NIST Handbook 135
1995 edition

LIFE-CYCLE COSTING MANUAL
for the Federal Energy Management Program

Sieglinde K. Fuller
Stephen R. Petersen

U.S. DEPARTMENT OF COMMERCE
Technology Administration
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[1] At Boulder, CO 80303.
[2] Some elements at Boulder, CO 80303.

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Abstract

Handbook 135 is a guide to understanding the life-cycle cost (LCC) methodology and criteria established by the Federal Energy Management Program (FEMP) for the economic evaluation of energy and water conservation projects and renewable energy projects in all federal buildings. It expands on the life-cycle cost methods and criteria contained in the FEMP rules published in 10 CFR 436, Subpart A, which applies to all federal agencies. The purpose of this handbook is to facilitate the implementation of the FEMP rules by explaining the LCC method, defining the measures of economic performance used, describing the assumptions and procedures to follow in performing evaluations, giving examples, and noting NIST computer software available for computation and reporting purposes. An annual supplement to Handbook 135, *Energy Price Indices and Discount Factors for LCC Analysis*, NISTIR 85-3273-X is also published by NIST to provide the current discount rate and discount factors needed for conducting an LCC analysis in accordance with the FEMP rules. This annual supplement is required when using Handbook 135.

This new edition of Handbook 135 replaces the 1987 version. The new edition is extensively revised and organized around the key steps in an LCC analysis. There are no longer separate sections for new and existing buildings and for solar programs, as the methodology no longer distinguishes between these projects.

Keywords

benefit-cost analysis; building economics; building technology; capital investment decisions; cost effectiveness; economic analysis; energy conservation; energy economics; life-cycle cost analysis; public buildings; renewable energy; water conservation.

Ordering

Copies of this document are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161, at (800) 553-6847 or (703) 487-4650. The document contains 212 pages, cover to cover.

Preface

Why a New Edition of Handbook 135?

Handbook 135 was developed for use in performing life-cycle cost analysis (LCCA) of investments in energy and water conservation projects and renewable energy resource projects for federal buildings and facilities. The Federal Energy Management Program (FEMP) of the U.S. Department of Energy (DOE) has codified the rules for performing LCCA of such investments in the Code of Federal Regulations, 10 CFR 436, Subpart A, *Methodology and Procedures for Life-Cycle Cost Analysis* [1]. These rules apply to both new and existing buildings owned or leased by the Federal Government. These economic evaluations are required by the Federal Energy Management Improvement Act of 1988 (Public Law 100-615) and the National Energy Conservation Policy Act (NECPA) of 1978 (P.L. 95-619).

This 1995 edition of NIST Handbook 135, *Life-Cycle Costing Manual for the Federal Energy Management Program*, represents a major revision of earlier versions. Handbook 135 was originally published in 1980 and last revised in 1987. This new edition incorporates numerous changes in the FEMP rules for performing life-cycle cost analysis of energy- and water-conservation projects in federal buildings and facilities. The principal changes in the rules since the last edition are:

- Starting with 1991, DOE sets the discount rate each year on October 1 for the upcoming fiscal year, rather than using the same discount rate each year.
- There are no longer any special provisions for certain investment categories such as solar heating systems. For example, the 10 percent tax credit on solar energy conservation investments has been eliminated.
- The FEMP rules now apply uniformly to both new and existing buildings.
- The FEMP LCC methodology has been made more flexible by allowing for a planning/construction period before a project is put into service, and by allowing alternative cash flow conventions, e.g., mid-year discounting.
- Agencies are directed to use actual energy prices at the building site rather than average national or regional prices.
- Agencies may rank projects competing for limited funds by using either the Savings-to-Investment-Ratio or the Adjusted Internal Rate of Return.
- Water conservation projects are now also subject to the life-cycle costing rules established by FEMP for energy conservation projects.

The subject matter in this new edition has been reorganized to follow more closely the step-by-step procedures for performing an LCCA. Rather than emphasizing the theoretical underpinnings of benefit-cost analysis in general, we have tried to include and emphasize topics of practical value to analysts who are called upon to perform economic analysis of energy and water conservation projects using the FEMP methodology. In this attempt, we have profited greatly from the questions and comments received from participants in FEMP-sponsored LCC workshops that we have conducted several times each year for the past 10 years.

The treatment of LCCA in this handbook is directed towards engineers and architects, energy analysts and managers, and budget analysts and planners of federally owned facilities. The handbook is also intended for managers who need to interpret LCC studies performed by contractors or other analysts and make decisions based upon them. Even though the emphasis of this handbook is on explaining and amplifying the FEMP LCC requirements for the economic evaluation of energy and water conservation in federal buildings, the underlying methodology is based on general economic theory and is generic enough to be useful for LCC analyses in the private sector as well.

DOE has actively consulted with and received substantial assistance from the National Institute of Standards and Technology (NIST) in developing and amending the FEMP LCC rules. In addition, for the past 15 years NIST has provided significant technical assistance to DOE in support of the FEMP LCC methodology, including the publication of this handbook and its Annual Supplement to Handbook 135, the development of supporting computer programs, and the teaching of two-day LCC workshops for Federal Energy Managers and other interested participants at many locations throughout the United States.

FEMP life-cycle costing methods and procedures set forth in 10 CFR 436, Subpart A, are to be followed by all federal agencies, unless specifically exempted, in evaluating the cost effectiveness of potential energy and water conservation projects and renewable energy projects in federally owned and leased buildings. To the extent possible, these projects should be evaluated separately from non-energy and non-water related projects in federal buildings. The current FEMP discount rate for energy- and water-related projects is published in the Annual Supplement to Handbook 135, *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis* [2], which is updated annually at the beginning of the federal fiscal year.

While this handbook focuses on the requirements of the FEMP LCC rules as they apply to federal buildings and facilities, the LCC methodology presented is entirely consistent with American Society for Testing and Materials (ASTM) standards on building economics [3], including:

E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems,
E964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems,
E1057 Practice for Measuring Internal Rate and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems,
E1074 Practice for Measuring Net Benefits for Investments in Buildings and Building Systems,
E1121 Practice for Measuring Payback for Investments in Buildings and Building Systems, and
E1185 Standard Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems

LCC-Supporting Publications and Training

Publications and Computer Software

As called for by NECPA, the National Institute of Standards and Technology has provided technical assistance to DOE/FEMP in formulating LCC methods, handbooks, factors, and software for economic analysis of energy and water conservation and renewable energy projects in the Federal Government. Handbook 135 is the first of a five-volume set of guides and computer software which NIST has published in support of FEMP. In addition to Handbook 135, these reports include:

(1) ***The Annual Supplement to NIST Handbook 135 and SP 709***, *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis 199X*, National Institute of Standards and Technology, NISTIR 85-3273-X, October 19XX [2].

This report, updated annually, provides energy price indices and discount factor multipliers needed to estimate the present value of energy and other future costs. The data are based on energy price projections developed by the Energy Information Administration of the U.S. Department of Energy. Users of Handbook 135 will need the most recent version of this report to perform LCC analyses for federal projects in years after 1995. (See ordering information below.) This report is referenced throughout this manual as the Annual Supplement to Handbook 135.

Note: For LCC analyses in the Department of Defense, NIST publishes a special version of this report, NISTIR 4942-X, *Present Worth Factors for Life-Cycle Cost Studies in the Department of Defense* [4], which is updated annually on October 1. The present worth factors for annually recurring costs in this report are based on mid-year discounting (as required by DoD), rather than on end-of-year discounting as in NISTIR 85-3273-X.

(2) ***The NIST "Building Life-Cycle Cost" (BLCC) Computer Program***, NISTIR 5185-2, National Institute of Standards and Technology, January 1995 [5]. The BLCC computer program serves as the primary support software for handbook 135. This program is updated annually on October 1 to incorporate the most recent changes in discount rates and DOE/EIA energy price escalation rates. For more information on this program, see appendix B.

(3) *DISCOUNT—A Program for Discounting Computations in Life-Cycle Cost Analyses*, NISTIR 4513, National Institute of Standards and Technology, updated annually in October [6].

The DISCOUNT program computes discount factors and related present values, future values, and periodic payment values of cash flows occurring at specific points. DISCOUNT is especially useful for solving life-cycle cost analysis problems which do not require the comprehensive summation and reporting capabilities provided by the BLCC program. DISCOUNT is updated each year on October 1 to incorporate the most recent DOE/EIA energy price escalation rates. For more information on this program, see appendix B.

(4) *ERATES—Program for Computing Time-of-Use, Block, and Demand Charges for Electricity Usage*, NISTIR 5186, National Institute of Standards and Technology, May 1993 [7].

ERATES is a computer program for calculating monthly and annual electricity costs under a variety of electric utility rate schedules. Both kWh usage and kW demand can be included in these costs. Most typically these calculations will be used to support engineering-economic studies which assess the cost effectiveness of energy conservation measures or measures to shift electricity use from on-peak to off-peak time periods. For more information on this program, see appendix B.

Representatives of federal agencies and contractors to the federal government can order these publications and computer programs, free of charge, from:

Enterprise Advisory Services, Inc.
1525 Wilson Blvd, Suite 1200
Arlington, VA 22209-9998
(703) 243-4900

Individuals not associated with the Federal Government can also request limited copies of the Annual Supplement to NIST Handbook 135 from this address. For others interested in obtaining the BLCC and related computer programs, please contact one of the following organizations for price and ordering information:

Energy Information Services
PO Box 381
St. Johnsbury,VT 05819-0381
(802) 748-5148

FlowSoft
5 Oak Forest Court
Saint Charles, MO 63303
(314) 441-1022

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

Workshops and Training Videos

NIST conducts two- and three-day workshops, sponsored by DOE/FEMP on *Life-Cycle Costing for Energy Conservation in Buildings* and *Building Energy Analysis* at various locations around the country several times each year. The workshops include training and software for both *BLCC* and *"A Simplified Energy Analysis Method" (ASEAM)*. You can obtain a schedule of workshops from the Office of Applied Economics, National Institute of Standards and Technology, Bldg. 226, Room B226, Gaithersburg, MD 20899, (301) 975-6132.

An introduction to the FEMP LCC methods is provided in three video training films in a series called *"Least-Cost Energy Decisions:"* (1) *"An Introduction to Life-Cycle Cost Analysis;"* (2) *"Uncertainty and Risk;"* and (3) *"Choosing Economic Evaluation Methods."* The video films and companion workbooks can be ordered from Video Transfer, Inc., 5709-B Arundel Avenue, Rockville, MD 20852, (301) 881-0270.

Further Information

Further information on the Federal Energy Management Program can be obtained from the Federal Energy Management Program Staff, Office of the Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy. Please direct communication to: FEMP, EE-90, U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, DC 20585.

Though aimed primarily at supporting FEMP LCC methods and criteria, these publications, software, videos, and workshops can also be used by state and local governments and the private sector for conducting LCC analysis of buildings and building systems. The NIST LCC software in particular is adaptable to FEMP LCC criteria, OMB Circular A-94 criteria, private sector usage with tax analysis, and general LCC analysis.

Acknowledgments

Our appreciation goes first of all to the many participants in the NIST LCC workshops who have been giving us constructive feedback, identifying the areas that needed expansion or fine-tuning to make the handbook more valuable to practitioners of LCC analysis. In addition, we are grateful to

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INTRODUCTION TO LIFE-CYCLE COST ANALYSIS

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Chapter 1

INTRODUCTION TO LIFE-CYCLE COST ANALYSIS

1.1 WHY USE LIFE-CYCLE COST ANALYSIS?

Life-cycle cost analysis (LCCA) is an economic method of project evaluation in which all costs arising from owning, operating, maintaining, and ultimately disposing of a project are considered to be potentially important to that decision. LCCA is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance (including occupant comfort, safety, adherence to building codes and engineering standards, system reliability, and even aesthetic considerations), but that may have different initial investment costs; different operating, maintenance, and repair (OM&R) costs (including energy and water usage); and possibly different lives. However, LCCA can be applied to any capital investment decision in which higher initial costs are traded for reduced future cost obligations. LCCA provides a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run.

Energy conservation projects provide excellent examples for the application of LCCA. There are abundant opportunities for improving the thermal performance of building envelope components (e.g., walls, windows, roofs) in new and existing buildings to reduce heat loss in winter and heat gain in summer. Similarly, there are many alternative heating, ventilating, and air conditioning (HVAC) systems which can maintain acceptable comfort conditions throughout the year, some of which are considerably more energy efficient (or use less expensive fuels) than others. When energy conservation projects increase the initial capital cost of a new building or incur retrofit costs in an existing building, LCCA can determine whether or not these projects are economically justified from the investor's viewpoint, based on reduced energy costs and other cost implications over the project life or the investor's time horizon.

But the use of LCCA does not stop when a cost-effective energy conservation project has been identified. There are almost always a number of cost-effective design alternatives for any given building system. For example, thermal insulation can be installed over a wide range of thermal resistance values in walls and roofs. Window systems are available over a wide range of thermal conductance values and with a variety of sun-blocking films. Many of these alternatives may be cost effective, but (usually) only one can actually be used in a given application. In such cases, LCCA can be used to identify the **most** cost-effective alternative for that application. This is generally the alternative with the lowest life-cycle cost.

LCCA can also be used to prioritize the allocation of funding to a number of independent capital investment projects within a facility or agency when insufficient funding is available to implement them all. This application involves the ranking of projects by their Savings-to-Investment Ratio (SIR) or by their Adjusted Internal Rate of Return (AIRR), supplementary measures of economic performance based on LCCA.

LCCA stands in direct contrast to the Payback method of economic analysis. The Payback method generally focusses on how quickly the **initial investment** can be recovered, and as such is not a measure of **long-term** economic performance or profitability. The Payback method typically ignores all costs and savings occurring after the point in time in which payback is reached. It also does not differentiate between project alternatives having different lives, and it often uses an arbitrary payback threshold. Moreover, the Simple Payback method, which is commonly used, ignores the **time-value of money** when comparing the future stream of savings against the initial investment cost.

LCCA is a powerful tool of economic analysis. As such, it requires more information than do analyses based on first-cost or short-term considerations. It also requires additional understanding on the part of the analyst of concepts such as **discounted cash flow**, **constant versus current dollars**, and **price escalation rates**. The alternative, however, is to ignore the long-run cost consequences of investment decisions, to reject profitable investment opportunities, and to accept higher-than-necessary utility costs.

There are other incentives to use LCCA for project evaluation. Tables of present-value factors for use with different types of cash flows greatly simplify the computational requirements of an LCCA. And NIST LCC computer programs will help you **organize, compute, document, and report** your analyses. This handbook will provide you with the basic understanding, examples, and discount factors that you will need to undertake a successful LCC evaluation. You should also recognize that the most difficult part of any analysis of energy and water conservation projects is usually the estimation of their annual energy-related and water-related savings and corresponding reductions in utility bills. This activity alone often requires as much as 90 percent of the effort needed to support a credible project analysis. Once you have mastered the basic principles of LCCA, you will find that the additional information that it provides to the decision maker is well worth the relatively small additional effort that it requires.

The LCCA methodology outlined in this handbook is limited to the economic analysis of project alternatives and the prioritization of independent projects when allocating a limited budget among such projects within a facility or agency. Engineering, design, and calculation of loads and energy usage for buildings and building systems are not covered in any detail in this handbook. Moreover, this handbook does not provide initial cost data; operating, maintenance, and repair (OM&R) cost data; or expected lives of building systems. However, resources are suggested for finding such data.

1.2 THE LCC METHOD AND SUPPLEMENTARY MEASURES OF ECONOMIC ANALYSIS

The life-cycle cost (LCC) method of economic analysis is the basic building block of LCCA. The LCC method, as applied in this handbook, is used to compute the LCC of a building system or combination of interdependent systems. The LCC is the total cost of owning, operating, maintaining, and (eventually) disposing of the building system(s) over a given study period (usually related to the life of the project), with all costs adjusted (discounted) to reflect the time-value of money. But the LCC of a building system has little value by itself. It is most useful when it can be compared to the LCC of other design alternatives which can perform the same function, in order to determine which alternative is most cost effective for this purpose. These alternatives are called "mutually exclusive" alternatives because only one alternative for each system evaluated can typically be selected for implementation.

In calculating the LCC for a building system (or combination of systems), all future costs are generally discounted to their present-value equivalent (as of the Base Date) using the investor's minimum acceptable rate of return as the discount rate. However, the LCC can also be estimated in annual value terms. An annual value is the cost resulting from amortizing all project costs evenly over the study period, taking into account the time-value of money. The LCC methodology outlined in Handbook 135 is based on the present-value method. However, the BLCC computer program, which supports the FEMP LCC calculation method, computes the LCC of a project alternative in both present-value and annual-value terms. (See appendix B for more information about the BLCC program.)

There are three supplementary measures of economic performance that are consistent with the LCC method of project evaluation which are used in Handbook 135. These are **Net Savings (NS)**, **Savings-to-Investment Ratio (SIR)** and **Adjusted Internal Rate of Return (AIRR)**. They are consistent with the LCC method because they are based on the same stream of costs and savings over the same study period. NS can be used in place of the LCC measure itself to determine the most cost-effective project alternative when evaluating two or more mutually exclusive project alternatives. Within any group of mutually exclusive project alternatives, the alternative with the lowest LCC will also have the highest NS. The SIR and AIRR measures are useful primarily for **ranking** independent projects (for example, a new roof on building A and a new heating system in building B) when faced with a budget that is insufficient to fund all of the cost-effective projects identified for a particular facility or agency. *The SIR and AIRR should not be used to identify the most cost effective project alternative (for example, the most economic level of* *insulation)*. The computation and proper use of these supplementary economic measures will be discussed further in chapters 6 and 7.

1.3 LCCA FOR FEDERAL PROJECTS

This handbook provides guidance to federal agencies for using LCCA to evaluate capital investment projects which reduce future operating and maintenance costs of federal facilities. The Federal Energy Management Program (FEMP) of the U.S. Department of Energy has published life-cycle costing rules and procedures in its Code of Federal Regulations, 10 CFR 436, Subpart A [1]. These FEMP rules are to be followed by all federal agencies, unless specifically exempted, in evaluating the cost effectiveness of potential energy and water conservation projects and renewable energy projects in federally owned and leased buildings. To the extent possible, these projects should be evaluated separately from non-energy and non-water related projects in federal buildings. The current DOE discount rate for energy- and water-related projects is published in the Annual Supplement to Handbook 135, *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis* [2]. This supplement is published each year at the beginning of the federal fiscal year.

For projects not related to energy or water, Office of Management and Budget (OMB) Circular A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," [3] with annual updates to appendix C, provides the necessary methodology and discount rates. The underlying methodologies used by DOE/FEMP and OMB are essentially identical. However, the DOE/FEMP discount rate is different from the OMB discount rate, and the FEMP LCC rules include a maximum study period length of 25 years (plus any planning/construction period); OMB does not have a maximum study period length.

LCC analysts in the U.S. Department of Defense (DoD) should note that there is a Tri-Services memorandum of agreement (MOA) on "Criteria/Standards for Economic Analyses/Life Cycle Costing for MILCON Design," which is updated periodically. This memorandum is basically consistent with the FEMP LCC rule, as promulgated in 10 CFR 436. However, at present the MOA recommends (but does not require) the use of mid-year discounting for all annually recurring costs. It also recommends the lumping together of all initial investment at the midpoint of construction for projects which have a Service Date later than the Date of Study. This is different than the Handbook 135 approach, which uses the end-of-year discounting convention and recommends the phasing-in of investment costs as they are incurred over the planning/construction period. NIST publishes a special set of discount factor tables for DoD, *Present Worth Factors for LCC Studies in the Department of Defense* [4]. These tables, which are updated annually, are based on the mid-year discounting convention preferred by DoD. The BLCC computer program discussed in this handbook can be run in a "military construction (MILCON)" mode that follows the recommended method outlined in the Tri-Services MOA.

1.4 ORGANIZATION OF HANDBOOK 135

Table 1-1 lists 10 key steps in the LCCA of a capital investment project. Chapters 2 to 8 in Handbook 135 follow these steps, building up from the most basic requirements of project identification and documentation to considerations on how to use the LCC results for decision making. Appendices A to F expand on some of the subjects treated in the chapters and provide supporting information, tables, and worksheets. An index assists the user in locating specific topics. Definitions of key terms and a list of abbreviations are provided in a glossary at the very end of the handbook.

You will not need any computational tool more powerful than a four-function calculator to work through this handbook. A calculator with an exponential key (y^x) will allow you to solve some of the basic discounting and future-cost formulas presented in chapter 3, but the precalculated discount factors provided in this handbook and in the Annual Supplement to Handbook 135 will be sufficient for most applications.

Table 1-1
Key Steps in an LCC Analysis

1. Define problem and state objective
2. Identify feasible alternatives
3. Establish common assumptions and parameters
4. Estimate costs and times of occurrence for each alternative
5. Discount future costs to present value
6. Compute and compare LCC for each alternative
7. Compute supplementary measures if required for project prioritization
8. Assess uncertainty of input data
9. Take into account effects for which dollar costs or benefits cannot be estimated
10. Advise on the decision

Chapters

Chapter 2: *Getting Started* covers the steps in an LCCA that are required to get started, including defining the project objective and identifying feasible alternatives. It also discusses the importance of tailoring the level of effort to the needs of the project and establishing documentation requirements for the analysis.

Chapter 3: *Discounting and Inflation in LCC Analysis* establishes common assumptions and parameters for the economic evaluation of the alternatives. It also shows how to discount future costs to present value and to adjust costs for the effects of inflation and/or price escalation over time in a consistent fashion for each alternative being evaluated.

Chapter 4: *Estimating Costs for LCC Analysis*, treats the types of costs specific to the project alternatives to be analyzed, especially investment-related costs, non-fuel OM&R costs, energy and water costs, and the timing of those costs. It also discusses what to do with non-quantifiable effects.

Chapter 5: *Calculating Life-Cycle Costs* covers the procedures and gives examples for computing the total LCC for each project alternative and comparing the results in order to select the most economic alternative.

Chapter 6: *Calculating Supplementary Measures* provides formulas and examples for computing supplementary measures of economic analysis, such as Net Savings, Savings-to-Investment Ratio, Adjusted Internal Rate of Return, and Payback Period, for any one alternative relative to a designated base-case alternative.

Chapter 7: *Applying LCC Measures to Project Investments* addresses various uses of the LCC method and supplementary measures of economic performance to solve different types of capital investment problems related to energy and water conservation in buildings.

Chapter 8: *Dealing with Uncertainty in LCC Analysis* addresses uncertainty assessment in LCCA and focuses on how to use sensitivity analysis to deal with uncertain input data.

Appendices

Appendix A: *Special Topics in LCC Analysis* addresses the optimal timing of retrofit projects, fuel switching and variable energy usage, and the use of utility rate schedules in energy cost calculations. Each topic is illustrated with one or more examples.

Appendix B: *Software for LCC Analysis of Buildings and Building Systems* describes the NIST computer programs available for LCCA, discounting operations, and related computations.

Appendix C: *Worksheets for Life-Cycle Cost Analysis* provides worksheets for manual LCC computations and an illustration of how they may be used.

Appendix D: *Compendium of Discounting and Price Escalation Formulas* contains a variety of discounting formulas and price escalation formulas that are frequently used in LCCA, with a brief description and example of each.

Appendix E contains *Selected Tables of Energy Price Indices and Discount Factors 1995* from the Annual Supplement to Handbook 135, which are referenced or used in the examples in this handbook.

Appendix F provides a summary of the FEMP Program on *Evaluating Energy Savings Performance Contracts* (formerly known as "Shared Savings"), with an example of a net savings comparison between the use of agency funding and contractor funding for an energy project.

CHAPTER 2

GETTING STARTED

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Chapter 2

GETTING STARTED

2.1 PRELIMINARY CONSIDERATIONS

Life-cycle cost analyses can range widely in complexity. The specifics of each project dictate the degree of complexity warranted for the LCCA and its documentation. It is therefore useful to give some thought to planning the study before the data acquisition and computation phases.

2.1.1 Timing of Life-Cycle Cost Analysis

The planning, design, and construction process of a project comprises a myriad of decisions. Some of these decisions are economic in nature, others involve political, social, or aesthetic considerations. Design decisions usually have the greatest impact on total project costs early in this process. With each successive set of decisions, there tends to be less opportunity to make cost-saving changes in the design of a building or building system. Therefore, the earlier LCC considerations are included in the planning and design process, the greater the potential cost savings that can be expected.

2.1.2 Level of Effort

Since economic analysis itself requires resources—time and money—the effort should be tailored to the needs of the project. The scope of an analysis might vary from a "back-of-the-envelope" study to a detailed analysis with thoroughly researched input data, supplementary measures of economic evaluation, complex uncertainty assessment, and extensive documentation. The greater the potential savings, the greater the visibility of the project, and the greater the pressure to make a choice based on criteria other than economics, the more important it is to have a thoroughly researched, carefully performed, and well documented study.

This handbook presents a manual approach to conducting LCC analyses, using present value factors from the current edition of the Annual Supplement to Handbook 135 to perform present value calculations. Optional worksheets are provided in appendix C of this handbook for use with the manual approach. By reading this handbook and working through the examples manually you will develop a sufficient level of familiarity with LCCA principles to make sound investment decisions related to energy and water conservation projects in federal buildings.

Once you understand the basic principles of LCCA, however, it is recommended that you use the NIST computer software developed under the sponsorship of FEMP for performing life-cycle cost analyses of buildings and building systems. The use of these programs can greatly reduce the time and effort spent on formulating the analysis, performing the computations, and documenting the study. These programs, which provide a wide range of computational support, from the calculation of present-value factors to detailed LCC analysis and documentation, are described in appendix B.

2.1.3 Level of Documentation

LCC studies, whether small or large, need to be carefully documented in order to keep track of the evaluation process, to create a decision-supporting record, and to have information easily accessible for future studies. The format should be simple and easy to understand. Table 2-1 provides a list of items to be documented in an LCCA report. The extent of the documentation should be related to the complexity of the decision and in proper proportion to the scale of the overall project.

Table 2-1
Items to be Documented in an LCC Analysis

1 Project Description
- General information
- Type of decision to be made
- Constraints

2 Alternatives
- Technical description
- Rationale for including them
- Non-monetary considerations

3 Common Parameters
- Study period
- Base date
- Service date
- Discount rate
- Treatment of inflation
- Operational assumptions
- Energy and water price schedules

4 Cost Data and Related Factors
- Investment-related costs
- Operating-related costs
- Energy usage amounts, by type
- Water usage and disposal amounts
- Timing of costs
- Cost data sources
- Uncertainty assessment

5 Computations
- Discounting
- Computations of life-cycle costs
- Computations of supplementary measures

6 Interpretation
- Results of LCC comparisons
- Uncertainty assessment
- Results of sensitivity analysis

7 Non-monetary Savings or Costs
- Description of intangibles

8 Other Considerations
- Narrative

9 Recommendations

2.2 DEFINE THE PROJECT AND STATE THE OBJECTIVE

The first step in a life-cycle cost analysis is to identify what has to be analyzed. It is important to understand how the analysis will be used and what type of decision is to be made in structuring the analysis and in selecting a method of economic evaluation.

2.2.1 Project Description

The project description should identify general information related to the building system being considered for design, replacement, or retrofit. This can include the type of building and activities within, occupant usage and comfort requirements (e.g., thermostat settings and lighting requirements), the types of energy and relevant rate schedules available at the building site, climatic variables affecting building energy use, and the type and energy efficiency of the existing or anticipated HVAC system (where relevant). It should list the technical criteria and desirable design features by which candidate alternatives will be evaluated, as well as technical and regulatory constraints.

2.2.2 Type of Investment Decision

In order to define and delineate the requirements of the economic analysis, it is helpful to identify the type of investment decision to be made for the project. The following list identifies the five primary types of investment-related decisions related to energy and water conservation projects in buildings that are addressed in this handbook. Table 2-2 lists examples for each of these investment types.

(1) Accept or reject a single project or system option
(2) Select an optimal efficiency level for a building system
(3) Select an optimal system type from competing alternatives
(4) Select an optimal combination of interdependent systems
(5) Rank competing projects to allocate a limited budget

An **accept/reject project** is an optional project which you would generally implement only when you can show it to be cost effective. For this type of investment decision you only evaluate the cost effectiveness of undertaking the project relative to not undertaking it. You do not compare one project alternative against another, as in the next three decision types.

The **optimal efficiency level** is the most cost-effective level of energy or water efficiency (or analogous performance parameter) for a building system. The efficiency of a system can vary over a wide range, but usually the higher the efficiency, the higher the initial investment cost. The most cost-effective level of energy or water efficiency for a building system is likely to vary from location to location depending on energy and water prices and the intensity of usage.

The **optimal system** is the most cost-effective system **type** for a particular application. The choice of system type may affect the energy performance of a building, but the selection is not based on energy or water efficiency considerations, per se. For example, the choice between an electric heat pump and a gas furnace is more likely to be based on relative energy prices and maintenance costs than on their relative energy efficiencies.

Interdependent building systems are systems which interact from an energy performance or energy cost standpoint. For example, the efficiency of the space heating system must be considered in evaluating the cost effectiveness of insulation in the exterior wall and roof systems. Heat gain from lighting fixtures will reduce the heating requirements and increase the cooling requirements of a building and thus must be considered in evaluating alternative HVAC systems for that building. When evaluating alternative designs for two or more interdependent systems at the same time, their interdependent effects must be included in the energy and economic analysis. This generally requires that total building energy usage be calculated for each alternative combination of systems considered, not the energy use for each system independently.

The first four decision types listed here are referred to in this handbook as **mutually exclusive** decisions because, while two or more alternatives may be considered for each system, only one alternative is selected for implementation. (You do not generally install two levels of insulation in a wall, or install two heating systems for the same space heating requirements.)

The fifth decision type is fundamentally different from these first four because it does not involve mutually exclusive choices. Instead, it deals with the **prioritization of independent projects** when a set of independent, cost-effective, projects has been identified but funding is insufficient to implement them all. In this situation, you rank the projects in decreasing order of cost effectiveness as a guideline to allocating available funding. In essence, your goal is to determine the most cost-effective subset of projects that can be implemented within the available level of funding.

Table 2-2
Types of Economic Decisions and Examples

1. **Accept or reject optional projects**
   - Add storm windows to existing single-pane windows
   - Install a solar water heater
   - Install a storm door
   - Install a night-setback thermostat
   - Install a water-saving commode

2. **Specify level of energy efficiency for a designated building system or component**
   - Specify insulation R-value in exterior wall
   - Specify seasonal efficiency rating of an air conditioning system
   - Specify size of collector area of a solar heating system
   - Specify annual fuel utilization efficiency for a furnace
   - Specify the U-value for a window system

3. **Select optimal system or component among competing designs**
   - Select type of heating and cooling system:
     electric heat pump or gas furnace with electric air conditioner
   - Select exterior wall construction:
     masonry or wood frame; rigid foam or mineral wool insulation
   - Select lighting fixture type

4. **Select optimal combination of interdependent systems or components**
   - Specify efficiency of heating and cooling systems *and* insulation R-values for building envelope
   - Specify type of lighting system *and* efficiency of heating and cooling systems
   - Select the size of a solar heating system *and* the efficiency of an auxiliary heating system

5. **Rank independent projects**
   - Select among numerous cost-effective energy and water conservation projects being proposed at a given government facility or institution
   - Select among numerous cost-effective energy and water conservation proposals from two or more government facilities or institutions

In chapter 7 you will see that the LCC measure by itself is generally sufficient to solve the first four of these investment decision types, while the Savings-to-Investment Ratio (SIR) or Adjusted Internal Rate of Return (AIRR) are most useful when solving the fifth type of investment decision.

2.2.3 Designating a Project as an Energy Conservation Project

In general, FEMP LCC evaluation criteria are applicable to all investments in energy and water conservation and renewable energy projects in federal facilities. This includes cogeneration projects and any project for which the type of energy to be used is to be determined in the economic analysis. To the extent possible, energy-related and non-energy-related investment decisions which are part of the same project should be evaluated separately. (Water-related decisions should be treated the same as the energy-related decisions discussed here.)

Thus,

- the economic evaluation of alternative candidates for a particular building or building system significantly affecting the energy use of a federal building should be conducted using the FEMP LCC criteria, including the DOE discount rate; and

- the economic evaluation of two substantially different buildings or building systems being considered for the same use, both incorporating approximately the same degree of energy conservation in design and using approximately the same amount of energy (so that the purpose of the evaluation is not primarily to assess energy-related savings) should generally be conducted using the criteria and discount rate specified in OMB Circular A-94.

However,

- if a project involves energy usage only peripherally, and the energy-related and non-energy-related parts of the investment cannot be broken out, the decision as to whether to use OMB Circular A-94 criteria or FEMP criteria is left to the judgment of the analyst.

An individual federal agency might wish to require that a specified percentage of project savings be energy savings before the FEMP LCC evaluation criteria can be applied. But the FEMP LCC rule does not specifically require such a screening criterion.

2.3 IDENTIFY FEASIBLE ALTERNATIVES

When selecting project alternatives for economic evaluation, it makes good sense to focus on technical features whose potential economic consequences and energy or water conservation attributes are significant. Given that energy costs often rise faster than other costs, it is expedient to look for alternatives that save future costs in return for a higher initial investment. It is essential to recognize that the problem solution can be no better than the best alternative identified for evaluation.

2.3.1 Identifying Constraints

Before identifying the alternatives to be evaluated, it is useful to consider any constraints that may exclude some alternatives from the economic analysis right at the outset. There may be physical, functional, safety-related, building-code-related, budgetary, and other constraints. For example, the building location may preclude the use of solar energy; natural gas may not be available at the building site; the building may be a historic building whose original appearance must be preserved; the available budget may be insufficient to allow the acquisition of a more energy-efficient system even if it is expected to be cost effective.[1]

[1] See appendix G for information on using energy savings performance contracts and other means of financing federal energy and water conservation projects.

Identifying constraints before beginning the analysis will save the time and effort that would have to be spent analyzing alternatives that are not practical.

2.3.2 Identifying Technically Sound Alternatives

Once the overall project has been described, the next step is to identify all **technically sound and practical alternatives**. Acceptable alternatives must not degrade the overall building performance: they must be comfort-compatible, reliable, serviceable, user-friendly, safe, and at a minimum, neutral with regard to occupant productivity and design aesthetics. They must satisfy the technical performance specifications set out in the project description. They should not make a significant negative impact on usable space in the building.

However, there are practical limits to the extent to which the search for technically sound alternatives must be conducted. For example, a technically sound project alternative which has both higher first costs and higher operating-related costs than other practical alternatives will not likely be cost effective. Such an alternative need not be considered further unless it offers benefits which are difficult to quantify in dollar terms but may nonetheless make it desirable from the investor's standpoint. Incorporation of such benefits into the final decision is discussed further in chapter 4. For some project alternatives that are not formally considered for further analysis, it may still be wise to identify them and the basic reason for not fully evaluating them in the project documentation.

2.4 SET THE STUDY PERIOD

The study period for an LCCA is the time over which the costs and benefits related to a capital investment decision are of interest to the investor. Since different investors have different time perspectives with regard to a capital investment project, there is no one correct study period for a project. But **the same study period must be used in computing the LCC of each project alternative** being compared for a given purpose. The study period begins with the base date and includes the planning/construction period (if any) and the service period (or beneficial occupancy period).

2.4.1 Base Date, Service Date, and Planning/Construction Period

Before establishing the relevant study period for an LCCA of two or more project alternatives, you must first define the relevant **base date** and **service date** for the analysis. The **planning/construction (P/C)** period is the elapsed time between the base date and service date.

2.4.1.1 The base date

The **base date** is the point in time to which all project-related costs are discounted in an LCCA. The base date is usually the first day of the study period for the project, which in turn is usually the date that the LCCA is performed. In this handbook the base date will always be synonymous with the beginning of the study period. In a constant dollar analysis, the base date usually **defines the time reference for the constant dollars** (e.g., 1995 constant dollars). It is **essential** that you use the same base date and constant-dollar year for all of the project alternatives to be compared. If you set the base date to the date that the LCCA is performed, then the constant-dollar basis for the analysis will be the current date, and you can use actual costs as of that date without adjusting for general inflation.

The simplest method of selecting a base date for a project analysis is to declare the year only (e.g., 1995). The implicit assumption in this case is that initial investment costs are incurred at the beginning of this year and that all future costs (whether investment-related or operation-related) are incurred during this year or during subsequent years throughout the study period, without assigning a particular date within those years. If the analysis warrants, you can specify the month or even the exact day for the base date, and specify all future costs in the same manner. Use of the simpler method is generally preferred when conducting an LCCA without the aid of a computer program.

If future costs are specified by year only, it is recommended that you discount those costs from the end of the year in which they occur. The supporting tables of discount factors for LCCA of federal energy conservation projects provided in the Annual Supplement to Handbook 135 assume end-of-year cash flows. However, the FEMP rules for LCC analysis (10 CFR 436) allow you to discount costs from any point in time during the year. If the timing of a future cost is identified more precisely within the year, you can discount that cost from the point of time identified or from the end of the year. You do not need to discount initial investment costs incurred on the base date because they are already in present value.

The base date is also important to the FEMP LCC methodology because it serves as the reference date for estimating all future costs. That is, future costs are calculated from their cost as of the base date with the use of appropriate price escalation rates. (See sections 3.3.3 on *Price Escalation* and 3.3.4 on *Real Escalation of Energy-Related Cash Flows*.)

Do not include "sunk costs." Sunk costs are costs that were incurred or committed to before the base date of your LCCA. By definition, sunk costs cannot be changed by the selection of any project alternative and thus cannot affect its LCC or the LCC of competing alternatives. This is an especially important consideration when setting up the base case for an existing building or building system against which new alternatives are to be evaluated. Only costs to be incurred **on or after the base date** should be included in the base case. If scrapping the existing system to accommodate a new system will generate a positive (or negative) cash flow, this should be included in the analysis since it will occur on or after the base date.

2.4.1.2 The service date

The service date is the date on which the project is expected to be implemented; operating and maintenance costs (including energy- and water-related costs) are generally incurred after this date, not before. (Energy and water costs incurred during construction or installation, or inherent in the building materials, are considered to be part of the initial investment cost and do not need to be specifically identified or evaluated in an LCCA.) For a new building the service date is sometimes referred to as the **occupancy date**.

In a simple LCCA, it may be convenient to assume that all initial investment costs are incurred on the base date and that the project (or building) is immediately put into service. That is, the base date and the service date are assumed to be the same, as shown in figure 2-1. In a more complex analysis, the service date can occur later than the base date, as shown in figure 2-2. Although manual calculations are more complex when the base date and service date do not coincide, LCC software (such as the BLCC program) perform the necessary calculations automatically.

