

The authors recommend that the proposed user interface concept be developed in the next stage of the project. The concept has caught the interest of the design professional who will be using it and will ultimately stimulate more attention to energy efficiency in building design. Unfortunately, the sense of an energy crisis has passed and most designers and building owners have come to view the current cost of energy for building operation as acceptable, if not comfortable. The proposed concept, which attracted

favorable attention and comment when presented at a seminar in 1987 at the ASHRAE meeting in Ottawa, has the potential of providing a useful and stimulating tool for energy conservation. This potential should be developed to the point that it is realized.

Issue 2: What user interface hardware and software development environments should be used as "standards" for development of the Targets model user interface?

Technology and capabilities in both hardware and software areas are advancing rapidly. Examples of features that have improved dramatically are processor speed; available RAM; on-line disk storage capacity and access speed; and screen display resolution. The user interface hardware and software features chosen for the development stage work will depend upon the user groups targeted for implementation of the Targets methodology. It is likely that many of the users will tend to be "early adopters" of the more advanced desktop environments and will be using the more advanced technologies, higher processor speed, more RAM, and disk storage.

So far in this project, all development has been in the IBM PC™ or compatible desktop environment. The Apple Macintosh™ represents an alternative hardware environment. The Macintosh has many desirable capabilities (user interface and graphics in particular) and now has a reasonably large (and rapidly growing) user base.

Recommendation

The development process of the user interface should continue to be keyed to the most advanced hardware and software that can reasonably be expected to be available in the marketplace at the time the project is completed. The project must keep a close watch on the changes in hardware and software that occur throughout the user interface development process. The team must be able to identify and use the best hardware and software development environments available if the user interface is to be successful and reasonable development costs and times maintained. Public domain constraints must also be kept in mind, and the software developed should be compatible with at least both the IBM (and compatibles) and Macintosh hardware.

Issue 3a: Can a really easy-to-use interface be developed for such a complex methodology?

Issue 3b: How much priority should the user interface receive in terms of overall project resources?

Experience with other software development projects indicates that as much as 50% of project resources may be required for user interface development. Two areas within the user interface that are likely to be most expensive to develop are

- the ability to deal with a variety of input formats (that is, varying levels of input detail)
- including a robust data input capability (including routines for handling geometric input) in the user interface.

The difficulty is that, while multi-level data input and geometric input are likely to be very expensive to develop, they are both essential if the Targets model is to succeed as an effective aid in design.

Efforts have been made during the concept stage to develop a conceptually robust user interface model. At the same time, in recognition of projected limited development resources, the proposed user interface module has been structured so that it can be developed incrementally.

Recommendations

To summarize, recognizing both the high priority of the user interface development and the need for incremental development, the following development steps are recommended:

- The user interface should continue as a very high priority in the development of the overall Targets model.
- The best possible software system design and programming talent be identified and engaged to work on the user interface, especially during the development stage where detailed system features will be delineated.
- Every attempt should be made to develop a robust user interface.
- If development of all the input features is not feasible, all levels of the user interface should be developed in at least a few areas (or for a few items) to thoroughly test the concept and determine if full development is possible.
- Text-based, menu-based, icon-based, and graphics-based user interface features should be developed in parallel.
- Some means should be found to include capabilities to handle geometric input within the user interface.

Issue 4: How important is geometric input handling capability to the intended audiences relative to other user interface features?

One user interface objective is to minimize user effort required to enter data. Thus, any procedures that will contribute significantly to achieving that goal is important. If architects cannot represent their buildings' geometry reasonably well, they will tend to feel that the target produced will not represent their buildings, no matter how good the other features are. This aspect will become increasingly important as design-oriented software, software that permits sketching, becomes more prevalent in the marketplace.

Building physical characteristics and building costs are directly linked to building areas and volumes. Linking these elements can involve considerable amounts of input (coordinates as well as quantitative data). If a user could supply these data to the Targets model in a geometric format, or from another application in a geometric format, the input process would be easier for the designer.

Several options are available, each with its own set of mixed blessings:

- Option 1:** Make no attempt to develop robust geometric input capabilities for the user interface, but concentrate on text, menu, and icon modes.
- Option 2:** Develop robust, public domain geometric input capabilities from scratch as part of the user interface.

- Option 3:** Develop hooks into proprietary software packages (both sketch packages and CADD packages) that already provide these geometric input capabilities.

Recommendation

The authors prefer Option 3 because it is the lowest-cost path toward attaining robust geometric input capabilities within the Targets model. This possibility should be explored as soon as possible, developing hooks into proprietary software packages that already handle the complexities of geometric input. This exploration should include examining cost-sharing the development and identifying ways of limiting the negative impacts of using proprietary software.

4.2 Input and Characteristics Development

There are several key issues relating to quality within the Targets model.

- Issue 1:** How should the Targets model address various forms of "priority energy?" Priority energy is the energy from a characteristic, usage, or piece of equipment (above the range established by consensus for typical conditions) that the building owner deems essential for the effective operation of the building or business. Priority energy includes a number of direct and indirect energy uses associated with space function objectives (e.g., computer installations) and with design objectives (e.g., large west-facing fenestration areas to capture an outstanding view). Issues related to priority energy are discussed in detail in Volume 2, Appendix F.

Recommendation

It has not yet been determined at which stage in the Targets model priority energy is best considered. Input data could be categorized differently, or weighted to indicate levels of priority. Certain defaults normally required during target setting could be overridden but 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. The issue of priority energy must be addressed in setting targets, and examined in detail in the development stage.

- Issue 2:** What are the limits of customizing building features when determining a target during the target setting mode of operation? How much can the input be modified?

Users will not be able to describe all features of their proposed design in the target setting mode, even in the voluntary guidelines application. To do so would result in a target that was 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 the materials and systems and strategies would be made to apply to all, or a group of Targets model users. For example, ASHRAE, AIA, and IES could determine which factors, as well as the values or ranges of those factors, they consider appropriate for good energy-conserving practice, and require use of those factors during the target setting mode.

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 application. Note that the

establishment of maximum allowable inputs is not within the scope of the Targets project, although it has been frequently discussed. This issue is discussed in detail in Volume 4.

The resolution of this question regarding the maximum inputs allowable during target setting involves

- the perception of reliability by the user
- the ability of the team to create reasonable default values for factors not input by the user
- the tendency to use or abuse the targets as a means of facilitating 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 mode, would require setting a new target.

Recommendations

While the final resolution of this issue is beyond the scope of this project, recommendations should be made and work initiated through interaction with the review committees within ASHRAE, AIA, and IES.

4.3 Analysis Control and Search Routine Modules

Issue 1: Should the search methods focus on optimum points, or on reasonable ranges, or both? How should this be done and be presented?

The search routines within the Targets model must be sensitive to not only optimum points but also to the breadth of solutions that approach reasonably close to the optimum. In many cases, it may be much more important to identify the shape of the solution set than to identify a precise optimum point. Presenting results about an energy or cost minimum would focus on a single best solution, but would say little about the terrain nearby. There may be only a few alternatives that are virtually as good, or there may be a wide range of alternatives that are equally acceptable, given the accuracy of the overall methodology.

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. This issue is discussed in detail in Volume 2 within the analysis control and search routine modules task report.

Issue 2: Should the Targets model search methodology be a disaggregated one? Disaggregation needs to be addressed at least in terms of space functions, building geometry, and design strategies.

Disaggregating a problem involves breaking it up into smaller subproblems whenever possible. In general, components of the problem can be disaggregated when they are not interdependent. Normally, a disaggregated problem is more tractable. For example, different search techniques might be applied to subcomponents of the problem after it is disaggregated.

Recommendations

Since disaggregation reduces search efforts, it is considered desirable to disaggregate the search problem whenever possible. The question then becomes how much disaggregation is possible, and beneficial, as part of the Targets search methods?

Issue 3: Is there a need to further disaggregate space functions?

Disaggregating buildings to the space function level is a cornerstone of the approach employed in the Targets model. Two basic types of space functions have been designated: thermal and lighting. In different circumstances, each can be a subset of the other. Is further disaggregation necessary, say to tasks; interior versus exterior zones; top floor versus intermediate floors; skylighting versus none; roof/ceiling loads?

Recommendations

Under some circumstances, disaggregation beyond the space functions may be required. The fenestration effective aperture parametric example in Section 5 of Volume 2 provides an example of the need for such disaggregation.

Issue 4: 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. 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 re-aggregating from the results of disaggregated searches?

Recommendation

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

Issue 5: What is the potential for disaggregation related to the impacts of different energy-conserving design strategies?

The office building fenestration effective aperture parametric example in Section 5 of Volume 2 describes a situation in which at least 13 major design variables are potentially interacting. 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 model be able to choose how much interaction to consider, at a cost of possibly much longer run times to conduct a search?

Recommendation

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

Issue 6: What forms (curves, etc.) will the analyses results take as variations in the characteristics sets that are tested (linear, convex, discontinuous, etc.)?

The path of a series of solutions tested 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 the variables chosen and the objective function. The path will be a function of the type and degree of interaction present between variables.

By recognizing the different 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.

Issue 7: When addressing energy costs, how much disaggregation is possible relative to analysis of complex commercial building utility rate structures?

Very little research has been conducted 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. How can such searches be reasonably disaggregated across the range of factors addressed in the previous issue on disaggregation?

Recommendation

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

Issue 8a: How many design strategies, or technologies, need to be considered in the search routines for target setting within the Targets model?

Issue 8b: How should the targets change as the design strategies being considered change?

Issue 8c: Should a user of the Targets model have any choice about which design strategies are to be considered in setting a custom target for a building design?

Analyses conducted during the concept stage 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. This implies that 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 not to 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

The impact of including/excluding a given technology in generating targets should be examined thoroughly in the next stages of work. The results of this examination are expected to provide valuable information for resolving the above issues and for providing guidance to any group that will be using the methodology to develop standards and codes.

The project 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.

Issue 9: How much provision should be included in the Targets model for future technological change?

Recommendations

Examples provided in Volume 2 lead to the recommendation that strong provisions for including new technologies need to be built into the Targets model. Otherwise, it is likely to have an effective life span shorter than its gestation period.

Issue 10: 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.

Recommendation

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.

Issue 11: 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?

There is considerable effort required for the development of any data source for the Targets model, and a considerable amount of art, judgment, and in-depth knowledge of the subject area is required for the entire process. The steps to develop energy libraries are involved and expensive. To develop response-surface models requires additional, nontrivial steps and 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.

Recommendations

Further analysis is needed to determine the best approach(es) to use for the search routines. Given the information available at this time, the authors feel that the energy response library approach seems to be the more promising one, especially in conjunction with other approaches. Considerable more information is needed on the cost of, and benefits that might come from, the use of the response-surface approach before it can be properly evaluated.

4.4 Energy Module

An effective, time-efficient, and accurate microcomputer-based building energy simulation tool will be required if the Targets methodology is to meet its objectives. A number of issues have arisen in the process of selecting a simulation tool.

Issue 1: How should the energy module be structured?

Four alternative energy module structures (and two hybrid structures) were considered during the concept stage of the Targets project:

- Select, and modify to the extent necessary, a single energy model capable of serving in all aspects of the Targets model.
- Select more than one model. Choose a range of models, starting with a fast, relatively simple model and one or more models with capabilities that build to a comprehensive, full-featured model.
- Do not include an energy model in the Targets model. Instead, develop a set of interface/translation capabilities to allow the use of one or more external energy models to perform the energy analysis tasks.
- Develop one or more regression-based correlation procedures to serve the energy analysis needs of the project.

Consideration of these possible alternatives by the Targets team, discussions with project consultants, and the review at the energy simulation experts meeting has led to the following recommendations.

Recommendations

- Provide a single, consistent hourly energy analysis procedure for use throughout all design stages of use of the Targets model. Consistency is essential.
- Provide, as an option, an input/output procedure to allow the Targets model to interface with a number of energy analysis tools in both the public domain and in the private sector.

The first alternative, to identify and modify an existing building energy simulation tool, was thus recommended by the energy simulation experts and has been implemented by the project team. A procedure for allowing, as an option, the use of other energy analysis tools will also be developed. However, this will be developed only to the extent of defining consistent input and output hooks to accommodate the use of external programs. It is assumed that the actual interfaces will be developed by those who develop the external programs.

Issue 2: Which criteria should be used to define the energy module?

It is clear that there are four principal criteria for judging energy model performance: time, flexibility, consistency, and accuracy. Unfortunately, these criteria are often in conflict.

Recommendations

The following criteria were recommended:

General. The energy simulation model must:

- be easily integrated into the overall Targets model
- be capable of providing a full detailed analysis or an abbreviated, or compact, analysis when less precision is required.

Time. Time is a major criterion. The time of concern is the time to set a target, to complete a design analysis, or to 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 following time estimates are recommended as guidelines for energy model performance 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 stage.
- 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.
- Output should be available in both graphic and numeric forms to minimize the time required to review results. The output should be structured so that several options can be compared visually without great effort. The time required to review summary output should be no more than 5 to 10 minutes. Both the graphic and tabular data should be available for a more detailed review when desired.

It is recognized that the time goals outlined above will not be easily reached. The first prototype models 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 what run times are required to satisfy the various groups of Targets model users.

Flexibility. Flexibility is a major source of concern. Much of the opposition to the BEPS project grew out of the perception that it was not flexible.

- Maximum flexibility is required. The range of envelope, lighting, and HVAC options that can be simulated must be as broad as possible. The program must be structured so that additional options can be added as 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 simulation tool 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 simulation tool selected must provide access to hourly load and energy use results at space, systems, and plant levels. It would be desirable to have output that defines illumination levels, thermal criteria, and the state of the air flow at each point in the HVAC system. Having these data available for diagnostic/educational purposes would significantly increase the value of the Targets model.

Accuracy and Consistency. In many ways, consistency may be more important than accuracy, but both criteria must be defined carefully.

- A single energy 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 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 generated with the same analysis tool, emphasis should be 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 but instead toward addressing those issues critical to the success of the Targets methodology in guiding the design of energy-efficient and cost-effective buildings.

Recommendations

Based on extensive discussion within the project team and the results of the meeting of energy simulation experts, the following recommendations are made:

- A single energy simulation tool should be used.
- The simulation tool should be capable of running in a compact hourly analysis mode with the option of a full 8760-hour analysis when desired. The compact hourly analysis procedure should be developed as the primary model of operation. Regression-based procedures should be used only in a secondary role.
- The energy model should have the capability of providing hourly output for appropriate periods of time, as well as seasonal and annual output.
- A public domain program should be selected as the starting point for developing the energy model used in the Targets model. A single model to be part of the Targets model package should be developed first. The hooks for external energy models, including private sector programs, should be developed as part of the Targets project.