Except in the case of replacing operating equipment for energy or water conservation purposes, you should use the **same service date for all project alternatives** if you intend to compare their LCCs. A project alternative that can be put into service sooner than another (e.g., a new office building) has additional benefits (e.g., its earlier availability to the user) and earlier operation-related costs (e.g., energy usage) which invalidate the direct comparison of LCCs. Replacing operating equipment for energy or water conservation purposes is considered to be an investment timing problem. Replacement timing is treated as a special topic in appendix A.

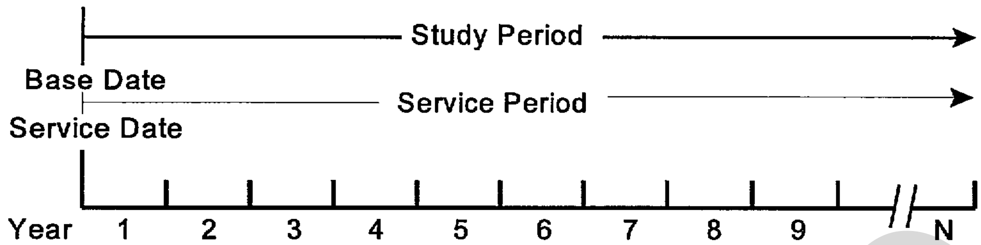


Figure 2-1
Coinciding Study Period and Service Period.

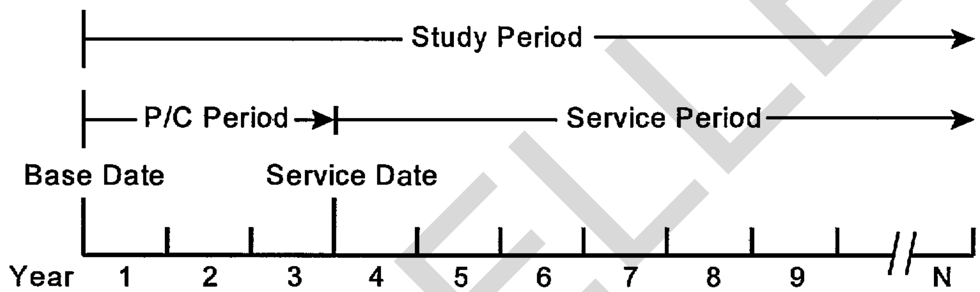


Figure 2-2
Phased-in Planning and Construction Period.

2.4.1.3 The planning/construction period

When there is a delay between the beginning of the study period and the service date, the intervening time is called the **planning/construction (P/C) period**. The P/C period is depicted in figure 2-2. In a FEMP LCCA only initial investment costs are incurred during the P/C period. You can phase in initial investment costs over the P/C period, or assign them all to any one point of time during the P/C period (for example, to the midpoint of the P/C period). In either case, **you must discount any initial investment costs occurring after the base date to their present value as of the base date.**

2.4.2 Length of Study Period and Service Period

The **study period** for an LCCA is the time over which the costs and benefits related to a capital investment decision are of interest to the decision maker. Thus, the study period begins with the base date and includes both the P/C period (if any) and the relevant service period for the project. The **service period** begins with the service date and extends to the end of the study period. In a FEMP LCCA, all operation-related costs are assumed to be incurred during the service period.

Sometimes the study period will coincide with the life of the project, and sometimes it will not, depending on the time horizon of the investor. But it is essential that you **use the same study period when evaluating mutually exclusive project alternatives**. However, the use of the same study period for each project is not required when ranking independent projects for funding allocation based on their SIR or AIRR.

The current maximum **service period** for a FEMP LCCA, as prescribed by 10 CFR 436, is **25 years**. The maximum **study period** is therefore 25 years **plus** the P/C period.

2.4.2.1 Study period determined by expected system life

Your LCCA may focus on the system itself in determining an appropriate common service period and study period for evaluating system alternatives. This is usually the case when the expected life of the system is shorter than the time-horizon of the investor. In this case, the FEMP rules in 10 CFR 436 require that the common service period be set equal to the life of the system alternative with the longest expected life (not to exceed 25 years). You should extend the life of any alternative which would end before the end of the common service period by assuming a **replacement of some or all of its components one or more times** during the service period. If you assume such replacements, they will usually have a residual value at the end of the study period which you should include in your calculations. (See chapter 4 for suggestions on how to determine residual values and sources for estimating project lives.)

2.4.2.2 Study period determined by investor's time horizon

While system service life may be the basis for setting an appropriate service period in most LCC analyses of federal energy and water conservation projects, the time horizon of the investor should also be considered. This is especially true for leased buildings and for buildings that are expected to be sold or extensively renovated before the end of the service period based on the expected life of the alternatives. Again, the service period of the LCCA cannot exceed 25 years for projects subject to FEMP LCC rules. Keep in mind that **the shorter the study period, the more critical becomes the estimate of the residual value** of the project. (However, if the building is scheduled for demolition or major rehabilitation at the end of the study period, the residual value may be zero.)

CHAPTER 3

DISCOUNTING AND INFLATION IN LCC ANALYSIS

CONTENTS

Chapter 3

DISCOUNTING AND INFLATION IN LCC ANALYSIS

Chapter 2 discussed the need to establish a **common study period, base date, and service date** when conducting an LCC analysis of two or more project alternatives. It is also essential that **the same discount rate and inflation treatment** be used in LCC analyses of multiple project alternatives. This chapter explains the fundamentals of discounting future costs to present value,[1] the use of **constant dollars** in an economic analysis as a way of treating inflation, and the adjustment of future costs for real price escalation. The methodology presented in this handbook for discounting and treating inflation is in accordance with the requirements of 10 CFR 436. It is identical to the methodology prescribed in OMB Circular A-94 and is consistent with most engineering-economics textbooks.

3.1 DISCOUNTING FUTURE AMOUNTS TO PRESENT VALUE

Project-related costs occurring at different points in time must be discounted to their **present value** as of the base date before they can be combined into an LCC estimate for that project. The discount rate used to discount future cash flows to present value is based on the investor's time-value of money. In the private sector, the investor's discount rate is generally determined by the investor's minimum acceptable rate of return (MARR) for investments of equivalent risk and duration. Since different investors have different investment opportunities, the appropriate discount rate can vary significantly from investor to investor. However, the discount rate to be used for energy- and water-conservation investments in federal buildings and facilities is established each year by DOE. The discount rate for other federal projects is established by the Office of Management and Budget. Section 3.1.2 describes federal discount rates in more detail.

3.1.1 Interest, Discounting, and Present Value

When we choose among potential project investments, we are sensitive to the timing of the cash flows generated by those investments. We generally prefer a dollar to be received (or saved) earlier rather than later. For example, we would prefer the annual yield schedule {$100, $100, $100, $100} to the annual yield schedule {0, 0, 0, $400}, even though they both have the same total cash amount. An investor prefers cash receipts earlier rather than later for two primary reasons: dollars generally loose purchasing power over time due to inflation, and cash amounts received earlier can be reinvested earlier, thereby earning additional returns.

When a cash amount is invested at a given interest rate, the future value of that cash amount at any point in time can be calculated using the mathematics of compound interest. Suppose that an initial sum of P_0 dollars is invested for t years at a rate of interest, i, compounded annually. In one year, the yield would be iP_0, which, added to the principal, P_0, would give us

$$P_1 = P_0 + iP_0 = P_0(1 + i) \qquad (3.1)$$

[1] In some LCC analyses, all costs are converted to an annualized (or levelized) amount. However, the annualized method of discounting is not recommended for use in FEMP LCC analyses and is not discussed further in this handbook.

After t years, the future compound amount would be

$$P_t = P_0(1 + i)^t \tag{3.2}$$

Conversely, if we know the interest rate and the value of an interest-earning amount at the end of the first year, we can compute the initial investment amount using

$$P_0 = \frac{P_1}{(1 + i)^1} \tag{3.3}$$

And if we know the interest rate and the value of an interest-earning amount at the end of t years, we can compute the initial investment amount using

$$P_0 = \frac{P_t}{(1 + i)^t} \tag{3.4}$$

The discount rate is a special type of interest rate which makes the investor **indifferent** between cash amounts received at different points in time. That is, the investor would just as soon have one amount received earlier as the other amount received later. The mathematics of discounting is identical to the mathematics of compound interest. The discount rate, d, is used like the interest rate, i, shown in equations 3.3 and 3.4 to find the present value, PV, of a cash amount received or paid at a future point in time. Thus we can find the present value of a future amount received at the end of year t, F_t, using

$$PV = \frac{F_t}{(1 + d)^t} \tag{3.5}$$

For example, with a discount rate of 5 percent, the present value of a cash amount of $100 receivable at the end of five years is $78.35. To the investor with a 5 percent discount rate, these two amounts are time equivalent. The investor would have no preference between $78.35 received today and $100 received at the end of five years.

Project-related costs which occur at different points in time over a study period cannot be directly combined in calculating an LCC because the dollars spent at different times have different values to the investor. These costs must first be discounted to their present-value equivalent amounts; only then can the costs be summed to yield a meaningful LCC that can be compared with the LCC of other alternatives.

In section 3.3 on adjusting for inflation, the difference between **constant-dollar** and **current-dollar** cash amounts is addressed. For now, you should recognize that the discounting of future cash flows to present value is not the same as adjusting future costs for general inflation. Even when costs are expressed in constant dollars, they must be discounted to reflect the time-value of money, which is usually greater than the rate of general inflation. The discount rate used with constant-dollar amounts is different from the discount rate used with current-dollar amounts. A **real** discount rate (net of general inflation) is used **with constant-dollar amounts.** A **nominal** discount rate (inclusive of general inflation) is used with **current-dollar amounts.** However, the discounting formulas shown in section 3.2 of this chapter to convert future costs to present value are applicable to both cases.

3.1.2 DOE Discount Rate vs. OMB Discount Rate

For energy and water conservation and renewable resource projects under FEMP, the U.S. Department of Energy has legislative authority to establish the appropriate discount rate, using the procedure specified in 10 CFR 436. For fiscal year 1995 the **real** DOE discount rate is 3.0 percent (excluding general inflation); the **nominal** DOE discount rate is 6.6 percent (including general inflation). This distinction will be explained in section 3.3. **The current DOE discount rate is published each year on October 1 in the Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis, 199X, NISTIR 85-3273**. The DOE discount rate applies only to investments in federally owned or leased facilities.

Most other federal projects, i.e., non-energy or water-related projects, are required to use OMB discount rates. These are specified in ***OMB Circular A-94*** (revised October 1992). Appendix C to Circular A-94 is updated annually on about March 1 to provide the current discount rates applicable for the 12 months following. The OMB discount rates are determined in part by the life of the investment and in part by who receives the benefits from the investment.

Once you decide whether the LCC analysis of a building system should be evaluated using the FEMP discount rate or the OMB discount rate, this rate should be used for all of the cost components (e.g., capital investment, energy, water, and OM&R costs) of that system. Do not use different discount rates to determine the present value of costs which will be added together or which will be compared with the costs of competing alternatives.

3.2 DISCOUNT FORMULAS AND DISCOUNT FACTORS

Table 3-1 summarizes the discounting operations most frequently used in an LCC analysis. These operations can be divided into two types:

(1) **A method for discounting one-time amounts** to present value. The definition of one-time amounts includes costs occurring at irregular or non-annual intervals. Examples of one-time costs are a capital replacement at the end of year 8, painting at five-year intervals, and a residual value at the end of the study period.

(2) **A method for discounting a series of annually recurring amounts** to a present value. Examples of annually recurring costs are routine maintenance costs occurring each year over the study period in the same amount (uniform amounts) and annual energy costs based on the same level of energy consumption from year to year but increasing from year to year at some known or estimated escalation rate (non-uniform amounts).

Each of the **discount formulas** shown in table 3-1 includes a future amount or an annually recurring amount, and a subformula which can be used to compute a corresponding **discount factor**. The computed discount factor is a scalar number by which an amount is multiplied to get its present value. The four discount factors shown in table 3-1 are those most often used in FEMP LCC analyses, i.e., the

- Single Present Value (SPV) factor,
- Uniform Present Value (UPV) factor,
- Uniform Present Value factor modified for price escalation (UPV*), and
- FEMP UPV* factor for use with energy costs.

Table 3-1
Present-Value Formulas and Discount Factors for Life-Cycle Cost Analysis.

PV formula for one-time amounts The **Single Present Value (SPV) factor** is used to calculate the present value, PV, of a future cash amount occurring at the end of year t, F_t, given a discount rate, d. $PV = F_t \times \frac{1}{(1+d)^t}$	$PV = F_t \times SPV_{(t,d)}$  The **SPV factor** for d = 3% and t = 15 years is **0.642**.
PV formula for annually recurring uniform amounts The **Uniform Present Value (UPV) factor** is used to calculate the PV of a series of equal cash amounts, A_0, that recur annually over a period of n years, given d. $PV = A_0 \times \sum_{t=1}^{n} \frac{1}{(1+d)^t} = A_0 \times \frac{(1+d)^n - 1}{d(1+d)^n}$	$PV = A_0 \times UPV_{(n,d)}$  The **UPV factor** for d = 3% and n = 15 years is **11.94**.
PV formula for annually recurring non-uniform amounts $PV = A_0 \times \sum_{t=1}^{n} \left(\frac{1+e}{1+d}\right)^t = A_0 \frac{(1+e)}{(d-e)}\left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$ The **Modified Uniform Present Value (UPV*) factor** is used to calculate the PV recurring annual amounts that change from year to year at a **constant** escalation rate, e (i.e., $A_{t+1} = A_t \times (1+e)$), over n years, given d. The escalation rate can be positive or negative.	$PV = A_0 \times UPV^*_{(n,d,e)}$  The **UPV* factor** for e = 2%, d = 3%, and n = 15 years is **13.89**.
PV formula for annually recurring energy costs (FEMP LCCA) The **FEMP UPV* factor** is used to calculate the PV of annually recurring energy costs over n years, which are assumed to change from year to year at a **non-constant** escalation rate, based on DOE projections. FEMP UPV* factors are precalculated for the current DOE discount rate and published in tables Ba-1 through Ba-5 of the Annual Supplement to Handbook 135.	$PV = A_0 \times UPV^*_{(reg,\ ft,\ rt,\ d,n)}$  The **FEMP UPV* factor** for region (reg) = 3, fuel type (ft) = electricity, rate type (rt) = commercial, d = 3%, and n = 15 is **12.12** (1995).

These discount factors can be precalculated to reduce the amount of work needed in a manual LCCA. Exhibits 3-1 to 3-3 and appendix E show examples of precalculated discount factor tables for FEMP LCCA. A comprehensive set of discounting formulas is presented in appendix D.

Note: Once you decide that the LCC analysis of a building system is to be performed using either the FEMP discount rate or the OMB discount rate, this rate should be used for the present-value calculations of all of the cost components (e.g., capital investment, OM&R costs, as well as energy and water costs) for the base case and the alternatives. Do not use different discount rates to calculate the present value of costs that will be added together or that will be compared with the cost of competing alternatives.

3.2.1 Discounting One-Time Amounts

The **Single Present Value (SPV) factor**, when multiplied by the future one-time amount, will yield the present value of that amount.

Example: A replacement cost of $1,000 incurred at the end of year 5, discounted to present value using a 3 percent discount rate, yields a present value of $862.61.

$$PV = \$1{,}000 \times \frac{1}{(1 + 0.03)^5} = \$862.61 \tag{3.6}$$

Exhibit 3-1, a table taken from the Annual Supplement to Handbook 135, provides the computed SPV factors for time periods of 1 to 30 years, based on current (fiscal year 1995) discount rates for federal projects. The SPV factor shown in Exhibit 3-1 for 5 years at a 3 percent discount rate is **0.863,** which when multiplied by the future amount of $1,000, yields the same present value as equation 3.6 (with allowance for rounding), i.e.,

$$PV = \$1{,}000 \times 0.863 = \$863.00 \tag{3.7}$$

3.2.2 Discounting Annually Recurring Amounts

Annually recurring amounts may be either **uniform** amounts or **non-uniform** amounts. Uniform amounts have the same dollar value from year to year, whereas non-uniform amounts change from year to year, either decreasing or increasing at a **constant rate** or at a **variable rate**.

3.2.2.1 Annually recurring uniform amounts

The **Uniform Present Value (UPV) factor**, when multiplied by the annually recurring cost, yields the present value of the entire stream of costs over the designated number of years.

Example: An annual maintenance cost of $100 over 5 years, discounted to present value using a 3 percent discount rate, yields a present value of $457.97.

$$PV = \$100 \times \frac{(1 + 0.03)^5 - 1}{0.03(1 + 0.03)^5} = \$457.97 \tag{3.8}$$

Computed UPV factors for FEMP and OMB LCC analyses, based on the current federal discount rates, can be found in table A-2 of the Annual Supplement to Handbook 135. Exhibit 3-2 shows a reproduction of this table for FY 1995, when the FEMP discount rate was set at 3.0 percent. The UPV factor shown in Exhibit 3-2 for 5 years at a 3 percent discount rate is **4.58**, which, when multiplied by the annual amount of $100 yields the same present value as eq (3.8) (with allowances for rounding).

Exhibit 3-1
SPV Factor Table from Annual Supplement to Handbook 135

Table A-1. SPV factors for finding the present value of future single amounts (non-fuel, 1995)

Single Present Value (SPV) Factors

Year of Occurrence (t)	DOE Discount Rate 3.0%	OMB Discount Rates[a] Short Term[b] 2.5%	OMB Discount Rates[a] Long Term[c] 2.8%
1	0.971	0.976	0.973
2	0.943	0.952	0.946
3	0.915	0.929	0.920
4	0.888	0.906	0.895
5	0.863	0.884	0.871
6	0.837	0.862	0.847
7	0.813	0.841	0.824
8	0.789	0.821	0.802
9	0.766	0.801	0.780
10	0.744	0.781	0.759
11	0.722		0.738
12	0.701		0.718
13	0.681		0.698
14	0.661		0.679
15	0.642		0.661
16	0.623		0.643
17	0.605		0.625
18	0.587		0.608
19	0.570		0.592
20	0.554		0.576
21	0.538		0.560
22	0.522		0.545
23	0.507		0.530
24	0.492		0.515
25	0.478		0.501
26	0.464		0.488
27	0.450		0.474
28	0.437		0.462
29	0.424		0.449
30	0.412		0.437

[a] OMB discount rates as of March 1994. OMB rates are expected to be revised in February 1995.
[b] Short-term discount rate based on OMB discount rate for 7-year study period.
[c] Long-term discount rate based on OMB discount rate for 30-year study period.

Exhibit 3-2
UPV Factor Table from Annual Supplement to Handbook 135

Table A-2. UPV factors for finding the present value of future single amounts (non-fuel, 1995)

	Uniform Present Value (UPV) Factors		
	FEMP	OMB Discount Rates[a]	
Year of Occurrence (t)	Discount Rate 3.0%	Short Term[b] 2.5%	Long Term[c] 2.8%
1	0.97	0.98	0.97
2	1.91	1.93	1.92
3	2.83	2.86	2.84
4	3.72	3.76	3.73
5	4.58	4.65	4.61
6	5.42	5.51	5.45
7	6.23	6.35	6.28
8	7.02	7.17	7.08
9	7.79	7.97	7.86
10	8.53	8.75	8.62
11	9.25		9.36
12	9.95		10.07
13	10.63		10.77
14	11.30		11.45
15	11.94		12.11
16	12.56		12.76
17	13.17		13.38
18	13.75		13.99
19	14.32		14.58
20	14.88		15.16
21	15.42		15.72
22	15.94		16.26
23	16.44		16.79
24	16.94		17.31
25	17.41		17.81
26	17.88		18.30
27	18.33		18.77
28	18.76		19.23
29	19.19		19.68
30	19.60		20.12

[a] OMB discount rates as of March 1994. OMB rates are expected to be revised in February 1995.
[b] Short-term discount rate based on OMB discount rate for 7-year study period.
[c] Long-term discount rate based on OMB discount rate for 30-year study period.

3.2.2.2 Annually recurring non-uniform amounts

The **Modified Uniform Present Value (UPV*) factor**, can be used to convert to present value annually recurring costs that change from year to year at a constant escalation rate, e, i.e., $A_{t+1} = (1+e)A_t$.

Example: A maintenance cost of $100 occurs annually and is expected to increase at 2 percent per year over 5 years. When discounted to present value using a discount rate of 3 percent, it will yield a present value of $485.62. Note that the annual amount is specified at the price level of the base date when using the UPV or UPV factors.*

$$PV = \$100 \times \frac{(1 + 0.02)}{(0.03 - 0.02)} \left[1 - \left(\frac{1 + 0.02}{1 + 0.03} \right)^5 \right] = \$485.62 \qquad (3.9)$$

The computed UPV* factor for 5 years, at a discount rate of 3 percent and a constant escalation rate of 2 percent, is **4.8562.**

UPV* factor tables which include constant escalation rates are not included in this handbook or the Annual Supplement to Handbook 135. The FEMP LCC methodology assumes that prices for goods and services other than energy change at approximately the rate of general inflation, so that in a constant-dollar analysis the real escalation rate is zero. (The use of constant dollars and real escalation rates in FEMP LCC analyses is covered in section 3.3.) The NIST DISCOUNT program can be used to calculate these factors using any combination of discount rate, escalation rates, and study period. See appendix B for more information on this program.

3.2.2.3 Annually recurring energy costs

The **FEMP Modified Uniform Present Value (FEMP UPV*) factor** is a special UPV* factor for use with annually recurring energy costs. FEMP UPV* factors are precalculated factors, based on the current DOE discount rate and on energy price escalation rates projected by DOE's Energy Information Administration. The DOE escalation rates vary by year, region, fuel type, and rate type. The forecast is based on a mid-range scenario with regard to the performance of the domestic economy and world oil prices over 30 years. The FEMP rules in 10 CFR 436 require that these DOE energv price escalation rates be used in LCC analyses of energy-conservation projects in federal facilities.

Current FEMP UPV* factors are published in the Annual Supplement to Handbook 135, tables Ba-1 through Ba-5. Separate tables are published for each of the four major census regions of the United States and for the U.S. Average. These FEMP UPV* factors, when multiplied by the annual energy cost (as calculated using energy prices as of the base date),[2] yield the present value of energy costs for the number of years indicated, given the current DOE discount rate. The FEMP UPV* tables for fiscal year 1995 are included in appendix F of this manual.

Example: Assume that you are evaluating an energy conservation project in a federal building located in Connecticut. The annual cost of natural gas for space heating is $20,000, using commercial gas prices as of the beginning of the study period (1995). The present value of these annual gas costs over 20 years can be computed by multiplying the annual cost of $20,000 by the appropriate FEMP UPV factor of 17.51. The present value is*

$$\$20{,}000 \times 17.51 = \$350{,}200 \qquad (3.10)$$

Table Ba-1 for census region 1, as published in the Annual Supplement to Handbook 135 for FY 1995, is shown in exhibit 3-3. The top of the table shows the states located in the census region covered in the table.

[2] See section 4.6.1 for more details related to the calculation of annual energy costs.

Since DOE forecasts of energy price escalation rates vary by **fuel type** (electricity, distillate and residual fuel oils, natural gas, LPG, and coal) and by **rate type** (residential, commercial, and industrial), FEMP UPV* factors are computed for each combination of energy type and rate type over study periods ranging from 1 to 30 years. The FEMP UPV* factor of **17.51** is found in the section headed "Commercial," in the column headed "NTGAS," in the row where N, the number of years, is equal to 20.

3.2.3 Discounting When There is a Planning/Construction Period

For LCC analyses in which a planning/construction (P/C) period occurs before the service date, special consideration must be given to **annually recurring costs** before discounting them to present value. For **one-time costs** occurring at any time during the study period, the SPV factor is used as shown above. That is, the present value at the base date is calculated with the appropriate SPV factor for the number of years between the base date and the time the cost is incurred. However, this is not the case with annually recurring costs. Annually recurring costs are not generally incurred during the P/C period, but instead are usually assumed **to begin at the date the project is put into service**. The use of a UPV or UPV* factor based on the full study period, which includes the P/C period, would implicitly include in the present-value calculation annually recurring costs that did not occur in the P/C period. To exclude those costs for the length of the P/C period, take the following steps:

(1) Look up (or calculate) the UPV (UPV*) factor for the number of years in the entire study period (including the P/C period).

(2) Look up (or calculate) the UPV (UPV*) factor for the years in the P/C period.

(3) Use the positive difference between the two factors as the appropriate UPV (FEMP UPV*) factor by which to multiply the annual recurring cost (specified in base-date prices).

This procedure will give the present value as of the base date of the annually recurring costs over the service period only.

Example: Assume that natural gas to be used in a new heating system in a commercial building in census region 1 is estimated to cost $20,000 per year, based on gas prices at the base date. This system is expected to be put into service three years after the base date and to continue in use for 20 years after the service date. Compute the present value, as of the base date, of the cost of natural gas over the 20 year service period.

(1) From exhibit 3-3, the FEMP UPV* factor for region 1, commercial natural gas, for 23 years (3 years P/C period plus 20 years of usage), is **19.79**.

(2) The corresponding FEMP UPV* factor for 3 years (the P/C period) is **2.94**.

(3) The appropriate FEMP UPV* factor for computing the present value of the natural gas usage over 20 years as of the base date is **16.85** (=19.79-2.94), which when multiplied by $20,000 yields a present value of $337,000.

Exhibit 3-3
UPV* Discount Factor Table from Annual Supplement to Handbook 135

Table Ba-1. UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type, FY 1995
Discount rate = 3.0 percent (FEMP)

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

	RESIDENTIAL				COMMERCIAL					INDUSTRIAL					TRANSPORT	
N	ELEC	DIST	LPG	NTGAS	ELEC	DIST	RESID	NTGAS	COAL	ELEC	DIST	RESID	NTGAS	COAL	GASLN	N
-	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-
1	0.98	0.98	0.98	0.99	0.96	0.98	1.01	1.00	1.00	0.96	0.98	1.01	1.00	0.95	1.01	1
2	1.93	1.94	1.95	1.96	1.90	1.94	2.03	1.98	1.97	1.89	1.95	2.04	1.99	1.88	2.02	2
3	2.86	2.88	2.91	2.92	2.80	2.90	3.07	2.94	2.92	2.79	2.91	3.08	2.96	2.78	3.02	3
4	3.77	3.82	3.85	3.86	3.69	3.86	4.10	3.89	3.84	3.66	3.86	4.12	3.93	3.74	4.00	4
5	4.65	4.75	4.78	4.77	4.55	4.81	5.13	4.82	4.75	4.52	4.82	5.15	4.88	4.69	4.97	5
6	5.53	5.67	5.71	5.67	5.38	5.76	6.16	5.73	5.63	5.35	5.78	6.19	5.81	5.56	5.93	6
7	6.38	6.58	6.62	6.56	6.20	6.71	7.20	6.63	6.52	6.16	6.73	7.25	6.75	6.41	6.88	7
8	7.22	7.49	7.53	7.43	7.00	7.67	8.26	7.52	7.38	6.96	7.69	8.31	7.67	7.23	7.81	8
9	8.05	8.39	8.42	8.27	7.77	8.62	9.33	8.39	8.22	7.72	8.65	9.39	8.58	8.03	8.73	9
10	8.86	9.28	9.30	9.12	8.53	9.56	10.39	9.26	9.04	8.47	9.60	10.46	9.49	8.81	9.64	10
11	9.65	10.15	10.17	9.95	9.26	10.50	11.44	10.12	9.82	9.19	10.54	11.53	10.39	9.57	10.53	11
12	10.43	11.01	11.02	10.77	9.97	11.42	12.50	10.96	10.57	9.90	11.47	12.60	11.28	10.30	11.40	12
13	11.20	11.86	11.85	11.58	10.67	12.33	13.56	11.81	11.31	10.59	12.38	13.68	12.18	11.02	12.26	13
14	11.95	12.69	12.68	12.40	11.35	13.23	14.61	12.66	12.02	11.27	13.29	14.75	13.07	11.73	13.11	14
15	12.71	13.51	13.48	13.20	12.02	14.12	15.63	13.50	12.71	11.93	14.19	15.78	13.96	12.43	13.94	15
16	13.44	14.32	14.28	13.98	12.66	14.99	16.64	14.32	13.37	12.58	15.08	16.81	14.84	13.10	14.75	16
17	14.17	15.11	15.06	14.76	13.28	15.86	17.65	15.14	14.02	13.20	15.95	17.84	15.71	13.77	15.55	17
18	14.88	15.89	15.84	15.52	13.88	16.71	18.65	15.94	14.66	13.82	16.81	18.86	16.57	14.42	16.34	18
19	15.57	16.65	16.60	16.27	14.47	17.56	19.65	16.73	15.28	14.41	17.66	19.88	17.42	15.05	17.12	19
20	16.26	17.40	17.35	17.01	15.04	18.39	20.64	17.51	15.88	14.99	18.50	20.90	18.27	15.68	17.89	20
21	16.92	18.14	18.08	17.74	15.60	19.21	21.63	18.28	16.47	15.56	19.33	21.91	19.11	16.29	18.65	21
22	17.58	18.86	18.81	18.45	16.13	20.01	22.61	19.04	17.05	16.12	20.15	22.92	19.93	16.90	19.39	22
23	18.22	19.57	19.52	19.15	16.66	20.81	23.59	19.79	17.62	16.65	20.96	23.93	20.75	17.49	20.13	23
24	18.85	20.27	20.23	19.85	17.17	21.60	24.56	20.53	18.17	17.18	21.76	24.94	21.56	18.07	20.86	24
25	19.46	20.96	20.92	20.53	17.66	22.38	25.52	21.26	18.71	17.69	22.55	25.94	22.35	18.63	21.57	25
26/a	20.06	21.63	21.60	21.20	18.14	23.14	26.49	21.98	19.24	18.19	23.33	26.94	23.14	19.19	22.28	26
27/a	20.65	22.30	22.27	21.86	18.60	23.90	27.44	22.68	19.76	18.68	24.10	27.94	23.91	19.74	22.98	27
28/a	21.23	22.95	22.94	22.51	19.06	24.64	28.40	23.38	20.26	19.15	24.86	28.94	24.68	20.28	23.66	28
29/a	21.80	23.59	23.59	23.14	19.50	25.38	29.34	24.07	20.75	19.62	25.61	29.93	25.44	20.80	24.34	29
30/a	22.35	24.22	24.23	23.77	19.92	26.11	30.29	24.75	21.24	20.07	26.35	30.92	26.19	21.32	25.01	30

3.3 ADJUSTING FOR INFLATION

Inflation reduces the purchasing power of the dollar over time; deflation increases it. When future amounts are stated in actual prices as of the year in which they are expected to occur, they are said to be **in current dollars**. Current dollars are dollars of any one year's purchasing power, **inclusive** of inflation. That is, they reflect changes in the purchasing power of the dollar from year to year. In contrast, **constant dollars** are dollars of uniform purchasing power, **exclusive** of inflation. Constant dollars indicate what the same good or service would cost at different times if there were no change in the general price level—no general inflation or deflation—to change the purchasing power of the dollar.

To make a meaningful comparison between costs occurring at different points in time, those costs must be adjusted for changes in the purchasing power of the dollar. To measure costs with inflated or deflated dollars is meaningless, just as it would be meaningless to measure a building's dimensions with an elastic tape measure. The adjustment of costs from current to constant dollars is not the same as discounting future costs to present value. The former adjusts only for changes in the purchasing power of the dollar; the latter adjusts for an individual investor's time-value of money. The appropriate discount rate needed to adjust future costs to their present value will be different depending on whether future costs are stated in constant dollars or current dollars. Even when costs are expressed in constant dollars, the discount rate is usually positive, reflecting the real earning power of money over and above the general rate of inflation.

3.3.1 Two Approaches for Dealing with Inflation

The FEMP methodology for LCC analysis allows cash flows to be stated either in constant dollars or in current dollars. However, the constant dollar method is preferred and is the methodology supported by Handbook 135, the Annual Supplement to Handbook 135, and the BLCC computer program.

The constant dollar approach has the advantage of avoiding the need to project future rates of inflation or deflation. **The price of a good or service stated in constant dollars is not affected by the rate of general inflation**. For example, if the price of a piece of equipment is $1,000 today and $1,050 at the end of a year in which prices in general have risen at an annual rate of 5 percent, the price stated in constant dollars is still $1,000; no inflation adjustment is necessary. In contrast, if cash flows are stated in current dollars, future amounts include general inflation, and an adjustment is necessary to convert the current-dollar estimate to its constant-dollar equivalent. This adjustment is important because constant- and current-dollar amounts must not be combined in an LCCA.

There are two ways to arrive at constant dollar amounts in an LCCA. Both methods need to be looked at in combination with the discount rate.

Method 1: Estimate future costs and savings in **constant** dollars and discount with a "**real**" discount rate, i.e., a discount rate that **excludes** the rate of inflation, or

Method 2: Estimate future costs and savings in **current** dollars and discount with a "**nominal**" discount rate, i.e., a discount rate that **includes** the rate of inflation.

Both of these approaches will yield the same present value results, and thus support the same conclusion, provided consistent assumptions are made about the real discount rate and the rate of inflation. However, **it is generally easier to conduct an economic analysis in constant dollars** because the rate of inflation from year to year over the study period need not be estimated. The analyst chooses a reference date for fixing the value of the dollar and expresses all future amounts in dollars of the same value, for example, in constant 1995 dollars. The reference date is usually chosen to coincide with the beginning of the study period, but it could be any date.

It is important in this context to distinguish between a **present value** analysis, where future costs are adjusted to time-equivalent values, and a **budget analysis,** where funds must be appropriated for year-to-year disbursements. The purpose of a present-value analysis is to determine whether the overall savings justify the planned investment **at the time the investment decision is being made**. A budget analysis must include general inflation to assure that sufficient funding will be appropriated **in future years** to cover **actual** expenses. The current dollar method is generally more appropriate in private sector analyses when tax effects must be included, since taxes are computed on actual cash flows.

3.3.2 Derivation of the Real Discount Rate

Note: The current DOE discount rates (real and nominal) are published in the Annual Supplement to Handbook 135. You do not need to derive either of these rates. This section describes the underlying mathematical relationship between the real and nominal discount rates. The 10 CFR 436 states that the real DOE discount rate cannot be lower than 3 percent or greater than 10 percent.

In every-day business activities, discount rates are usually based on **market** interest rates, that is, **nominal** interest rates which include the investor's expectation of general inflation. **Market interest rates** generally serve as the basis for the selection of a **nominal** discount rate, which is used to discount future costs expressed in current dollars. In contrast, the **real** discount rate needed to discount constant dollar amounts to present value reflects only the **real earning power of your money**, not the rate of general inflation. The real discount rate, d, can be derived from the nominal discount rate, D, if the rate of inflation, I, is known. It is important to recognize that the real discount rate, d, is not found by simply subtracting the rate of inflation, I, from the nominal discount rate, D. Rather, the relationship is as follows:

$$d = \frac{1 + D}{1 + I} - 1 \tag{3.11}$$

Example: Given an inflation rate, I, of 4.0 percent and a nominal discount rate, D, of 7.0 percent, the real discount rate, d, is computed as 2.9 percent, or more precisely

$$\frac{1 + 0.07}{1 + 0.04} - 1 = 0.02885 \tag{3.12}$$

Likewise, if I and d are known, the nominal discount rate, D, can be calculated according to the formula

$$D = (1 + I)(1 + d) - 1 \tag{3.13}$$

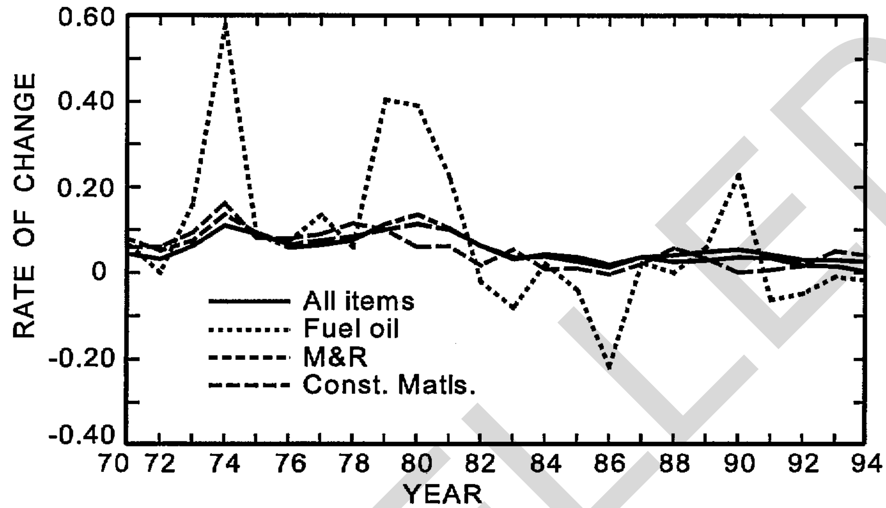
Example: Given an inflation rate of 4.0 percent and a real discount rate of 3.0 percent, the nominal discount rate would be 7.1 percent, or more precisely

$$(1 + 0.04)(1 + 0.03) - 1 = 0.0712 \tag{3.14}$$

For a rough estimate of real or nominal discount rates, it is acceptable to just subtract or add the rate of inflation, but to assure that the results of an economic evaluation are exactly the same no matter whether cash flows are stated in current or in constant dollars, the rates need to be computed according to the above formulas.

3.3.3 Price Escalation

Few commodities have prices that change at exactly the rate of general inflation (that is, the rate of change in the price level of all items) year after year, but many commodities have prices which change at a rate close to that of general inflation over time. Figure 3-1 shows, for the years 1970 through 1994, the rate of general inflation and the rates of (nominal) price escalation for several commodities related to buildings: maintenance and repair costs, construction materials, and fuel oil.



Data Source: Consumer Price Indexes, U.S. Dept. Commerce, Bureau of Labor Statistics

Figure 3-1
Rate of Price Changes for Home-Related Items Compared with "All Items".

As is evident from figure 3-1, only for fuel oil have price escalation rates deviated substantially from the rate of general inflation over most of these years; rates of price change for the other home-related items shown have closely tracked the rate of change in the general price level so that the relative price change for these items is zero. For this reason, the FEMP LCC methodology, which recommends that future costs be expressed in constant dollars, generally assumes a zero real (differential) escalation rate for all non-energy-related.

3.3.3.1 Nominal price escalation

In order to estimate the actual cost of a particular commodity as of some future date, C_t, where t is the number of time periods between the base date and the date that the cost is incurred, the cost of that commodity as of the base date, C_0, must be adjusted to reflect the **nominal price escalation rate, E,** for that commodity over the t time periods, using the following formula:

$$C_t = C_0 (1 + E)^t \tag{3.15}$$

Example: A replacement of $1,000 today, which escalates at a nominal rate of 3 percent per year will cost approximately $1,344 ten years from now.

$$C_{10} = \$1,000 (1 + 0.03)^{10} = \$1,344 \tag{3.16}$$

The **nominal** rate of price escalation, E, can be, but is not necessarily, the same as the rate of **general** inflation, I, which represents the rate of increase in prices for all goods and services.[3]

3.3.3.2 Real price escalation

If the nominal rate of price escalation, E, for a particular commodity is different from the general rate of inflation, then a **real** (differential) rate of escalation, e, can be computed as

$$e = \frac{1 + E}{1 + I} - 1 \tag{3.17}$$

For example, given an inflation rate, I, of 4.0 percent and a nominal escalation rate, E, of 5.0 percent, the real escalation rate, e, is computed as 0.96 percent, or more precisely

$$e = \frac{1 + 0.05}{1 + 0.04} - 1 = 0.009615 \tag{3.18}$$

Or, given the real escalation rate, the **nominal escalation rate** can be computed as

$$E = (1 + I)(1 + e) - 1 \tag{3.19}$$

For example, given an inflation rate of 4.0 percent and a real escalation rate of 2.0 percent, the nominal escalation rate would be 6.1 percent, or more precisely

$$E = (1 + 0.04)(1 + 0.02) - 1 = 0.0608 \tag{3.20}$$

Just as the real discount rate, d, is not exactly the difference between the nominal discount rate, D, and the rate of general inflation, I, the real escalation rate, e, for a commodity is not exactly the difference between the nominal escalation rate, E, and the rate of general inflation, I.

In order to estimate the cost, C_t, of a particular commodity in constant base-year dollars as of some future point in time t, where t is the number of time periods between the base date and the date that the cost is incurred, the cost of that commodity today, C_0, must be adjusted to reflect the **real price escalation rate, e,** for that commodity over the t time periods, using the following formula

$$C_t = C_0 (1 + e)^t \tag{3.21}$$

Example: A replacement cost of $1,000 today, which escalates at a real rate of 1 percent per year (i.e., 1 percent greater than the general inflation rate), will cost approximately $1,105 ten years from now, in base-year constant dollars.

$$C_{10} = \$1{,}000\ (1 + 0.01)^{10} = \$1{,}105 \tag{3.22}$$

And if that replacement cost decreases in real terms (i.e., its nominal escalation rate is less than the rate of general inflation), then its future cost in constant base-year dollars will be less than its cost as of the base date.

[3] Just as the rate of general inflation may not be constant from year to year, E may not be constant from year to year. When E is not constant from year to year, the cost of a commodity in year t must be calculated by compounding the annual escalation rates as follows

$$C_t = C_0\,(1+E_1)\,(1+E_2)\,(1+E_3)\,...\,(1+E_t)$$

Example: If in the previous example, the real escalation rate were assumed to be -1 percent (i.e., 1 percent less than the general inflation rate), then that cost would be approximately $904 ten years later, in constant base-year dollars.

$$C_{10} = \$1{,}000\ (1 - 0.01)^{10} = \$904 \tag{3.23}$$

Table 3-2 summarizes the formulas used to calculate the real and nominal discount rates and escalation rates needed to adjust LCC cash flows for the underlying inflation rate (I).

Table 3-2
Summary of Inflation-Adjustment Formulas

Nominal Discount Rate:	D	=	(1 + d)(1 + I) - 1
Real Discount Rate:	d	=	(1 + D)/(1 + I) - 1
Nominal Escalation Rate:	E	=	(1 + e)(1 + I) - 1
Real Escalation Rate:	e	=	(1 + E)/(1 + I) - 1

3.3.4 Real Escalation of Energy-Related Cash Flows

For energy-related costs, the FEMP LCC methodology requires the use of DOE-projected real escalation rates by fuel type, rate type, and census region, as published in the Annual Supplement to Handbook 135. The FEMP UPV* factors published in that supplement, which incorporate these escalation rates, are automatically applied in an LCC analysis that is performed using the NIST BLCC and DISCOUNT computer programs. However, 10 CFR 436 does permit the use of alternative real escalation rates for a FEMP LCC analysis for those years for which the local energy supplier can give a firm estimate of the anticipated rate of price increase. In such a case, the computation of the appropriate UPV* factor is more complex and should generally be performed using the NIST BLCC computer program or software consistent with this program.

3.3.5 Illustration of Discounting Constant-Dollar and Current-Dollar Cash Flows

Use a real discount rate, d,
if you express cash flows in **constant** dollars, including only the differential rate of price escalation;

Use a nominal discount rate, D,
if you express cash flows in **current** dollars, including both the differential rate of price escalation and general inflation.

The following example shows that both approaches result in the same present value and thus support the same decision.

Example: Suppose you want to know the present value of an AC compressor that you expect to replace in 15 years. If it were replaced today, the price would be $5,000. Due to advanced manufacturing processes, you expect that the price of compressors will increase at a rate of 2 percent lower than general price inflation. You estimate the rate of general price inflation to be 5 percent per year. You know that your real discount rate is 3 percent. To sum

I	=	0.05	t	=	15 years
d	=	0.03	D	=	(1 + 0.03)(1 + 0.05) - 1 = 0.0815
e	=	-0.02	E	=	(1 - 0.02)(1 + 0.05) - 1 = 0.029

Constant dollars and **real** discount rate

$$PV = F_t \times \left[\frac{1+e}{1+d}\right]^t$$

$$= 5000 \times \left[\frac{1-0.02}{1+0.03}\right]^{15} \quad (3.24)$$

$$= 5000 \times 0.4741$$

$$= \$2,370.30$$

Current dollars and **nominal** discount rate

$$PV = F_t \times \left[\frac{1+E}{1+D}\right]^t$$

$$= 5000 \times \left[\frac{1+0.029}{1+0.0815}\right]^{15} \quad (3.25)$$

$$= 5000 \times 0.4741$$

$$= \$2,370.30$$

CHAPTER 4

ESTIMATING COSTS FOR LCC ANALYSIS

CONTENTS

Chapter 4

ESTIMATING COSTS FOR LCC ANALYSIS

4.1 RELEVANT EFFECTS

There are numerous costs associated with acquiring, operating, maintaining, and disposing of a building or building system. Which of these costs needs to be included is one of the first decisions to be made when performing a life-cycle cost analysis (LCCA) of alternative energy conservation strategies. To answer this question, it is necessary to look at the **economic effects** that will result from each design alternative. To the extent feasible, these effects need to be quantified in dollar terms. For effects that cannot be expressed as dollar amounts, a verbal account should be given so that they can be included in the analysis at least in a qualitative way.

It is not necessary to include all project-related costs in an LCCA of project alternatives. Only those costs that are **relevant** to the decision and **significant** in amount are needed to make a valid investment decision. Costs are relevant to the decision when they change from alternative to alternative. Costs that are approximately the same for each alternative are not a determining factor in the choice among the alternatives and therefore can be omitted from the LCC calculation. Inclusion of such costs will not produce erroneous results but may incur data collection and analysis costs which could be avoided. Costs are significant when they are large enough to make a credible difference in the LCC of a project alternative. Energy costs, for example, are likely to be relevant and significant in the analysis of alternative window designs for an office building but not in the analysis of low-flow bathroom fixtures. Assessing the relevance and significance of project costs in an LCCA is largely a matter of engineering judgment.

Sunk costs should be **excluded** from an LCCA. These are costs that have been incurred or committed to in the past and thus cannot be avoided by a future decision. For example, the cost of a recently replaced fuel tank for an oil heating system being converted to natural gas is a sunk cost (except for its salvage value, if any).

In the LCCA of federal energy and water conservation projects, tax effects and finance costs (i.e., interest charges) are generally not relevant and can be omitted from the LCCA. However, when evaluating alternative methods of funding energy and water conservation projects for federal facilities (e.g., full agency funding versus negotiated "shared savings" plans or utility demand-side management incentives), the relative cost effectiveness of the projects under each of these funding alternatives should be evaluated from an LCC perspective before deciding which method(s) of funding are most advantageous to the federal government. (This subject is discussed further in appendix G, "Evaluating Energy Savings Performance Contracts.")

4.2 COST CATEGORIES

There are various ways of classifying the cost components of an LCCA, depending on what role they play in the mechanics of the methodology. The most important categories in LCCA distinguish between investment-related and operational costs; initial and future costs; and single costs and annually recurring costs.

4.2.1 Investment Costs vs. Operational Costs

Life-cycle costs typically include both investment costs and operational costs. The distinction between investment and operation-related costs is most useful when computing supplementary economic measures such as the Savings-to-Investment Ratio and Adjusted Internal Rate of Return. These measures evaluate savings in operation-related costs with respect to increases in capital investment costs. This distinction will not affect the LCC calculation itself, nor will it cause a project alternative to change from cost effective to non-cost effective or vice versa. However, it may change its ranking relative to other independent projects when allocating a limited capital investment budget. (Budget allocation methods are discussed in section 7.5.)

All **acquisition costs**, including costs related to planning, design, purchase, and construction, are **investment-related costs**. The FEMP LCC methodology in 10 CFR 436 also requires that **residual values** (resale, salvage, or disposal costs) and **capital replacement costs** be included as investment-related costs. Capital replacement costs are usually incurred when replacing major systems or components, paid from capital funds. Operating, maintenance, and repair (OM&R) costs, including energy and water costs, are operational costs. Replacements which are related to maintenance or repair (e.g., replacing light bulbs or a circuit board) are usually considered to be OM&R costs, not capital replacement costs. OM&R costs are usually paid from an annual operating budget, not from capital funds.

4.2.2 Initial Investment Costs vs. Future Costs

The distinction between initial investment costs and future costs is most useful when computing the Simple or Discounted Payback measures. The costs incurred in the planning, design, construction and/or acquisition phase of a project are classified as **initial investment costs**. They usually occur before a building is occupied or a system is put into service. Those costs that arise from the operation, maintenance, repair, replacement, and use of a building or a system during its occupancy or service period are **future costs**. Residual values at the end of a system life, or at the end of the study period, are also future costs.

4.2.3 Single Costs vs. Annually Recurring Costs

It is useful to establish two categories of project-related costs based on their frequency of occurrence. This categorization determines the type of present-value factor to be used for discounting future cash flows to present value.

(1) **Single costs** (one-time costs) occur at one or more times during the study period at non-annual intervals. Initial investment costs, replacement costs, residual values, maintenance costs scheduled at intervals longer than one year, and repair costs are usually treated as single costs. The **SPV factor** is the appropriate present-value factor for single costs.

(2) **Annually recurring costs** are amounts that occur regularly every year during the service period in approximately the same amount, or in an amount expected to change at some known rate. Energy costs, water costs, and routine annual maintenance costs fall into this category. The appropriate present value factor for annually recurring amounts is the **UPV factor** or **UPV* factor**. If recurring costs are the same each year, the **UPV factor** is the appropriate present value factor. If the annual amounts are expected to change at a known rate, the **UPV* factor** is the appropriate present value factor.

4.3 TIMING OF CASH FLOWS

LCC analysis requires that all project-related costs be identified by time of occurrence as well as amount. However, it is a well-accepted convention in LCCA to use simplifying models of cash flows rather than to attempt to reproduce the exact timing of all costs. Thus costs which may occur at different times during the year may all be treated as occurring at the same time each year, in order to simplify the discounting operations. Computer-assisted LCCA makes it more convenient to compute single costs from their actual time of occurrence during the year.

4.3.1 FEMP Cash-flow Conventions

FEMP LCC rules (10 CFR 436) allow both single and annually recurring costs to be discounted either from the actual time of occurrence or from the end of the year in which they occur. The FEMP convention (as reflected historically in Handbook 135 and the discount factor tables in the Annual Supplement to Handbook 135) for manual calculations has been to discount all costs from the **end of the year** in which they occur. However, since LCC computer programs (e.g., BLCC) are now used for most LCC computations, other cash flow conventions are often used. The most appropriate cash flow convention for any given cost category varies with the complexity of the analysis, the computational basis (manual versus computer), and specific agency requirements.

When using manual methods, its is usually sufficient to discount all costs from the end of the year in which they occur. The present value tables provided in the Annual Supplement to Handbook 135 are based on this end-of-year discounting convention. With computer-aided analysis, the recommended method is to discount all single costs from the time of occurrence and to discount annually recurring costs from the end of each service year (consistent with the UPV or UPV* factors shown in this handbook). However, for military construction projects in the U.S. Department of Defense (subject to the Tri-Services Memorandum of Agreement [11], reproduced in appendix E), initial investment costs are usually discounted from the mid-point of construction, and annually recurring OM&R costs (including energy and water costs) are discounted from the mid-point of each service year. A special compilation of present value tables has been provided by NIST to DoD for this purpose [4].

4.3.2 Cash-flow Diagrams

A cash-flow diagram for a project alternative, as shown in figure 4-1, provides a convenient way of visualizing all relevant costs and their timing. A horizontal time-line represents the study period and marks each year and key dates; e.g., the base date, the occupancy or service date, and the end of the study period. Years can be marked in calendar-year terms (e.g., 1995) or in elapsed years from the base date (e.g., 1, 2, 3,...). There is no standard convention for showing costs on a cash flow diagram, but positive costs are typically shown above the horizontal time-line, and negative costs (e.g., residual values) are shown below the time-line. The cash flow diagram for project "A" in figure 4-1 shows a study period of 15 years, from January 1995 through December of 2009. An initial investment of $5,000 is shown at the base date, with a residual value of $200 at the end of the study period. Annually recurring OM&R costs of $600 (in base-date dollars) are shown, along with a one-time OM&R cost of $400.

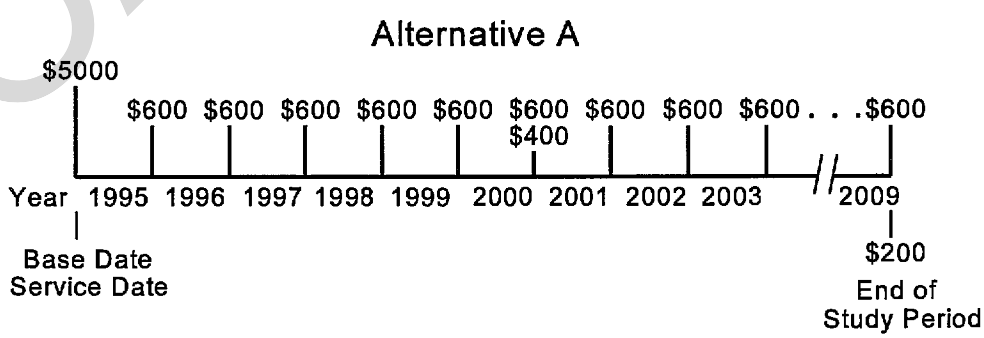


Figure 4-1
Cash-Flow Diagram.

4.4 USING BASE-DATE PRICES TO ESTIMATE FUTURE COSTS

Most cost data for an LCCA are likely to be estimates. The analysis is often performed early in the decision-making process before detailed initial cost data are available, and future costs by their nature are uncertain. The difficult task of obtaining estimates of future costs is made somewhat easier by the fact that the FEMP LCC methodology bases future cost estimates on their corresponding cost as of the base date of the LCCA, usually the date on which the analysis is performed. Section 3.3.3 provides the methodology used to convert prices (or costs) at the base date to prices (or costs) at a future date when appropriate price escalation rates are available. However, this step is not usually required in an LCCA, since price escalation rates are included in the present-value factors. (See section 3.2.2.2 for information on discounting non-uniform annual amounts.)

If there is reason to believe that the basic supply and demand conditions for a particular good or service remain the same as those for most other goods and services, it can be assumed that its price will change at roughly the rate of general price inflation. That is, the real price escalation rate is equal to zero. This means that **in a constant-dollar analysis**—where the rate of inflation is not included in the computations—**the future price of an item is identical to the base-date price**. One of the basic assumptions of the FEMP LCC methodology is that prices for all goods and services, other than for energy and water, will increase at approximately the same rate as general inflation. However, if there is a documentable basis for assuming that prices change at a rate different than general inflation (for example, when price escalation rates are established in a maintenance contract), these rates can be used in the analysis.

Even in the case of energy and water prices, the base-date price is used as the basis for estimating future prices in the FEMP LCC methodology. DOE provides price escalation rates for use in estimating future energy prices, but these are used with local energy price schedules as of the base date. DOE does not provide price escalation rates for water because these rates are very sensitive to existing and projected infrastructure conditions at the community level.

4.5 ESTIMATING INVESTMENT-RELATED COSTS

4.5.1 Estimating Initial Investment Costs

Initial investment costs are probably the least difficult of the project costs to estimate because they occur relatively close to the present time. Quotes for purchase and installation costs can often be obtained from local suppliers or contractors. You can also develop estimates by adding unit costs obtained from construction cost-estimating guides. Table 4-1 lists some of these guides. They are published as tables or made available in computerized form.

Since the estimates are based on different underlying assumptions and have different emphases, we recommend that you use the same data set for analyzing each of the alternatives being considered for a project in order to get consistent and comparable results.

Detailed estimates of construction costs are not necessary for preliminary economic analyses of alternative building designs or systems. Such estimates are usually not available until the design is quite advanced and the opportunity for cost-reducing design changes has been missed. For very large projects you may want to use a standard format for organizing construction cost data to facilitate the retrieval and review of the data. UNIFORMAT II [9], which has been published as a standard classification scheme by ASTM [10], organizes costs into three levels for each of 12 work categories (e.g., category 03, superstructure; category 06, interior construction; and category 12, site work). The hierarchical system allows for cost estimates

Table 4-1
Suggested Cost Estimating Guides for LCC Analysis*

BOECKH Underwriter's Valuation Manual
E. H. Boeckh Co., American Appraisal Association, Inc.
525 E. Michigan St., Milwaukee, WI 53201
(414) 780-2800

BNI BUILDING NEWS
BNI Publications
3055 Overland Ave., Los Angeles, CA 90034
(310) 202-7775

CERL M&R DATABASE
USACE Engineer Division HV
CEHND-ED-ES (Terry Patton)
P.O. Box 1600, Huntsville, AL 35807-5301
(205) 895-3373

DOLLARS AND CENTS OF SHOPPING CENTERS
The Urban Land Institute
625 Indiana Ave., NW, Suite 400, Washington, DC 20004-2930
(202) 624-7000

THE DOWNTOWN & SUBURBAN OFFICE BUILDING EXPERIENCE EXCHANGE REPORT (EER)
Building Owners & Managers Association International (BOMA)
1201 New York Ave., NW, Suite 300, Washington, DC. 20005
(202) 408-2662

MEANS BUILDING CONSTRUCTION COST DATA
MEANS FACILITIES M&R COST DATA
MEANS FACILITIES MAINTENANCE AND REPAIR COST DATA
R. S. Means Co., Inc.
100 Construction Plaza, Box 800, Kingston, MA 02364-0800
(617) 585-7880

NATIONAL CONSTRUCTION ESTIMATOR
BUILDING COST MANUAL
BERGER BUILDING COST FILE
Craftsman Book Company
P.O. Box 6500, Carlsbad, CA 92008
(619) 438-7828

RICHARDSON'S GENERAL CONSTRUCTION ESTIMATING STANDARDS
RICHARDSON'S PROCESS PLANT CONSTRUCTION ESTIMATING STANDARDS
Richardson Engineering Services
P.O. Box 9103, Mesa, AZ 85214-9103
(602) 497-2062

*Most of the listed publishers issue additional, more specialized, cost guides.

at a broader level at the beginning of the project and at a more detailed level as the design of the project progresses.

4.5.2 Estimating Capital Replacement Costs

The number and timing of capital replacements depends on the estimated life of the system and the length of the service period. You can use the same sources that provide cost estimates for initial investments to obtain estimates of replacement costs and expected lives. A good starting point for estimating future replacement costs is to use their cost as of the base date. In a FEMP LCCA conducted in constant dollars with real price escalation rates equal to zero, the future cost will be the same as the base-date cost. When a non-zero real price escalation rate is appropriate, consult section 3.3.3 to see how to compute future replacement costs and present values.

4.5.3 Estimating Residual Values

The residual value of a system (or component) is its **remaining value** at the end of the study period, or at the time that it is replaced during the study period. Residual values can be based on value in place, resale value, salvage value, or scrap value, net of any selling, conversion, or disposal costs.

The residual value of a system at the end of its expected useful life is likely to be small or even negative (due to removal or disposal costs) if the system needs complete replacement or the building is being demolished. However, for systems with expected lives extending beyond the end of the study period, the residual value should be based on their value in place, not on their "salvage" value as if they were to be removed from the building at that point. A building system which is functioning in place adds significant value to the building and this value should be reflected in its residual value. As a general rule of thumb, the residual value of a system with remaining useful life in place can be calculated by **linearly prorating its initial cost**. For example, for a system with an expected useful life of 15 years which was installed five years before the end of the study period, the residual value would be approximately 2/3 [=(15-5)/15] of its initial cost.

If you are estimating the residual value of a building system or component in constant dollars, using the initial cost as the starting point for your estimate, you will not need to adjust the residual value for price changes between the base date and the time that the residual value is realized, unless the price of similar systems changes at a rate significantly different than the rate of general inflation. If you are estimating the residual value in current dollars, you will need to adjust the residual value for general inflation and any real price increase. (Real and nominal price escalation calculations are shown in section 3.3.3.)

When the study period is very long, the residual value of the original system may be small and largely offset by disposal costs. Discounting further diminishes its weight in the analysis, and so it is often less important to improve the estimate of a residual value than of other input values. But when the study period is short, the estimate of the residual value may become a critical factor in assessing the cost effectiveness of a capital investment project, and thus it should be given careful consideration. The residual value estimate for a capital replacement, needed to extend the life of an alternative to the length of a common study period, may also be a critical factor in the LCCA and thus care should be given in estimating this value.

4.6 ESTIMATING OPERATIONAL COSTS

4.6.1 Estimating Energy Costs

Energy conservation projects are expected to reduce the annual energy consumption, and thus the long-run operational costs, of a building. But these savings are not used directly in computing the LCC of a project. Instead, the annual energy consumption for each project alternative is used in computing its corresponding present-value **energy cost**. Since energy costs are included in the LCC of each project, energy savings are reflected in the difference in LCC between alternatives.

The FEMP LCC rules in 10 CFR 436 require the following considerations when computing energy related costs in an LCCA:

- Measure the quantity of energy used (or saved) at the building site, by energy type (e.g., electricity, gas, oil). Do not use resource energy data, e.g., the amount of energy needed to generate and transmit the energy to the building site.
- Use current, local, energy price schedules for the type of fuel or energy used. Do not use national or regional average prices.
- Use DOE energy price escalation rates unless you have projected escalation rates from the utility supplying the energy.

Each of these topics is discussed in more detail in the following subsections.

4.6.1.1 Quantity of energy used

Estimating annual amounts of energy required for a given building function (or for the entire building) with and without an energy-conserving project is primarily an engineering function. These estimates can be based on technical specifications, energy-estimating equations and nomographs, or on computer simulations.

Energy consumption amounts should be estimated for each type of energy used by the building or building system being evaluated. In the simplest case, where there is a flat-rate energy price, annual energy quantities will be sufficient. However, if different prices are in effect during different usage periods (e.g., summer and winter), estimates of energy usage in each time period will also be needed. And if demand charges are relevant, monthly power demand amounts needed for demand charge calculations must also be estimated.

Computer simulation programs such as ASEAM (DOE), DOE-2 (DOE), BLAST (DoD), and ESPRE (EPRI) can be used to estimate energy usage in buildings over an entire year. When selecting a program, it is important to match the capabilities of the program to the type of building and systems to be evaluated. It is also important to consider whether you need annual, monthly, or hourly energy consumption data and monthly power demand data for computing energy costs. For example, if time-of-use rates are relevant, you must have hourly energy consumption data; monthly estimates will not be sufficient. You should use engineering judgment to verify that estimates of energy usage and corresponding energy savings for project alternatives are reasonable and consistent before proceeding to the economic analysis.

4.6.1.2 Local energy prices

Energy prices are needed to convert energy usage to annual energy costs. The FEMP LCC rule requires that an LCCA of an energy conservation project be based on **actual energy prices effective at the building site** rather than on regional or national average prices. Unit prices as billed by the local utility (or fuel delivery company), including relevant taxes or surcharges, should be used in computing annual costs for each fuel type used. The appropriate energy prices should be based on the utility's rate schedule **effective on the base date of the study**, even if the service period (and thus energy usage) does not begin until some later time. The FEMP methodology starts with energy prices as of the base date and converts those prices to their future cost equivalent in each year of the service period using price escalation rates for the specific fuel type, rate type, and region.

The appropriate energy price to be used in computing annual energy costs depends on the nature of the project alternatives to be evaluated. In cases where an energy conservation project changes the amount of a specific energy type used, and unit prices vary with usage amounts (e.g., a declining block-rate price schedule is imposed), the **price of the last unit used** in each billing period is the most appropriate energy price for the analysis. On the other hand, if two systems using different fuel types are being compared, the **average unit price** is more relevant. In this latter case, there may be no energy savings, just a switch in fuel types.

Other factors that should be considered in estimating annual energy costs (especially with regard to electricity usage) are:

- summer and winter rate differentials
- time-of-use rates
- block rate schedules (usually declining block rates)
- demand rates

The inclusion of these rate schedules in an economic analysis may require energy usage data by month instead of by year, and in the case of time-of-use rates, energy usage must be estimated on an hourly basis. For most larger buildings, peak power demand data, usually on a monthly basis, is needed to estimate monthly demand charges. You do not need to include fixed monthly energy charges (e.g., a "customer charge") in the energy cost analysis unless you are comparing systems using different fuel types.[1]

Section 3 of appendix A provides examples of computing annual energy costs when rate schedules depart from a flat unit energy price.

If annual energy consumption for a project is not expected to be constant over the entire service period, it will be necessary to compute annual energy costs separately for each year and discount these annual costs to present value individually as single amounts. The BLCC computer program facilitates this process by allowing the annual energy usage amounts to be scaled up or down from a base amount. An example of non-constant annual energy usage calculations is shown in appendix A.

4.6.1.3 DOE energy price escalation rates

FEMP rules require that DOE energy price escalation rates be used in LCC analyses of federal energy conservation and renewable resource projects. These rates are included in the FEMP UPV* factors for energy costs found in the Annual Supplement to Handbook 135. You do not need to compute future energy prices when computing an LCC for a project alternative. This section shows how to compute future energy prices if they are needed for cash flow projections or for computing payback measures which include energy price escalation.

Following the FEMP convention for calculating life-cycle costs in **constant-dollars** terms, you need to take into account only **real energy price escalation rates** when computing future energy costs. The energy

[1]BLCC versions 4.0 and later can include monthly kWh usage and kW demand data for a project alternative and can read block rate and demand rate schedules set up by the NIST ERATES program. The ERATES program can also be used to calculate an average kWh cost given a time-of-use kWh rate schedule and hourly kWh usage data. This average cost can then be used with BLCC along with the annual kWh consumption to calculate annual electricity costs.

price escalation rates provided by DOE (as published each year in the Annual Supplement to Handbook 135 and as used in the BLCC computer program) are real rates. To estimate future energy costs in constant dollars, use the appropriate energy price indices in tables Ca-1 through Ca-5 of the Annual Supplement to Handbook 135 (reproduced in appendix E) to adjust energy prices as of the base date.

Example: If the price for electricity as of the base date is $0.082/kWh, and the price index for electricity rates for the year 2000 is 0.97, then the constant-dollar estimate of the electricity price in the year 2000 is

$$\$0.08/\text{kWh} \times 0.97 = \$0.0776/\text{kWh} \qquad (4.1)$$

When using the Ca tables in the Annual Supplement to Handbook 135, be sure to find the index that is appropriate to the DOE region, fuel type, rate type, and number of years in your analysis.

If you use real energy price escalation rates in a **current-dollar analysis**, you need to include the **estimated annual rate of inflation** with those rates. Tables S-1 through S-5 in the Annual Supplement to Handbook 135 provide price indices for inflation rates of 3, 4, 5, and 6 percent; you can use those price indices to estimate future energy costs in current dollars in the same way shown above for the constant dollar indices.

4.6.2 Water Costs

Water costs should be handled much like energy costs. There are usually two types of water costs: **water usage** and **water disposal**. Each of these types may have its own unit costs and price escalation rates. Water prices may also be subject to **block rate** price schedules. When block rate schedules are used, it is generally the price of the last block of usage in each pricing period that is most relevant for a water conservation study. The amount of water used or conserved should be measured at the building site. The water price schedule should also be the schedule in effect **at the building site**. Do not use regional or national average water prices. There are no DOE water price escalation rates. If projected price escalation rates for water are not available, then assume that they will increase at the same rate as general inflation. In a constant dollar analysis this means that you can use the standard UPV factors published in table A-2 of the Annual Supplement to Handbook 135. (This is the same table of factors used for non-fuel OM&R costs. The UPV table for FY 1995 is included in appendix E, table E/A-2, of this handbook.)

Water costs, like energy costs, are assumed to begin with the service date and continue through the service period until the end of the study period. Water use in the construction phase of a project is not explicitly included in the LCCA of a water conservation project, but should be included in the initial investment cost.

4.6.3 Estimating Other Operating, Maintenance, and Repair Costs

Operating, maintenance, and repair (OM&R) costs are often more difficult to estimate than other building expenditures. Since operating schedules and standards of maintenance vary from building to building, there is great variation in these costs, even for buildings of the same type and age. It is therefore especially important to use engineering judgment when estimating these costs.

OM&R costs generally begin with the service date and continue through the service period. Some OM&R costs are annually recurring costs which are constant from year to year or change at some estimated rate per year. The present value of annual recurring costs over the entire service period can be estimated using appropriate UPV or UPV* factors. (See section 3.2.2.) Others are single costs which may occur only once or at non-annual intervals throughout the service period. These must be discounted individually to present value. (See section 3.2.1.)

4.6.3.1 Estimating OM&R costs from cost estimating guides

Ongoing efforts to standardize OM&R costs have produced a number of helpful manuals and databases, examples of which are listed in table 4-1. Keep in mind that if OM&R costs are essentially the same for each of the project alternatives being considered, they do not have to be included in the LCCA.

Some of the data estimation guides listed in table 4-1 derive cost data from statistical cost-estimating relationships of historical data (BOMA, MEANS) and report, for example, average owning and operational costs per square foot, by age of building, geographic location, number of stories, and number of square feet in the building. The CERL M&R Database derives data from time-motion studies which estimate the time required to perform certain tasks. It covers four major building systems (architectural, electrical, plumbing, and HVAC) and provides indices for estimating the cost of keeping selected building components in good service condition. At the lowest level of data aggregation, the CERL database provides data for about 3,000 typical tasks needed to maintain and repair building components.

4.6.3.2 Estimating OM&R costs from direct quotes

A more direct method of estimating non-fuel OM&R costs is to obtain quotes from contractors and vendors. For cleaning services, for example, you can get quotes from contractors, based on prevalent practices in similar buildings. Maintenance and repair estimates for equipment can be based on manufacturers' recommended service and parts replacement schedules. You can establish these costs for the initial year by obtaining direct quotes from suppliers. For a constant-dollar analysis, the annual amount will be the same for the future years of the study period, unless, as is sometimes the case, OM&R costs are expected to rise as the system ages. In this latter case, the real (differential) escalation rate for that cost must also be included in the analysis.

4.6.4 Other Relevant Costs or Benefits

4.6.4.1 Utility rebates

Utility companies have been giving one-time or phased-in rebates to promote investment in more energy-efficient buildings or systems in support of their demand-side management (DSM) programs. If a rebate is granted after the base date of the study, you need to discount it to present value—just like any other cost or benefit—before subtracting it from initial investment costs.

4.6.4.2 Taxes and finance charges

Since this handbook deals with energy conservation projects in federal buildings, taxes need not be taken into consideration. Likewise, the cost of financing projects can be disregarded in an LCCA of this type unless the financing is specifically tied to the project. (This is not usually the case for federal buildings. If financing is provided by an energy savings performance contractor, an LCCA of the project financing is not required. See appendix G for more information on this subject.) In private-sector analyses, these factors should be included if they are expected to make a significant difference in the outcome of the analysis.

4.6.4.3 Non-monetary benefits and costs

Non-monetary benefits and costs are project-related effects for which you have no objective way of assigning a dollar value. Examples of non-monetary effects may be the benefit derived from a particularly quiet HVAC system or from an expected, but hard to quantify, productivity gain due to improved lighting. These items, by their nature, are external to the LCCA, and thus do not directly affect the calculation of a project's cost effectiveness. Nevertheless, you should consider significant non-monetary effects in your final investment decision, and they should be included in the project documentation.

In some cases you can provide an order-of-magnitude dollar value of a subjective benefit or cost. For example, the value of an attractive view from larger north-facing windows (which use more energy than smaller windows having the same thermal characteristics) might be estimated by looking at the rent differential of similar buildings with and without that feature. For a retrofit project having an LCC greater than its base case (which would thus be rejected on a dollar cost basis), but having significant non-monetary benefits, you can subjectively judge whether or not the non-monetary benefits outweigh the LCC penalty. If the decision-maker judges that the non-monetary benefits of a project are greater than its LCC penalty, the project can be accepted as "cost effective."

4.6.4.4 Revenues

LCC analysis is most appropriately used to evaluate the relative costs of design alternatives which satisfy a particular set of performance requirements. It is not generally appropriate for evaluating the cost effectiveness of alternative revenue-producing projects, such as buildings constructed to produce rental income. For example, you would not use an LCCA to determine whether to build a 20-unit apartment building or a 40-unit building. These decisions are better evaluated using Benefit-Cost Analysis and Rate-of-Return measures. However, if there are small differences in revenue between one design alternative and another, they can be included in the LCCA by adding them to (when negative) or subtracting them from (when positive) annual operation-related costs.

CHAPTER 5

CALCULATING LIFE-CYCLE COSTS

CONTENTS

Chapter 5

CALCULATING LIFE-CYCLE COSTS

In this handbook we define life-cycle cost analysis (LCCA) to include both the LCC method *per se* and certain supplementary measures: Net Savings, Savings-to-Investment Ratio, and Adjusted Internal Rate of Return. LCCA is the **standard method** required by the Department of Energy's Federal Energy Management Program (FEMP) for evaluating energy and water conservation investments in federal buildings. The FEMP criteria for performing LCCA, as published in 10 CFR 436, are summarized in table 5-1. The examples in chapters 5, 6, and 7 integrate LCCA and the FEMP LCCA criteria.

The basic LCC method is the most straightforward method of accounting for present and future costs of an energy-conservation project over its life-cycle. When using the LCC method for evaluating buildings or building systems, we typically look at two or more project alternatives for the same purpose (e.g., different R-values of insulation in an exterior wall or different HVAC systems), only one of which will be selected for implementation. To determine the **relative** cost effectiveness of these mutually exclusive alternatives, we need to compute the LCC for each alternative and the base case, compare them, and choose the alternative with the lowest LCC. Only when compared to the LCC of a base case or another alternative intended for the same purpose does the LCC provide useful information. The LCCs are comparable only if computed with the same economic assumptions and with the same study period, base date, and service date. In addition, it is essential that only alternatives that satisfy minimum performance requirements be considered for LCCA.

This chapter first describes the **LCC method** and then illustrates how to compute the life-cycle costs for a base case and an alternative. Chapter 6 explains how to calculate supplementary measures—**Net Savings (NS)**, **Savings-to-Investment Ratio (SIR)**, **Adjusted Internal Rate of Return (AIRR)**, and **Discounted** and **Simple Payback**. Chapter 7 demonstrates how these methods can be applied to typical cost-effectiveness decisions related to energy and water conservation projects in federal buildings.

5.1 THE LIFE-CYCLE COST (LCC) METHOD

LCCA allows you to organize and compute the costs of acquiring, owning, operating, maintaining, and ultimately disposing of a building or a building system. Once you have cost estimates, by year, for two or more competing alternatives, a discount rate, and a study period, you are ready to calculate the LCC for each alternative.[1] To calculate the LCC, first compute the present value of each cost to be incurred during the study period, using the DOE discount rate. Then sum these present values for each alternative to find its LCC. If other performance features are similar among the alternatives, the alternative with **the lowest LCC** is the preferred alternative; that is, it is the most cost-effective alternative for the application studied.

The calculations can be performed either manually or with a computer program. The NIST BLCC computer program, which can greatly facilitate FEMP LCC analyses for energy conservation projects, has the FEMP criteria built in and is largely self-documenting. More information about the BLCC program is presented in appendix B. Simple analyses can easily be done by hand or with the help of the worksheets from appendix C.

[1] All through this handbook we use the word "alternative" to include the base case when discussing the LCC method in a general way.

Table 5-1
Summary of Criteria for FEMP LCC Analyses

FEMP CRITERIA FOR ECONOMIC ANALYSIS	DESCRIPTION
	METHODOLOGY
Evaluation Method	Life-cycle cost analysis
Discounting Approach	Present value (PV) at the base date
Cost Measurement Basis	Constant dollars as of the base date
Cash-Flow Convention	End-of-year cash flows or when incurred
Evaluation Criteria	• Lowest life-cycle cost • Highest net savings • SIR > 1 for ranking • AIRR > FEMP discount rate for ranking
Uncertainty Assessment	Sensitivity analysis
	DATA AND PARAMETERS
Base Date	Date of Study / Beginning of study period
Service Date	Beginning of service period when building is occupied or system taken in service
Study Period	Planning/Construction period (if any) added to maximum 25-year service period
Discount Rate	A real rate, determined annually by DOE
Energy Prices	Local energy prices at the building site used to calculate annual energy costs for each energy type
Cost Escalation • Energy Prices • Non-Energy Prices	 DOE-projected differential energy price changes (included in FEMP UPV* discount factors for each energy type) 0% differential price change (unless justified by reliable projections)
	DOCUMENTATION
Basic Requirement	Written record for every economic analysis
Format	BLCC computer printouts; worksheets, additional records

5.1.1 General Formula for LCC

The following is the general formula for the LCC present-value model:

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1 + d)^t} \tag{5.1}$$

where:

LCC = Total LCC in present-value dollars of a given alternative,
C_t = Sum of all relevant costs, including initial and future costs, less any positive cash flows, occurring in year t,
N = Number of years in the study period, and
d = Discount rate used to adjust cash flows to present value.