Issue 3: An energy analysis tool with all the desired attributes does not exist in the public domain. Moreover, the resources necessary to develop one as part of this project are not available. Therefore, one of the existing tools must

be chosen as a starting point for the Targets energy model. Which of the existing energy simulation procedures can best be modified to meet project requirements?

The following recommendations were made by the energy simulation experts attending the March meeting in Washington, D.C.:

- Do not spend a lot of project time and resources selecting and modifying the energy model--concentrate on the user interface and data management issues. Start with a single program, and make only those modifications necessary to meet the basic project objectives.
- The initial choice of an energy model will not be as critical if the Targets model shell is designed to ultimately accommodate an interface with a number of existing public domain programs, with private sector programs, and with future energy analysis programs.
- The needs of the design analysis/evaluation mode, required for both the voluntary targets and standards and codes development applications, are the most taxing and should be used to define the overall range of capabilities required in the energy module. An energy model that meets the criteria set for this mode of use will also meet the needs of the target setting mode.

Recommendations

Acting on the above, the project team recommends selecting and modifying DOE-2.1D to serve as the initial energy model.

The public domain simulation tool that would most nearly meet Targets methodology needs, the proposed kernel approach, will probable not be available during the Targets project lifetime. Thus, DOE-2.1D was reluctantly selected as the initial basis of the energy model to be developed in the next stage of the project.

Even though it was felt that the energy balance approach used in BLAST and HVACSim is preferable, and that the systems and equipment simulation options in HVACSim were generally better, a number of factors tipped the decision toward DOE-2.1D. Despite DOE-2.1D's limitations in specific areas, it appears to be, overall, the most complete and the most flexible approach available at this time. The DOE-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. It is felt that DOE-2.1D can be modified to provide the required output and to run in the compact analysis mode.

Issue 4: The capabilities of DOE-2.1D do not meet project energy model criteria.
How should DOE-2.1D be modified to meet project objectives?

Recommendations

The following actions should be taken to adapt DOE-2.1D to meet the needs of the Targets methodology:

- Create an interface for DOE-2.1D with the user interface module.

- Modify DOE-2.1D to provide hourly loads output that includes the effects of variable space temperature. This is necessary, as real hourly load and energy use data are essential for both design analysis/evaluation and the cost and economic analysis modules.
- Evaluate DOE-2.1D systems and equipment algorithms and modify them as necessary to provide for more flexibility in defining systems. The systems and equipment modules must provide options for selecting individual system, control, and equipment components. The predefined sets of systems and equipment components in DOE-2.1C do not provide an adequate range of selection.
- Convert DOE-2.1D for operation on a desktop computer. Develop a desktop computer version of DOE-2.1D that is in the public domain and can be modified for Targets model use.
- Provide options for limiting the periods of analysis and using simplifying assumptions at those points in the design process where speed is more important than precision.
- Develop any new output routines that may be needed to provide the necessary hourly load, energy use, and system property data. This may require the development of a means of interfacing with database and graphics programs (or subroutines) to provide a user-friendly output.

Work on the DOE-2.1D modifications recommended above should begin as soon as possible. These modifications represent a major effort and will be required for completion of much of the development stage work.

Issue 5: The prospects for reducing DOE-2.1D run time by reducing the number of calculations are quite good. How can the time required for each energy analysis be reduced while still meeting the flexibility, consistency, and accuracy requirements?

A full 8760-hour analysis procedure, with the benefit of a faster computer, might be acceptable under some circumstances. However, run time is critical in the early application of both the target setting and design analysis/evaluation modes. It is clear that more than just a faster computer will be needed if the Targets methodology is to be successful. A procedure that will reduce the number of computations and time required to analyze the impact of one design strategy or technology relative to another is essential. This is particularly true when iterative or interactive analysis techniques are used in the target setting and design analysis/evaluation modes.

Recommendations

- Develop the compact analysis procedure as a means of reducing run time.
- Define a procedure for selecting the minimum set of weather data necessary to meet project requirements.
- Define a procedure for determining the impact of operating schedules.
- Define a procedure for evaluating system control and equipment performance features.

Work on the compact analysis procedure should continue. The developments recommended above should be completed as soon as possible. This development will require significant effort in the next stage of the project.

4.5 Building Cost Module

Issue 1: Given the lack of an appropriate existing public domain cost model and the complexity and the high anticipated cost of developing a new building cost model from scratch, is the inclusion of a building cost module cost-effective?

Several options to developing a building cost module were suggested:

- Option 1: Proceed with the development of a full-featured building cost module (needed so economics can be included in the Targets methodology, but very expensive to develop).
- Option 2: Provide limited cost information, at system summary level only, in the Targets building cost module.
- Option 3: Do not include a building cost module in the Targets model at all. (This would lower cost and eliminate much complexity, but no economic evaluation would be possible within the Targets model.)

Recommendations

The authors recommend that a full-featured building cost model be developed, if resources permit. Several alternative approaches could reduce, or spread out, required development resources:

- Consider joint development with one or more private sector organizations with existing models that already meet some of the Targets criteria.
- Seek sources of joint funding for development. For example, utility companies might be very interested in the projected capabilities of the Targets methodology.
- Use 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. (This option is considered risky, given the importance of reliable cost data in the economic comparison of alternative energy-saving design technologies.)

Although Option 1 is clearly the most desirable, it is by far the most resource-intensive in terms of developing a working Targets model. It is expensive for two reasons. First, considerable effort will be 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 major calculation elements of the Targets model, thus increasing the resource levels required for these other modules.

The decision as to whether or not the building cost module should be developed at this time should be deferred until there is a clearer picture of the funding available. In preparation for a decision, a more detailed estimate should be prepared of the resources required to develop the building cost module.

Issue 2: What is the required breadth of building cost analysis? Should the building cost analysis be limited to costs of just the energy systems? Should costs of impacted nonenergy systems also be included? Should the cost of the entire building be included?

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 nonenergy 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.

Option 3 should be pursued, for the following reasons. Option 1, although 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. This option could be used for research purposes only, but not for the custom building design objectives for which the Targets methodology is intended. The conclusion from a number of concept stage discussions is that design practitioners would find the construction costs and ensuing economic analyses so misleading as to be considered incorrect. They would thus not trust any results of the Targets building cost module that are based on these data. Under these conditions, it is likely that the entire Targets methodology would be considered simplistic and thus suspect 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 methodology. Further, it is sometimes very difficult to distinguish clearly between costs that are energy-related and those that are not.

The Targets methodology has the charge of testing various energy-saving strategies in an economic context, rather than solely on the basis of energy units saved. We are assuming that Targets model users will be professionals with sufficient experience to recognize the ripple of changes across many building systems resulting from major changes to a building system of specific interest. If users are presented with an answer in isolation--one that ignores obvious changes to other systems--they will immediately recognize the limitations of this approach. A single major fault in the Targets model, such as an incomplete and inaccurate building cost module, could undermine user faith and acceptance (if not eliminate it entirely).

The designer must also be able to evaluate the economics of energy-related design strategies relative to a broad range of nonenergy-related criteria. When making design decisions, whole-building costs provide a benchmark against which to measure the relative value of energy-related design strategies. In this context, the whole-building cost is an essential element of the Targets building cost module.