5.1.2 LCC Formula for Building-Related Projects

The general LCC formula shown in eq (5-1) requires that all costs be identified **by year** and **by amount**. This general formula, while straightforward from a theoretical standpoint, can require extensive calculations, especially when the study period is more than a few years long and for annually recurring amounts, for which future costs must first be calculated to include changes in prices. A simplified LCC formula for computing the LCC of energy and water conservation projects in buildings can be stated as follows:

$$LCC = I + Repl - Res + E + W + OM\&R \tag{5.2}$$

where:

LCC = Total LCC in present-value dollars of a given alternative,
I = Present-value investment costs,
Repl = Present-value capital replacement costs,
Res = Present-value residual value (resale value, scrap value, salvage value) less disposal costs,
E = Present-value energy costs,
W = Present-value water costs, and
OM&R = Present-value non-fuel operating, maintenance, and repair costs.

This formula takes advantage of **UPV (uniform present value) factors** to compute the present value of annually recurring costs, whether constant or changing. By using appropriate UPV factors, the LCC can be calculated without first computing the future annual amount (including price escalation) of each annually recurring cost over the entire study period, summing all those costs by year and discounting them to present value. Instead, only the **annual amount in base year dollars (i.e., a one-time amount) and the corresponding UPV factor** need to be identified.

The following two examples apply the LCC method, combined with the FEMP criteria, to determine whether an investment in energy-saving features for a new HVAC system is economically worthwhile. Example 5-1 assumes that all initial investment costs occur **in a lump sum** at the base date, that there is only **one energy type**, and that the two candidate systems have **equal useful lives**. In example 5-2 we will relax these assumptions and illustrate an LCC calculation where some of the initial investment costs are **phased in** during a planning/construction (P/C) period, where **two fuel types** are used, and where the two candidate systems have **unequal useful lives.**

In both these examples, it is assumed that an existing HVAC system in a federally-owned building must be replaced. However, the application of LCCA would be identical for HVAC system selection in a new federal building.

5.2 SELECTION OF HVAC SYSTEM FOR OFFICE BUILDING: SIMPLE EXAMPLE

We look at a conventional HVAC system as our base case (BC) and compare it with an alternative (A) that includes several energy-saving features. The system with the lower LCC will be accepted as the cost-effective system. The HVAC system is to be installed in a federal office building in Washington, DC. All initial investment costs are assumed to be incurred at the beginning of the study period. The parameters and assumptions common to both the base case and the alternative are as follows:

***Location*:**	Washington, DC; DOE Region 3
***Discount Rate*:**	Current FEMP discount rate: 3% real for constant-dollar analysis
***Energy Prices*:**	Fuel type: Electricity at $0.08/kWh, local rate as of base date Rate Type: Commercial
Discount Factor:	FEMP UPV* factor based on a 3% (real) discount rate
Useful Lives of Systems:	20 years
Study Period:	20 years
Base Date:	January 1995

5.2.1 Example 5-1a: Base Case—Conventional Design

The base case (BC) is a constant-volume HVAC system with a reciprocal chiller, without night-time setback and economizer cycle. The relevant cash flows as of today, the base date, are:

- **$103,000** Initial investment costs, assumed to occur in a lump sum
- **$ 12,000** Replacement cost for a fan at the end of year 12
- **$ 3,500** Residual value at the end of the 20-year study period
- **$ 20,000** Annual electricity costs (250,000 kWh at $0.08/kWh)
- **$ 7,000** Annual OM&R costs

The cash-flow diagram in figure 5-1 below shows these cost items and their timing for the base case. Initial investment costs are assumed to occur on January 1, 1995. The two other one-time amounts—the fan replacement and the residual value—are assumed to occur at the end of the respective years. Since this is a constant-dollar analysis and no real price escalation (that is, price escalation different from general inflation) is expected for either the fan replacement or the residual value, the 1995 dollar amounts can be used as estimates of the future costs of these items in years 2006 and 2014. Likewise, OM&R costs are expected to remain the same in constant-dollar terms so that equal annual amounts in base-date (January 1995) dollars can be used throughout the study period. As for the electricity cost, the annual amount in base-date dollars is all that is needed because the FEMP UPV* factor includes the energy price escalation rates projected by DOE.

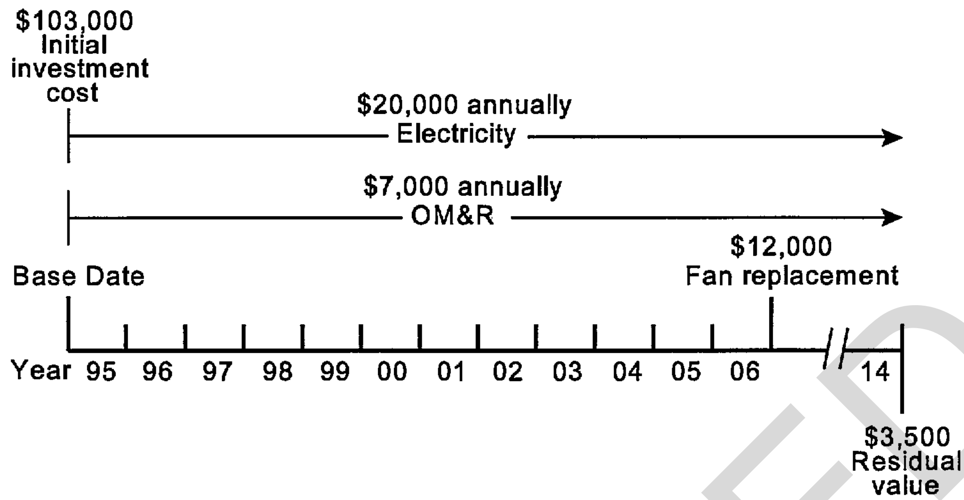


Figure 5-1
Cash Flow Diagram for the Conventional HVAC Design.

Table 5-2 summarizes the input data and calculations for the Base Case: the relevant amounts in base year dollars (column 2), the year of occurrence (column 3), and the appropriate discount factors (column 4). Column 5 shows the calculated present-value cost for each cost category and their sum, the total LCC for the Base Case.

Table 5-2
Data Summary for Conventional HVAC Design: Base Case—Simple Example

Cost Items (1)	BaseDate Cost (2)	Year of Occurrence (3)	Discount Factor (4)		Present Value (5)=(2)x(4)
Initial investment cost	$103,000	Base date	already in present value		$103,000
Capital replacement (fan)	$12,000	12	SPV_{12}	0.701	$8,412
Residual value	($3,500)	20	SPV_{20}	0.554	($1,939)[a]
Electricity: 250,000 kWh at $0.08/kWh	$20,000	annual	FEMP UPV^*_{20}	15.13	$302,600
OM&R	$7,000	annual	UPV_{20}	14.88	$104,160
Total LCC					**$516,233**

[a] The residual value is subtracted from the LCC.

In this example, the LCC of **$516,233** for the conventional design serves as a baseline against which the LCC of the energy-saving alternative system will be compared.

5.2.2 Example 5-1b: Alternative—Energy-Saving Design

The project alternative (A) is a system with constant air volume, with a reciprocal chiller, night-time setback for heating and air-conditioning, and economizer cycle. The relevant cash flows as of today, the base date, are:

- **$110,000** Initial investment costs, assumed to occur in a lump sum at the base date
- **$ 12,500** Replacement cost for a fan at the end of year 12
- **$ 3,700** Residual value at the end of the 20-year study period
- **$ 13,000** Annual electricity costs (162,500 kWh at $0.08/kWh)
- **$ 8,000** Annual OM&R costs

Since the types of cash flows and their timing are assumed to be the same for both the base case and the alternative, a cash flow diagram for the alternative would be analogous to the one in figure 5-1. Table 5-3 shows the summary of input data and calculations.

Table 5-3
Data Summary for Energy-Saving HVAC Design Alternative—Simple Example

Cost Items (1)	Base Date Cost (2)	Year of Occurrence (3)	Discount Factor (4)	Present Value (5)=(2)x(4)
Initial investment cost	$110,000	Base date	already in present value	$110,000
Capital replacement (fan)	$12,500	12	SPV_{12} 0.701	$8,762
Residual value	($3,700)	20	SPV_{20} 0.554	($2,050)
Electricity: 162,500 kWh at $0.08/kWh	$13,000	annual	FEMP UPV^*_{20} 15.13	$196,690
OM&R	$8,000	annual	UPV_{20} 14.88	$119,040
Total LCC				**$432,442**

The LCC decision criterion for choosing one design over another is that the system with the **lower LCC is the preferred system**. If you assume that the input values are reasonably certain and there are no significant non-monetary costs or benefits that need to be taken into account, then you would choose the energy-conserving HVAC system because its LCC of $432,442 is lower than the LCC of $516,233 of the conventional design.

Since the Net Savings measure is simply the difference in present-value LCC between a base case and an alternative, it can easily be calculated from the two LCC amounts. For the energy-saving design, the NS for the 20-year study period is thus

$$NS_A = \$516{,}233 - \$432{,}442$$
$$\mathbf{NS_A = \$\ 83{,}791.}$$

This means that the energy-saving design saves $83,791 in present-value dollars over the 20-year study period, **over and above** the 3 percent minimum acceptable real rate of return already taken into account through the discount rate. If the LCC of an alternative is lower than the LCC of the relevant base case, it must have positive Net Savings.

5.3 SELECTION OF HVAC SYSTEM FOR OFFICE BUILDING: COMPLEX EXAMPLE

A second example of an LCCA is presented here with more complex analytical requirements. Suppose that the initial cost of the HVAC system in example 5-1a is to be **phased in** during the two-year P/C period instead of being charged to the project as a lump-sum at the beginning of the study period. The study period will be extended by two years to 22 years to include a P/C period of two years and a service period of 20 years. Furthermore, suppose that the **useful lives** of the two systems are **different**: 15 years for the base case and 20 years for the alternative. A substantial portion of the base-case system will need to be replaced at the end of its useful life of 15 years, at a cost of $60,000, to prolong its useful life to at least 20 years. However, this replacement will increase its residual value to $20,000 at the end of the 20-year study period. Finally, assume that each system uses two different fuel types, electricity and natural gas.

5.3.1 Example 5-2a: Base Case—Conventional Design

The cash flow diagram in figure 5-2 reflects the assumptions for the base case. The study period in this example is 22 years because **the two-year P/C period is added** to the service period of 20 years. The base date is January 1, 1995. Initial investment costs are charged in two installments, at the end of 1995 and end of 1996. Capital replacement costs are charged for the fan unit after 12 years of service (end of 2008) and for plant renovation after 15 years of service (end of 2011). Annually recurring costs, such as energy costs and OM&R costs, begin to be incurred after the service date (January 1, 1997), and are discounted to present value from the end of each year thereafter until the end of the study period (end of 2016).[2]

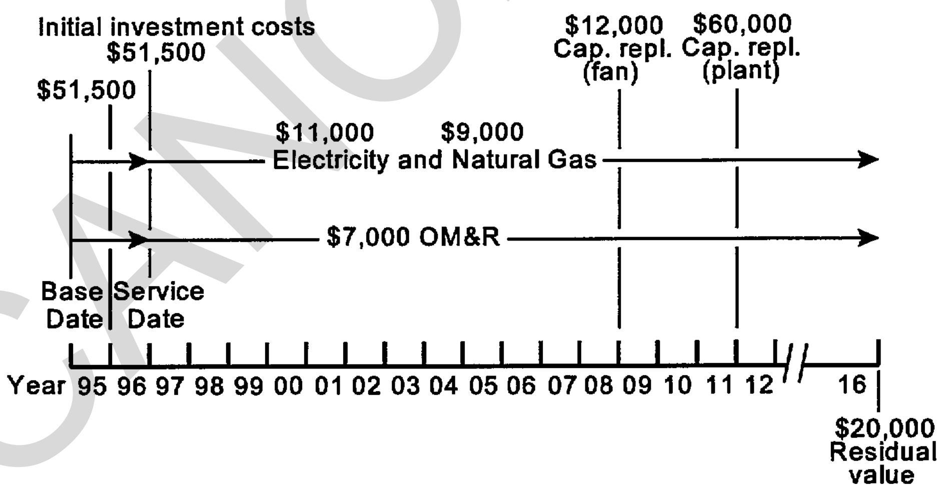


Figure 5-2
Cash Flow Diagram for the Conventional HVAC Design, Base Case.

[2]From a present-value standpoint, a cost occurring at the end of one time period is equivalent to the same cost occurring at the beginning of the next time period.

Table 5-4 shows these costs, their time of occurrence, the appropriate discount factors for a 3 percent discount rate, present values, and total LCC for the base case.

Table 5-4
Data Summary for Conventional HVAC Design: Base Case—Complex Example

Cost Items (1)	Base Date Cost (2)	Year of Occurrenc (from Base Date) (3)	Discount Factor (4)	Present Value (5)=(2)x(4)
Initial Investment Cost:				
1st Installment at midpoint of construction	$51,500	1	SPV_1 0.971	$50,007
2nd Installment at beginning of service period	$51,500	2	SPV_2 0.943	$48,564
Capital replacement (fan)	$12,000	14	SPV_{14} 0.661	$7,932
Capital replacement (plant)	$60,000	17	SPV_{17} 0.605	$36,300
Residual value	($20,000)	22	SPV_{22} 0.522	($10,440)
Electricity 125,000 kWh at $0.08/kWh	$10,000	annual	FEMP UPV* 14.28	$142,800
Natural Gas 1700 GJ at $5.93/GJ (≈1800 MBtu)	$10,080	annual	FEMP UPV* 17.03	$171,662
OM&R	$7,000	annual	UPV 14.03	$ 98,210
Total LCC				**$545,035**

When costs are phased in during the P/C period, the **base date** of the study and the **service date** do not coincide as they did in the previous example. Operational costs usually begin at the service date but must be discounted to the base date. To calculate the correct UPV factor when the service date is later than the base date, you subtract the UPV factor for the P/C period (two years in this example) from the UPV factor for the entire study period (22 years). This procedure is described in detail in chapter 3, section 3.2.3. In this example, the discount factor for calculating the present value of the electricity cost at a discount rate of 3 percent, for region 3, commercial sector, is derived as follows: Deduct from the FEMP UPV* factor for 22 years (16.21) the FEMP UPV* factor for 2 years (1.93) to get 14.28. The UPV* factor for commercial natural gas and UPV factor for non-fuel OM&R costs are derived in a similar fashion.[3]

5.3.2 Example 5-2b: Alternative—Energy-Saving Design

The cash-flow diagram for the energy-conserving alternative is analogous to the one shown in figure 5-2 for the base case. The major difference is that the energy-saving alternative does not require a plant replacement because its useful life is equal to the service period of 20 years.

Table 5-5 shows the data inputs and the computed life-cycle costs for the energy-conserving alternative. As before, the total LCC for the alternative is lower than for the base case. Net savings for the energy-

[3]FEMP UPV* factors are from table Ba-3 (Census region 3) in the Annual Supplement to Handbook 135. The UPV factors for OM&R costs are from table A-2 in the same report.

saving alternative are a positive amount of **$87,744** ($545,035 - $457,291) over the length of the study period.

Table 5-5
Data Summary for Energy-Saving HVAC Design Alternative—Complex Example

Cost Items (1)	Base Date Cost (2)	Year of Occurrence (from Base Date) (3)	Discount Factor (4)		Present Value (5)=(2)x(4)
Initial Investment Cost					
1st Installment at midpoint of construction	$55,000	1	SPV_1	0.971	$53,405
2nd Installment at beginning of service period	$55,000	2	SPV_2	0.943	$51,865
Capital replacement (fan)	$12,500	14	SPV_{14}	0.661	$8,262
Residual value	($3,700)	22	SPV_{22}	0.522	($1,931)
Electricity 100,000 kWh at $0.08/kWh	$8,000	annual	FEMP UPV*	14.28	$114,240
Natural Gas 1180 GJ at $5.93/GJ (≈ 1250 MBtu)	$7,000	annual	FEMP UPV*	17.03	$119,210
OM&R	$8,000	annual	UPV	14.03	$112,240
Total LCC					**$457,291**

5.4 SUMMARY OF THE LCC METHOD

The LCC method provides a consistent means of accounting for **all costs** related to a particular building function, building system, or related project over a given study period. In general, an LCCA is needed to demonstrate that the additional investment cost for a project alternative is more than offset by its corresponding reduction in operating and maintenance costs (including energy and water costs), relative to the base case. The following are key points which should be recognized when using the LCC method for project evaluation:

- Choose among two or more mutually exclusive alternatives on the basis of lowest LCC.
- All alternatives must meet established minimum performance requirements.
- All alternatives must be evaluated using the same base date, service date, study period, and discount rate.
- Positive cash flows (if any) must be subtracted from costs.
- Effects not measured in dollars must be either insignificant, uniform across alternatives, or accounted for in some other way.

CHAPTER 6

CALCULATING SUPPLEMENTARY MEASURES

CONTENTS

Chapter 6

CALCULATING SUPPLEMENTARY MEASURES

With the same set of input data and assumptions needed for an LCCA of two or more project alternatives—present and future costs, a discount rate, and a study period—it is possible to calculate supplementary measures of economic performance for those same alternatives. The supplementary measures described in this chapter are **Net Savings (NS)**, the **Savings-to-Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR), Discounted Payback (DPB),** and **Simple Payback (SPB)**. The first three of these supplementary measures, if computed and applied correctly, are consistent with LCCA; that is, they will give the same results when determining whether or not a project alternative is cost effective. However, when evaluating mutually exclusive project alternatives, only the Net Savings measure is always consistent with the LCC method in identifying the alternative with the lowest LCC.

Some of these supplementary measures are sometimes needed to meet specific regulatory requirements. For example, the FEMP LCC rules (10 CFR 436) require the use of either the SIR or AIRR for ranking independent projects competing for limited funding. And some federal programs, such as Energy Savings Performance Contracts, require the Simple Payback to be computed in project evaluations.

The supplementary measures described in this section are all **relative** measures of economic performance. That is, they are computed **for a project alternative relative to an identified base case**. The choice of the base case can have a significant effect on the value computed for these measures. Thus it is important to consider this choice carefully. In general, the base case has a lower investment cost and higher operational costs than the alternative being evaluated. In fact, the primary reason for the LCCA of a project or project alternative is **to demonstrate that its operational savings are sufficient to justify its additional investment cost**. For optional retrofit projects in existing buildings (e.g., replacement of existing light fixtures with high efficiency fixtures), the base case is usually the continuation of the existing situation, with no initial investment cost but (presumably) high energy or water costs. For new buildings, or mandatory retrofit projects (e.g., replacing a non-functioning HVAC system), the base case is generally the project alternative which has the lowest investment-related cost over the relevant study period.

It is also important that the **incremental** nature of the investment be understood when computing these supplementary measures with regard to a base case, especially when the base case has its own investment-related costs. These measures are not intended to determine the profitability of the entire investment in a project, but whether the investment **over and above** that required by the base case is justified.

In example 5-1b, the total present-value investment-related cost of the energy-conserving HVAC system is the sum of initial investment cost, replacement costs, and residual value:

$$\$116,712 = \$110,000 + \$8,762 - \$2,050$$

But the incremental investment-related cost is only $7,239, the difference between the investment costs of the energy-saving alternative and the base case:

$$\$7,239 = \$116,712 - (\$103,000 + \$8412 - \$1939)$$

Only the incremental investment must be justified by the operational savings.

This chapter describes each of the five supplementary measures and shows how to compute them. The measures are illustrated with examples using the data and assumptions provided in example 5-1. Further examples of how these measures are applied to typical investment decisions will be given in chapter 7.

6.1 NET SAVINGS (NS)

The Net Savings (NS) measure is a variation of the Net Benefits (NB) measure of economic performance of a project. The NB method measures the difference between present-value benefits and present-value costs for a particular investment over the designated study period. The NB measure is generally applied when positive cash flows (e.g., rent) are intended to justify the investment in a project (e.g., a new office building). The NS method is applied **when benefits occur primarily in the form of future operational cost reductions** (e.g., energy and water cost savings). The NS method calculates the net amount, in present-value dollars, that a project alternative is expected to save over the study period. Because the net savings are expressed in present-value terms, they represent savings over and above the amount that would have been earned from investing the same funds at the minimum acceptable rate of return (i.e., the discount rate).

The Net Savings for a project alternative, relative to a designated base case, can be calculated by simply subtracting the LCC of the alternative from the LCC of the base case. That is,

$$NS = LCC_{\text{Base Case}} - LCC_{\text{Alternative}}$$

As long as the NS is greater than zero, the project is considered to be cost effective relative to the base case. This is equivalent to requiring that the LCC of a project alternative be lower than the LCC of its base case. When evaluating multiple, mutually exclusive project alternatives, the alternative with the greatest NS will be the same alternative that has the lowest LCC. Thus **the LCC and NS methods are entirely consistent and can be used interchangeably.** The advantage of the LCC method relative to the NS method when evaluating multiple alternatives is that the former does not require that the base case be specifically identified.

NS can also be calculated from individual cost differences between the base case and alternative (e.g., differences between initial investment costs, between energy costs, and between OM&R costs). While this requires additional calculations compared to the simple method shown above, these intermediate calculations are needed to compute the SIR and AIRR. Thus computing NS using individual cost differences is useful as a check to ensure that the SIR and AIRR calculations are based on correct intermediate calculations. That is, the NS should be exactly the same whether computed by the comparison of LCCs or by using individual cost differences. The following presents the latter method of NS computation in detail.

6.1.1 General Formula for NS

Net Savings can be calculated using individual cost differences by applying the following general formula:

$$NS_{A:BC} = \sum_{t=0}^{N} \frac{S_t}{(1+d)^t} - \sum_{t=0}^{N} \frac{\Delta I_t}{(1+d)^t} \qquad (6.1)$$

where

$\mathbf{NS_{A:BC}}$	=	NS, in present value dollars, of the alternative (A), relative to the base case (BC),
$\mathbf{S_t}$	=	Savings in year t in operational costs associated with the alternative,
$\mathbf{\Delta I_t}$	=	Additional investment-related costs in year t associated with the alternative,
t	=	Year of occurrence (where 0 is the base date),

d	=	Discount rate, and
N	=	Number of years in study period.

Note that while the summation index (t=0 to N) is shown for operational savings, such savings will normally not be incurred on the base date but only after the project is put into service.

6.1.2 NS Formula for Building-Related Projects

The general NS formula shown above requires that the savings and costs in each year be calculated and discounted to present value. This general formula can require extensive calculations, especially when future costs include price changes and when the study period is more than a few years long. A more practical NS formula for building-related projects takes advantage of present value factors (SPV, UPV, and UPV*) to compute the present value of each cost category before combining them into operation-related or investment-related cost categories:

$$NS_{A:BC} = [\Delta E + \Delta W + \Delta OM\&R] - [\Delta I_0 + \Delta Repl - \Delta Res] \qquad (6.2)$$

where

$\mathbf{NS_{A:BC}}$	=	Net Savings, that is, operation-related savings minus additional investment costs for the alternative relative to the base case,	
ΔE	=	$(E_{BC} - E_A)$	Savings in energy costs attributable to the alternative,
ΔW	=	$(W_{BC} - W_A)$	Savings in water costs attributable to the alternative,
ΔOM&R	=	$(OM\&R_{BC} - OM\&R_A)$	Savings in OM&R costs,
$\mathbf{\Delta I_0}$	=	$(I_A - I_{BC})$	Additional initial investment cost required for the alternative relative to the base case,
ΔRepl	=	$(Repl_A - Repl_{BC})$	Additional capital replacement costs,
Δres	=	$(Res_A - Res_{BC})$	Additional residual value, and

where **all amounts are in present value**.

Note that some of these terms may have negative values. It is important to preserve the appropriate signs when entering the input values in any of the equations for the supplementary measures.

6.1.3 NS Computation

Using the input values of example 5-1(a and b), *Selection of HVAC System for Office Building*, we calculate NS by subtracting the total additional investment costs from the total operational savings. Table 6-1 summarizes this procedure.

The resulting amount, **$83,791**, is the same amount that we calculated by deducting the total LCC of the alternative from the total LCC of the base case in example 5-1. The positive NS indicates that this project alternative is cost-effective when compared to the base case.

In chapter 7, applications of NS are shown for evaluating accept/reject decisions, as well as for levels of system efficiency, system selection, and interdependent systems. However, the NS computed for individual projects is not useful for ranking a number of independent projects subject to limited funding. See section 6.2 on the Savings-to-Investment Ratio for information on ranking independent projects.

Table 6-1
Computation of Net Savings for Energy-Saving HVAC Design—Simple Case

Cost Items	PV Base Case[a]	PV Alternative[b]	PV Difference
Operational Savings (BC-A)			
Electricity costs	$302,600	$196,690	$105,910
OM&R costs	$104,160	$119,040	($14,880)
Total savings			**$91,030**
Additional Investment Costs (A-BC)			
Initial investment cost	$103,000	$110,000	$7,000
Capital replacement (fan)	$8,412	$8,762	$350
Residual value	$1,939	$2,050	($111)
Total add. investment costs			**$7,239**
NET SAVINGS = $91,030 - $7,239 = **$83,791**			

[a] Input values taken from table 5-2.
[b] Input values taken from table 5-3.

6.1.4 Summary of NS Method

- NS is a useful measure of economic performance for investments which reduce operational costs.
- NS is a relative measure; it must be calculated with respect to a designated base case.
- NS can be calculated from the difference in total LCC or in individual cost categories.
- Project alternatives must be evaluated over the same time periods and with the same discount rate.
- An investment is cost effective if its NS is positive; NS is only positive when the LCC of the alternative is lower than the base case.
- Significant effects not measurable in dollar terms need to be accounted for in some other way.

6.2 SAVINGS-TO-INVESTMENT RATIO (SIR)

The SIR is a measure of economic performance for a project alternative that expresses the relationship between its savings and its increased investment cost (in present value terms) as a ratio. It is a variation of the Benefit-to-Cost Ratio for use when benefits occur primarily as reductions in operation-related costs. Like the NS measure, SIR is a relative measure of performance; that is, it can only be computed with respect to a designated base case. This means that the same base date, study period, and discount rate must be used for both the base case and the alternative.

A project alternative is generally considered economically justified relative to a designated base case when its SIR is greater than 1.0. This is equivalent to saying that its savings are greater than its incremental investment costs, and that its net savings are greater than zero. However, it is important to recognize that when evaluating multiple, mutually exclusive, project alternatives, the alternative with the **lowest LCC** is the most cost effective alternative. The project alternative with the lowest LCC is **not** generally the alternative with the highest SIR. For example, a single layer of insulation in roof assembly is likely to have a higher SIR than a thicker layer, but the latter may be more cost effective on a LCC basis. **Do NOT use the SIR for choosing among mutually exclusive project alternatives.** The SIR for a project is most useful as a means of ranking that project along with other independent projects as a guide for allocating limited investment funding. This application is explained in detail in section 7.5.

6.2.1 General Formula for SIR

The general formula for the SIR is comprised of the same terms used in the differential cost formula for the NS computation:

(1) the operation-related savings attributable to the project alternative, and
(2) the additional investment-related costs attributable to the project alternative.

The general formula for the SIR simply rearranges these two terms as a ratio:

$$SIR_{A:BC} = \frac{\sum_{t=0}^{N} S_t \;/\; (1+d)^t}{\sum_{t=0}^{N} \Delta I_t \;/\; (1+d)^t} \tag{6.3}$$

where

$\mathbf{SIR_{A:BC}}$	=	Ratio of PV savings to additional PV investment costs of the (mutually exclusive) alternative relative to the base case,
$\mathbf{S_t}$	=	Savings in year t in operational costs attributable to the alternative,
$\mathbf{\Delta I_t}$	=	Additional investment-related costs in year t attributable to the alternative,
t	=	Year of occurrence (where 0 is the base date),
d	=	Discount rate, and
N	=	Length of study period.

6.2.2 SIR Formula for Building-Related Projects

The general SIR formula shown above requires that the savings and incremental investment costs in each year be calculated and discounted to present value. This general formula can require extensive calculations, especially when future costs must first be calculated to include changes in prices and when the study period is more than a few years long. A more practical SIR formula for building-related projects is shown below. This formula takes advantage of present value factors to compute the present value of each cost category.

$$SIR_{A:BC} = \frac{\Delta E + \Delta W + \Delta OM\&R}{\Delta I_0 + \Delta Repl - \Delta Res} \tag{6.4}$$

where

$\mathbf{SIR_{A:BC}}$	=	Ratio of operational savings to investment-related additional costs, computed for the alternative relative to the base case,	
ΔE	=	$(E_{BC} - E_A)$	Savings in energy costs attributable to the alternative,
ΔW	=	$(W_{BC} - W_A)$	Savings in water costs attributable to the alternative,
ΔOM&R	=	$(OM\&R_{BC} - OM\&R_A)$	Difference in OM&R costs,
$\mathbf{\Delta I_0}$	=	$(I_A - I_{BC})$	Additional initial investment cost required for the alternative relative to the base case,
ΔRepl	=	$(Repl_A - Repl_{BC})$	Difference in capital replacement costs,
ΔRes	=	$(Res_A - Res_{BC})$	Difference in residual value, and

where **all amounts are in present values**.

The numerator and denominator of this equation are identical to the corresponding savings and investment-related terms of NS eq (6.2) shown above.

According to the FEMP LCC rules as stated in 10 CFR 436, investment-related costs include capital replacement costs as well as initial investment costs, less the project's residual value at the end of the study period. The FEMP method of economic analysis evaluates the return on **all** incremental capital investment in the project over the study period, not just the incremental initial investment.

6.2.3 SIR Computation

In the NS calculations shown in table 6-1, the values of the terms needed to compute the SIR were found to be as follows:

Numerator:	PV of operational savings attributable to the alternative:	**$91,030**
Denominator:	PV of additional investment costs required for the alternative:	**$7,239**

Hence

$$SIR_{A:BC} = \frac{\$91,030}{\$7,239} = 12.6 \qquad (6.5)$$

A ratio of 12.6 means that the energy-conserving design will generate an average return of $12.6 for every $1 invested, *over and above the minimum required rate of return* imposed by the discount rate. The project alternative in this example is clearly cost effective. A ratio of 1.0 would indicate that the cost of the investment just equals its costs; a ratio of less than 1.0 indicates an uneconomic alternative which would cost more than it would save.

6.2.4 Summary of SIR Method

- An investment is cost effective if its SIR is greater than 1.0; this is equivalent to having net savings greater than zero.
- The SIR is a relative measure; it must be calculated with respect to a designated base case.
- When computing the SIR of an alternative relative to its base case, the same study period and the same discount rate must be used.
- The SIR is useful for evaluating a single project alternative against a base case or for ranking independent project alternatives; it is not useful for evaluating multiple mutually exclusive alternatives.
- Significant effects not measurable in dollar terms need to be accounted for in some other way.

6.3 ADJUSTED INTERNAL RATE OF RETURN (AIRR)

The AIRR is a measure of the **annual percentage yield** from a project investment over the study period. Like the NS and SIR measures, the AIRR is a **relative** measure of cost effectiveness. That is, it must be computed relative to a designated base case. This means that **the same** base date, study period, and discount rate must be used for both the base case and the alternative.

The AIRR is compared against the investor's **minimum acceptable rate of return** (MARR), which is generally equal to the **discount rate** used in the LCC analysis. If the AIRR is greater than the MARR, the project is economic; if it is less than the MARR, the project is uneconomic. If the AIRR equals the discount rate, the project's savings just equal its costs and the project is economically neutral.

You can use the AIRR for the same applications as the SIR. You can use it to decide whether to accept or reject a single project alternative (relative to a base case) or to allocate a given investment budget among a number of independent projects. Like the SIR, the AIRR should **NOT** be used to select among multiple, mutually exclusive project alternatives. **The alternative with the highest AIRR will NOT generally be the alternative with the lowest LCC.**

The AIRR, in contrast to the conventional Internal Rate of Return (IRR) measure, explicitly assumes that the savings generated by a project can be reinvested at the discount rate for the remainder of the study period. (If these savings could be reinvested at a higher rate than the discount rate, then the discount rate would not represent the opportunity cost of capital.) The IRR implicitly assumes that interim proceeds (savings) can be reinvested at the **calculated** rate of return on the entire project, an assumption which leads to **over-estimation of the project's yield if the calculated rate of return is higher than the reinvestment rate**. The AIRR and the IRR are the same only if the investment yields a single, lump-sum payment at the end of the study period, or in the unlikely case when the reinvestment rate is the same as the calculated IRR.

There is another consideration that advises against the use of the IRR: more than one rate of return may make the value of the savings and investment streams be equal, as required by the definition of the internal rate of return. This may be the case when capital investment costs (such as replacement costs) are incurred during later years, giving rise to negative cash flows in some years.

For these reasons, the AIRR is generally considered to be a more accurate measure of the rate of return on a capital investment and more consistent with the overall LCC method. In addition, it can be calculated directly by using a simple mathematical formula, whereas the IRR must be approximated by iteration.

6.3.1 Simplified Formula for AIRR

The most straightforward method of calculating the AIRR requires that the **SIR** for a project (relative to its base case) be calculated first. Then the AIRR can be computed easily using the following formula:

$$AIRR = (1 + r)\,(SIR)^{\frac{1}{N}} - 1 \qquad (6.6)$$

where r = the reinvestment rate and N = the number of years in the study period. Using the SIR of 12.6 calculated for example 5-1b, and a reinvestment rate of 3 percent (the MARR), the AIRR is found as follows:

$$AIRR_{A:BC} = (1 + 0.03)\,(12.6)^{\frac{1}{20}} - 1 = 0.1691 \qquad (6.7)$$

Since an AIRR of **16.9** percent for the alternative is greater than the MARR, which in this example is the FEMP discount rate of 3 percent, the project alternative is considered to be cost effective in this application.

6.3.2 Mathematical Derivation of the AIRR

Note: This section provides background information on the mathematical derivation of the AIRR measure. Its purpose is to provide a better understanding of the AIRR. It is not intended to be used for direct calculation of the AIRR. For direct calculation of the AIRR use the simplified formula in the previous section.

The AIRR can be defined mathematically as follows:

Find i for which

$$\frac{\sum_{t=0}^{N} S_t\,(1+r)^{N-t}}{(1+i)^N} - \sum_{t=0}^{N} \frac{\Delta I_t}{(1+r)^t} = 0 \qquad (6.8)$$

where

S_t = Annual savings generated by the project, reinvested at the reinvestment rate,

r = Rate at which available savings can be reinvested, usually equal to the MARR (i.e., the discount rate), and

$\Delta I_t/(1+r)^t$ = PV investment costs on which return is to be maximized.

In this equation, operational savings are reinvested at a given reinvestment rate (r) each year until the end of the study period and summed, to arrive at a "**terminal value**" of savings (TVS). All capital investment costs are discounted to present value (PVI) using that same reinvestment rate. The implicit interest rate (i) which makes the present value of TVS equal to PVI is the AIRR. In general, the interest rate which makes the present value of a future amount (F) equivalent to a present amount (P) can be found as follows:

$$i = \left[\frac{F}{P}\right]^{\frac{1}{N}} - 1 \qquad (6.9)$$

This equation can be used to find the AIRR when TVS, PVI, and N are known:

$$AIRR = \left[\frac{TVS}{PVI}\right]^{\frac{1}{N}} - 1 \qquad (6.10)$$

where

TVS = the terminal value of operational savings, and

PVI = the present value of capital investment costs.

6.3.3 Summary of AIRR Method

- The AIRR measures economic performance as an annual rate of return on investment.
- A single project alternative is cost effective relative to its base case when its AIRR is greater than the appropriate discount rate.
- The AIRR is a relative measure; it must be calculated with respect to a designated base case.
- When computing the AIRR of an alternative relative to its base case, the same study period and discount rate must be used.
- The AIRR, like the SIR, can be used to evaluate a single project alternative against a base case, and to rank independent projects when allocating a limited budget.
- Effects not measured in dollars are not included and need to be accounted for in some other way.

6.4 SIMPLE PAYBACK (SPB) AND DISCOUNTED PAYBACK (DPB)

There are two payback measures that are often used for economic analysis of a capital investment: Simple Payback (SPB) and Discounted Payback (DPB). Both SPB and DPB measure the time required to recover **initial investment costs**. They are expressed as the number of years elapsed between the beginning of the service period and the time at which cumulative savings (net of any incremental investment costs incurred after the service date) are just sufficient to offset the incremental initial investment cost of the project. Both of these payback measures are **relative** measures; that is, they can only be computed with respect to a designated base case.

DPB is the preferred method of computing the payback period for a project because it requires that cash flows occurring each year **be discounted** to present value before accumulating them as savings and costs. If the DPB is less than the length of the service period used in the analysis, the project is generally cost effective. This is consistent with the requirement that the LCC of the project alternative be lower than the LCC of the base case. In practice, however, the payback criterion typically applied (i.e, the number of years allowed for payback to occur) is usually a subjectively chosen time period considerably shorter than the project's expected service period. Furthermore, it is possible that capital replacement costs or increased OM&R costs can occur after the year of payback, which would negate the cost effectiveness of the project.

SPB, which is more frequently used, does not use discounted cash flows in the payback calculation. In most practical applications the SPB also ignores any changes in prices (e.g., energy price escalation) during the payback period. Like DPB, the acceptable SPB for a project is also typically set at an arbitrary time period often considerably less than its expected service period. The SPB for a project will generally be shorter than its DPB since undiscounted cash flows are greater than their discounted counterparts (assuming a positive discount rate).

Both these payback measures ignore all costs and savings, as well as any residual value, occurring after the payback date. **Payback is not a valid method for selecting among multiple, mutually- exclusive, project alternatives**; only the LCC and NS measures should be used for this purpose. Nor should payback measures be used to rank independent projects for funding allocation.

In general, payback is best used as a **screening method** for identifying single project alternatives that are so clearly economical that the time and expense of a full LCCA is not warranted. However, when uncertainty about the useful life of a project is a major consideration, the discounted payback method can also be used to determine an acceptable lower bound on its useful life.

6.4.1 General Formula for Payback

The payback period is the minimum number of years, y, for which

$$\sum_{t=1}^{y} \frac{(S_t - \Delta I_t)}{(1 + d)^t} \geq \Delta I_0 \qquad (6.11)$$

where

y = Minimum length of time (usually years) over which future net cash flows have to be accumulated in order to offset initial investment costs,
$\mathbf{S_t}$ = Savings in operational costs in year t associated with a given alternative,
$\mathbf{\Delta I_0}$ = Initial investment costs associated with the project alternative,
$\mathbf{\Delta I_t}$ = Additional investment-related costs in year t, other than initial investment costs, and
d = Discount rate.

If the discount rate is zero, y is the SPB; if the discount rate is non-zero, y is the DPB. This equation results in an integer solution to the payback period. While interpolation can be used to determine a non-integer solution (e.g., 2.35), the data do not generally support such precision.

6.4.2 Payback Formula for Building-Related Projects

The formula shown above is general in nature. A formula more specific to energy and water conservation projects in buildings can be stated as:

Find the minimum number of years, y, for which

$$\sum_{t=1}^{y} \frac{[\Delta E_t + \Delta W_t + \Delta OM\&R_t - \Delta Repl_t + \Delta Res_t]}{(1 + d)^t} \geq \Delta I_0 \qquad (6.12)$$

where

ΔE_t	=	$(E_{BC} - E_A)_t$	Savings in energy costs in year t,
ΔW_t	=	$(W_{BC} - W_A)_t$	Savings in water costs in year t,
$\Delta OM\&R_t$	=	$(OM\&R_{BC} - OM\&R_A)_t$	Difference in OM&R costs in year t,
$\Delta Repl_t$	=	$(Repl_A - Repl_{BC})_t$	Difference in capital replacement cost in year t,
ΔRes_t	=	$(Res_A - Res_{BC})_t$	Difference in residual value in year t (usually zero in all but the last year of the study period),
d	=		Discount rate, and
ΔI_0	=	$(I_A - I_{BC})_o$	Additional initial investment cost.

This equation provides the most accurate method for computing both Simple and Discounted Payback. It can require extensive computations when the payback period is long, especially when price escalation rates are required for the analysis. However, manual calculations are not necessary if the NIST BLCC program is used to compute SPB and DPB. Moreover, the BLCC program will compute the cumulative cash flows in every year of the study period to make sure that once payback has been reached it is not reversed by one-time costs incurred in a later year.

6.4.3 Payback Computation

The following example will show how equation 6.12 is solved manually. It is based on the data and assumptions that are used in example 5-1(a and b), with relevant assumptions and data (table 6-2) repeated here.

Location:	Washington, DC
Rate type:	Commercial
Base date:	January 1995
Service date:	January 1995
Study Period:	20 years
Discount rate:	3% real (FEMP rate for FY 95)
Treatment of Inflation:	Constant dollars

Table 6-2
Cost Data from Example 5-1: Selection of HVAC System for Office Building—Simple Case

Initial investment costs, assumed to occur in a lump sum at the base date	$103,00	$110,00
Replacement cost for a fan at the end of year 12	$12,000	$12,500
Residual value at the end of the 20-year study period	$3,500	$3,700
Annual electricity costs	$20,000	$13,000
Annual OM&R costs	$7,000	$8,000

To solve equation 6.12 for both SPB and DBP, it is convenient to use **energy price indices** for each year to convert the $7,000 annual energy savings ($20,000 - $13,000) at base-date prices to their future-cost equivalent. These energy price indices are provided in the **"Ca" series of tables** in the Annual Supplement to Handbook 135 for 1995. For this example, table Ca-3 provides the energy price indices for region 3 (Washington, DC, and the South), electricity, commercial rates, beginning in 1995. The Ca tables from the Annual Supplement to Handbook 135 for 1995 are provided in appendix F of this handbook. *Note that these price indices represent only real changes in prices from the base date (i.e., net of general inflation) since this study is conducted in constant dollars.* The price indices should be normalized so that the index for the energy price at the base date is 1.0.

Table 6-3 provides a summary of payback calculations for the first six years of the study period. The first column of this table shows the year of the study period. The second column shows the energy price indices taken from table Ca-3 for each year. These indices, multiplied by the annual energy savings at base date prices, provide the savings expected as of the end of each of the six years, as shown in column (3). (These costs are in constant dollars because general inflation is not included.) The fourth column shows the difference in annual OM&R cost, which is constant throughout the study period in constant-dollar terms. (That is, OM&R costs are assumed to be the same each year in constant dollars.) The fifth column shows cumulative savings, undiscounted (d=0%). These are used for computing SPB. The sixth column shows the present value of cumulative savings (d=3%). The seventh column shows the difference in initial investment cost between the base case and the alternative to be $7,000 ($120,000 - $113,000). This amount is shown for each year to make the calculation of net savings across each row more apparent. The eighth column shows the undiscounted net savings, which turn positive in the second year. The ninth column shows the discounted net savings which also turn positive in the second year. Thus both SPB and DPB occur in the second year, when net savings first become positive. (Interpolation can be used to determine the month as well, but is not normally needed.) An additional column for the difference in capital replacement costs could be included here but is not needed for this example since it is not incurred until year 12 and is not likely to reverse the solution for the payback period.

Table 6-3
Payback Analysis for Example 5-1

Service Year (1)	Energy Price Index[A] (2)	Annual Energy Saving (3)	Annual ΔOM&R (4)	Cumulative Savings d=0% (5)	Cumulative Savings d=3% (6)	Initial Investment Cost (7)	Net Savings d=0% (8)=(5)-(7) (8)	Net Savings d=3% (9)=(6)-(7) (9)
1	1.01	$7,070	($1,000)	$6,070	$5,893	$7,000	-$930	-$1,107
2	1.01	$7,070	($1,000)	$12,140	$11,615	$7,000	$5,140	$4,615
3	1.00	$7,000	($1,000)	$18,140	$17,106	$7,000	$11,140	$10,106
4	1.00	$7,000	($1,000)	$24,140	$22,437	$7,000	$17,140	$15,437
5	1.01	$7,070	($1,000)	$30,210	$28,673	$7,000	$23,210	$20,673
6	1.02	$7,140	($1,000)	$36,350	$33,815	$7,000	$29,350	$25,815

[A]This index represents the energy price level at the end of each service year, based on an index of 1.00 at the base date.

6.4.4 Alternative SPB Computation

In the limited case where ΔE_t, ΔW_t, and $\Delta OM\&R_t$ are assumed to be **the same** in every year (i.e., there is no price escalation and quantities of energy and water saved each year are the same) and there are no additional non-annually recurring OM&R or replacement costs, the SPB can be computed as follows:

$$SPB = \frac{\Delta I_0}{[\Delta E_0 + \Delta W_0 + \Delta OM\&R_0]} \tag{6.13}$$

Equation 6.13 is often used in practice. As a screening tool for qualifying projects that are clearly cost effective, this is acceptable. Applying this simplified SPB formula to example 5-1b, we get a SPB of **1.17** years for the energy-conserving HVAC alternative.

$$PB = \frac{\$110{,}000 - \$103{,}000}{(\$20{,}000 - \$13{,}000) + (\$7{,}000 - \$8{,}000)} = 1.17 \text{ year} \tag{6.14}$$

Since the additional replacement cost does not occur until year 12 and there is little difference in the residual value at the end of the 20 year life of both systems, an SPB in the second year of a 20-year study period is a strong indication that the project alternative is cost effective and may not warrant further economic analysis unless it is competing with other projects for limited investment funding.

6.4.5 Summary of Payback Methods

- SPB and DPB measure how long it takes to recover initial investment costs.
- DBP includes the time-value of money in the calculation.
- Payback is useful only as a rough guide for accept/reject decisions and is not recommended as a criterion for selecting among mutually exclusive alternatives or for ranking independent projects.

CHAPTER 7

APPLYING LCC MEASURES

TO PROJECT INVESTMENTS

CONTENTS

Chapter 7

APPLYING LCC MEASURES TO PROJECT INVESTMENTS

The previous chapters of this handbook were devoted to the mechanics of LCC analysis and the special requirements of the FEMP rules of 10 CFR 436 for economic analysis of energy and water conservation projects in federal facilities. This chapter shows how to apply LCC analysis and supplementary economic measures (NS, SIR, and AIRR) to different types of investment decisions related to these projects.

Five types of capital investment decisions frequently encountered in evaluations of energy and water conservation projects are identified in chapter 2:

(1) Accept or reject a single project or system option
(2) Select an optimal efficiency level for a building system
(3) Select an optimal system type from competing alternatives
(4) Select an optimal combination of interdependent systems
(5) Rank independent projects to allocate a limited capital investment budget

The term "optimal," as used here, means the most cost-effective choice from available alternatives; it does not refer to technical performance and does not include project alternatives that are not available at the required time and place. The first four of these investment decisions are similar in that they all involve the evaluation of **mutually exclusive** alternatives. That is, of the two or more choices being considered (even an accept/reject decision must have a base case for comparison), only one alternative can be selected. The fourth decision involves the **simultaneous analysis** of two or more interdependent systems, where each system has two or more mutually exclusive alternatives. These first four decision types identify the most cost-effective project alternative(s) in the sense that they minimize life-cycle costs. However, they do not address the problem of a budget constraint: that is, how do you allocate a limited capital investment budget among a number of **independent** (competing) projects so as to maximize the effectiveness of that budget. This is the domain of the fifth decision type. Table 2-1 in chapter 2 provides examples for each of these decision types.

7.1 ACCEPT OR REJECT A SINGLE PROJECT ALTERNATIVE

An **accept/reject** decision relates to the economic evaluation of a project having a **single** design or system option which you are considering for purchase. No competing alternatives are considered in this analysis (although it is usually advisable to consider other alternatives). You will either accept this project or reject it, depending on its cost effectiveness. Examples might include the decision to

- install storm windows over existing single-pane windows,
- install an air-lock door in a building entryway, or
- replace an electric hot water heater with a gas-fired water heater.

Even a single project alternative must be evaluated against a base case. The base case for a single project alternative is generally the "do-nothing" alternative. This base case will typically have no initial investment cost, but higher operational (e.g., energy or water) costs than the project to be evaluated. In some cases the base case may require a capital replacement to prolong its life to the end of the study period selected for evaluating the project alternative.

When a project is being evaluated as an accept/reject proposition, each of the following economic decision criteria consistently indicate a cost-effective project:

- Life-Cycle Cost (LCC) of project less than LCC of base case
- Net Savings (NS) of project greater than zero
- Savings-to-Investment Ratio (SIR) greater than 1.0
- Adjusted Internal Rate of Return (AIRR) greater than the discount rate

Each of these criteria is used to solve the following example:

7.1.1 Example 7-1: Decision to Accept/Reject Storm Windows

Install 10 storm windows over existing single-pane windows in a ranger's house in a National Park located in the Western Region of the United States.

Initial cost (installed):	$800
Base date:	January 1995
Service date:	January 1995
Expected life:	20 years
DoE discount rate:	3% (real)
Replacement schedule:	none
Residual value:	zero
Fuel oil price (January 1995):	\$7.52/GJ (≈\$1.11/gallon)
Electricity price (January 1995):	$0.08/kWh (no demand charges)
Location:	DoE Region 4 (West)
Rate type for energy:	residential
FEMP UPV* factors:	for distillate fuel oil: 17.88
	for electricity: 16.75

Annual building energy usage:	With existing windows:		
	space heating:	84.40 GJ #2 fuel oil	(≈571 gallons)
	space cooling:	4.43 GJ Electricity	(≈1,230 kWh)
	With storm windows:		
	space heating:	76.43 GJ #2 fuel oil	(≈518 gallons)
	space cooling:	4.17 GJ Electricity	(≈1,157 kWh)
Annual savings:	With storm windows:		
	space heating:	7.97 GJ #2 fuel oil	(≈53 gallons)
	space cooling:	0.26 GJ electricity	(≈73 kWh)

Additional considerations:
Additional window-washing requirements will be performed by occupants as a housekeeping chore at no additional cost to government. Occupant comfort on cold days will be improved.

7.1.1.1 LCC Solution

The LCC formula can be used to solve this accept/reject investment problem. This formula is applied to both the base case and the alternative to determine which has the lower LCC.

$$LCC = I_0 + Repl - Res + E + OM\&R \tag{7.1}$$

where

LCC = Total LCC in present value dollars of a given alternative,
I_0 = Initial investment costs,
Repl = Present-value capital replacement costs,
Res = Present-value residual (resale value, scrap value, salvage value) less disposal costs,
E = Present-value energy costs, and
OM&R = Present-value non-fuel operating, maintenance, and repair costs.

LCC solution for "do-nothing" base case (do not install storm windows):

I_0 = 0
Repl = 0
Res = 0
E = 84.4 GJ x $7.52/GJ x 17.88 + 1230 kWh x $0.08/kWh x 16.75 = $12,996
OM&R = 0

LCC = $12,996

LCC solution for alternative (install storm windows):

I_0 = $800
Repl = 0
Res = 0
E = 76.43 GJ x $7.52/GJ x 17.88 + 1157 kWh x $0.08/kWh x 16.75 = $11,827
OM&R = 0

LCC = $800 + $11,827 = $12,627

Conclusion: The LCC for storm windows (**$12,627**) is lower than the LCC for existing windows (**$12,996**); installing storm windows is cost effective and should be accepted.

7.1.1.2 NS Solution

This accept/reject problem can also be solved by using the NS method. The NS is a measure of the expected long-run profitability of the project to be undertaken. You can calculate the NS by simply taking the difference between the LCC of the base case (do not install storm windows) and the LCC of the alternative (install storm windows), i.e.,

$$\$12{,}996 - \$12{,}627 = \$369$$

However, for this example we will use the NS formula for building-related projects presented in section 6.1.2. This helps us set up the same problem for solution with SIR and AIRR in the next sections.

$$NS_{A:BC} = [\Delta E + \Delta OM\&R] - [\Delta I_0 + \Delta Repl - \Delta Res] \qquad (7.2)$$

where:

$\mathbf{NS_{A:BC}}$	=	Present Value Net Savings, that is, operational savings minus additional investment costs for the alternative relative to the base case,	
$\mathbf{\Delta E}$	=	$(E_{BC} - E_A)$	Savings in energy costs attributable to the alternative,
$\mathbf{\Delta OM\&R}$	=	$(OM\&R_{BC} - OM\&R_a)$	Savings (or increase) in OM&R costs,
$\mathbf{\Delta I_0}$	=	$(I_A - I_{BC})$	Additional initial investment cost required for the alternative relative to the base case,
$\mathbf{\Delta Repl}$	=	$(Repl_A - Repl_{BC})$	Additional capital replacement costs, and
$\mathbf{\Delta res}$	=	$(Res_A - Res_{BC})$	Additional residual value.

$\mathbf{\Delta E}$	=	7.97 GJ x \$7.52/GJ x 17.88 + 73 kWh x \$0.08 x 16.75 = \$1,169
$\mathbf{\Delta I_0}$	=	\$800
NS	=	**\$1,169 - \$800 = \$369**

Conclusion: Net savings (**\$369** in present-value terms) is positive; the storm windows are cost effective. These net savings, or "profit", will be earned in addition to the 3 percent real rate of return implicit in the LCC calculations as a result of discounting.

7.1.1.3 SIR Solution

The SIR method can also be used to determine whether to accept or reject the storm window investment. It expresses the savings that can be achieved for each dollar invested in the energy-saving alternative. The SIR must be greater than 1.0 for the storm windows to generate more savings than costs. In this calculation we use the SIR formula for building-related projects as presented in section 6.2.2:

$$SIR_{A:BC} = \frac{\Delta E + \Delta OM\&R}{\Delta I_0 + \Delta Repl - \Delta Res} \qquad (7.3)$$

$$SIR = \$1{,}169/\$800 = 1.46$$

Conclusion: The storm windows' SIR of **1.46** passes the test for cost effectiveness. For each one dollar invested in the storm windows, \$1.46 will be saved, over and above the 3 percent discount rate reflecting the minimum acceptable rate of return.

7.1.1.4 AIRR Solution

The AIRR method can be used to evaluate the cost effectiveness of the storm windows when you are interested in a measure of project **yield per year**. If the AIRR for the storm windows is greater than the required rate of return (as reflected in the 3 percent discount rate in our example), it indicates that the annual yield of the energy-saving project exceeds that of the next best opportunity for investing your funds. The simplified formula for computing the AIRR, as presented in section 6.3.1, is used here to compute the AIRR of the storm windows.

$$\begin{aligned} AIRR &= (1 + r) \times (SIR)^{\frac{1}{20}} - 1 \\ &= (1 + 0.03) \times (1.46)^{\frac{1}{20}} - 1 \\ &= 0.0497 \\ AIRR &\approx 5.0\% \end{aligned} \tag{7.4}$$

Conclusion: The AIRR of **5.0 percent** (real) for the storm windows is greater than the real discount rate of 3.0 percent. The AIRR solution shows that the storm windows are cost effective, consistent with the results of the LCC, NS, and SIR analyses.

7.2 SELECT OPTIMAL EFFICIENCY LEVEL

The **optimal efficiency level** refers to the problem of selecting the most cost-effective level of energy performance (or other scalable performance parameter) for a building system. "Efficiency level" here means that a given set of performance requirements can be achieved with different amounts of resource input (e.g., energy or water); the lower the input requirement, the higher the efficiency. The energy efficiency of a building system can vary over a wide range while producing approximately the same level of thermal comfort, convenience, or light. Good examples of this type of decision include the selection of

- the level of insulation to be installed in a roof, wall, or floor of a building,
- the level of thermal performance for window systems,
- the seasonal efficiency of a furnace or boiler,
- the seasonal coefficient of performance (SCOP) for an air conditioner or heat pump system,
- the collector area of a solar heating system.

Generally we can assume that the more efficient the system, the higher its investment cost. This type of decision is different from the accept/reject decision shown above because the object is not to determine whether or not a particular efficiency level is cost effective. Instead, the objective is to determine which of the available efficiency levels is the **most cost effective** for the application being considered.

Consider the case of thermal insulation in the exterior envelope of a building. Insulation can generally be installed over a wide range of R-values (resistance values) in most exterior components, and in general the higher the R-value the lower the energy loss (or gain) through that component. However, these savings are subject to diminishing marginal returns; that is, each additional unit saves less than the one before. While the first units may be extremely cost effective, beyond some point it no longer pays to install additional insulation.

The optimal energy efficiency level for a building system, whether roof, walls, windows, lighting, or heating and cooling equipment, is generally the level which minimizes LCC or maximizes Net Savings. Both of these measures will give an identical solution if applied properly. Do NOT use the SIR, AIRR, or payback measures to determine this solution. The efficiency level with the highest SIR or AIRR (or shortest payback) will not be the economically optimal level. The SIR and AIRR measures usually decline with each additional unit of efficiency, since the additional energy savings generated tend to decline with each unit increase in efficiency.

7.2.1 Example 7-2: Decision on Optimal Level of Insulation

This example illustrates the computation of **LCC** and **NS** measures to determine the **optimal** R-value of attic insulation to be installed in a new house on a military base in Ohio. The key dates and assumptions are as follows:

Base date:	January 1995
Service date:	January 1995
Expected life:	25 years
Replacement schedule:	none
Residual value:	none
Electricity price:	$0.08/kWh (January 1995)
Location:	DoE Region 2 (Midwest)
Rate type for energy:	residential
FEMP UPV* for electricity:	19.58

Five different levels of batt insulation are being considered, ranging from R-11 to R-49. Note that the optimal R-value for any given building is determined by a number of factors, including climate, fuel prices, the efficiency and operating schedule of the heating and cooling equipment, the incremental cost of each level of insulation considered, and the study period and discount rate selected for the analysis.

Table 7-1 shows the initial cost and annual kWh usage for space heating and cooling for each R-value being evaluated. The annual kWh cost is found by multiplying the annual kWh usage by the unit kWh cost at the base date price ($0.08/kWh). Life-cycle energy costs, in present value dollars, are found by multiplying the annual kWh cost by the FEMP UPV* factor for electricity in DOE region 2. (This factor is taken from table Ba-2 of the Annual Supplement to Handbook 135 for 1995, reproduced in appendix F.) The LCC is the sum of initial cost and present-value life-cycle energy costs. R-38 has the lowest LCC (**$11,300**) and the highest Net Savings (**$3,741**) in this example. Thus R-38 is considered to be the economically optimal R-value for this particular application. (Of course, for other energy types or prices, or for a different set of heating and cooling requirements, the optimal R-value may be different.) Table 7-1 also shows the SIR for each level of insulation relative to the R-0 level. Note that the R-value with the highest SIR (R-11) is NOT the level of insulation with the lowest LCC.

One of the advantages of using the LCC method for solving the optimal-efficiency problem is that **you do not have to identify a base case**. Whether or not the R-0 is included in the analysis, the LCC of each of the other R-values will be the same. One of the advantages of using the Net Savings method is that you do not need to know the total annual energy usage for space heating and cooling; you can use the annual energy savings. But with the Net Savings method you must identify a base case from which the energy savings are referenced; in our example the base case is the R-0 level.

Table 7-1
Cost Data, LCCs, and Net Savings for Selecting Optimal Insulation Level

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Initial		Energy Cost		Total	Net	
R-Value	Cost ($)	Annual kWh	Annual ($)	Life (PV) ($)	PV LCC ($)	Savings ($)	SIR
R-0	0	9602	768	15,041	15,041	0	n/a
R-11	300	7455	596	11,678	11,978	3,063	11.21
R-19	450	7055	564	11,051	11,501	3,540	8.87
R-30	650	6804	544	10,658	11,308	3,733	6.74
R-38	800	6703	536	10,500	11,300	3,741	5.78
R-49	1000	6628	530	10,382	11,382	3,658	4.66

7.3 SELECT OPTIMAL SYSTEM TYPE

Optimal system selection refers to the problem of selecting the most cost-effective system **type** for a particular application. Examples of this investment decision category include

- selection of the HVAC system type (e.g., electric, gas, heat pump),
- selection of wall construction type (e.g., masonry, wood frame, or curtain wall), or
- selection of water heater type to be installed in a new building (e.g., gas, electric, solar).

The choice of system type may affect the energy use of the building, but the amount of energy used is not generally a primary consideration in the selection. For example, the choice between concrete-masonry construction and curtain wall construction for exterior walls of an office building may be dictated more by long-term maintenance costs and fire-safety considerations than by energy usage, but that choice will affect the heat loss and heat gain through the wall. The choice of fuel type for space heating also falls into this category, since it is not a matter of fuel utilization efficiency but of cost effectiveness in the particular application that is to be considered.

7.3.1 Example 7-3: Selection of Optimal Type of HVAC System

In example 7-3 we look at five different types of heating/cooling systems being considered for installation in a house on a military base in Ohio. The key dates and assumptions are as follows:

Base date:	January 1995
Service date:	January 1995
Expected life:	15 years
Replacement schedule:	none
Residual value:	none
Discount rate:	3% real
UPV factor for OM&R costs (15 years):	11.94
Location:	DOE Region 2 (Midwest)

Annual space heating load:	52.75 GJ (≈50 MBtu)	
Annual space cooling load:	21.10 GJ (≈20 MBtu)	
Fuel prices as of base date:	Electricity:	$22.20/GJ (≈0.08/kWh, $23.40/MBtu)
	Fuel oil:	$ 7.58/GJ (≈$1.12/gallon, $8.00/MBtu)
	LPG:	$10.43/GJ (≈$1.01/gallon, $11.00/MBtu)
	Natural gas:	$7.58/GJ (≈$0.80/therm, $8.00 MBtu)
Rate type for energy:	Residential	
FEMP UPV* factors:	Electricity:	12.80
	Fuel oil:	14.00
	LPG:	14.02
	Natural gas:	13.41

Four different fuel types are available at the site: electricity, fuel oil, LPG, and natural gas. We can assume that the optimal energy-utilization efficiency for each system type (i.e., the efficiency level with the lowest LCC) has already been determined before making the decision as to which system type is most cost effective for this house. To make this problem easier, each system is assumed to have the same expected life (15 years). The optimal heating/cooling system will depend on the annual space heating and cooling requirements, the price per GJ or MBtu of fuel, the seasonal efficiency of each system, OM&R costs, the study period, and the discount rate.

Table 7-2 shows, for five different HVAC system alternatives, the system-specific data needed for computing annual energy usage and life-cycle costs: initial costs, annual OM&R costs, and seasonal efficiency. Table 7-3 shows the LCC solution for each of the five systems. Initial costs are lowest for the electric base board (BB) system with window air conditioner and highest for the natural gas furnace. (The cost of the fuel oil and LPG furnaces include a storage tank. The cost of the natural gas furnace includes the installation of a pipeline from the street.)

Table 7-2
System Types, Costs, and Seasonal Efficiency Data
Used to Select Optimal Type of HVAC System (Example)

System Type	Initial Cost ($)	Annual OM&R Cost ($)	Seasonal Efficiency[a]
Electric BB/Window AC	2,500	75	1.00/3.0
Heat Pump (Central)	4,000	200	2.00/3.0
Oil Furnace/Central AC	4,500	125	0.82/3.0
LPG Furnace/Central AC	4,500	100	0.85/3.0
Nat Gas Furnace/Central AC	5,000	100	0.85/3.0

[a] Seasonal coefficient of performance for heat pump. Central systems are assumed to have an additional 10% duct loss.

Table 7-3
Present-Value Costs, LCC and NS Solutions for Selecting Optimal Type of HVAC System

System Type	Present Value Costs ($) Initial	OM&R	Energy	LCC ($)	NS ($)	SIR
Electric BB/Window AC	2,500	895	16,988	20,384	n/a	n/a
Heat Pump (Central)	4,000	2,388	10,548	16,936	3,447	3.30
Oil Furnace/Central AC	4,500	1,493	9,806	15,798	4,585	3.29
LPG Furnace/Central AC	4,500	1,194	12,304	17,998	2,386	2.19
Nat Gas Furnace/Central AC	5,000	1,194	9,230	15,424	4,960	2.98

In this example the natural gas furnace/central AC has the lowest LCC (**$15,424**) and highest Net Savings (**$4,960**) of the five systems and is therefore the most cost effective system choice for this specific application. Note, however, that it does not have the highest SIR. The heat pump, which ranks third in terms of LCC, has the highest SIR (**3.30**). The SIR is not a valid method for determining the HVAC system with the lowest LCC.

7.4 SELECT OPTIMAL COMBINATION OF INTERDEPENDENT SYSTEMS

Determining the optimal design or energy efficiency for a number of interdependent systems within a building generally requires a **simultaneous energy analysis** to properly account for the **interaction among the systems**. This interaction results when the use of one system affects the energy use of other systems in the same facility. For example, as the thermal envelope of a building becomes tighter (i.e., more insulation and more efficient window systems are employed), the energy savings from efficiency improvements to the heating/cooling system diminish, making the latter improvements less cost effective. Similarly, as the efficiency of the heating/cooling system is increased, the energy savings from the insulation and window improvements diminish, making these less cost effective as well.

Building system interactions that are most likely to have an impact on energy savings are those related to

- HVAC system efficiency,
- the thermal integrity of the overall building envelope, and
- lighting system efficiency and usage.

Interactions among the various envelope components themselves (including windows, walls, and roof) are less important, difficult to measure, and difficult to document. The time to pay most attention to system interactions is during the design phase of a new building. Retrofit projects in an existing building are usually more restrictive in terms of the number of systems that can be substantially modified at the same time.

It is not conceptually difficult to perform a simultaneous analysis of several building systems. This basically requires a **whole-building energy analysis** (using a load simulation program such as ASEAM, DOE-2, or BLAST) **for each combination** of system specifications to be evaluated. The calculated energy usage for the whole building reflects the interaction of these building systems. The difference in building energy usage from one combination of system specifications to another is the savings attributable to all of the changes. There is no need to estimate savings attributable to individual systems or conservation measures when performing this analysis. Some whole-building energy analysis programs can be set up in a parametric mode which automatically changes one or more system parameters (e.g., the R-value of wall insulation or heating system efficiency) with each run.

While whole-building energy analysis is not conceptually difficult, the number of potential system combinations to be evaluated can be very large and unwieldy. In general, **only practical and balanced combinations of alternatives need to be considered**. Thus it is unlikely that a low level of roof insulation and a high-efficiency window glazing would be used together. Unlikely system combinations should be eliminated to the extent possible before performing an energy analysis on the remaining combinations.

Once the energy usage of each combination of systems is estimated, an LCC analysis can be performed for each combination of system specifications. This LCC is based on the total initial investment costs, replacement costs, residual values, and OM&R costs for each combination of systems being evaluated, and the corresponding energy usage for that combination (all in present value terms). **The most cost-effective combination of building system specifications is the combination with the overall lowest LCC**.

7.4.1 Example 7-4: Selection of Optimal Combination of Thermal Envelope and HVAC System Efficiency

This example shows an LCC analysis for a hypothetical administration building being designed for a West Coast location. Five different levels of thermal efficiency (i.e., resistance to heat loss and heat gain) in the envelope system (E_1 through E_5), and three different levels of HVAC energy conversion efficiency (H_1 through H_3) are being considered for this building. Higher levels of efficiency have higher initial costs but use less energy than lower levels. Two energy types are assumed, natural gas for heating, electricity for cooling and for fans. Since the envelope and HVAC systems are interdependent from an energy usage standpoint, the energy analysis must be performed for the entire building rather than for the individual systems. The design objective in this example is to determine which envelope and HVAC system combination results in the lowest LCC.

The basic economic and technical assumptions needed for this analysis are as follows:

Base Date:	January 1995		
Service Date:	January 1995		
Expected life:	25 years		
Replacements:	none		
Residual value:	none		
Discount rate:	3% real		
UPV factor for OM&R costs:	11.94		
Location:	DOE Region 4 (West)		
Rate type for energy:	Residential		
Fuel prices as of Base Date:	Electricity:	\$22.00/GJ	(≈\$0.079/kWh, \$23.21/MBtu)
	Natural gas:	\$7.00/GJ	(≈\$7.39/MBtu)
FEMP UPV* factors:	for electricity:	20.05	
	for natural gas:	21.19	

Initial cost:

Envelope System	Initial Cost ($)	HVAC System	Initial Cost ($)
E_1	0	H_1	0
E_2	5,000	H_2	15,000
E_3	10,500	H_3	37,000
E_4	22,000		
E_5	40,000		

Annual natural gas usage (GJ) by envelope and HVAC alternative:

Envelope System	HVAC System ($)		
	H_1	H_2	H_3
E_1	1,285	1,124	1,058
E_2	1,221	1,068	1,005
E_3	1,163	1,018	958
E_4	1,112	973	915
E_5	1,067	933	878

Annual electricity usage (GJ) by envelope and HVAC alterative:

Envelope System	HVAC System ($)		
	H_1	H_2	H_3
E_1	350	300	266
E_2	332	285	253
E_3	318	272	242
E_4	306	262	233
E_5	298	255	226

Each level of envelope efficiency shown builds on the previous level, increasing the initial investment cost of the building but reducing annual heating and cooling requirements. Likewise, each HVAC system alternative shown has a higher initial investment cost but reduces the energy needed to satisfy a given heating and cooling load. The base level for both the envelope and the HVAC equipment is shown to have zero initial cost because it is assumed that these represent minimum acceptable levels of performance. Only investment costs **above these minimum levels** of performance are needed for this analysis. To make the problem easier to demonstrate, OM&R costs are assumed to be the same for each level of envelope efficiency and each level of HVAC system efficiency, no replacements are needed during the 25-year study period, and the residual value of each alternative is assumed to be zero. In addition, the potential reduction in the initial cost of the HVAC system due to a downsizing of maximum heating and cooling loads is also assumed to be negligible. Thus the LCC shown here is simply the sum of the initial cost of the envelope and system improvements plus the present value of natural gas and electricity costs for space heating and cooling. For example, the LCC of the combination E_2 and H_3 can be computed as follows:

$LCC_{E2,H3}$	=	\$15,000	(initial cost of E_2)
	+	\$37,000	(initial cost of H_3)
	+	1,005 GJ x \$7.00/GJ x 21.19	(PV cost of natural gas)
	+	253 GJ x \$22/GJ x 20.05	(PV cost of electricity)
	=	\$302,670	

The LCC for each envelope and HVAC system combination from example 7-4 is shown in table 7-4. The first column shows LCC calculations for each of the five thermal envelope alternatives, given the base-level HVAC system. If the base-level HVAC system H_1 were to be selected, the most cost-effective envelope alternative would be E_4, with an LCC of **\$321,920**. If HVAC system H_3 were to be selected, the most cost-effective envelope alternative would be E_3, with a total LCC of **\$296,346**. If the base-level thermal envelope E_1 were selected, the most cost-effective HVAC system would be H_3, with an LCC of **\$311,266**. But if E_5 were selected, the most cost-effective HVAC system would be H_2 with an LCC of **\$305,872**. The combination with the lowest LCC **(\$296,346)** is E_3,H_3.

Table 7-4
LCC Solution for Selecting the Optimal Combination of Building Envelope and HVAC System

	HVAC System (\$)		
Envelope System	**H_1**	**H_2**	**H_3**
E_1	344,989	314,053	311,266
E_2	332,556	304,130	302,670
E_3	323,278	296,479	296,346
E_4	321,920	296,893	297,498
E_5	329,716	305,872	306,922

The LCC method is the most appropriate method for evaluating interactive system combinations. The **Net Savings** measure can also be used to determine the optimal combination; the combination with the highest NS is the same as the combination with the lowest LCC. However, in order to compute the Net Savings, a base case system combination must be identified first (e.g., E_1,H_1 in this example) and the Net Savings for each combination to be evaluated must be computed with respect to that base case. The choice of the combination with the highest SIR and AIRR, or the shortest Payback, will NOT yield the correct combination in most cases.

In this example the difference in the LCC for some combinations close to the optimal combination (E_3,H_3) is relatively small. The determination of the optimal combination is likely to be quite **sensitive to uncertain parameters** such as OM&R costs or future energy costs. Thus fine tuning of this method by examining large numbers of potential combinations of interdependent systems is probably not warranted either from a design cost or LCC standpoint. Still it is important to recognize that the interaction among building systems can affect the economics of design choices and to understand how to take these considerations into account.

7.5 RANKING INDEPENDENT PROJECTS FOR FUNDING ALLOCATION

Up to this point, this chapter has shown how LCC and related measures of economic analysis can be used to determine cost-effective choices **among mutually exclusive project alternatives**. These are applications where only one alternative for any given system is to be selected. This section addresses the use of economic analysis to rank two or more **independent** projects—all of which have already been shown to be cost effective—in order to allocate limited funding. Independent projects are projects that can be implemented in the same or different buildings without significantly affecting the cost effectiveness of one another.

Since all of the independent projects being considered have already been identified as cost effective, it would generally be advantageous to implement them all. However, there may be insufficient investment funding for this purpose and it is therefore important that the funding available be allocated to achieve the **greatest overall Net Savings**. The FEMP LCC rules (10 CFR 436) require the use of either the SIR or AIRR measures for establishing priority for ranking independent projects. Projects are ranked in order of SIR or AIRR and funded in descending rank order until the available funding runs out. If additional funding is made available at a later time, it will be allocated to the remaining projects (and any new projects introduced in the interim) using this same criterion. **The same results will be achieved by using either the SIR or AIRR for ranking projects.** In the remainder of this section only the SIR method will be demonstrated.

*Note that only the SIR and AIRR measures provide an acceptable method for ranking independent projects for funding purposes. Do **NOT** use the LCC, Net Savings, or Payback measures for individual projects as a means of ranking them with other independent projects.*

If **several interdependent projects** have been identified for potential funding, these are best evaluated by combining them into a single project with a combined SIR and ranking this project along with other independent projects. The **information on individual projects** within a set should be preserved to allow selections from the set when budget limitations preclude funding all projects within a set.

A practical advantage of using the SIR measure for ranking independent projects is that the same study period is not required for each project, as it is when evaluating mutually exclusive projects. This is especially important when funding projects are submitted by different analysts or for different buildings. For example, if new roof insulation in one building is evaluated with a study period of 25 years and a new computer-control system for HVAC equipment in a different building is evaluated with a study period of 15 years, the two projects can still be ranked by their individual SIRs when allocating funding. This advantage is based on the implicit assumption that any project can be replicated (i.e., replaced with a similar system having similar costs and savings) at the end of its life. However, when calculating SIRs for ranking independent projects, do NOT include project replication in the analysis (i.e., do not include project replacements in order to force a longer life).

If an SIR is calculated when performing an analysis of mutually exclusive alternatives for a given project (although it is not necessary for that analysis), the resulting SIR may not be appropriate for ranking that project with respect to other independent projects. If the project analysis included capital replacements in order to force a common study period, the project's SIR will need to be recalculated without the replacements before it can be used for project ranking.

7.5.1 Example 7-5: Simple SIR Ranking

Table 7-5 demonstrates the most straightforward application of the SIR ranking method. Six independent conservation projects are proposed for funding, but **only $7,000 is available** for funding conservation projects this year. All six projects have already been shown to be cost effective relative to their corresponding base cases in that they have an SIR greater than 1.0 and Net Savings greater than zero. If $16,000 were available to fund these projects, all six could be funded at a present-value Net Savings of $39,000.

Table 7-5
SIR Ranking of Independent Projects for Example 7-5

	Initial Cost ($)	Total Savings ($)	SIR	Net Savings ($)	Cumulative Investment ($)	Cumulative Net Savings ($)
Project A	1,000	10,000	10.0	9,000	1,000	9,000
Project F	1,000	5,000	5.0	5,000	2,000	14,000
Project E	2,000	8,000	4.0	6,000	4,000	20,000
Project C	3,000	10,000	3.3	7,000	7,000	27,000
Project B	5,000	15,000	3.0	10,000	12,000	37,000
Project D	4,000	6,000	1.5	2,000	16,000	39,000

The projects are listed in table 7-5 in declining order of their SIR. The column labeled "Cumulative Investment" indicates how far down the list the $7,000 funding will reach. Projects A, F, E, and C will be funded with a cumulative Net Savings of $27,000. No other combination of projects from this list that can fit into the $7,000 budget constraint can produce greater cumulative Net Savings.

7.5.2 Example 7-6: SIR Ranking of Indivisible Projects

In example 7-5 the top four projects, as ranked by SIR, fit **exactly** into the available capital investment budget. This may not always be the case. Table 7-6 shows eight independent projects which together have a total investment cost of $27,500. However, only $12,000 in capital funding is available this year. The projects are funded in declining order of SIR. But when project H (ranked 5th, with an SIR of 2.0 and an initial cost of $10,000) is reached, it cannot be funded within the remaining funding of $4,500 ($12,000-$7,500). If project H is **divisible** into smaller parts, each having the same SIR, then the remaining $4,500 should be invested in that project. But if H cannot be divided up, the solution to this problem becomes more complex. Project H should be **skipped over** for now, and project G, at $4,000, should be included. This leaves **$500 uninvested** if no other project can be broken down into smaller pieces.

The combination of projects B, C, D, F, and G have a total investment cost of **$11,500** and a combined Net Savings of **$20,300**. Alternatively, the $12,000 could be allocated to projects B and H, which have a total investment cost of **$12,000** and a combined Net Savings of **$18,000**. Since the ultimate objective is to fund the package of projects with the greatest overall Net Savings, the first package is selected. (Uninvested funding, if any, should not be included in the Net Savings. It can be ignored.)