Recommendations

A whole-building cost estimating program is needed if the objectives of the project are to be fully met. Developing an accurate whole-building cost module 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. In addition, the significant level of effort required to develop the whole-building portion of the building

cost model may be incidental compared to the effort required to develop the detailed cost methodology for each of the energy design strategies. Therefore, Option 3 should be selected.

Issue 3: Is there a need to generate detailed databases for energy-related cost information?

If the building cost module is to be accepted, it must provide economical, readily accessible, up-to-date, and reliable cost data. 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, and about many energy design strategy options, are simply not available in current databases.

Recommendation

At least portions of detailed, energy-related cost databases will need to be developed for use in the Targets model.

Issue 4: What mechanisms are required within the building cost module to access cost data in various cost databases (with different storage formats and structures)?

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

Recommendation

A detailed review of two or three of the best existing cost databases should be conducted. The purpose of the review is to identify the specific energy-related building components for which cost data are unavailable.

Issue 5: What mechanism for updating the detailed, energy design strategy-related costs is required within the building cost module?

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. If mechanisms for updating these data are not provided, the module will quickly become obsolete. Updating could be done using a user-controlled automated procedure within the Targets model, or it may be done manually (item by item) to a master cost database.

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.

Recommendation

New options for cost data maintenance need to be explored. Some provisions need to be made for continued funding for updating the data.

Issue 6: How much effort will be required to develop a building cost module and an associated database of building costs that meet the requirements of the Targets methodology?

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 and another 6 person-years for developing a sufficiently detailed energy-related building cost database. This indicates a total resource requirement of 12 person-years.

Recommendation

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 graphic requirements and alert the team to holes in the methodology.

4.6 Energy Cost Module

Very few issues have surfaced relative to the energy cost module during the concept stage. However, the resolution of many issues raised about the energy module, the building cost module, and the economic analysis module will directly impact requirements for the energy cost module. Indeed, the level of detail required for the energy cost module is a direct consequence of decisions made in these other areas.

Issue 1: How much effort should go into developing a reasonable set of typical utility rate structures and associated data?

Utility rate structures can be complex and vary substantially, both over time and by location and building features. Given that one objective of the Targets methodology is to have the targets reflect economic cost-effectiveness, this complexity cannot be sidestepped. 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.

Recommendation

The authors recommend that a set of typical rate structures be developed for use in conjunction with the energy cost module portion of the Targets methodology. We also recommend that sources for up-to-date local utility costs data be identified, and a means be devised to access these data sources so that they can be used in conjunction with the typical rate structures.

These tasks may 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 Targets model. The accuracy and reliability of the energy cost data entering the energy cost module is of major importance to the overall reliability of the economic results of the Targets methodology.

4.7 Economic Analysis Module

Issue 1: Which economic objective(s) should be included in the Targets methodology?

Recommendations

The economic analysis module should be constructed to permit the use of multiple, alternative economic objectives. A minimum set should include the following objective options:

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

The primary focus for development should be Option 1.

In voluntary uses of the Targets model, users should be able to choose the most appropriate economic objective for their purposes from among the several available. The primary focus should be on Option 1 (EROOC), with additional options available in voluntary applications.

Issue 2a: 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 2b: Equity of cost-effective energy conservation across various building functional uses is considered important in standards setting applications. How can it be analyzed, attained or approximated?

Recommendations

Present value (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 model, equity issues should be examined very closely, with regard to both regional variations and building functional use variations. ROI and/or IRR should be used to assess equity issues across regions, design strategies, energy conservation technologies, and building functional uses.

5.0 Plans for Future Work

The work accomplished in the concept stage has defined, in detail, a conceptual structure for the overall Targets methodology and for each of its individual modules. Recommendations for items to be included in a development stage workplan are, in large measure, implicit in the recommendations presented in Section 4 of this volume. More detailed recommendations for the future development of each module of the Targets methodology are presented below in Section 5.1.

5.1 Future Work

In this section, the future development activities related to the individual Targets modules and other elements of the overall methodology are described.

5.1.1 User Interface

Major steps proposed by the authors for user interface development include the following:

- Complete the taxonomy structure of the user interface in more detail and consistency.
- Explore the possibilities of collaborative software development with private sector software developers. Three types of software developers could be approached: those producing CADD packages, "windows" user interface environments, and object-oriented database packages. Collaborative development will reduce costs, improve the Targets products, and assist in its more widespread use.
- Select several federal and private organizations to participate in the prototype testing activities.
- Develop one or more working user interface prototypes. This will help ensure consistency, and will facilitate review. Several "menuing" software packages are available that can facilitate the development of such working prototypes.
- Obtain feedback from potential users as to the features of the working prototypes(s). This is considered critical to proper detailed development of an effective user interface. Reviewers should be from several different expected user disciplines.
- Link the working user interface prototypes to the other elements of the Targets model.
- Test the operation of the user interface prototypes(s) when linked to the other Targets model elements. Conduct this test within the project team, and also have testing done externally.

5.1.2 Input Module

Future work on the input module will be concentrated in two areas--case-study testing of the characteristics set taxonomy and developing consensus databases.

"Manual" Case-Study Testing

The characteristics set taxonomy was tested on a conceptual level by organizing an existing set of building descriptors within the framework of the taxonomy and its supporting exhibits. This exercise verified that the level of detail is sufficiently rigorous to address a wide range of energy design problems.

The complexity of the Targets model, especially the relationship between the cost, search routine, and characteristics development modules, requires that the next level of testing for each of these modules be thought out carefully. The most useful approach would be to assemble a test case that combines each of these elements in such a way as to develop the linkages between each. These linkages appear to be the greatest logistical challenge facing the Targets project.

The Targets methodology will not be successful if it is not clearly based on the process through which energy-efficient buildings are designed. The most useful test case will follow a design process that is typical yet effective from the standpoint of energy efficiency and industry acceptance. It cannot be seen as nontraditional or costly, but rather as a simplification of a specialized and occasionally acceptable portion of the design process. For this reason, it is recommended that at least one comprehensive energy-efficient design case study be run through the complete Targets model in its current conceptual form in preparation for testing the concepts via software-based prototypes.

This case study could be theoretical or based on an actual project, but would include the full range of design phases, from schematic to contract documents. A well-defined set of design strategies/technologies should be evaluated as part of this design process, based on very specific economic criteria. It is suggested that these include simple modifications to single subsystems or components (e.g., insulation, glazing, lighting, HVAC) as well as complex decisions involving multiple subsystems (e.g., daylighting).

Particular attention should be paid to the linkages that occur between costs, building characteristics and performance. Required data will be revealed for each, and the relationships between these elements will be available as a tool for developing the connections and detail appropriate to the Targets methodology.

Conceptual testing has been done to some extent for many of the individual modules of the Targets model and at a variety of levels. By following a single design project through each mode of use and for all proposed modules, the development team will have a chance to address the key issues before the Targets model progresses too far beyond its current conceptual state. The exercise of running a complete case study would test the Targets concept as a whole. This could still be done at a theoretical level: DOE-2 could be used in conjunction with the FBLCC program and input from practitioners and Target team members. If the final product is to be a computerization of a known process, it is too early to break from a paper representation of the methodology. Much could be learned and serious mistakes averted if the current conceptual version of the Target model were applied to a very specific and comprehensive design process.

Development of Consensus Database

A data format, based on the Targets taxonomy, must be developed to aid in establishing ranges of values for the consensus databases. Much of this will be related to space functions and acquired by consensus judgment of qualified professionals. The initial values are required fairly early in the development stage to facilitate the use of case studies in evaluating the concept phase work. Once the formats are determined, some of the work related to establishing the values can be undertaken by the various energy review committees of the sponsoring societies.

5.1.3 Characteristics Development Module

"Manual" Case-Study Testing

This projected task was discussed in detail in Section 5.1.2. The task is mentioned here as well because of its importance to further development of the characteristics development module.

Develop Algorithms and Rules

It is necessary to further develop the algorithms and rules necessary to transfer factors into characteristics and to pre-select or narrow the range of characteristics passed on to the analysis control module. These include algorithms for lighting, which have never before been a significant part of energy simulation tools, and algorithms that convert data on a space-function basis to groupings, zones, floors, facades, or the whole building, and back again. This would include cumulative cost calculations, thermal zoning, and other functions. In addition, algorithms and pre-selection rules, based largely on the judgment of experts, should be developed to screen the entire set of all possible characteristic options into a smaller set, by ruling out obvious inconsistencies and mutually exclusive combinations.

Establish Procedures Related to Priority Energy

The entire priority energy issue needs to be explored in much greater depth, for its resolution will strongly impact overall Targets results. The exploration should include producing a process for incorporating such concerns, and testing the process within the overall Targets methodology.

5.1.4 Analysis Control Module

Future work on the analysis control module will focus on four areas, discussed in the following paragraphs.

"Manual" Case-Study Testing

As with several of the other modules, a first step in developing the analysis control module into a software prototype should be to test the concept manually on one or more building designs. This will provide the necessary fine-tuning before extensive software development is undertaken.

Relationship to Targets Taxonomy and User Interface

At the beginning of the concept stage, the analysis control module, the user interface, and the Targets taxonomy were each addressed as separate tasks. It seems appropriate to the authors to continue this separate treatment for at least a while longer. However, there is considerable overlap among the three elements. This proposed task activity will look closely at these overlaps and interactions, to determine how to develop each portion in conjunction with the others or whether they should, in fact, be combined into a single future activity.

Develop Approach to Modular Development

This task will address the modularity issue mentioned in Section 4.3. It will also identify methods for ensuring a successful modular and incremental development process, structure, and sequence.

Develop and Test Prototype Software

This task will result in development and testing of a working software prototype for the analysis control module that will interface with software prototypes of the other Targets modules.

5.1.5 Search Routine Module

The original work plan for the search routine module could not be accomplished in the concept stage without additional and unanticipated work. Insufficient information exists to properly select and apply optimization tools to the problem without further delineating the problem. This conclusion has come from detailed discussions with the optimization expert brought onto the team. This issue, and proposed avenues to its resolution, are discussed in the following sections.

Development of Criteria for Success

Explicit performance objectives are needed. The criteria for selection described earlier in this report provide a first cut toward this end.

Research and Development Needs

Given the lengthy run times, the use of a brute force approach to both selecting and using optimization methods seems imprudent, lengthy, and expensive as an R&D approach, at least using DOE-2. Two options seem possible, either singly or in parallel: 1) develop pre-calculated libraries of energy simulation input/output data to use to make the needed assessments and 2) use a simpler energy simulation model, with a much shorter run time (some 25 times faster on currently available hardware). These two options are discussed below.

Libraries of Energy Response Data. During the concept stage, it became apparent that more information was needed on the forms of the solutions to the Targets model optimization problem. This information is needed to properly assess which specific optimization tools can be applied, either to the optimization problem as a whole or to portions of the problem.

If such libraries of energy response data prove useful, then additional questions arise. How many runs? How much data is needed to be stored from each run? How much loss in accuracy will occur (and when) if the library of stored energy runs is the only source of data?

A first step is to define an adequate library of DOE-2 runs (inputs and outputs) and associated costs and economics to use to assess the questions outlined above, especially those concerning the forms of solutions and the possibility of disaggregation.

This library of DOE-2 runs (inputs and outputs) can then be used to assess the solution forms for the energy portion of the optimization problem. Because energy is only one component, the library of DOE-2 runs also needs to be evaluated, in conjunction with associated building and energy costs, to assess the full optimization problem. A first cut at this should permit assessment of possible

- disaggregation approaches
- optimization tools that might be used
- further experiments that may need to be done.

A proposed starting point for defining the library of DOE-2 runs is via discussion of basic search principles. The discussion should focus on 1) the relationships between search variables and objective

functions; 2) identifying possible sets of search parameters to be addressed; and 3) addressing changes in the sets of parameters. Participants in such a discussion should include persons knowledgeable in building energy design (specifically envelope, lighting, and HVAC design), energy simulation modeling, experimental design, search methods, and optimization.

Results of past research can be used as starting points for the energy data library. However, data from such previous research is unlikely to completely satisfy current data needs. In short, additional sets of DOE-2 runs are likely to be needed.

Increasing the Speed of the Energy Model. With a faster energy model, the search routines can consider more options and more detail. Several alternatives have been identified as possible routes to a faster energy calculation capability.

- Use a simpler model. Use of a simpler, hence faster, public domain energy simulation tool would speed the search process. The tradeoff is that such use would result in reduced precision and reduced accuracy of the energy simulation results. Thus, one approach 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. Because run time for ASEAM 2.1 on an MS DOS computer is about 45 seconds, robust runs become one day+ efforts and are thus more feasible in an R&D setting. Using brute force nonlinear or dynamic programming methods appears 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.
- Use a "compacted" version of an hourly model. Reducing the run time of an hourly energy simulation model like DOE-2 would speed the entire search process. Ways for reducing DOE-2 run times are discussed in Volume 2 of this report. However, it is not clear that feasible reductions in DOE-2 run times will be sufficient for some search methods to produce reasonable overall run times.
- Use a response-surface model.

Process and Review

Given the nature of the problems discussed above, it is likely that the solution process will be iterative. First results will probably raise additional questions, requiring refinement, adjustment, and further analysis. This process may occur more than once. Thus, an iterative process of technical work coupled with thorough review, discussion, and refinement is envisioned for the search routine module.

5.1.6 Energy Simulation Module

Once the criteria had been defined and DOE-2.1D had been selected as the basis of the Targets model energy module, the project team's attention turned to defining future work in two areas: modification of DOE-2.1D and development of the compact analysis approach.

DOE-2.1D Modifications

The team concluded that the following actions should be taken in the development stage to adapt DOE-2.1D to meet the needs of the Targets model:

- Modify DOE-2.1D to provide hourly loads output that includes the effects of variable space temperature. This is necessary as real hourly load and energy use data are essential for both design analysis/evaluation and the cost and economic analysis modules.
- Evaluate DOE-2.1D systems and equipment algorithms and modify them as necessary to provide for more flexibility in defining systems. The systems and equipment modules must provide options for selecting individual system, control, and equipment components. The predefined sets of systems and equipment components in DOE-2.1C do not provide an adequate range of selection.
- Convert DOE-2.1D for operation on a desktop computer. Develop a desktop computer version of DOE-2.1D that is in the public domain and can be modified for Targets model use.
- Provide options for limiting the periods of analysis and to use simplifying assumptions at those points in the design process where speed is more important than precision.
- Develop any new output routines that may be needed to provide the necessary hourly load, energy use, and system property data. This may require the development of a means of interfacing with database and graphics programs (or subroutines) to provide user-friendly output.