Table 7-6
SIR Ranking of Indivisible Projects

Projects	Initial Cost ($)	Total Savings($)	Net Savings($)	SIR	Rank
A	3,000	4,000	1,000	1.33	8
B	2,000	10,000	8,000	5.00	1
C	2,000	6,000	4,000	3.00	2
D	2,500	6,000	3,500	2.40	4
E	3,000	4,500	1,500	1.50	7
F	1,000	2,800	1,800	2.80	3
G	4,000	7,000	3,000	1.75	6
H	10,000	20,000	10,000	2.00	5
Competing projects combinations:					
BCDFG	11,450	31,800	20,350		
BH	12,000	30,000	18,000		

7.5.3 Example 7-7: Ranking Variable-Size Projects With a Funding Constraint

In examples 7-5 and 7-6, each of the independent projects being considered for funding had already been evaluated **individually** to determine that they were cost effective investments before they were submitted for funding. Implicitly it is assumed that each of these projects had been **previously evaluated relative to other mutually exclusive alternatives**, and the most cost effective alternative (i.e., the alternative with the lowest LCC, not the alternative with the highest SIR) was selected for the funding competition. There are circumstances in which it may be advantageous to perform both the funding evaluation and the cost-effectiveness evaluation simultaneously.

Table 7-7 shows six independent projects, one of which, B, could be implemented at two different levels (or sizes), B_1 and B_2 (e.g., replacement windows with double glazing or triple glazing). Based on the Net Savings criteria for project cost effectiveness, it is clear that B_2 is the more cost effective alternative because it has higher Net Savings than B_1 (**$11,000** versus **$10,000**). If this list of projects were to be sent forward to another office for a funding decision, generally only the more cost effective alternative (B_2) would be included in the list of projects and B_1 would not be considered in the funding decision process. But, under limited circumstances, the funding allocation analysis can be made simultaneously with the analysis of the individual project alternatives. In general, a simultaneous analysis of this type should only be performed when (1) the available funding level is fixed, with no prospect for additional funding at a later date, and (2) the decision to allocate funding is made at the local level, not centrally (where simultaneous analysis of multiple projects with multiple, mutually exclusive, alternatives is impractical).

Before exploring this type of analysis further, consider the following problem: If project B is funded at the B_1 level, it will generally preclude level B_2 from being implemented later. For example, once double-pane replacement windows are installed, it will be impractical to upgrade them further. Installation of the lower efficiency alternative will have a long-term negative impact on the building's energy performance and energy-related costs.

Table 7-7
Ranking Variable-Size Projects

Project Alternative	Initial Cost ($)	PV Savings ($)	Net Savings ($)	SIR	Incremental SIR
A	12,000	60,000	48,000	5.0	
B_1	5,000	15,000	10,000	3.0	3.0
B_2	6,000	17,000	11,000	2.8	2.0
C	6,000	7,000	1,000	1.2	
D	3,000	12,000	9,000	4.0	
E	8,000	12,000	4,000	1.5	
F	5,000	14,500	9,500	2.9	

Thus, in the face of a **budget constraint** on energy conservation projects, two strategies might be considered first when dealing with projects of variable size:

(1) Try to **win an increase in the available budget** by showing that the current budget size precludes a cost-effective design option that will have a long-term effect on the building's performance.

(2) **If more funding is expected** at a later time, determine whether the variable-size project, or another project with a higher SIR, can be postponed without adversely affecting the overall building performance. This will allow the variable-size project to be implemented at its economic level, either now, or later when the funding becomes available.

If project B is an optional project and only considered at level B_2, a $20,000 budget would be allocated using the SIR ranking methodology as described above. Projects A, D, and F will be funded this year, with an aggregate Net Savings of $66,500. Project B (at the B_2 level) will be skipped over now but will be next in line for funding when it becomes available.

If project B is not an optional project that can be postponed, and the budget constraint is still $20,000, then project B must be evaluated **incrementally** to determine the best allocation of the budget. That is, the SIR for B_1 is calculated first ($15,000/$5,000 = **3.0**) and then the SIR for B_2 relative to B_1 is calculated ($2000/$1000 = **2.0**). Now the projects, including both B_1 and B_2, are ranked by SIR. (Note that even if the incremental SIR for B_2 were higher than the incremental SIR for B_1, B_1 would have to be implemented before B_2.) The optimal allocation of the $20,000 budget goes to A, D, and B_1, with an aggregate Net Savings of **$67,000**. No other combination of projects that fit within the budget constraint will produce a higher Net Savings.

The Net Savings for package ADF (**$66,500**) is lower than that for ADB$_1$ (**$67,000**). However, package ADF does not preclude project alternative B_2 from being implemented at a later time, which will then increase Net Savings by an additional **$1,000**. If the additional funding is expected soon, this delay is economically justified.

7.6 SUMMARY OF PROJECT EVALUATION MEASURES

Table 7-8 summarizes the proper application of LCC and supplementary economic measures to the five different types of capital investment problems discussed in this chapter. Each cell of the matrix shows whether or not the measure is appropriate for the corresponding decision type. Where it is appropriate, the evaluation criterion to be used for the decision is also shown.

The **LCC** measure itself is the most straightforward measure for evaluating the first four decision types shown in this matrix, those that involve a choice among mutually-exclusive system alternatives. The decision criterion is always the same for the LCC measure: **choose the alternative (or combination of interdependent system alternatives) with the lowest LCC**, unless significant non-monetary benefits from another alternative appear to justify the difference in LCC. An advantage of the LCC measure over the supplementary measures is that it does not require the identification of a base case when computing the LCC for each alternative. Still, two or more alternatives must be evaluated using consistent economic assumptions in order to use the LCC measure successfully.

The **NS measure** is an equally reliable and consistent measure for evaluating mutually exclusive alternatives. However, this measure does require that a base case be identified before the NS can be computed. Since NS is the difference between the LCC of any alternative and the LCC of the designated base case, the alternative with the greatest NS will be the same as the alternative with the lowest LCC.

The **SIR** and **AIRR** measures are of more limited usefulness. When evaluating mutually exclusive project alternatives, these measures are appropriate only for accept/reject decisions. In this case they are completely consistent with the LCC and NS measure if calculated correctly. When evaluating multiple, mutually exclusive, project alternatives (as in the case of system efficiency, system selection, and combinations of interdependent systems) the SIR and AIRR measures should NOT be used. It is especially important NOT to select the project alternative with the highest SIR or AIRR. Only the LCC and NS measures are appropriate for this purpose.

The **SPB** and **DPB** measures are primarily useful as screening tools. They are not consistent with the LCC methodology and will not consistently give the same result. When evaluating a project with multiple alternatives, it is especially important NOT to select the alternative with the shortest payback, as this is rarely the alternative with the lowest LCC.

The fifth type of project decision shown in table 7-8 is that of establishing project priority for independent projects already identified as cost effective. This is generally necessary when insufficient funding is available to implement all of these projects. When allocating a fixed budget among cost-effective projects, these projects should be ranked in declining order of their SIR or AIRR (both will give the same results if based on the same input values). Then the projects should be funded in that order until the budget is exhausted. Ultimately, the package of alternatives **with the greatest combined Net Savings** provides the most cost effective allocation of the investment budget. The LCC, Net Savings, and Payback measures for independent projects are inappropriate measures for ranking those projects.

Table 7-8
Economic Measures of Evaluation and Their Uses

Type of Decision	Appropriate LCC Economic Measures (Evaluation Criteria)				
	LCC	NS	SIR	AIRR	Payback
Accept / Reject	yes (minimum)	yes (> 0)	yes (> 1.0)	yes (> discount rate)	no
Level of Efficiency	yes (minimum)	yes (maximum)	no	no	no
System Selection	yes (minimum)	yes (maximum)	no	no	no
Combination of Interdependent Systems	yes (minimum combined LCC)	yes (maximum combined NS)	no	no	no
Project Priority (Independent Projects)	no	no	yes (descending order)*	yes (descending order)*	no

* Fund in descending order of SIR or AIRR until budget is exhausted. Select the group of projects that fits within budget and has the greatest aggregate Net Savings.

CHAPTER 8

DEALING WITH UNCERTAINTY IN LCC ANALYSIS

CONTENTS

Chapter 8

DEALING WITH UNCERTAINTY IN LCC ANALYSIS

Having computed a series of economic measures, whether by hand or by computer program, does not mean that the work of the analyst is completed. LCC analysis requires some thought as to what these measures mean and how they are going to be used. When you perform an LCC analysis, you might take "**best-guess**" estimates and use them in the LCC equations as if they were certain. But investments in energy conservation are long-lived and necessarily involve at least some uncertainty about project life, operation and maintenance costs, and many more factors that affect project economics. If there is substantial uncertainty concerning cost and time information, an LCC analysis may have little value for decision-making. It therefore makes sense to assess the degree of uncertainty associated with the LCC results and to take that additional information into account when making decisions. The FEMP rules in 10 CFR 436 propose that if uncertainty assessment "casts substantial doubt on the results of an LCC analysis, federal agencies are advised to obtain more reliable data or eliminate the alternative."

It needs to be pointed out that even though you may be uncertain about some of the input values, especially those occurring in the future, it is still better to include them in an economic evaluation rather than to base your decision on first costs only. **Ignoring uncertain long-run costs implies that they are expected to be zero**, a poor assumption to make.

8.1 APPROACHES TO TREATING UNCERTAINTY IN LCCA

Numerous treatments of uncertainty and risk appear in the technical literature. Table 8-1 lists a number of approaches often used to assess uncertainty with regard to investment decisions. When decision makers are faced with an investment choice under uncertain conditions, they are mostly concerned about accepting a project whose actual economic outcome might be less favorable than what is acceptable. But there is also the risk of passing up a good investment. All of the techniques in table 8-1 provide information, albeit at different levels of detail, to account for this uncertainty.

Deterministic approaches use single-value inputs, that is, they measure the impact on project outcomes of changing one uncertain key value or a combination of values at a time. The result shows how the change in input value changes the outcome, with all other things held constant.

Probabilistic approaches, by contrast, are based on the assumption that no single figure can adequately represent the full range of possible alternative outcomes of a risky investment. Rather, a large number of alternative outcomes must be considered and each such possibility must be accompanied by an associated probability. So, when probabilities of different conditions or occurrences affecting the outcome of an investment decision can be estimated, probability analysis can estimate the weighted average, or expected value, of a project's outcome. If the outcome is expressed in terms of a probability distribution, statistical analysis can be performed to measure the degree of risk. In the case of deterministic methods, the analyst determines the degree of risk on a subjective basis.

No single technique in table 8-1 can be labeled the "best" technique in every situation. What is best depends on the relative size of the project, availability of data, availability of resources (time, money, expertise), computational aids, and user understanding. In this chapter, we primarily discuss **sensitivity analysis** and **breakeven analysis**, which are deterministic approaches to uncertainty assessment. They are easy to perform and easy to understand and require no additional methods of computation beyond the ones used in LCC analysis. Since probabilistic methods have considerable informational requirements, they make uncertainty assessment much more complex and time-consuming, and before embarking on this course, it makes sense to test first the sensitivity of the analysis results to any changes in input values.

This is not to say that you should not use probabilistic methods if there is a serious question about the certainty of cost and time data, provided the size of the project or its importance warrant their use. NIST Special Publication 757, *Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Building Investments* [12], describes in depth the techniques listed in table 8-1, both deterministic and probabilistic. It discusses the advantages and disadvantages of each technique to help the decision maker choose the appropriate one for a given problem. An introduction to these techniques is presented in a NIST videotape entitled *Uncertainty and Risk, Part II,* in a series on *Least-Cost Energy Decisions for Buildings* [13].

Table 8-1
Selected Approaches to Uncertainty Assessment in LCC Analysis

APPROACHES TO UNCERTAINTY ASSESSMENT	
Deterministic	**Probabilistic**
1. Conservative Benefit and Cost Estimating	1. Input Estimates Using Probability Distributions
2. Breakeven Analysis	2. Mean-Variance Criterion and Coefficient of Variation
3. Sensitivity Analysis	3. Decision Analysis
4. Risk-Adjusted Discount Rate	4. Simulation
5. Certainty Equivalent Technique	5. Mathematical/Analytical Technique
6. Input Estimates Using Expected Values	

Source: *Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Building Investments* [12].

8.2 SENSITIVITY ANALYSIS

Sensitivity analysis can help in several ways to assess the uncertainty of an LCCA. It is a technique for determining which input values, if different, would make a crucial difference to the outcome of the analysis. It can also calculate a range of outcomes to determine the lower and upper bounds of a project's LCC or NS, or any other measure of economic evaluation. In a slightly different context, the same technique can be used to test various scenarios, perhaps using either a set of more pessimistic or more optimistic values than the expected ones.

There are several formal methodologies for performing sensitivity analysis, but to apply it in its simplest way, it is sufficient to

- vary uncertain input values, one at a time,
- recalculate the measure of evaluation (LCC, NS, SIR, AIRR, DPB), and
- look at the resulting change and draw conclusions about the degree of uncertainty.

The following sections will illustrate an application of sensitivity analysis, again using the input values of example 5-1, *Selection of HVAC System for Office Building—Simple Case.*

8.2.1 Identifying Critical Inputs

To identify input values critical to the LCC of the energy-conserving alternative in example 5-1b, simply increase the uncertain input values, one at a time, by a certain percentage, say 10 percent, and recalculate the LCC. Then compare the percentage changes in the LCCs that result from the change in the input values.

*Note that federal agencies are directed to use the **DOE energy price escalation rates and discount rate** as published, without testing for sensitivity.*

Table 8-2
Identifying Critical Inputs for Energy-Saving HVAC Alternative[a]

Cost Item	Input value increased by 10%	Change in LCC in PV $	Change in LCC in %
Initial investment cost	$121,000	11,000	+2.5
Capital replacement (fan)	$13,750	937	+0.02
Residual value	($4,070)	(205)	<-0.01
Electricity	$14,300	19,669	+4.5
OM&R	$8,800	11,904	+3.0

[a] The impact calculations are based on the following input data for the energy-saving HVAC alternative:
Discount rate: 3%
Study period: 20 years

Initial investment cost:	$110,000	Annual electricity cost:	$13,000
Capital replacement cost in year 12:	$12,500	Annual OM&R cost:	$8,000
Residual value (salvage):	($3,700)	Total LCC for Alternative	$432,442

From table 8-2 it is clear that in the case of the energy-conserving HVAC alternative the inputs critical to the economic outcome are electricity costs, OM&R costs, and initial investment costs. A 10 percent increase in electricity cost increases the LCC for the alternative by **4.5 percent**; a 10 percent increase in OM&R costs increases the LCC by **3 percent**, and a 10 percent increase in initial investment cost increases the LCC by **2.5 percent**. Changes in the other input values in table 8-2 have a much smaller effect on LCC. In this case, it may be advisable to spend additional time and money on determining the degree of uncertainty associated with the annual costs of electricity and OM&R. There is usually somewhat less uncertainty associated with initial investment cost because it occurs at or close to the base date.

8.2.2 Estimating a Range of Outcomes

One way to get a better understanding of what might be the risk of accepting an uneconomic project is to use the sensitivity analysis technique to calculate the range of possible outcomes. You can **estimate the upper and lower bounds** of an economic measure by recalculating the measure with the lowest and highest likely cost estimate. Knowing that the electricity cost has the greatest impact on LCC and, by the same token, on Net Savings, you want to determine the range of Net Savings for the energy-saving alternative, based on the most likely highest or lowest electricity cost. Let's assume that because of the uncertainty about how much electricity the alternative system will actually use, the present value of energy costs for the 20-year study period could be 20 to 40 percent higher or lower than the best-guess estimate you used.

In figure 8-1 the range of Net Savings is computed with input values based on these assumptions. Net Savings for the energy-saving alternative would drop to **$44,453** from the best-guess Net Savings of $83,791 if the alternative HVAC system used 20 percent more electricity than expected, and would increase to **$123,129** if its electricity consumption were 20 percent less than expected.

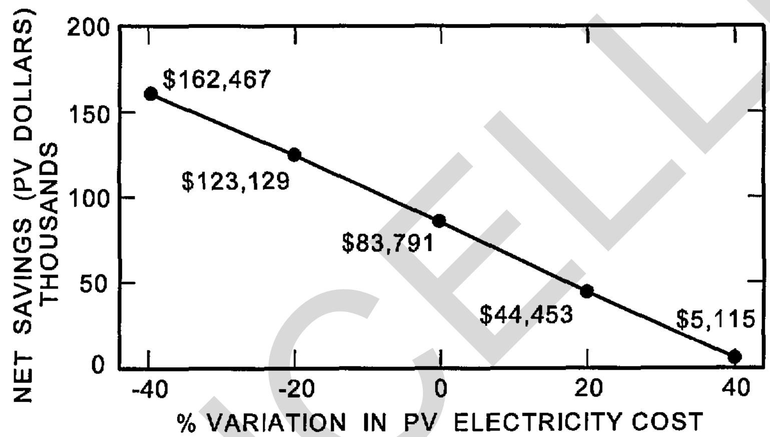


Figure 8-1
Sensitivity Analysis for NS of Energy-Saving HVAC Alternative.

Serving as an assessment of uncertainty, this test shows that even if the PV electricity cost increased by 20 percent because of higher-than-expected energy usage, the HVAC system with the night-time setback and economizer cycle would still be preferred over the conventional system. Even with a 40 percent increase in energy usage the system would still generate more savings (NS = **$5,115**) than it would cost when compared with the base case over a period of 20 years. By visually extending the line in figure 8-1 to the x-axis, you would however conclude that the breakeven point would be reached at an only slightly higher than 40 percent increase in the alternative's energy consumption.

8.2.3 Testing Possible Alternative Scenarios

The technique for testing the sensitivity of the analysis outcome to changes in input values can be extended to test various scenarios. In this case several input values, with varying degrees of uncertainty, may be looked at simultaneously and tested in combination. As before, you test one **combination** at a time, with all other values held constant. For example, a combination to be tested might be lower energy consumption combined with higher OM&R costs than in the best-guess scenario.

When testing different scenarios, you need to be aware that scenario analysis can be misleading if all pessimistic or all optimistic values are combined when calculating economic measures. Such combinations, which may not be very likely in the real world, would bias your decision towards, in one case, rejecting economic projects, and in the other case, accepting uneconomic projects.

8.2.4 Advantages and Disadvantages of Sensitivity Analysis

The major advantage of sensitivity analysis is that it can be performed when there are few resources and little time to use more sophisticated techniques. The results of a sensitivity analysis can easily be included in the analysis documentation as text, tables, or graphs.

The disadvantage is that sensitivity analysis provides no direct information on the likelihood of different outcomes. Decision makers still have to choose between alternatives on the basis of their own best judgment as to the likelihood of the various input values or scenarios occurring. Nevertheless, sensitivity analysis adds important information without requiring additional resources.

8.3 BREAKEVEN ANALYSIS

When a performance variable or an assumption is critical to the economic success of a project, decision makers often want to know the **maximum or minimum value** of an input that will allow the project to still break even. For example, with respect to the energy-saving HVAC system, you may want to know the **minimum amount of energy savings** the project needs to produce to cover the additional investment-related costs of the project. Or you may want to know the **maximum amount you can afford to pay for increased OM&R costs** for the energy-saving system and still break even relative to the savings achieved.

To perform a breakeven analysis, take the following steps:

- Construct an equation that sets operational savings equal to additional investment-related costs for a given alternative,
- Specify the values of all inputs except the breakeven variable,
- Solve for the breakeven variable algebraically.

The equation for a typical energy- and water-conserving project would set operational savings equal to investment-related costs:

$$S = \Delta C$$
$$[\Delta E + \Delta OM\&R + \Delta W] = [\Delta I_0 + \Delta Repl - \Delta Res] \qquad (8.1)$$

where

S	=	Operational savings for the alternative relative to the base case,	
ΔC	=	Investment-related additional costs for the alternative relative to the base case,	
ΔE	=	$(E_{BC} - E_A)$	Savings in energy costs attributable to the alternative,
ΔOM&R	=	$(OM\&R_{BC} - OM\&R_A)$	Difference in OM&R costs,
ΔW	=	$(W_{BC} - W_A)$	Difference in water costs,
ΔI_0	=	$(I_{0A} - I_{0BC})$	Additional initial investment cost required for the alternative relative to the base case,
ΔRepl	=	$(Repl_A - Repl_{BC})$	Difference in capital replacement costs,
ΔRes	=	$(Res_A - Res_{BC})$	Difference in residual values, and

where **all amounts are in present values.**

8.3.1 Computation of Breakeven Value

The operational savings and investment-related additional costs for the energy-saving HVAC alternative were calculated in table 6-1, and are as follows:

Operational Savings:

$$\begin{aligned} \Delta E &= \$105{,}910 \\ \Delta OM\&R &= (\$14{,}880) \end{aligned}$$

Investment-Related Additional Costs:

$$\begin{aligned} I_0 &= \$7{,}000 \\ \Delta Rep &= \$350 \\ \Delta Res &= (\$111) \end{aligned}$$

Rearranging the terms of equation 8.1 and isolating the unknown value on the left hand side, you can solve for the breakeven value—in this example the minimum PV energy savings needed to offset the additional investment-related costs:

$$\begin{aligned} \Delta E &= -\Delta OM\&R - \Delta W + [\Delta I_0 + \Delta Rep - \Delta Res] \\ \Delta E &= -(-\$14{,}880) - 0 + [\$7{,}000 + \$350 - \$111] \\ \Delta E &= \mathbf{\$22{,}119} \end{aligned}$$

This means that the PV energy savings of the alternative system need to be **at least $22,119** for the project still to be economically worthwhile. This breakeven amount corresponds to the point in figure 8-1 where the NS line meets the x-axis and where NS equals zero.

The breakeven value for the OM&R costs of the energy-conserving alternative of this example are

$$\begin{aligned} \Delta OM\&R &= -\Delta E - \Delta W + [\Delta I_0 + \Delta Rep - \Delta Res] \\ \Delta OM\&R &= -\$105{,}910 - 0 + [\$7{,}000 + \$350 - \$111] \\ \Delta OM\&R &= \mathbf{-\$98{,}671} \end{aligned}$$

This breakeven result means that as long as the increase in OM&R costs for the energy-saving alternative stays below $98,671, the system remains preferable to the conventional system.

8.3.2 Advantages and Disadvantages of Breakeven Analysis

Breakeven Analysis has the advantage that it can be computed **quickly and easily** with the information already available from the life-cycle cost calculation. Breakeven values are especially useful as **benchmarks** for comparison against the predicted performance of uncertain variables. Knowing at what point a change in input value will render a project uneconomic gives decision makers an indication of the risk involved and allows them to take into account the uncertainty associated with input data. Thus breakeven analysis contributes implicitly to the assessment of project risk.

As already mentioned in chapter 4, section 4.6.4, breakeven analysis also provides a lower bound for benefits and an upper bound for costs when there are **nonmonetary** benefits and costs to be considered. For example, assume that the energy-saving HVAC alternative has the lower life-cycle cost but the conventional system has some nonmonetary benefit, such as much quieter operation. Having evaluated the monetary savings and costs, you know that the implicit dollar value of the conventional system's lower noise level would have to be around $83,000 (the difference in LCC between the two alternatives) to offset the net savings of the alternative.

The disadvantage of breakeven analysis is, as with sensitivity analysis, that it provides no measure of the likelihood of different outcomes.

APPENDIX A

SPECIAL TOPICS IN LCC ANALYSIS

CONTENTS

Appendix A

SPECIAL TOPICS IN LCC ANALYSIS

This appendix addresses several special topics related to the use of LCC analysis for project decisions. These topics include

- optimal timing of a retrofit project,
- fuel switching and variable annual energy usage, and
- utility rate schedules in energy cost calculations.

Each topic is illustrated with one or more examples.

A.1 OPTIMAL TIMING OF AN OPTIONAL RETROFIT PROJECT

When is it cost effective to replace a functioning building system with a more energy- (or water-) efficient system? For example, when does it pay to replace existing incandescent lighting fixtures with fluorescent fixtures? When replacing a functioning system with a new system, the investment cost that needs to be economically justified is the total installed cost of the new system. Contrast this requirement to the case of replacing a non-functioning system or selecting a system for a new building, where the choice is between two or more new systems, all of which have acceptable performance specifications. In the latter case, only the difference in investment cost between the lowest first-cost system and a more efficient system must be justified by the expected energy savings.

A.1.1 Example A-1: Timing of an Air Conditioner Replacement

An existing air conditioner uses 10 000 kWh per year at a current price of $0.10/kWh, expected to increase by 1 percent per year in real terms (i.e., over and above general inflation). The annual cost of electricity for space cooling using the existing system is $1,000. This air conditioner is expected to last for about five more years. Replacing the existing system with a new high efficiency air conditioner will cost $5,000 and reduce annual kWh hour consumption for space cooling by 40 percent. The new system is expected to last 20 years. Should we replace the air conditioner now or wait until it dies?

General rule for timing of replacements: As long as the annualized investment cost of a new system is less than its expected yearly savings, and the yearly savings are expected to remain constant or increase over time, it is cost effective to replace the existing system now.

The annualized investment cost of a project is found by multiplying the project's initial investment cost (less present value of residual value, if any) by the appropriate Uniform Capital Recovery (UCR) factor. The UCR factor should be based on the expected life of the new system, without replacements.

The formula for the UCR factor is:

$$\text{UCR factor} = \left[\frac{d(1 + d)^N}{(1 + d)^N - 1}\right]$$

where
d = the discount rate, and
N = the life expectancy of the system (or study period, if less).

Note: The UCR factor is the inverse of the UPV factor for the same number of years and same discount rate.

The UCR factor for an investment with a life of 20 years and a discount rate of 3.0 percent is .0672. For a new system with an investment cost of $5,000 the annualized investment cost is $336 ($5,000 x .0672). As long as the annual savings are expected to be at least $336, the replacement is economically justified. In this example, the annual savings are $400 (40 percent of $1,000) at today's energy prices. Thus the replacement system is cost effective in this example. If the annual savings were only $325 dollars at current prices, the replacement would not be cost effective now. But energy costs are expected to increase at 1 percent per year, so that by the end of the fourth year they are expected to grow to $338 ($325 x 1.01^4). Thus the optimal timing for this investment appears now to be at the end of the fourth year. In fact, energy prices should be monitored over the next few years to determine if and when the replacement actually becomes cost effective. (Note: The annual savings should include changes in OM&R costs, if any, as well as energy savings.)

The optimal timing of the system replacement does not depend on the remaining life of the existing system. This is because the cost of the existing system is a sunk cost (assuming that it has no salvage value when removed). Even if the existing system is expected to last for the life of the building, this general rule for timing of replacements holds.

The replacement timing problem can also be set up for solution using the LCC method of project evaluation. For the base case, assume the existing system operates at current energy consumption levels until it dies at the end of year five, and then is replaced by the new system operating at its lower energy usage rate. For the alternative case, assume that the existing system is replaced now and that the lower energy usage rate is realized immediately. Set the study period equal to the life of the new system (not to exceed the 25-year FEMP rule). The delayed replacement will have a residual value based on its remaining life at the end of the study period (five years in this example). If the LCC of the immediate replacement is lower than the LCC of the delayed replacement, the immediate replacement is economically justified.

The result of the LCC analysis method is sensitive to the valuation of the residual value of the delayed replacement and therefore may not give exactly the same results as the general rule for timing of replacements using the UCR factor. Furthermore, calculating the LCC of only two alternatives (immediate replacement and delayed replacement for five years) will not provide information about optimal project timing if the optimal timing falls somewhere between the two years. If the difference in the LCC of the immediate and delayed replacements is small, the optimal year of replacement may fall between those two years. In this case the LCC analysis must be repeated for delayed replacement in successive years to determine which replacement year yields the lowest LCC.

A.2 FUEL SWITCHING AND VARIABLE ENERGY USAGE

In most of the examples presented in this handbook, annual energy usage rates remain constant throughout the service period for any given project alternative. Some project evaluations involve switching from one fuel type to another after a certain number of years. Others involve phasing in of new systems which may increase or decrease annual energy usage over time. The following two examples show how to deal with variable energy usage in LCC analysis. The BLCC computer program discussed in appendix B provides a convenient way of handling such problems, since it allows the user to index annual energy usage of each type relative to nominal usage levels.

A.2.1 Example A-2: Fuel Switching

A coal-fired boiler is expected to be converted to natural gas five years from now to satisfy tightened emission standards. The boiler currently uses 1000 GJ (948 MBtu) of coal per year at a current cost of $3.00/GJ ($3.16/MBtu). After conversion to natural gas, the boiler is expected to use 900 GJ (853 MBtu) due to improved firing efficiency. The current natural gas price at the building site is $3.41/GJ

($3.60/MBtu). DOE energy price escalation rates for region 1 are available for industrial coal and gas. (These rates are implicit in the FEMP UPV* factors for those fuels published in the Annual Supplement to Handbook 135.) What is the present value of fuel usage for this boiler over the next 20 years, given the 1995 DOE discount rate (3 percent real) and projected DOE energy price escalation rates? Using the FEMP UPV* factors from table Ba-1 for 1995 (as reproduced in appendix F), the solution is calculated as follows:

PV energy cost = 1000 GJ x 3.00/GJ x 4.69 + 900 GJ x 3.41/GJ x 13.39 = **$55,164**

where

4.69	=	FEMP UPV* for region 1, industrial coal, 5 years		
13.39	=	18.27 - 4.88, derived from:		
		18.27	=	FEMP UPV* for region 1, industrial natural gas, 20 years
		4.88	=	FEMP UPV* for region 1, industrial natural gas, 5 years

Note that the FEMP UPV* for the natural gas usage for years 6 through 20 (13.39) is based on the difference between the FEMP UPV* factor for 20 years and the corresponding factor for 5 years. Note also that the FEMP UPV* factor for natural gas is applied to the current gas price, not the price at the time of the conversion.

A.2.2 Example A-3: Projects With Phased-in Energy Savings

A central steam plant with four boilers is being modified, with one boiler being replaced each year for the next four years. The boiler being replaced will be shut down at the beginning of the year and the new boiler will be put into service at the end of the same year. Each of the three active boilers will deliver one-third of the annual heating requirements during the replacement period. The existing boilers have a seasonal efficiency of approximately 60 percent. The new boilers will have a seasonal efficiency of approximately 80 percent. The boilers use natural gas at a current price of $7.00 per GJ ($7.39 per MBtu). The annual heating output requirement for the plant is 100 000 GJ (94,787 MBtu). What is the present value of the natural gas usage projected for the next 20 years, assuming a discount rate of 3 percent (real) and DOE energy price escalation rates for industrial usage in DOE region 1.

Year 1 energy usage:	166 667 GJ (100 000 GJ/0.6)
Year 2 energy usage:	152 779 GJ (0.6667 x 100 000 GJ/0.6 + 0.3333 x 100 000 GJ/0.8)
Year 3 energy usage:	138 888 GJ (0.3333 x 100 000 GJ/0.6 + 0.6667 x 100 000 GJ/0.8)
All subsequent years:	125 000 GJ (100 000 GJ/0.8)

Solution:
Find FEMP UPV* factors for four different periods (region 1, industrial natural gas, 1995 from table Ba-1 in appendix F):

Year 1	UPV^*_1 for year 1	= 1.00
Year 2	UPV^*_2 for year 2 - UPV^*_1 for year 1 = (1.99 - 1.00)	= 0.99
Year 3	UPV^*_3 for year 3 - UPV^*_2 for year 2 = (2.96 - 1.99)	= 0.97
Years 4-20	UPV^*_4 for year 20 - UPV^*_3 for year 3 = (18.27 - 2.96)	= 15.31

Calculate present values:

PV =	UPV^*_1 x 166 667 GJ x $7.00/GJ x 1.00	=	$ 1,166,669
+	UPV^*_2 x 152 779 GJ x $7.00/GJ x 0.99	=	$ 1,058,758
+	UPV^*_3 x 138 888 GJ x $7.00/GJ x 0.97	=	$ 943,050
+	UPV^*_4 x 125 000 GJ x $7.00/GJ x 15.31	=	$13,396,250
		=	**$16,564,727**

A.3 IMPACT OF UTILITY RATE SCHEDULES ON LCC CALCULATIONS

Most of the examples in this handbook are based on a flat-rate energy price applied to annual energy usage. For some studies this may be appropriate, but for others this may introduce significant error into the analysis. There are several factors that should be considered in computing annual energy or water costs: (1) even flat rates may vary by time of year; (2) block rate schedules or time-of-use rates may have a significant effect on monthly and annual energy costs; and (3) demand charges applied to peak energy usage may make up a significant part of the total energy cost. Each of these topics is demonstrated by example here.

Before proceeding to these examples, consider the type of project and the objective of your economic analysis. If an energy conservation project has a relatively small impact on the whole building energy usage and on peak demand, a flat-rate energy price may be satisfactory for the analysis. In this case the rate used should reflect the price of the last unit of energy use in each relevant time period (e.g., the price of the last kWh used each month in the case of block rate schedules). You may still want to use different rates for different times of the year if these rates differ significantly. In such cases you must also specify the corresponding energy usage by time of year (e.g., usage during months when summer rates are in effect and usage during months when winter rates are in effect).

If the project causes the price of the energy or water units conserved to shift to a lower or higher block rate, or if the project involves a comparison of the cost of different energy types used for the same purpose (e.g., using gas or electricity to heat a house), then the relevant rate schedules must be considered in the economic analysis. Likewise, if the project affects peak power demand (or other service subject to a demand charge), demand charges must be considered in the analysis.[1]

The extent to which complex rate schedules can be meaningfully included in the economic analysis depends to some extent on the type of energy analysis that is performed in support of the project. To apply block rate schedules, monthly energy usage must be computed. To apply time-of-use rates, hourly energy usage for an entire year may be needed; at a minimum the energy consumption for each time period subject to a different rate must be available. To apply demand rates, peak power demand by month (or some other period specified by the utility) is required. The whole-building energy simulation program used to compute energy usage for each project alternative must match the task at hand, or the results will have no meaning.

The examples provided here are based on electricity usage and demand. This same methodology can be used for other services (e.g., water and natural gas) subject to variable rate schedules.

A.3.1 Energy Cost Calculations with Block Rates

The annual savings attributable to individual energy conservation projects often can be estimated without a detailed analysis of the electricity rate schedule. However, the price of the last unit of energy or water usage in the relevant billing period (i.e., the marginal price) must be used in these calculations. For example, consider this "declining" block rate schedule, where the kWh price for higher levels of usage each month is less than for the lower levels of usage.

[1]The NIST ERATES computer program, discussed in appendix B, provides a convenient means of assessing the impact of block rates, time-of-use rates, and demand rates on annual electricity costs. Block rate and demand rate schedules set up with the ERATES program can also be imported into the NIST BLCC program and be used to evaluate building energy usage subject to a wide range of rate schedule specifications.

Table A-1
Declining Block-Rate Schedule

Monthly kWh Consumption	Price per kWh
First 1000 kWH	$0.10
1001 - 5000 kWh	$0.08
All additional kWh	$0.05

In addition, there may be a fixed monthly "customer charge" independent of the amount of monthly energy usage.

If the building in which the conservation measure is to be installed uses a minimum of 7500 kWh/month, the annual electricity cost before and after the conservation measure is implemented can be calculated using the marginal $0.05/kWh rate. Since the purpose of the analysis is to calculate the annual savings in electricity costs (rather than the actual electricity bill), there is no need to calculate "before and after" electricity costs using the entire rate schedule. This method implicitly assumes that the energy savings are not large enough to change the marginal rate, i.e., to shift it to a lower block. If such a shift does occur, "before and after" electricity costs must be estimated using rates from each relevant part of the schedule and the corresponding kWh consumption at those rates. Use of the marginal rate for "before and after" energy costs will result in an incorrect calculation of the annual energy cost for each alternative. However, the difference in annual energy costs between the base case and alternative (i.e., the savings) will be computed correctly.

A.3.1.1 Example A-4: Use of a flat rate energy price with a conservation measure

Three different levels of roof insulation (designated by thermal resistance, or R-value) are being evaluated to determine which has the lowest LCC. The building is heated and cooled with an electric heat pump system. The block-rate schedule shown above applies in winter months (October through May); in summer months the marginal kWh rate for usage above 5000 kWh/month is $0.08/kWh. In addition, a fixed customer charge of $10.00/month is levied. Monthly kWh consumption with or without the insulation is not expected to drop below 5000 kWh/month.

This analysis requires two energy usage amounts for each level of insulation: the number of kWh per year used in the summer months, which are charged at $0.08/kWh, and the number of kWh per year that are used in the winter months, which are charged at $0.05/kWh. Table A-2 shows the relevant energy consumption data and the calculations needed to determine the annual savings for each level of insulation. Since the relevant price per kWh does not change within the range of monthly kWh usage examined, the price per kWh above 5000 kWh/month can be used to find the annual cost of electricity in each of the two time periods (winter and summer). While the actual cost of electricity for this building is not computed here (this would require inclusion of the customer charge and the higher kWh prices for the first 5000 kWh/month), these additional costs would be the same for each insulation level and thus will not affect the annual savings.

Table A-2
Annual kWh Consumption and Cost for Roof Insulation Retrofit

Insulation Level	kWh Consumption Winter	kWh Consumption Summer	kWh Cost Winter @$0.05	kWh Cost Summer @$0.08	Annual kWh Cost	Annual Savings
Existing	60 000	30 000	$3,000	$2,400	$5,400	---
add R-5	57 000	28 500	2,850	2,280	5,130	$270
add R-10	56 000	28 000	2,800	2,240	5,040	360
add R-15	55 500	27 700	2,775	2,216	4,991	409

A.3.1.2 Example A-5: Comparison of whole building energy costs

Compare the annual energy cost for a building using the kWh consumption shown in table A-2 at the "existing insulation" level and subject to the kWh rate schedule shown above with the annual energy cost for the same building heated with natural gas. Assume that the kWh usage for the gas-heated building is 5000 kWh/month in the winter months, so that total electricity usage during those months is 40 000 kWh (8 months x 5000 kWh/month). Assume that the total natural gas usage for the winter months is 179 GJ (170 MBtu) billed at a flat rate of $5.20 per GJ (5.49/MBtu), plus a monthly customer charge of $10.00. If the total energy cost for each of these two buildings is being compared, the energy costs should reflect the customer charges and the block rate structure applied to the electricity costs. The solution can be calculated as follows:

(1) All electric building

	12 months x $10/month customer charge	= $120
+	12 months x 1000 kWh/month x $0.10/kWh	= $1,200
+	12 months x 4000 kWh/month x $0.08/kWh	= $3,840
+	(60 000 kWh - 8 months x 5000 kWh/month)	= 20 000 kWh x $0.05/kWh = $1,000
+	(30 000 kWh - 4 months x 5000 kWh/month)	= 10 000 kWh x $0.08/kWh = $800
	Total annual energy cost	= **$6,960**

(2) Gas-heated building

Electricity cost:

	12 months x $10/month customer charge	= $120
+	12 months x 1000 kWh/month x $.010/kWh	= $1,200
+	12 months x 4000 kWh/month x $0.08/kWh	= $3,840
+	(30 000 kWh - 4 months x 5000 kWh/month)	(10 000 kWh x $0.08/kWh) = $800
	Annual electric cost	= **$5,960**

Natural gas cost:

	12 months x $10.00/month customer charge	= $120.00
+	179 GJ x $5.20 /GJ	= $931
	Annual natural gas cost	= **$1,051**

Total annual energy cost = **$7,011**

Conclusion: The annual energy cost of the all-electric building is **$51** lower than the building using both electricity and natural gas, at base-date energy prices.