A meeting with the DOE-2 manager and staff at Lawrence Berkeley Laboratory (LBL) on July 8, 1988, indicated that these modifications were, for the most part, possible and could be accomplished within a reasonable time period. Each of these modifications and recommendations from the DOE-2 staff for completing them are discussed further below.

Loads and Systems Output Modifications. The modification to the DOE-2.1D to provide hourly loads based on variable space temperatures was discussed at length. It was recommended that a short module be developed to provide this output independent of the system-specific characteristics that now influence the hourly coil loads reports in the DOE-2.1D systems output. LBL estimated that this would require no more than a week or two of effort. It is recommended that this work be initiated as soon as the development stage begins.

The characteristics of DOE-2.1D systems and equipment modules have not yet been explored. The DOE-2.1D documentation had not been released by the end of the concept stage work. This evaluation must be completed as early in the development stage as possible. The evaluation will require a series of tests to define the extent to which the DOE-2.1D systems definitions can be modified and adapted to analyze various control strategies and combinations of systems components. The possibility that a sufficiently broad range of systems cannot be evaluated within DOE-2.1D remains a major source of concern. If the systems modifications included in DOE-2.1D are not adequate, the development of the Targets model may be delayed until an alternative simulation procedure can be identified or a new procedure developed.

Conversion to the Desktop Computer Environment. There is currently at least one version of DOE-2.1C that runs on a desktop machine (IBM AT or compatibles). However, it is a proprietary program and is not therefore suitable for this project. PNL has explored the process and problems of adapting DOE-2.1D to run on desktop equipment. It has concluded that the conversion can be made with a few weeks of effort. This work will be completed early in the development stage. It is important that the project team be working with a program and hardware configuration as close to that expected to be used early in the project development stage.

Obviously making sure that the Targets model and software will run on the best hardware available at the conclusion of the project is an option that will be chosen. The Targets model is being defined so as to be portable, so that it will run in a number of hardware and operating system environments. It is expected that the machines available at that time will be at least one order of magnitude faster than current machines. The project team is attempting to stay abreast of developments in both the hardware and software fields.

Modifying/Optimizing the DOE-2.1D Code. DOE-2.1D is a very large and complex code. It has been developed in stages and modified repeatedly. It is therefore very difficult to modify in any extensive way. The probability that the code could be optimized or converted to a more efficient language within the limitations on time and budget in this project is negligible. Any code-level modifications must be limited to those absolutely necessary to meet minimum project objectives. No attempt should be made to make broader improvements.

Developing the Energy Model User Interface

An extensive effort will be required to define and develop the user interface necessary for using the energy model in an interactive mode. This will be the single largest effort in the energy model work in the development stage of the project. The energy simulation experts repeatedly emphasized that the user interface will be the key element in this work. However, as energy model user interface issues are a part of the overall user interface question discussion, they have been addressed in Volume 4 of this report.

Develop Compact Analysis Procedure

The potential value of reducing the time required to complete an energy analysis was explored. A full 8760-hour analysis procedure, with the benefit of a faster machine, may be acceptable to set a final target and in the final design evaluation. Run time, however, is critical in the early application of the target setting and design analysis/evaluation modes. It is clear that more than just a faster machine will be needed if the Targets model is to be successful. A procedure that will reduce the number of computations and, thus, the time required to analyze the impact of one design strategy or technology relative to another, is essential if iterative or interactive analysis techniques are to be used in the target setting and design analysis/evaluation modes.

The prospects for reducing DOE-2.1D run time by reducing the number of calculations is good. This option has been selected by the project team as a major area of effort in the development stage of the work. Two approaches have been considered to achieve this. The first is to employ regression-based correlations in selected areas in the analysis. This technique has been used successfully for the Standard 90 envelope criteria. However, regression-based correlations aggregate results, providing only annual or, at best, seasonal information. The second approach, using a compact analysis procedure, preserves the hourly time step but examines many fewer sequential calculations. The ability to examine hourly loads is particularly important in terms of addressing peak load concerns. It also provides significant advantages when evaluating systems control and equipment performance, and is essential if energy cost and economic issues are to be handled adequately. Although regression-based correlations may be used in several areas of the analysis, the project team feels that it is necessary to develop compact hourly procedures. In developing this approach, they have also felt it important to use a procedure that provides diurnal load patterns rather than adopt a bin type of analysis procedure.

The energy analysis effort in the concept stage has therefore focused on defining a compact analysis procedure that will meet these objectives. Three areas were explored:

- defining a procedure for selecting the minimum set of weather data necessary to meet project requirements
- defining a procedure for determining the impact of operating schedules
- defining a procedure for evaluating system control and equipment performance features.

Selecting Weather Data Sets. Appropriate weather data at several levels of detail are needed for the Targets methodology. A rational procedure for choosing the daily weather data profiles for the compact analysis must be developed. Condensed weather data sets are needed for the run-time-sensitive initial target setting and design analysis/evaluation elements of the model. It is expected that the use of condensed weather data sets will reduce computation time by as much as a factor of ten. Complete and accurate 8760-hour weather data sets must also be obtained for setting the final target and running the final design evaluation. The use of the full 8760-hour data sets may be required for these functions to provide a higher level of user confidence.

Considerable evidence suggests that it is possible to examine the energy impact of a wide range of design strategies and technologies without carrying out 8760 sequential hourly calculations. Several of the proprietary energy analysis programs (the Carrier and Trane programs, for example) successfully use condensed data sets. European research also indicates considerable success with a "Short Reference Year" that is made up of 4 to 6 days from each month, resulting in data for 56 days to represent the year.

The condensed weather data sets should consist of a minimum number of 24-hour weather parameter profiles in the format now used in DOE-2. The use of the data in this format will alleviate any need to modify the weather data input data structure of the program. The number of profiles defined would be that necessary to evaluate the energy use characteristics of buildings in a specific location. It is estimated that the number of sets of daily weather data profile and schedule combinations required may range from as few as 20 to as perhaps many as 60.

The first task in developing the compact weather data sets is to define criteria for selecting the days to be used. There are two points of view from which these criteria could be considered. One is that of a climatologist, whose concerns cover a relatively broad range of climate characteristics. The other is that of an energy analyst, whose concerns focus on those climate characteristics that directly impact simulated energy use. This represents a smaller range of climatic factors: dry bulb temperature, wet bulb temperature or specific humidity, direct and diffuse solar radiation on vertical and horizontal surfaces, and daily temperature range. Under current circumstances, it would seem appropriate to focus on those climatic factors that most directly impact the energy simulation process, and to not be overly concerned with those factors that have little or no impact on the results of the calculation procedures to be used.

A methodology for selecting the compact weather data sets has been proposed. It uses a clustering methodology to identify days that are similar in terms of selected climate parameters. The first step in the analysis is to determine the number of days out of a year that fall into an arbitrarily selected number of clusters. The next step is to determine if the energy use associated with days in each cluster is similar and if it is distinct from the energy use for days in the other clusters. The objective is to determine the minimum number of clusters necessary to define the energy impact of the range of variation of climate over a year.

Once the minimum number of 24-hour weather parameter profiles has been identified, the final step is to define a weighting factor for each day to allow estimates of seasonal and annual energy use.

Evaluating the Impact of Operating Schedule. It has been suggested that the daily weather data profiles for the compact weather data set can be chosen without consideration of the operating schedule.

The next question relates to the thermal time constant of buildings. The thermal time constant depends on the extent to which the mass in a building stores heat (or cool) and, thus, the time delay between a change in external conditions, or internal load, and the time that the effect of such a change is sensed by the HVAC system. When the time constant is a matter of hours (as it is for most conditioned buildings), there seems to be little reason to use a 7-day week schedule in the compact analysis format. A week with 3 workdays and 1 weekend day may be sufficient to capture the effects of a schedule/thermal capacitance interaction. The use of an abbreviated week may allow a reduction in the total number of days the analysis may require. This possibility should be examined carefully in the development stage of the project, because it could help achieve significant run-time savings with compact analysis procedures.

Once the minimum number of daily weather profiles and the minimum schedule length have been defined, the number of days considered in a given analysis could be varied to suit the user's needs at any given stage of the design process.

Evaluating System Control and Equipment Performance. An ability to display the effect of system control strategies and equipment performance characteristics on both annual and peak energy use and energy cost is essential in the design analysis mode. A lack of understanding of when savings can be achieved, or the extent of the savings possible, often leads to unnecessary expenditures for controls and equipment. One of the major advantages of the compact analysis procedure proposed is that it will allow an effective display of analysis results. It is possible to examine hourly output for 20 or 30 days (especially if the output is graphic) and to note the significant changes that occur as designs are changed. It is not possible to do the same with 365 days of hourly output. Experience has shown that hourly output profiles can be very effective.

If a longer analysis period is chosen, for example in the final evaluation mode, it will still be valuable to have systems and equipment output for 20 or 30 selected days. The days chosen could easily be those that were used in the compact analysis.

5.1.7 Building Cost Module

The authors envision the following activities as appropriate next steps in developing the building cost module:

- Develop a working software prototype of the building cost template model.
- Link the prototype to other Targets model prototype elements.
- Test the operation of the prototype, both separately and with the rest of the Targets model elements.
- Refine the template approach based upon the testing results obtained.
- Develop additional template details and develop a revised prototype to test.

5.1.8 Energy Cost Module

The authors recommend taking a number of steps to further develop the proposed structure of the energy cost module in detail. The activities listed below would lead to integration of this module with the rest of the Targets model. The tests of energy cost module operation may indicate the need for further revisions and modifications to the conceptual structure that has already been defined.

1. Interface with other aspects of the Targets methodology. Adjust the energy cost module to suit other elements of the Targets model, especially the characteristics development, building cost, energy, and economic analysis modules.
2. Based upon the results of Step 1, refine the input/output requirements of the energy cost model.
3. Develop a working prototype of the proposed energy cost module within the Targets model. Because an appropriate energy cost model already exists, its internal development is not an issue. However, a number of details about its specific use within the overall Targets model still need to be resolved. These details include the following:
 - identifying and incorporating energy cost databases that might be used - An alternative is to have the user supply all energy cost input data for a locale.
 - means for generating any energy cost data that are not contained in available databases
 - specific methods for extracting data from those databases for use in the energy cost module (and coordination with the user interface development activities)
 - specific output data that will be produced, and level of detail, to ensure that the module will indeed supply all the detailed results needed for the projected types of economic analyses.
4. Test the prototype in conjunction with other elements of the Targets model.
5. Submit prototype to a group of potential users for thorough review and testing.
6. Based on the results of Step 5, modify the module. It is likely that some expansion of capabilities will be needed to satisfy all of the detailed output requirements needed for the economic analyses.
7. Incrementally develop documentation for user guidance as an integral part of the development process.
8. Develop a version of the energy cost model that is external to DOE-2.1D.
9. Develop a neutral file format to permit the use of the energy cost model with energy simulation tools other than DOE-2.1D.
10. Develop a set of typical utility rate structures for use with the energy cost module. This will involve coordination with the activities in the user interface task area.

11. If possible, develop a means for accessing energy costs from one or more energy cost databases to provide the user with an automatic access to relatively current energy costs without requiring direct user data entry.
12. Incorporate the above steps into a revised prototype.
13. Test the revised prototype.
14. Submit the revised prototype to a group of potential users for thorough review and testing.
15. Make further modifications based on feedback.

The 15-step process outlined above assumes two iterations through prototype development, testing, review, and revision. If Steps 5 and 14 are emphasized, two iterations should be sufficient. The authors feel that this course is the most efficient means of avoiding additional iterations or producing a misdirected product.

5.1.9 Economic Analysis Module

Future development activities envisioned by the authors for the economic analysis module include the following:

- Include the economic analysis features (i.e., economic objectives, economic indices, owner economic perspectives, and defaults for economic parameters) discussed in Section 3.1.9 into a working prototype of the search routine of the characteristics selection procedures within the Targets model.
- Select and incorporate a public domain economic calculation procedure and include it as part of the economic analysis calculation procedures.
- Test the prototype separately.
- Link the economic analysis module to the rest of the Targets model through the characteristic selection routines and test the combined modules.
- Submit the combined prototype to potential users for thorough review and testing. Obtain feedback.
- Based upon the testing and the feedback, revise the economic analysis routines. Develop a new prototype for testing and further review by potential users.

5.1.10 Software Engineering

The iteration process will continue until the data flow diagrams are taken down to the most complete level of detail. Minispecs and data dictionaries will be generated from the data flow diagrams. The minispecs will be written in such detail that they can easily be translated into a programming language. As the minispecs are encoded, the modules will be tested and integrated into the Targets model. Test cases will be generated and could later be incorporated as examples when showing how the model works.

As the implementation proceeds, there may be a need to reanalyze and redesign parts of the model that may not work effectively. This is a natural part of software development, and the software engineering

methodology should allow modifications to happen smoothly. Software engineering should produce a Targets model that can easily be tested and debugged. Excessive iteration in the first three steps will make the implementation smoother and save time by preventing having to redo the entire model after it is already in place. When the team feels that the model is complete and mostly debugged, an external review should be done by user representatives and other experts in the buildings design field to make sure that the model meets all potential user needs.

5.1.11 Data and System Integration

The next steps anticipated in the data and system integration task are as follows:

- Develop a detailed plan for the modular development of the taxonomy.
- Develop a software data structure for the taxonomy, or adopt an existing structure.
- Complete the Targets taxonomy structure in further detail, on an incremental basis.
- Explore the possibilities of collaborative database development with private sector software developers.
- Select several federal and private organizations to participate in the prototype testing activities.
- Develop and test one or more working database prototypes.
- Obtain feedback from potential users regarding the features of the working prototype(s). Reviewers should be from several different expected user disciplines.
- Link the working prototypes to the other elements of the Targets model.
- Test the operation of the prototype(s) when linked to the other Targets model elements. Conduct this test within the project team, and also have testing done externally.

5.2 Project Planning

The intent of this section is to discuss the direction of future work in a global rather than specific sense, to identify and evaluate the options available for the development stage work. Two developments have prompted the authors to undertake a review of the planned direction of the work. They are

- the realization that the proposed product is considerably more complicated than was anticipated at the end of the Phase 1 work
- the realization that limitations in resources (both time and money) could restrict the robustness of the Targets methodology developed.

It is important that the consequences following from these developments be understood before specific development stage plans are made for the project.