If only the heating costs are to be compared, the 20 000 kWh (60 000 kWh - 40 000 kWh) used for space heating at $.05/kWh provides the annual cost of electric space heating. (The customer charge for electricity and the other kWh consumption costs will still be incurred if the heating system is switched to natural gas.) Compare this with the total annual natural gas cost, including both the monthly customer charge and energy charge for 179 GJ/year. The customer charge for natural gas must be included in this cost since this would be avoided entirely in the all-electric building.

Electric heating only:	
20 000 kWh x $0.05/kWh	= **$1,000**
Gas heating only:	
12 months x $10.00/month customer charge	= $120.00
179 GJ x $5.20 /GJ	= $931
Total natural gas cost	= **$1,051**

Both solution methods show that heating with natural gas would cost **$51** more per year at current prices than heating with the electric heat pump system, given the utility rates shown.

A.3.2 Energy Cost Calculations with Time-of-Use Rates

Time-of-use rate schedules for electricity prices are becoming increasingly common in the United States. Typically, under a time-of-use schedule, different kWh rates are levied for usage at different times of the day and for different days of the week. For example, kWh prices may be very low during night hours, moderate during evening hours and all day on weekends, and quite high during the peak demand hours of the day. These rate schedules may vary by month of the year as well, especially if the utility has a pronounced summer or winter peak.

Calculating annual electricity costs using time-of-use rates can be complicated, regardless of whether or not these are to be used in an LCC analysis. The most challenging part of time-of-use calculations is determining the number of kWh hours used in each pricing period. This usually requires an hourly analysis of the energy requirements of a building system for each design alternative being considered. Energy cost calculations with time-of-use rates are especially critical for projects which shift kWh usage from one period to another.

The NIST ERATES program, described in appendix B, can be used to calculate annual electricity costs using time-of-use rates. However, this requires hourly kWh consumption for each of the 8760 hours of the year saved as a data file by an hourly load simulation program. The NIST BLCC program cannot import time-of-use schedules from ERATES as it can block rate and demand rate schedules. However, the ERATES program will calculate the average annual kWh price and the total kWh used over the year, which can be used to compute the life-cycle electricity cost in an LCC analysis performed with BLCC or other LCC programs.

If a conservation project is expected to reduce kWh usage proportionally in each pricing period, the annual savings for that project can be calculated using the same average price per kWh for both the "before and after" cases. If the project is expected to affect kWh usage in some periods more than others (e.g., a clock thermostat to lower indoor temperature settings during unoccupied hours), the savings (or additional cost in the case of load shifting) must be calculated for each pricing period and summed to arrive at an annual rate.

A.3.2.1 Example A-6: Load shifting with time-of-use kWh rates

Table A-3 shows the time-of-use rate schedule and corresponding kWh usage in each pricing period to be used in evaluating a proposed thermal storage project. This project is expected to reduce electricity usage by 5000 kWh/year during on-peak pricing periods but increase off-peak kWh usage by 6000 kWh/year. The expected annual savings is $600 ($4,500 - $3,900). Note that the same result would be obtained by multiplying the annual kWh usage by the corresponding weighted average kWh price. But this weighted average price must be calculated separately for both cases (the Base Case and Alternative). A single average kWh price for the year will not give the correct result for this example because the project does not affect all periods proportionally.

Table A-3
Annual kWh Costs With Time-of-Use Rates (Example)

Rate Period	Base Case		Alternative	
	Annual kWh	Annual Cost	Annual KWh	Annual Cost
Off peak hours @ $0.025/kWh	10 000	$250	16 000	$400
Shoulder hours @ $0.050/kWh	25 000	1,250	25 000	1,250
Peak hours @ $0.150/kWh	20 000	3,000	15 000	2,250
Total annual cost	55 000	$4,500	55 500	$3,900
Weighted average kWh cost		**$0.082**		**$0.070**

A.3.3 Energy Cost Calculations with Demand Charges

Demand charges are energy costs that are related to peak usage, usually measured over a short time interval (e.g., 15 minutes). Peak energy use of this sort is called peak power demand, and for electricity is typically measured in kW. Demand charges are generally levied on a monthly basis. For large users (especially industrial users), demand charges can make up as much as half of the monthly and annual electricity cost. Residential electricity rates do not typically include a demand charge but this may become more common in future years.

Demand charges can be very simple to calculate when they are levied in direct proportion to peak demand. If demand charges are levied as a flat rate per kW, the reduction in annual demand costs attributable to an energy conservation project can be calculated once the corresponding reduction in monthly kW demand has been determined. Simply multiply the reduction in kW demand for each month by the monthly demand charge for that month and sum these charges for the 12 months of the year.

However, rate schedules with demand charges are often quite complex. "Ratchet" clauses that use peak kW demand in previous months in calculating the demand charge for the current month require careful analysis. In addition, demand charge schedules (like kWh rate schedules) can use block rates (with declining or increasing kW rates for different levels of demand) or time-of-use rates, where a higher demand charge would be levied during periods of peak utility demand, and lower or no charge levied during off-peak periods. As with the case of kWh cost calculations, the more complex the demand charge schedule, the more information about kW demand is required both with and without the project. This requires careful consideration when selecting and running an appropriate building energy simulation program.

The NIST ERATES program is able to perform calculations of some demand charges, depending on the complexity of the rate schedule. The monthly kW demand on which the monthly charge is to be calculated can be entered into a kW demand file for a particular building. The kW demand charges, either as flat rates or as block rates, are entered into a demand schedule file. ERATES will calculate the corresponding annual kW demand charge based on the monthly kW demand or on the highest kW demand for the year. ERATES can also use hourly data for an entire year (8760 hours) as the basis for calculating demand charges. Both on-peak and off-peak time periods, by month, can be included in this analysis. The NIST BLCC program can read demand rate schedules set up with the ERATES program and calculate annual demand charges, based on monthly kW demand data for the project being evaluated.

APPENDIX B

SOFTWARE FOR

LCC ANALYSIS

OF BUILDINGS AND BUILDING SYSTEMS

CONTENTS

Appendix B

SOFTWARE FOR LCC ANALYSIS OF BUILDINGS AND BUILDING SYSTEMS

NIST, under sponsorship of the Federal Energy Management Program, has developed a set of four computer programs that provide economic analysis of proposed investments in buildings and building systems which are intended to reduce long-term operating costs: BLCC, QI (Quick Input), DISCOUNT, and ERATES.[1] These programs are especially useful for evaluating costs and savings related to energy and water conservation projects and for selecting project alternatives with the lowest life-cycle cost. Comparative economic measures can be computed for any project alternative, including Net Savings, Savings-to-Investment Ratio, Adjusted Internal Rate of Return, and Payback Period. These programs are appropriate for federal, state, and local government and private sector use. They are designed to run on most IBM-PC compatible microcomputers. No special hardware or graphics capabilities are required. BLCC, QI, and DISCOUNT are updated at the beginning of each federal fiscal year to include the current FEMP and OMB discount rates and the most recent DOE projections of energy price escalation rates. The program version number now includes the year for which it is current, e.g., BLCC version 4.2-95 is intended for use in fiscal year 1995.

B.1 THE BLCC PROGRAM

The NIST Building Life-Cycle Cost (BLCC) computer program provides comprehensive economic analysis of proposed capital investments that are expected to reduce long-term operating costs of buildings or building systems. Up to 99 alternative designs can be evaluated simultaneously to determine which has the lowest life-cycle cost. Comparative economic measures can be calculated for any design alternative relative to the designated base case. BLCC complies with American Society for Testing and Materials (ASTM) standards related to building economics [3] and this NIST handbook.

BLCC provides economic analysis for different project evaluation environments:

(1) **Federal Government**: Projects falling under Federal Energy Management Program (FEMP) guidelines, OMB Circular A-94 guidelines, or DoD Military Construction guidelines.

(2) **Private Sector**: Projects requiring analysis of tax consequences (for-profit buildings or homeowner-occupied housing).

(3) **General**: Projects which do not require tax analysis or specific LCC guidelines.

B.1.1 The BLCC User's Guide

A 100-page BLCC User's Guide is included on the BLCC program diskette. This guide provides instructions on program installation and execution, as well as instructions on how to conduct a BLCC analysis. All BLCC input requirements and their acceptable ranges are defined in the User's Guide. This guide can be printed directly from the disk (using WordPerfect 5.1 and HP LaserJet III printer).[2]

[1] For information on how to obtain BLCC and related programs, see the preface to this handbook.

[2] Printed copies of the BLCC user's guide are available to federal agencies and supporting contractors from ASI at the address shown in the preface to this handbook.

B.1.2 BLCC Analysis of Energy- and Water-Related Projects

BLCC is especially useful for evaluating energy conservation projects in buildings. For example, it can be used to determine the economically optimal level of insulation in an attic, select the most cost-effective heating and cooling system in a given building and location, or evaluate the cost effectiveness of a solar heating system. Estimates of annual energy requirements for each alternative and appropriate cost data are required for the analysis. Annually updated projections of rates of increase in energy prices from the U.S. Department of Energy (DOE), by fuel type, rate type, and region of the country, are available on the diskette and can be automatically retrieved into the analysis if desired. BLCC can perform block-rate and demand-rate calculations for electricity costs using rate schedules from the NIST ERATES program (see information on ERATES program). BLCC also has the capability of evaluating water conservation projects with data-entry screens for water usage and cost data.

B.1.3 BLCC Reports

Six different reports are generated by BLCC. Each can be displayed to the screen, sent to the printer, or saved to a disk file for later retrieval by word processor for inclusion in a larger report.

Reports by project alternative:

- Input data file listing
- Summary of life-cycle cost analysis
- Detailed life-cycle cost analysis
- Yearly cash flow analysis

Reports comparing project alternatives:

- Identification of lowest life-cycle cost alternative
- Comparative economic analysis between any two alternatives, including Net Savings
- Savings-to-Investment Ratio, Adjusted Internal Rate of Return on investment, Payback Period, annual energy savings (in physical units), and reductions in air pollution emissions

B.1.4 BLCC Input Data Requirements

BLCC is a menu-driven program with data-entry screens corresponding to the type of data needed for the analysis. An input data file must be created for each project alternative to be evaluated. LCC computations are performed automatically each time an input data file is created or modified. LCC computations for each project alternative are saved in a separate LCC output file.

Input requirements for a typical BLCC analysis consist of:

Project name
Base date
Study period (years)
Planning and construction period (years)
Discount rate
Initial capital costs and expected life
Cost phasing of initial costs
Capital replacement costs and expected life
Resale value at end of study period
Annually recurring O&M costs
Non-annually recurring O&M costs by year of occurrence

Annual energy and water consumption (by type)
Unit energy and water costs (by type)
Energy demand charges (annualized, by type)
Annual energy consumption indexing (by type)
Projected rates of price increases:
- Capital components
- O&M costs
- Energy and water costs (by type)

Financing variables (not in federal government analyses):
- Percent of initial costs borrowed
- Type of loan (e.g., amortized, interest only)
- Interest rate
- Life of loan
- Number of payments per year

Tax-related variables (private sector analyses only):
- Federal, state and local tax rate
- Depreciation method (e.g., straight line, accelerated, table look-up)
- Tax credits
- Property taxes
- Capital gains adjustment (if any)
- Depreciation recapture method

B.2 BLCC QUICK INPUT PROGRAM

The BLCC "Quick Input" program (QI), included on the BLCC diskette, can be used to set up multiple project alternatives for LCC analysis in a single input file. Although the range of input data is somewhat limited (for example, no private sector tax analysis is available), QI provides a convenient method for solving relatively simple LCC problems which require finding the lowest-LCC design alternative among many mutually exclusive alternatives for the same project.

In a QI data file, common assumptions (e.g., base date, study period, discount rate, and unit energy prices) are defined at the top, followed by line item entries for each alternative in "spread-sheet" format. QI can also evaluate different projects in the same building or facility, each with multiple design alternatives, all included in the same QI data file. This requires only that individual projects (1) must be evaluated using the same common LCC assumptions, and (2) must be functionally independent (i.e., the energy use of one system does not affect the energy use of another system in the same file).

QI can calculate the LCC for each project alternative in the input data file, identify the alternative with the lowest LCC for each project in the file, and report the Net Savings, Savings-to-Investment Ratio, and Adjusted Internal Rate of Return for the lowest-LCC alternative for each project. QI is ideal for the preliminary economic evaluation of multiple design alternatives. QI can also generate BLCC input data files for designated alternatives to facilitate more comprehensive analysis in BLCC.

QI provides LCC computational support to energy analyses performed by the DOE ASEAM 5.0 energy calculation program [14]. ASEAM 5.0 can append cost and energy usage data for each building design alternative that it evaluates to a designated QI data file for later LCC analysis with QI.

The BLCC User's Guide includes information needed to install and run the Quick Input program.

B.3 THE DISCOUNT PROGRAM

Included on the BLCC diskette is a stand-alone program called DISCOUNT, which performs the individual discounting operations required in most LCC analyses. DISCOUNT computes present values of future and periodic amounts, future values of present and periodic amounts, and annual-value equivalents of present and future amounts. DISCOUNT can compute the present value of annual payments which increase (or decrease) at fixed or varying rates over the life of the analysis.

DISCOUNT can access the DOE projections of energy price increases used in the BLCC program. It can then compute the present value of annual energy costs which are expected to increase over time at these projected rates. DISCOUNT also computes the discount factors corresponding to each of these operations, enabling it to substitute for extensive tables of discount factors. DISCOUNT is more flexible than such tables because it can accept non-integer discount rates, study periods, and price escalation rates, as well as price escalation rates which change from period to period.

DISCOUNT is most useful when evaluating individual components of a life-cycle cost problem that do not require the comprehensive analysis, summation, and reporting capability provided by BLCC. For example, using DISCOUNT, the present value of annual energy savings over 20 years, valued at $100 per year at current energy prices, but expected to increase yearly at 6 percent for the first 10 years and 4 percent for the remaining 10 years, discounted at 10 percent, can be quickly calculated as $1,334.02.

The User's Guide to the DISCOUNT program is included on the BLCC diskette with the DISCOUNT program. This guide can be printed directly from the disk.[3]

B.4 THE ERATES PROGRAM

ERATES is a stand-alone program which can be used for generating block-rate, time-of-use-rate, and demand-rate schedules for electricity prices. ERATES can compute monthly and annual electricity costs based on those schedules, given hourly kWh usage data or monthly kWh usage/kW demand data. BLCC and QI can compute annual kWh costs with monthly block-rate schedules imported from the ERATES program. BLCC and QI can also compute annual kW demand charges with monthly demand schedules imported from ERATES. The ERATES User's Guide is included with the ERATES program and can be printed directly from the disk using WordPerfect 5.1 and HP LaserJet III printer.[4]

B.5 ASEAM COMPATIBILITY

BLCC and Quick Input are compatible with ASEAM 5.0 (A Simplified Energy Analysis Method), developed for the U.S. Department of Energy. ASEAM is a modified bin method program for calculating the energy consumption of residential and simple commercial buildings. ASEAM calculations of annual energy consumption for each design alternative can be appended to a Quick Input data file. The life-cycle cost of each alternative is then computed by running the QI program. QI can then generate data files for more comprehensive analysis with BLCC. For more information about ASEAM, contact Enterprise Advisory Services, Inc. at the address listed in the preface to this handbook.

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[3] Printed copies of the DISCOUNT user's guide are available to federal agencies and supporting contractors from EAS at the address shown in the preface to this handbook.

[4] Printed copies of the ERATES user's guide are available to federal agencies and supporting contractors from EAS at the address shown in the preface to this handbook.

APPENDIX C

WORKSHEETS FOR LCC ANALYSIS

CONTENTS

Appendix C

WORKSHEETS FOR LCC ANALYSIS

INTRODUCTION

This appendix contains a series of worksheets for manually performing and documenting a life-cycle-cost analysis. LCC analyses can range widely in complexity. Sometimes a "back-of-the envelope" analysis is sufficient for evaluating a project; other times the project may require a more structured solution and documentation. While it is recommended that you use the BLCC computer program for the latter, there are occasions when a manual calculation procedure may be warranted. The worksheets provided in this appendix are intended as a guide to setting up, solving, and documenting such analyses. They are to be used in combination with the current version of the Annual Supplement to Handbook 135, *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*, which is published each year on October 1 for the following fiscal year. The worksheets are compatible with the federal life-cycle costing rules of both 10 CFR 436 and OMB Circular A-94.

The stepwise evaluation process followed by the worksheets is based on the assumption that you are reasonably familiar with the life-cycle-costing methodology and FEMP rules described in this handbook. This includes an understanding of the conceptual and computational requirements of present-value calculations, treatment of inflation, energy price escalation, maximum study periods, and evaluation criteria. If this is the case, these worksheets, together with the accompanying instructions, will guide you through a life-cycle-cost analysis in seven steps:

1. Project Identification
2. Cash-Flow Diagram
3. Input Data Summary
4. Present-Value Calculations
5. Savings-to-Investment Ratio
6. Discounted Payback Period
7. Selection

In the first part of the appendix we use Example 5-1 (a and b) of chapter 5, *Selection of HVAC System for Office Building—Simple Case* as an illustration of how the worksheets may be filled in. The second part contains blank worksheets that can be copied.

SAMPLE LCC ANALYSIS USING WORKSHEETS

HVAC System for Federal Office Building - Example 5-1

LIFE-CYCLE COST ANALYSIS

1. PROJECT IDENTIFICATION

PROJECT TITLE HVAC System for Federal Office Bldg.; L'Enfant Plaza ***FY*** 95

LOCATION Washington, D.C. ***DoE REGION*** 3

BASE DATE January, 1995 ***SERVICE DATE*** January, 1995

DESIGN FEATURE Heating, Ventilating, and Air Conditioning System

CONSTRAINTS No natural gas available at site

TYPE OF STUDY:

[✓] Energy and Water Conservation & Renewable Resources (FEMP)

[__] Other (OMB A-94)

BASE CASE AND ALTERNATIVES FOR LCC ANALYSIS

(A) Conventional HVAC System, constant air volume reciprocal chiller

(B) Energy-saving HVAC System, constant air volume reciprocal chiller, night-time setback, economizer cycle

(C

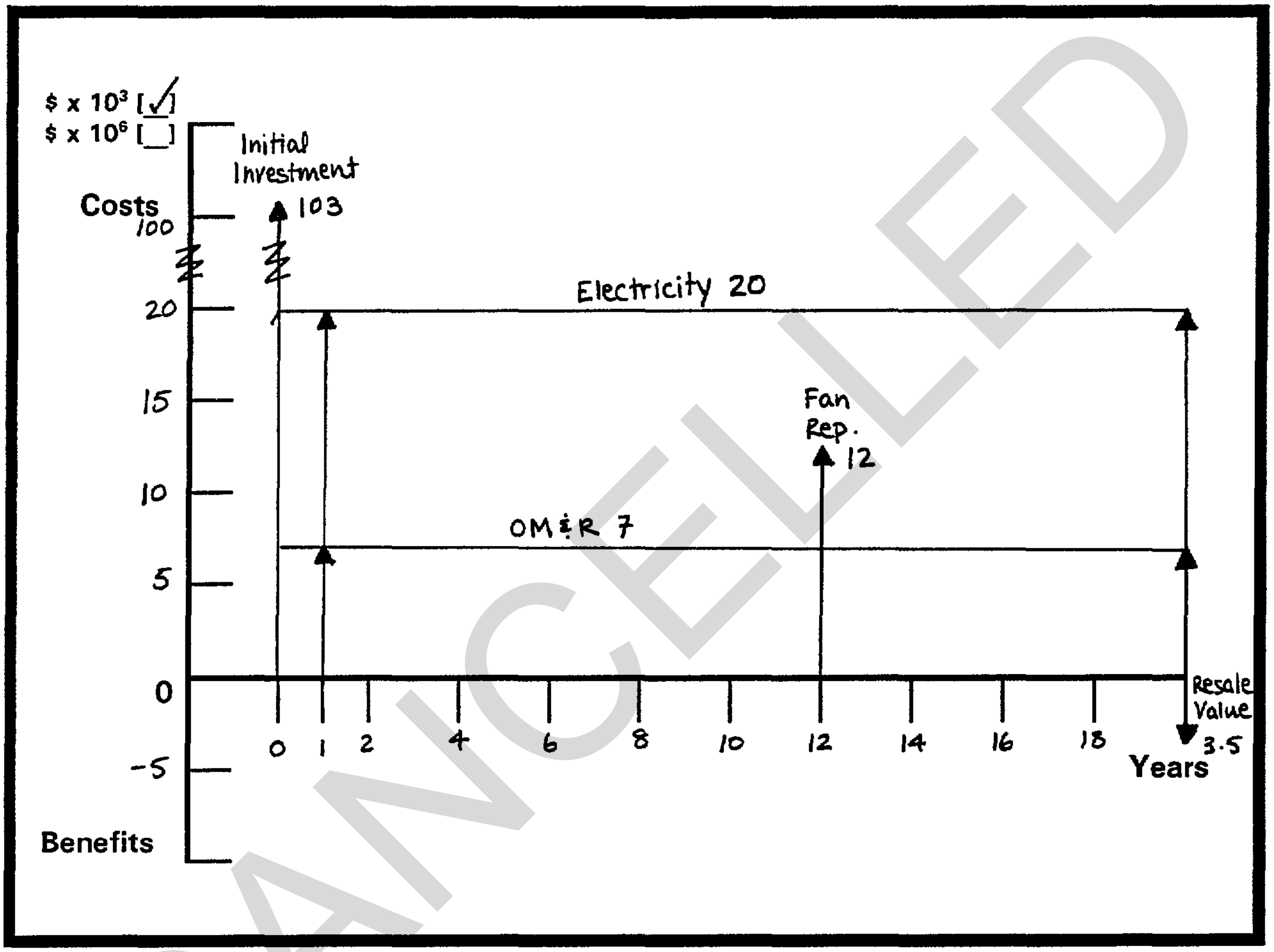
(D)

(E)

Analyst Scott Gillespie Phone (123) 555-6789 Date of Study 1.1.95

LIFE-CYCLE COST ANALYSIS
2. CASH-FLOW DIAGRAM

Project Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza **Alt. ID** A



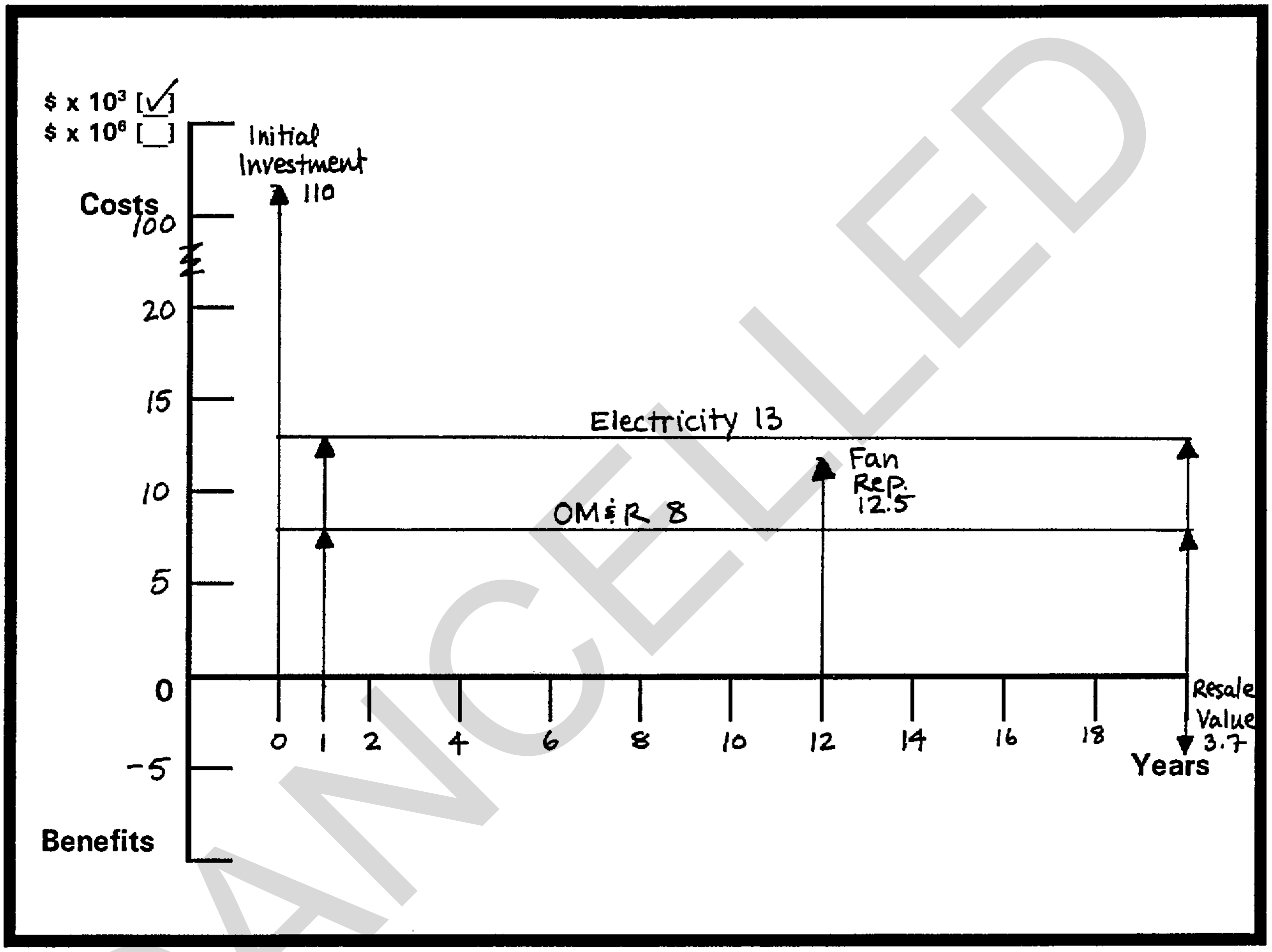
Comments:

Initial Investment: $103,000
Electricity: $20,000 Annual Cost, escalating at DoE rates
OM&R: $7,000 Annual Cost
Fan Replacement: $12,000 at end of year 12
Resale Value: $3,500 at end of year 20

LIFE-CYCLE COST ANALYSIS

2. CASH-FLOW DIAGRAM

Project Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza **Alt. ID** B



Comments:

Initial Investment: $110,000
Electricity: $13,000 Annual Cost, Escalating at DoE rates
OM & R: $8,000 Annual Cost
Fan Replacement: $12,500 at end of year 12
Resale Value: $3,700 at end of year 20

LIFE-CYCLE COST ANALYSIS

3. INPUT DATA SUMMARY

Project Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza **Alt. ID** A

TYPE OF COST OR BENEFIT (1)	(2)	(3)		(4)		(5)	(6)	(7)

One-Time Amounts	$-Amount on BD
	$ x 10³ [_]
	$ x 10⁶ [_]
		Years from		Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table

		BD	SD	Yes	No			No.
Initial Investment	103,000	0		✓			—	—
Fan Replacement	12,000	12		✓			—	A-1
Resale Value	3,500	20		✓			—	A-1

Annually Recurring Amounts	$-Amount on BD
	$ x 10³ [_]
	$ x 10⁶ [_]
		Number of Payments from	Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table

		SD	Yes	No			No.
OM&R	7,000	20		✓		—	A-2
Water:							
Energy: Electricity	20,000	20		✓		Diff.Esc. Rates for ENERGY Projects Embedded in Discount Factors	Ba-3

BD = Base Date
SD = Service Date

LIFE-CYCLE COST ANALYSIS
3. INPUT DATA SUMMARY

Project Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza Alt. ID B

TYPE OF COST OR BENEFIT (1)	(2)	(3)		(4)		(5)	(6)	(7)

One-Time Amounts	$-Amount on BD
	$ x 10³ [ ]
	$ x 10⁶ [ ]
		Years from		Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table

		BD	SD	Yes	No			No.
Initial Investment	110,000	0		✓			—	—
Fan Replacement	12,500	12		✓			—	A-1
Resale Value	3,700	20		✓			—	A-1

TYPE OF COST OR BENEFIT (1)	(2)	(3)	(4)		(5)	(6)	(7)

Annually Recurring Amounts	$-Amount on BD
	$ x 10³ [ ]
	$ x 10⁶ [ ]
		Number of Payments from	Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table

		SD	Yes	No			No.
OM&R	8,000	20		✓		—	A-2
Water:							
Energy: Electricity	13,000	20		✓		Diff.Esc. Rates for ENERGY Projects Embedded in Discount Factors	Ba-3

BD = Base Date
SD = Service Date

LIFE-CYCLE COST ANALYSIS
4. PRESENT-VALUE CALCULATIONS

Project Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza **Alt. ID** A

(1) INVESTMENT-RELATED AMOUNTS	(2) $-Amount on BD $ x 10^3 [ ] $ x 10^6 [ ]	(3) Discount Factor	(4) Present Value (4) = (2)x(3)
Initial Investment	103,000	1	103,000
Fan Replacement	12,000	.701	8,412
Resale Value	3,500	.554	1,939

(5) PV TOTALS (5) = Summation of (4) by type	
Initial Investment	$ 103,000
Capital Replacements	+ $ 8,412
Disposal Costs	+ $ 0
Salvage/ Resale Value	- $ 1,939
TOTAL INV.-RELATED COSTS	$ 109,473

OPERATION-RELATED AMOUNTS	$-Amount on BD $ x 10^3 [ ] $ x 10^6 [ ]	Discount Factor	Present Value (4) = (2)x(3)
OM & R	7,000	14.88	104,160
Electricity	20,000	15.13	302,600

Annual OM&R	$ 104,160
Non-Annual OM&R	+ $ 0
Energy	+ $ 302,600
Water	+ $ 0
Other	± $ 0
TOTAL OPERATION-REL. COSTS	$ 406,760

TOTAL PV LIFE-CYCLE COSTS = $ 516,233

BD = Base Date

LIFE-CYCLE COST ANALYSIS
4. PRESENT-VALUE CALCULATIONS

Project Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza Alt. ID B

(1) INVESTMENT-RELATED AMOUNTS	(2) $-Amount on BD $ x 10^3 [ ] $ x 10^6 [ ]	(3) Discount Factor	(4) Present Value (4) = (2)x(3)	(5) PV TOTALS (5) = Summation of (4) by type
Initial Investment	110,000	1	110,000	Initial Investment $ 110,000
				Capital Replacements + $ 8,763
Fan Replacement	12,500	.701	8,763	Disposal Costs + $ 0
Resale Value	3,700	.554	2,050	Salvage/ Resale Value - $ 2,050
				TOTAL INV.-RELATED COSTS $ 116,713

OPERATION-RELATED AMOUNTS	$-Amount on BD $ x 10^3 [ ] $ x 10^6 [ ]	Discount Factor	Present Value (4) = (2)x(3)	
OM&R	8,000	14.88	119,040	Annual OM&R $ 119,040
Electricity	13,000	15.13	196,690	Non-Annual OM&R + $ 0
				Energy + $ 196,690
				Water + $ 0
				Other ± $ 0
				TOTAL OPERATION-REL. COSTS $ 315,730

TOTAL PV LIFE-CYCLE COSTS = $ 432,443

BD = Base Date

CANCELLED

LIFE-CYCLE COST ANALYSIS

5. SAVINGS-TO-INVESTMENT RATIO

Proj. Title HVAC Selection for Fed. Office Bldg.; L'Enfant Plaza

SIR for: Alt ID B (Higher-first-cost alternative)

Relative to: Alt ID A (Lower-first-cost alternative)

Present Value Amounts from LCC Calculations

NUMERATOR
Operation-related Costs

	(1) Lower-first-cost Alt		(2) Higher-first-cost Alt		(3) Savings
Energy	302,600	–	196,690	=	$ 105,910
Water		–		=	$ 0
Annual OM&R	104,160	–	119,040	=	$ - 14,880
Non-ann. OM&R		–		=	$ 0
Other		–		=	$ 0
			TOTAL SAVINGS	=	$ 91,030

DENOMINATOR
Investment-related Costs

	(1) Higher-first-cost Alt		(2) Lower-first-cost Alt		(3) Add'l.Investment Costs
Initial Investment	110,000	–	103,000	=	$ 7,000
Capital Replacements	8,763	–	8,412	=	$ 351
Disposal		–		=	$ 0
Resale/Ret./Salv.	2,050	–	1,939	=	$(-111)
			TOTAL ADDITIONAL INVESTMENT	=	$ 7,240

Savings-to-Investment Ratio

$$SIR = \frac{\text{Total Savings}}{\text{Total Add'l Invest.}} = \frac{\$\ 91{,}030}{\$\ 7{,}240} = 12.6$$

LIFE-CYCLE-COST ANALYSIS

6. DISCOUNTED PAYBACK PERIOD

Proj. Title HVAC Selection for Fed. Bldg.; L'Enfant Plaza

DPB/SPB for: Alt ID B (Higher-first-cost alternative)

Relative to: Alt ID A (Lower-first-cost alternative)

Costs at BD [ ] $ x 10^3 [ ] $ x 10^6 — *SD* 0 *yrs. from BD* — *Discount Rate* 3 %

Lower-first-cost Alternative A minus Higher-first-cost Alternative B — Differential Amounts

		A		B		Differential Amounts
1. INITIAL INVESTMENT AMOUNT	in Base Date $	103,000	–	110,000	=	-7,000
2. ANNUALLY RECURRING AMOUNTS	in Base Date $					
OM&R		7,000	–	8,000	=	-1,000
Energy (1) ______		20,000	–	13,000	=	7,000
Energy (2) ______			–		=	
Other ______			–		=	
3. ONE-TIME AMOUNTS	in Base Date $					
Repairs			–		=	
Capital Replacements		12,000	–	12,500	=	-500
Other ______			–		=	

(1) Service Year	(2) Annual Energy Savings	(3) ΔOM&R and Other	(4) ΔReplacements	(5) PV Savings	(6) Cumulative PV Savings	(7) PV ΔInitial Investment	(8)=(6)+(7) PV Net Savings
1	7070	-1000	0	5894	5894	-7000	-1106
2	7070	-1000	0	5724	11618	-7000	4618
3	7000	-1000	0	5490	17108	-7000	10108
4	7000	-1000	0	5328	22436	-7000	15436
5	7070	-1000	0	5238	27674	-7000	20674
6	7140	-1000	0	5139	32813	-7000	25813
7	7210	-1000	0	5049	37862	-7000	30862
8	7210	-1000	0	4900	42762	-7000	35762
9	7210	-1000	0	4757	47519	-7000	40519
10	7210	-1000	0	4620	52139	-7000	45139
11	7140	-1000	0	4433	56572	-7000	49572
12	7070	-1000	-500	3905	60477	-7000	53477
13							
14							

DPB 2 **years after Service Date**

BD = Base Date
SD = Service Date

LIFE-CYCLE COST ANALYSIS
7. SELECTION

Project Title HVAC Selection for Federal Office Building; L'Enfant Plaza

1. ALTERNATIVES ANALYZED

Rank	Title/Description	Present Value [ ] $ x 10^3 [ ] $ x 10^6				
		Initial	Energy	OM&R	Other	Total LCC
A: 2	Conventional HVAC System	103,000	302,600	104,160	6473	516,233
B: 1	Energy-Saving HVAC System	110,000	196,690	119,040	6713	432,443
C:						
D:						
E:						
F:						

2. SENSITIVITY ANALYSIS [√] needed [ ] not needed

Test #	Parameter Changed		New Rank Order					
	Name	Percent	A	B	C	D	E	F
1	Energy cost for Alt. B	+10%	2	1				

3. SELECTION [√] by LCC [ ] other

Rank	Alternative No. and Title	Economic Advantages of Selected Alternative		Basis for Selection
		LCC Difference (=Net Savings)	Other (Initial, Energy, etc.)	
	B: Energy-Saving Alternative	83,790		Lower LCC

COMMENTS

LCC for Alt. B in test 1 was $452,112.

CANCELLED

BLANK WORKSHEETS

AND INSTRUCTION SHEETS

LIFE-CYCLE COST ANALYSIS

1. PROJECT IDENTIFICATION

*PROJECT TITLE*____ *FY*_____

*LOCATION*____ *DoE REGION*_______

*BASE DATE*______________________ *SERVICE DATE*______________________

*DESIGN FEATURE*____

*CONSTRAINTS*____

____

____

TYPE OF STUDY: [__] Energy and Water Conservation & Renewable Resources (FEMP) [__] Other (OMB A-94)

BASE CASE AND ALTERNATIVES FOR LCC ANALYSIS

(A) ____

____

(B) ____

____

(C ____

____

(D) ____

____

(E) ____

____

Analyst______________________ Phone______________ Date of Study______

1. Project Identification
INSTRUCTIONS

Step 1. PROJECT IDENTIFICATION

- Enter project name and fiscal year.
- Enter location. Enter DoE region (from *Annual Supplement*).
- Enter Base Date and Service Date.
- Enter design feature to be evaluated.
- List constraints. Add page if needed.
- Designate study as energy conservation study or OMB study.