5.2.1 Methodology Complexity

The concept stage work has changed the authors' perception of what will be required to develop the Targets methodology. The nature of the product now envisioned is more complex than it was two to three years ago. The increase in complexity stems from two decisions made near the end of the Phase 1 work. These decisions were

1. to incorporate cost and economic considerations directly in the procedure for selecting target values
2. to define custom targets, and to determine if a building design meets its target, using relatively complete energy, cost, and economic analyses running on microcomputers.

While these decisions are still viewed as correct and appropriate, the combined effect of the actions that have followed has been an increase in the complexity and in the difficulty of the development process.

For example, imbedding economic considerations within the Targets model will require the development of a full building cost module. The effort required to producing the cost and economic analysis modules may be somewhat like the effort that would be required to develop an entirely new energy model. Our expectations at the beginning of Phase 1, and even at the beginning of the concept stage of Phase 2, were that these aspects of the work would be much simpler than they are. Full development of the cost and economic modules will require considerably more time and more resources than originally estimated.

5.2.2 Limited Resources

The authors have been informed that the current and future resources available to the project may be limited. If resources are limited, even more time will be required to complete the development of the Targets methodology. In the case of the voluntary application of the Targets methodology, extending the development time would be unfortunate but not critical. Extending the development period, however, is not compatible with DOE's requirement to produce a federal buildings performance standard in the near future. It may therefore be necessary to limit the scope, and cost, of the work.

The Targets methodology, if developed in its complete form, would be of considerable value to the buildings design industry. It would make a significant contribution to the design of energy-efficient and cost-effective new commercial buildings and could make a significant contribution toward helping DOE meet its energy conservation goals. This is ultimately to the benefit of the country.

If the project continues, but with more limited goals, several questions must be answered:

- Which elements of the work proposed here should be developed in the near term?
- Which elements should be postponed?
- Which elements should be deleted altogether?

A limited implementation of the proposed work will contribute little of value unless choices of what to do and what not to do are made very carefully. These choices will be difficult.

5.3 Options

Based on the above, a number of options must be considered before beginning the next stage of the project. Although the development of the complete Targets methodology is preferred, it is recognized that this may not be possible.

In making the choices that will shape the future of the Targets project, it must be realized that it is essential that any Targets methodology produced provide guidance to designers during the design process. Most of the decisions that influence the ultimate energy efficiency or inefficiency of a design are made early in the design process. Unless there is a means of interacting with the design process, the Targets methodology will not achieve its stated goals. The design community will respond to the Targets methodology only if it helps them to understand, to see, the energy consequences of the decisions they make. A product that produces only a target number, $X \text{ Btu/ft}^2\text{-yr}$, checked at the end of the design would be of very limited value. The procedure developed must provide both targets and a means of tracking progress toward achieving those targets.

The following options, each limiting the development scope and effort in some way, are recommended for consideration.

5.3.1 Options with a Product

If one of the following options were selected, the product would be a working Targets methodology that would have the potential for being used in a limited standards-setting context. The product would have sufficient compliance procedures to be usable. The product scope would, however, be limited, compared with the complete product proposed. Possible options include those listed below.

1. No economics: Eliminate both building cost and energy cost from the first version of the Targets model. The cost and economics modules would be added in a later version.

Positive impacts: The development effort and technical complexity would be greatly reduced.

Negative impacts: This product will be liable to one of the criticisms leveled at the BEPS project, that economics are not included.

2. Limited economics (no building cost): Eliminate building cost considerations from the first version of the Targets model but consider energy costs. The building cost module would again be added in a later version.

Positive impacts: Almost as great a reduction in development effort and complexity would be realized as in Option 1. Further, energy costs can be considered.

Negative impacts: It would not be possible to evaluate tradeoff between first cost and energy costs over time.

3. Limited economics ("experimental" building cost): Same as Option 2, but include building cost study at a conceptual or schematic level of detail only.

Positive impacts: This option allows examination of many technical issues related to including building cost in the methodology.

Negative impacts: The degree of error inherent in analyses at this level may cause a loss of credibility and cause designers to doubt the accuracy of the whole product.

5.3.2 Options with No Product

Continue research that will lead to a product at an unspecified future date, that date being dependent on when sufficient funding is available. The following options are possible:

4. **Targets studies:** Continue the Targets project as a research effort, or a series of efforts to develop specific Targets modules, with no commitment as to when the whole of the Targets model might be produced. These efforts would continue as funds are available until the work is completed.
5. **Schematic Targets:** Develop a complete but preliminary Targets model that could be useful in the early design stages but would not necessarily provide precise guidance.

Positive impacts: A complete method would be available for guidance to designers when it would have the greatest impact.

Negative impacts: The preliminary Targets model cannot be used for standards compliance, for detail would be inadequate for compliance assessment in later design stages.

There appears to be no easy choice. Building design is complex and, to be truly useful, the Targets model must be able to accommodate that complexity. The needs of both the design and buildings industry and the public (by way of the need for energy-efficient, cost-effective buildings) must be considered. Funds are limited and, in a real sense, so is the time available to complete the work. Easy or not, a choice should be made and a clear direction charted before work begins on the development stage of the project.

Breaking the product into an initial target setting component while leaving the development of the compliance/design guidance component until later is not considered a viable option. This approach has three major problems.

First, developing a target setting mechanism that can withstand the rigors of close public scrutiny and defending this decision may require about as much effort as developing both the target mechanism and a reasonably complete procedure for demonstrating compliance. We feel the idea that a target setting mechanism alone can meet the project requirements is based on erroneous assumptions.

Second, without good compliance mechanisms, a target setting procedure will be viewed negatively, as just another attempt to regulate design. Thus, the goal of achieving voluntary use will not be achieved. It is our strong feeling that if the Targets model fails as an educational tool, it will fail as a standards tool.

Third, the goal of the Targets methodology is the effective improvement of energy conservation in buildings. This requires encouragement and knowledge, which the compliance/design guidance component can offer. All too often, energy limits are met by inappropriate design strategies, to the detriment of all. To create successful energy-conserving designs, designers must be educated as well as prompted with energy targets.

5.4 Recommendation

The authors recommend that Option 1 or Option 2 be pursued at this time. The tools required to produce energy-based targets are available, with some modification. Although these options are not ideal, they do seem possible.

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7.0 Acknowledgments

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W. W. Seaton	ASHRAE Subcontract Manager
J. E. Kaufman	IES Representative
E. W. Kennett	AIA Representative

Technical Team

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H. Deimer	Characteristics development module
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L. G. Bellenger	Building cost module
G. A. Hauser	Set selection and analysis control module
P. Dillingham	User interface demonstration
S. Hunt	User interface demonstration

PNL

D. B. Crawley	Project Manager
R. S. Briggs	Set selection and building cost module
P. K. Alley	Software engineering
J. R. Lewis	Software engineering
B. K. Johnson	Technical staff support
D. L. Hadley	Climate analysis methods
J. Evans	General software support, user interface graphics support
J. Arthur	Set selection procedures

For two major elements of the proposed Targets model--energy and building costs--the advice of experts was sought. In each case, a number of experts in the respective fields--energy simulation and building cost estimating--met in a 2-day workshop setting to share expertise relevant to the project. The comments, ideas, and recommendations contributed by the individuals listed below helped the project team determine the direction of the efforts taken in these two important areas.

Panels of Experts

Energy Simulation

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D. Hittle	Colorado State University
J. Pegues	Carrier Corporation
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