Step 2. BASE CASE AMD ALTERNATIVES

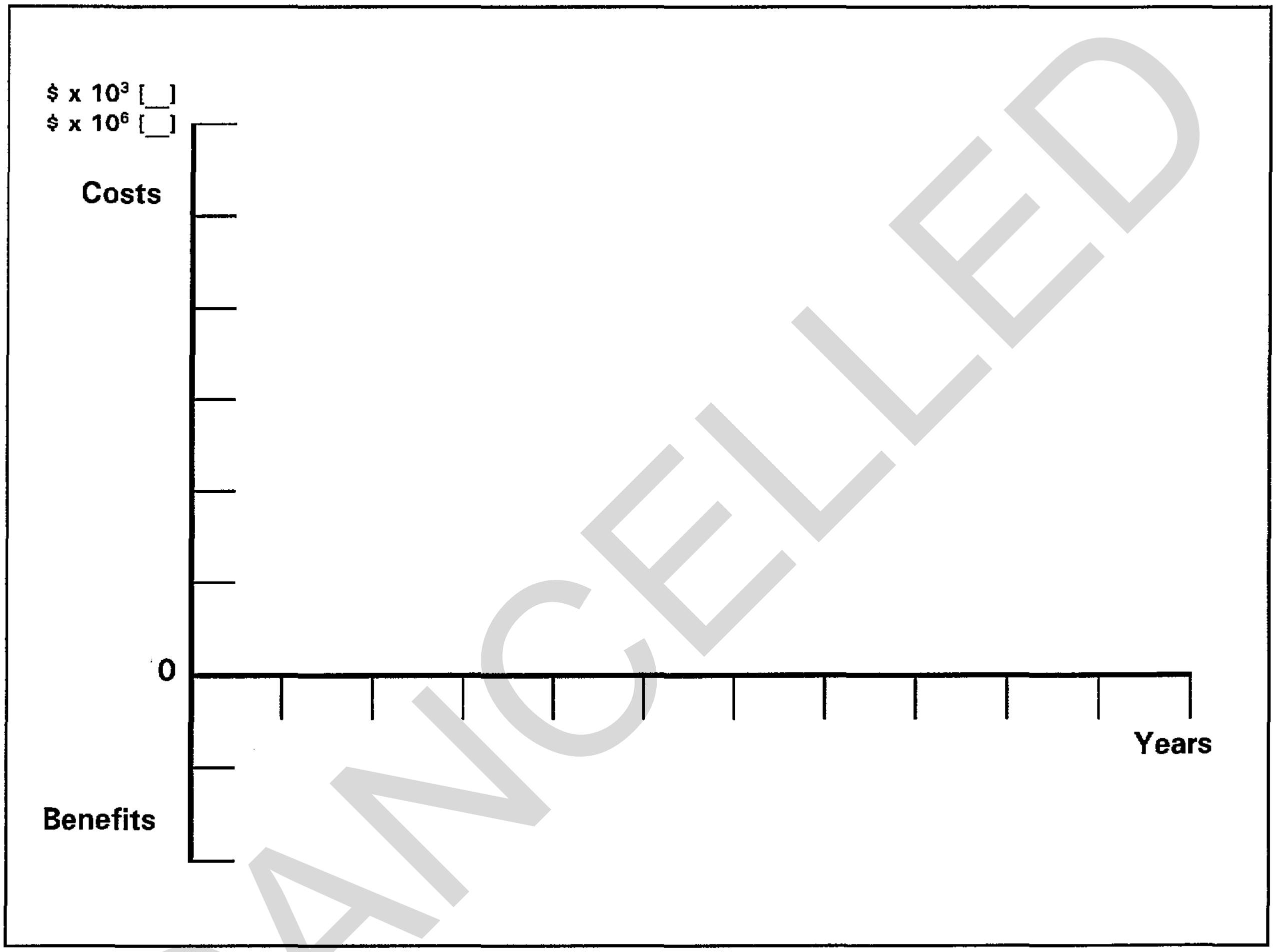
- Give title and brief description of base case and alternatives to be analyzed.

Step 3. GENERAL INFORMATION

- Enter name of analyst, phone number, and date study was completed.

LIFE-CYCLE COST ANALYSIS
2. CASH-FLOW DIAGRAM

Project Title____ **Alt. ID**______



Comments:

2. Cash Flow Diagram
INSTRUCTIONS

Step 1. KEY DATES

- Indicate years on horizontal axis and enter dates for Base Date (BD), Service Date (SD), and end of study period.

Step 2. CASH FLOWS

- Designate $-amounts as thousands or millions.
- Determine scale for dollar amounts on vertical axis.
- Enter anticipated cash flows:
  - Costs as positive amounts above the horizontal line (e.g., initial investment, energy, OM&R, disposal).
  - Benefits as negative amounts below the horizontal line (e.g., resale or salvage value).

LIFE-CYCLE COST ANALYSIS
3. INPUT DATA SUMMARY

Project Title____ Alt. ID_______

TYPE OF COST OR BENEFIT (1)	(2)	(3)		(4)		(5)	(6)	(7)

One-Time Amounts	$-Amount on BD
	$ x 10³ [_]
	$ x 10⁶ [_]
		Years from		Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table

		BD	SD	Yes	No			No.

Annually Recurring Amounts	$-Amount on BD
	$ x 10³ [_]
	$ x 10⁶ [_]
		Number of Payments from		Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table

		SD		Yes	No			No.
Water:								
Energy:							Diff.Esc. Rates for ENERGY Projects Embedded in Discount Factors	

BD = Base Date
SD = Service Date

3. Input Data Summary
INSTRUCTIONS

Step 1. IDENTIFICATION OF ALTERNATIVE

- Enter project title and identification data for alternative from *Project Identification* worksheet.

Step 2. ANALYSIS INPUT DATA

Col. (1) Enter types of costs or benefits as of the Base Date (BD):

One-time amounts:

Examples: Planning/Construction (P/C) or Acquisition Costs
Capital Replacement Costs
Major Repair Costs
Disposal Costs
Resale, Retention, or Salvage Value

Note: *P/C or Acquisition Costs may be assumed to occur in a lump sum at the beginning of the study period. All other one-time costs are assumed to occur at any time during the analysis period, the specific time depending on when they are actually expected to occur.*

Annually recurring amounts:

Examples: Routine OM&R Costs and Custodial Costs
Energy Costs: Electricity, distillate, residual, etc.,
Water Costs

Col. (2) Enter $-amounts as of the Base Date. (Designate as thousands or millions.)

Col. (3) For **one-time amounts**, enter the number of years after the Base Date (BD) and Service Date (SD) for which the costs or benefits occur.
For **annually recurring amounts**, enter the number of annual payments expected over the length of the study period.

Col. (4) Designate as investment-related or non-investment-related.

Col. (5) List data sources on a separate sheet and enter references here.

Col. (6) Enter differential escalation rate(s) for costs other than energy, if applicable.

Col. (7) Enter number of appropriate Discount Factor Table (for region, fuel type, sector, discount rate, differential escalation rate) from *Annual Supplement to Handbook 135*.

LIFE-CYCLE COST ANALYSIS

4. PRESENT-VALUE CALCULATIONS

Project Title____Alt. ID_______

(1) INVESTMENT-RELATED AMOUNTS	(2) $-Amount on BD $ x 10^3 [_] $ x 10^6 [_]	(3) Discount Factor	(4) Present Value (4) = (2)x(3)

OPERATION-RELATED AMOUNTS	$-Amount on BD $ x 10^3 [_] $ x 10^6 [_]	Discount Factor	Present Value (4) = (2)x(3)

(5) PV TOTALS

(5) = Summation of (4) by type

Initial Investment		$ ______
Capital Replacements	+	$ ______
Disposal Costs	+	$ ______
Salvage/ Resale Value	-	$ ______
TOTAL INV.-RELATED COSTS		$
Annual OM&R		$ ______
Non-Annual OM&R	+	$ ______
Energy	+	$ ______
Water	+	$ ______
Other	±	$ ______
TOTAL OPERATION-REL. COSTS		$

TOTAL PV LIFE-CYCLE COSTS = $______________

BD = Base Date

4. Present-Value Calculations
INSTRUCTIONS

Step 1. IDENTIFICATION OF ALTERNATIVES

- Enter project name and identification data for base case or alternative.

Step 2. PRESENT VALUE CALCULATION

Col. (1) Enter costs and benefits by category (investment-related or operation-related).

Col. (2) Enter $-amounts as of the Base Date (BD), from column (2) of *Input Data Summary*.

Col. (3) Enter discount factors from tables identified in column (7) of *Input Data Summary*.

Col. (4) Multiply $-amount (column (2)) by discount factor (column (3)) and enter present value in column (4).

Step 3. LIFE-CYCLE COST CALCULATION

Col. (5)
- Sum all investment-related costs (including resale, retention, or salvage values, if any, that have to be subtracted from costs). Enter in box.
- Sum all operation-related costs and enter in box.
- Add total investment-related costs and total operation-related costs from boxes and enter Total PV Life-Cycle Costs for alternative in bottom part of worksheet.

LIFE-CYCLE COST ANALYSIS

5. SAVINGS-TO-INVESTMENT RATIO

*Proj. Title*______________________ *SIR for:* Alt ID _______ (Higher-first-cost alternative)

______________________________ *Relative to:* Alt ID _______ (Lower-first-cost alternative)

Present Value Amounts from LCC Calculations

NUMERATOR

Operation-related Costs

	(1) Lower-first-cost Alt		(2) Higher-first-cost Alt		(3) Savings
Energy	________	–	________	=	$________
Water	________	–	________	=	$________
Annual OM&R	________	–	________	=	$________
Non-ann. OM&R	________	–	________	=	$________
Other	________	–	________	=	S________
			TOTAL SAVINGS	=	$

DENOMINATOR

Investment-related Costs

	(1) Higher-first-cost Alt		(2) Lower-first-cost Alt		(3) Add'l.Investment Costs
Initial Investment	________	–	________	=	$________
Capital Replacements	________	–	________	=	$________
Disposal	________	–	________	=	$________
Resale/Ret./Salv.	________	–	________	=	$(________)
			TOTAL ADDITIONAL INVESTMENT	=	$

Savings-to-Investment Ratio

SIR = Total Savings / Total Add'l Invest. = $________ / $ = ________

5. Savings-to-Investment Ratio
INSTRUCTIONS

Step 1. PROJECT IDENTIFICATION

- Enter project title and alternative identification data from *Project Identification* worksheet.
- Identify the higher-first-cost alternative for which the SIR is to be calculated, and the lower-first-cost alternative that serves as the base case.

Step 2. CALCULATION OF NUMERATOR

Col. (1) & (2) Enter present values of operation-related costs for each alternative from column (5) of the *Present Value Calculations* worksheets; in column (1), enter the costs attributed to the lower-first-cost alternative, in column (2) those attributed to the higher-first-cost alternative.

Col. (3) Subtract the costs of the higher-first-cost alternative from those of the lower-first-cost alternative and enter differences in column (3) as Savings. (There may be negative savings.)

- Sum savings to calculate Total Savings in operation-related costs.
- Enter Total Savings in box, as the **Numerator** of the ratio.

Step 3. CALCULATION OF DENOMINATOR

Col. (1) & (2) Enter present values of investment-related costs for each alternative from column (5) of the *Present Value Calculations* worksheet.

Col. (3) Subtract the costs of the lower-first-cost alternative from those of the higher-first-cost alternative and enter differences column (3) as additional investment-related costs. (If the difference in Resale/Retention/Salvage Value is positive, it needs to be deducted from the investment-related costs.)

- Sum additional investment-related costs to calculate Total Additional Investment.
- Enter Total Additional Investment in box, as the **Denominator** of the ratio.

Step 4. CALCULATION OF SAVINGS-TO-INVESTMENT RATIO

- In bottom part of form, enter Numerator and Denominator from boxes above and calculate ratio.
- Enter **SIR** of higher-first-cost alternative relative to lower-first-cost alternative.

LIFE-CYCLE-COST ANALYSIS
6. DISCOUNTED PAYBACK PERIOD

*Proj. Title*__________________ *DPB/SPB for*: Alt ID ________ (Higher-first-cost alternative)

__________________________ *Relative to:* Alt ID ________ (Lower-first-cost alternative)

Costs at BD [ ] $ x 10^3 [ ] $ x 10^6	*SD* ___ *yrs. from BD* *Discount Rate* ____%	Lower-first-cost Alternative ___ minus Higher-first-cost Alternative ___	Differential Amounts

1. INITIAL INVESTMENT AMOUNT in Base Date $

_______ – _______ = ______________

2. ANNUALLY RECURRING AMOUNTS in Base Date $

OM&R _______ – _______ = ______________
Energy
(1) ______________ _______ – _______ = ______________
(2) ______________ _______ – _______ = ______________
Other ______________ _______ – _______ = ______________

3. ONE-TIME AMOUNTS in Base Date $

Repairs _______ – _______ = ______________
Capital Replacements _______ – _______ = ______________
Other ______________ _______ – _______ = ______________

(1) Service Year	(2) Annual Energy Savings	(3) ΔOM&R	(4) ΔReplacements	(5) PV Savings	(6) Cumulative PV Savings	(7) PV ΔInitial Investment	(8) = (6) + (7) PV Net Savings
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

DPB_______years after Service Date

BD = Base Date
SD = Service Date

6. Discounted Payback

INSTRUCTIONS

Step 1. CALCULATION OF DIFFERENTIAL AMOUNTS

- Use cost figures as of the Base Date from column (2) of *Input Data Summary* sheets.
- Designate as thousands or millions.
- Enter number of years between Base Date (BD) and Service Date (SD).

Sec. 1 Calculate difference in initial investment costs between lower-first-cost and higher-first-cost alternative (usually a negative amount), as of the Base Date.

Sec. 2 Calculate differential amounts for annually recurring, fuel and non-fuel OM&R costs, as of the Base Date.

Sec. 3 Calculate differential one-time amounts for repairs and capital replacements, as of the Base Date.

Step 2. CALCULATION OF NET SAVINGS

Col. (1) Enter year (usually the first year of the service period) from which DPB is to be calculated.

Col. (2) Use separate sheet to calculate annual energy savings in year *t* for each energy type:
• Look up energy price index from *Tables Ca-1 to Ca-5* of the *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis 19xx, Annual Supplement to Handbook 135.*
Note: Always choose the end-of-year fuel price indices corresponding to the service year of the project. For example, if the base date is 1995 and the service date 1998, use the energy price index for 1998 as the appropriate index for the first service year.
• Multiply the energy savings for the year *t* by the appropriate energy price index to arrive at the end-of-year annual energy savings. Enter in column (2).

Col. (3) Sum and enter differential annual and non-annual OM&R costs and other differential costs for year *t*.

Col. (4) Enter differential one-time capital replacement costs for year *t*, if any.

Col. (5) Sum differential costs in columns (2), (3), and (4), and discount to Base Date, using the SPV factor for year *t*, based on the current FEMP discount rate. (For Simple Payback, no discounting is necessary). Enter PV savings for year *t*.

Col. (6) Add PV savings of year *t* to the cumulative PV savings of year *t-1* and enter amount.

Col. (7) Enter differential initial investment costs (usually a negative amount for the energy-saving alternative), discounted to Base Date.

Col. (8) Subtract differential PV initial costs from accumulated PV savings in year *t* to obtain PV Net Savings for year *t*.

Step 3. DERIVATION OF PAYBACK PERIOD

Repeat step 2 for each service year until Net Savings changes from a negative to a positive amount. The year in which the change occurs indicates the **Discounted Payback Period.**

LIFE-CYCLE COST ANALYSIS
7. SELECTION

Project Title____

1. ALTERNATIVES ANALYZED						
Rank	Title/Description	Present Value [ ] $ x 10^3 [ ] $ x 10^6				
		Initial	Energy	OM&R	Other	Total LCC
A:						
B:						
C:						
D:						
E:						
F:						

2. SENSITIVITY ANALYSIS [ ] needed [ ] not needed								
Test #	Parameter Changed		New Rank Order					
	Name	Percent	A	B	C	D	E	F

3. SELECTION [ ] by LCC [ ] other				
Rank	Alternative No. and Title	Economic Advantages of Selected Alternative		Basis for Selection
		LCC Difference (=Net Savings)	Other (Initial, Energy, etc.)	

COMMENTS

7. Selection
INSTRUCTIONS

Step 1. COMPARISON OF LCCs

- List all alternatives analyzed, their PV costs, and LCCs.
- Compare the LCCs and rank the alternatives in ascending order of their LCCs.
- Perform sensitivity analysis if there is uncertainty about the input values.

Step 2. SENSITIVITY ANALYSIS

- Perform sensitivity analysis and enter results.
- Correct ranking of alternatives if appropriate.

Step 3. SELECTION OF PREFERRED ALTERNATIVE

- If the selection is clear, enter the top-ranked alternative and document reasons.
- If the LCCs are nearly identical, consider non-quantifiable benefits or costs to assign the higher relative ranking. Document reasons.

APPENDIX D

COMPENDIUM OF DISCOUNTING AND PRICE ESCALATION FORMULAS

CONTENTS

Appendix D

COMPENDIUM OF DISCOUNTING AND PRICE ESCALATION FORMULAS

The formulas included in this appendix are divided into four categories:

(1) Price escalation formulas (constant and variable escalation rates)
(2) Present value formulas
(3) Future value formulas
(4) Annual value formulas

These formulas can be used to find the cost of a given good or service at a future point in time or to find the present value, future value, or annual value of a single or annually recurring cash amount incurred at a given point(s) in time. They can also serve as the basis for calculating general discount factors and price escalation factors to be used in LCC studies. These formulas are intended for use with a hand calculator (with exponential calculation capabilities) or for inclusion into a computer program or spread-sheet analysis. The NIST LCC software (BLCC, Quick Input, and DISCOUNT) uses most of these formulas. The NIST DISCOUNT program is especially useful for solving individual discounting and price escalation problems on a microcomputer (see appendix B). Note: All of these formulas are based on the end-of-year discounting convention. The factors pertaining to each of these discounting or price escalation formulas (e.g., the single present value factor from the single present value formula) is found by computing the portion of the formula shown in large brackets.

Before using these formulas, it is important to distinguish between a base-year or future-year cost and its present value, future value, or annual value. Base-year costs and future-year costs are project-related costs related to each other by the intervening rate of general inflation and changes in relative (real) price levels. The present value, future value, or annual value of a cost occurring at a given point in time differs from that cost in that they are dependent on the investor's perceived time-value of money, as reflected in the discount rate. Thus these values may vary from investor to investor depending on the discount rate used in their computation.

The following abbreviations are used in these formulas:

F_t = future value in year t
P = present value
A = annual value (equal amount in each year, $t = 1$ to n)
A_0 = annually recurring amount at prices as of time 0, the base date
A_t = annually recurring amount at prices as of time t, relative to the base date
C_0 = one-time cost at base-date prices
C_t = one-time cost at prices as of time t, relative to the base date
d = discount rate
e = price escalation rate (constant)
e_t = price escalation rate for year t
t = time period index (integer), where 0 is the base date, 1 is year one,..., and n is the last year in the study period
i = time period index for time periods 1 to t.

Note: If d is expressed in real terms (exclusive of general inflation) then e must also be expressed in real terms. If d is expressed in nominal (market) terms (inclusive of inflation) then e must also include general inflation.

D.1 PRICE ESCALATION FORMULAS

Price escalation formulas are used to find a future cost of a good or service at the end of the *nth* time period (usually years), given its base-year cost and the annual rate of price escalation for that commodity. If the analysis is conducted in constant dollars, the price escalation rate should be expressed in real terms (exclusive of general inflation); if the analysis is conducted in current dollars, the price escalation rate should be expressed in nominal terms (inclusive of general inflation).

D.1.1 Constant Escalation Rate

Application: to find C_t when C_0 is known and e is constant from year to year.

Formula:

$$C_t = C_o \times (1+e)^t$$

Example:
C_0 = \$1,000
e = 3% (.03)
t = 10

$$\$1{,}344 = \$1{,}000 \times (1+.03)^{10}$$

D.1.2 Variable Escalation Rate

Application: to find C_t when C_0 is known and e varies from year to year.

Formula:

$$C_t = C_o \times \prod_{i=1}^{t} (1+e_i)$$

Example:
C_0 = \$1,000
e_1 = 1% (.01)
e_2 = 2% (.02)
e_3 = 3% (.03)
e_4 = 4% (.04)
e_5 = 5% (.05)
t = 5

$$\$1{,}159 = \$1{,}000 \times (1.01)(1.02)(1.03)(1.04)(1.05)$$

D.2 PRESENT-VALUE FORMULAS

Present value formulas are used to find the present value of future amounts, when discount rate and the number of time periods (usually years) between the present time and the time of payment are known.

D.2.1 One-time Amounts

D.2.1.1 Single Present Value (SPV) formula

Application: to find P when amount at end of year t is known.

Formula:

$$P = C_t \times \left[\frac{1}{(1+d)^t}\right]$$

Example:

C_{10} = \$1,000
d = 5% (.05)
t = 10

$$\$614 = \$1{,}000 \times \left[\frac{1}{(1+.05)^{10}}\right]$$

D.2.1.2 Modified Single Present Value (SPV*) formula

Application: to find P when the amount at the end of year t is expressed in base-year dollars (C_0) and the price escalation rate is known.

Formula (constant e):

$$P = C_o \times \left[\frac{1+e}{1+d}\right]^t$$

Example:
C_0 = \$1,000
e = .03
d = .05
t = 10

$$\$825 = \$1{,}000 \left[\frac{1+.03}{1+.05}\right]^{10}$$

Formula (variable e):

$$P = C_o \times \frac{\prod_{i=1}^{t}(1+e_i)}{(1+d)^t}$$

Example:
C_0 = \$1,000
e_1 = 1% (.01)
e_2 = 2% (.02)
e_3 = 3% (.03)
e_4 = 4% (.04)
e_5 = 5% (.05)
t = 5
d = 5% (.05)

$$\$908 = \$1{,}000 \times \frac{(1.01)(1.02)(1.03)(1.04)(1.05)}{(1+.05)^5}$$

D.2.2 Annually Recurring Amounts

When costs occur on an annual basis, whether constant or changing at a known rate, the present value of each annual cost over a given number of years can be calculated with a single equation using Uniform Present Value factors.

Note: In the formulas for annually recurring amounts shown in section D.2.2, the number of time periods (n) can only be set to integer values. For time periods with decimal fractions, the present value of the cost incurred during the fractional time period must be calculated separately and added to the present value of the costs incurred during the integer time period.

D.2.2.1 Uniform Present Value (UPV) formula and factor

Application: to find P when A is known and constant.

Formula:

$$P = A_o \times \left[\frac{(1+d)^n - 1}{d(1+d)^n} \right]$$

Example:

A_0 = \$1,000

d = 5% (.05)

n = 10

$$\$7{,}722 = \$1{,}000 \times \left[\frac{(1+05)^{10} - 1}{.05(1+.05)^{10}} \right]$$

D.2.2.2 Modified Uniform Present Value (UPV*) formulas and factors

Application: to find P when A is known but varies from time period to time period at a constant escalation rate (e) or at a changing escalation rate (e_t).

Formula (constant e):

$$P = A_o \times \left(\frac{1+e}{d-e} \right) \times \left[1 - \left(\frac{1+e}{1+d} \right)^n \right]$$

Example:

A_0 = \$1,000

d = 5% (.05)

e = 3% (.03)

n = 10

Formula (variable e):

$$P = A_o \times \sum_{t=1}^{n} \frac{\prod_{i=1}^{t} (1+e_i)}{(1+d)^t}$$

Example:

C_0 = \$1,000

e_1 = 1% (.01)

e_2 = 2% (.02)

e_3 = 3% (.03)

n = 3

d = 5% (.05)

$$\$2{,}813 = \$1{,}000 \times \left[\frac{(1.01)}{(1.05)} + \frac{(1.01)(1.02)}{(1.05)^2} + \frac{(1.01)(1.02)(1.03)}{(1.05)^3} \right]$$

D.3 FUTURE VALUE FORMULAS

Future value formulas are used to find the cost at some future point in time (t) of a good or service when the cost of that good or service at the base date, the price escalation rate, and the number of time periods (usually years) between the base date and the future date are known. Only one future value formula is presented here, the single compound amount formula.

D.3.1 Single Compound Amount Formula

Application: to find the future value at time t_2 (F_{t2}) of an amount paid at time t_1 (C_{t1}),

where $t_2 > t_1$.

Formula:

$$F_{t2} = C_{t1} \times (1+d)^{(t2-t1)}$$

Example:
C_5 = \$1,000
t_1 = 5
t_2 = 10
d = 5% (.05)

$$\$1{,}276 = \$1{,}000\ (1+.05)^{(10\ -\ 5)}$$

D.4 ANNUAL VALUE FORMULA

The Annual-Value formula is used to determine an equal payment per time period (usually years) which is equivalent to a one-time cost or a stream of costs incurred during the same time period, given the time value of money as reflected in the discount rate (d). The Uniform Capital Recovery factor can be used to calculate this annual value, given the present-value of a cost or of a stream of costs computed using the same discount rate.

Uniform Capital Recovery (UCR) formula
Application: to find A when P is known.

Formula:

$$A = P \times \left[\frac{d(1+d)^n}{(1+d)^n - 1}\right]$$

Example:
P = \$1,000
d = 5% (.05)
n = 10

$$\$130 = \$1{,}000 \times \left[\frac{.05(1+.05)^{10}}{(1+.05)^{10} - 1}\right]$$

Note: Any single cost or stream of uneven costs over a given time period can be annualized over that time period by first finding the present value of that cost or stream of costs and then applying the UCR formula. For a stream of equal costs occurring in each time period over a given study period, the annualized cost is identical to that periodic cost when the same discount rate and study period are used.

APPENDIX E

SELECTED TABLES OF DISCOUNT FACTORS AND ENERGY PRICE INDICES FOR 1995

CONTENTS

Appendix E

SELECTED TABLES OF DISCOUNT FACTORS AND ENERGY PRICE INDICES

This appendix provides selected tables from the 1995 version of the Annual Supplement to Handbook 135 (ASHB135), *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*, NISTIR 85-3273-9 [2]. These tables are shown in this appendix because they are referenced in this handbook and used in a number of the examples. The table numbers in this appendix are the same as in ASHB135 but prefixed with "E/" to indicate that they are part of appendix E.

For fiscal years after 1995 the revision of ASHB135 for that year should be used as the source of these factors and indices. ASHB135 is revised and published each year on approximately October 1. It provides the discount factors, energy price indices, and underlying energy price escalation rates to be used in LCC analyses of federal investment projects, other than military construction projects in DoD.[1] Four different types of tables from ASHB135-1995 are included in this appendix:

(1) SPV factors for finding the present value of future single amounts (non-fuel),

(2) UPV factors for finding the present value of annually recurring uniform amounts (non-fuel),

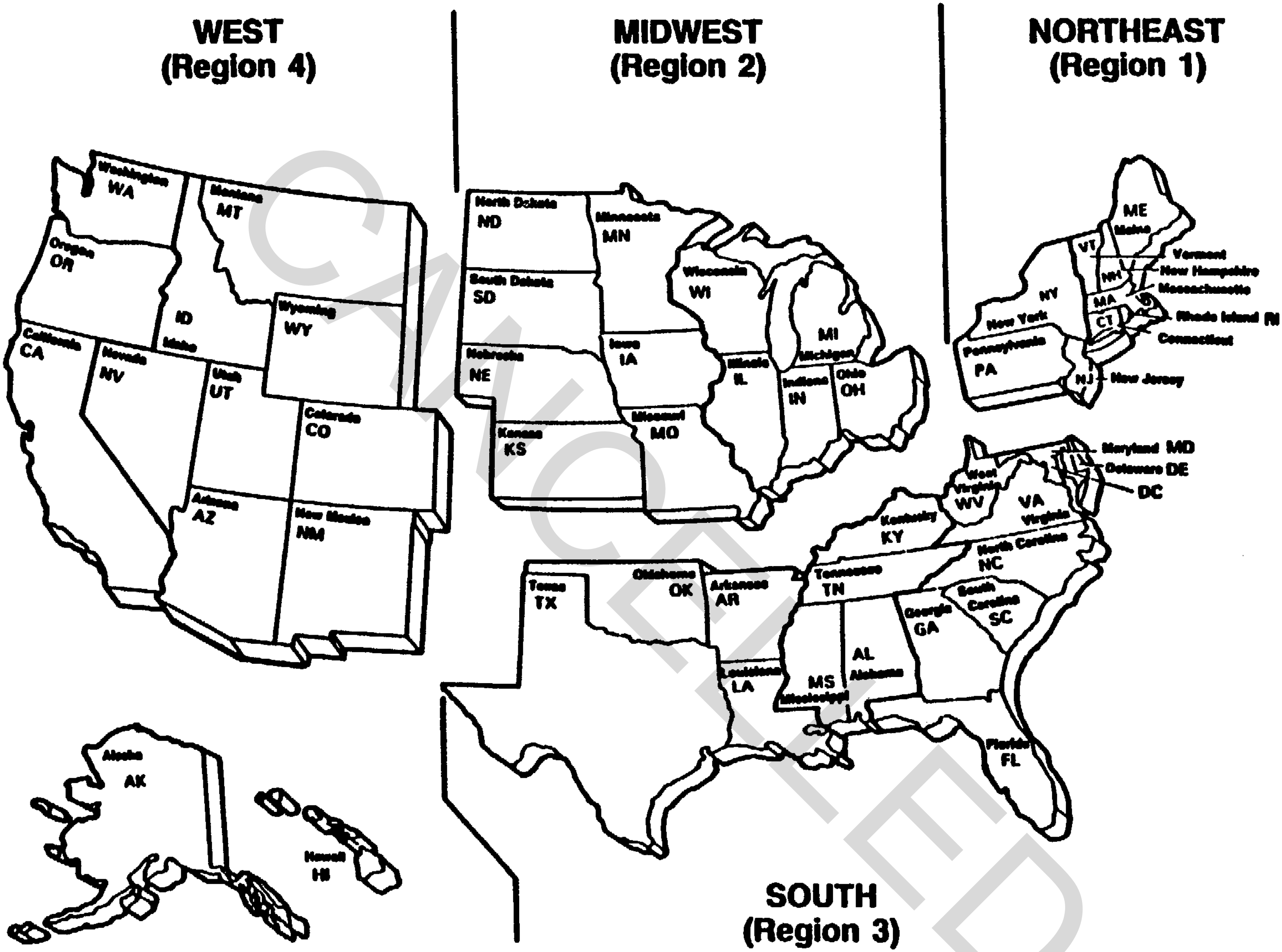
(3) FEMP UPV* Discount Factors adjusted for fuel price escalation, by region, fuel type, and rate type, and

(4) Projected fuel price indices (excluding general inflation), by region, fuel type, and rate type.

The first two tables (F/A-1 and F/A-2) provide present-value factors computed using both the FEMP discount rate of 3 percent for fiscal year 1995 and the current (1995) OMB discount rates (2.5 percent short-term and 2.8 percent long-term). The current FEMP discount rate should be used for all investments in energy- and water-conservation projects in federal facilities, as required by 10 CFR 436. The current OMB discount rates should be used for economic analysis of most other investments in federal facilities which affect their long-term owning and operating costs, as required by OMB Circular A-94.

The third set of tables (E/Ba-1 through E/Ba-5) provide FEMP UPV* factors computed for the four DOE regions shown in figure E-1 (Northeast, Midwest, South, and West) and for the United States average, all based on the DOE discount rate of 3 percent (real) for fiscal year 1995. The fourth set of tables (E/Ca-1 through E/Ca-5) provide end-of-year energy price indices for the years 1995-2024, by fuel type and rate type, for each the four DOE regions and for the United States average. These indices are all based on a price index of 1.00 for January 1995.

[1] For military construction projects in DoD, use discount factor tables from NISTIR 4942-2, *Present Worth Factors for Life-Cycle Cost Studies in the Department of Defense (1995)*, revised annually on October 1.



Source: U.S. Bureau of the Census

Figure E-1. Map of the United States Showing Census Regions.

Table E/A-1. SPV factors for finding the present value of future single amounts (non-fuel) for 1995

Single Present Value (SPV) Factors

Year of Occurrence (t)	DOE Discount rate 3.0%	OMB Discount Rates[a] Short term[b] 2.5%	OMB Discount Rates[a] Long Term[c] 2.8%
1	0.971	0.976	0.973
2	0.943	0.952	0.946
3	0.915	0.929	0.920
4	0.888	0.906	0.895
5	0.863	0.884	0.871
6	0.837	0.862	0.847
7	0.813	0.841	0.824
8	0.789	0.821	0.802
9	0.766	0.801	0.780
10	0.744	0.781	0.759
11	0.722		0.738
12	0.701		0.718
13	0.681		0.698
14	0.661		0.679
15	0.642		0.661
16	0.623		0.643
17	0.605		0.625
18	0.587		0.608
19	0.570		0.592
20	0.554		0.576
21	0.538		0.560
22	0.522		0.545
23	0.507		0.530
24	0.492		0.515
25	0.478		0.501
26	0.464		0.488
27	0.450		0.474
28	0.437		0.462
29	0.424		0.449
30	0.412		0.437

[a] OMB discount rates as of March 1994. OMB rates are expected to be revised in February 1995.

[b] Short-term discount rate based on OMB discount rate for 7-year study period.

[c] Long-term discount rate based on OMB discount rate for 30-year study period.

Table E/A-2. UPV factors for finding the present value of annually recurring uniform amounts (non-fuel) for 1995

	Uniform Present Value (UPV) Factors		
Year of Occurrence (t)	DOE Discount rate 3.0%	OMB Discount Rates[a] Short term[b] 2.5%	Long Term[c] 2.8%
1	0.97	0.98	0.97
2	1.91	1.93	1.92
3	2.83	2.86	2.84
4	3.72	3.76	3.73
5	4.58	4.65	4.61
6	5.42	5.51	5.45
7	6.23	6.35	6.28
8	7.02	7.17	7.08
9	7.79	7.97	7.86
10	8.53	8.75	8.62
11	9.25		9.36
12	9.95		10.07
13	10.63		10.77
14	11.30		11.45
15	11.94		12.11
16	12.56		12.76
17	13.17		13.38
18	13.75		13.99
19	14.32		14.58
20	14.88		15.16
21	15.42		15.72
22	15.94		16.26
23	16.44		16.79
24	16.94		17.31
25	17.41		17.81
26	17.88		18.30
27	18.33		18.77
28	18.76		19.23
29	19.19		19.68
30	19.60		20.12

[a] OMB discount rates as of March 1994. OMB rates are expected to be revised in February 1995.
[b] Short-term discount rate based on OMB discount rate for 7-year study period.
[c] Long-term discount rate based on OMB discount rate for 30-year study period.

Table E/Ba-1. UPV* Discount factors adjusted for fuel price escalation, by end use sector and fuel type, for [illegible]
Discount rate = 3.0 percent (DOE)

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

N	RESIDENTIAL ELEC	RESIDENTIAL DIST	RESIDENTIAL LPG	RESIDENTIAL NTGAS	COMMERCIAL ELEC	COMMERCIAL DIST	COMMERCIAL RESID	COMMERCIAL NTGAS	COMMERCIAL COAL	INDUSTRIAL ELEC	INDUSTRIAL DIST	INDUSTRIAL RESID	INDUSTRIAL NTGAS	INDUSTRIAL COAL	TRANSPORT GASLN	N
1	0.98	0.98	0.98	0.99	0.96	0.98	1.01	1.00	1.00	0.96	0.98	1.01	1.00	0.95	1.01	1
2	1.93	1.94	1.95	1.96	1.90	1.94	2.03	1.98	1.97	1.89	1.95	2.04	1.99	1.88	2.02	2
3	2.86	2.88	2.91	2.92	2.80	2.90	3.07	2.94	2.92	2.79	2.91	3.08	2.96	2.78	3.02	3
4	3.77	3.82	3.85	3.86	3.69	3.86	4.10	3.89	3.84	3.66	3.86	4.12	3.93	3.74	4.00	4
5	4.65	4.75	4.78	4.77	4.55	4.81	5.13	4.82	4.75	4.52	4.82	5.15	4.88	4.69	4.97	5
6	5.53	5.67	5.71	5.67	5.38	5.76	6.16	5.73	5.63	5.35	5.78	6.19	5.81	5.56	5.93	6
7	6.38	6.58	6.62	6.56	6.20	6.71	7.20	6.63	6.52	6.16	6.73	7.25	6.75	6.41	6.88	7
8	7.22	7.49	7.53	7.43	7.00	7.67	8.26	7.52	7.38	6.96	7.69	8.31	7.67	7.23	7.81	8
9	8.05	8.39	8.42	8.27	7.77	8.62	9.33	8.39	8.22	7.72	8.65	9.39	8.58	8.03	8.73	9
10	8.86	9.28	9.30	9.12	8.53	9.56	10.39	9.26	9.04	8.47	9.60	10.46	9.49	8.81	9.64	10
11	9.65	10.15	10.17	9.95	9.26	10.50	11.44	10.12	9.82	9.19	10.54	11.53	10.39	9.57	10.53	11
12	10.43	11.01	11.02	10.77	9.97	11.42	12.50	10.96	10.57	9.90	11.47	12.60	11.28	10.30	11.40	12
13	11.20	11.86	11.85	11.58	10.67	12.33	13.56	11.81	11.31	10.59	12.38	13.68	12.18	11.02	12.26	13
14	11.95	12.69	12.68	12.40	11.35	13.23	14.61	12.66	12.02	11.27	13.29	14.75	13.07	11.73	13.11	14
15	12.71	13.51	13.48	13.20	12.02	14.12	15.63	13.50	12.71	11.93	14.19	15.78	13.96	12.43	13.94	15
16	13.44	14.32	14.28	13.98	12.66	14.99	16.64	14.32	13.37	12.58	15.08	16.81	14.84	13.10	14.75	16
17	14.17	15.11	15.06	14.76	13.28	15.86	17.65	15.14	14.02	13.20	15.95	17.84	15.71	13.77	15.55	17
18	14.88	15.89	15.84	15.52	13.88	16.71	18.65	15.94	14.66	13.82	16.81	18.86	16.57	14.42	16.34	18
19	15.57	16.65	16.60	16.27	14.47	17.56	19.65	16.73	15.28	14.41	17.66	19.88	17.42	15.05	17.12	19
20	16.26	17.40	17.35	17.01	15.04	18.39	20.64	17.51	15.88	14.99	18.50	20.90	18.27	15.68	17.89	20
21	16.92	18.14	18.08	17.74	15.60	19.21	21.63	18.28	16.47	15.56	19.33	21.91	19.11	16.29	18.65	21
22	17.58	18.86	18.81	18.45	16.13	20.01	22.61	19.04	17.05	16.12	20.15	22.92	19.93	16.90	19.39	22
23	18.22	19.57	19.52	19.15	16.66	20.81	23.59	19.79	17.62	16.65	20.96	23.93	20.75	17.49	20.13	23
24	18.85	20.27	20.23	19.85	17.17	21.60	24.56	20.53	18.17	17.18	21.76	24.94	21.56	18.07	20.86	24
25	19.46	20.96	20.92	20.53	17.66	22.38	25.52	21.26	18.71	17.69	22.55	25.94	22.35	18.63	21.57	25
26/a	20.06	21.63	21.60	21.20	18.14	23.14	26.49	21.98	19.24	18.19	23.33	26.94	23.14	19.19	22.28	26
27/a	20.65	22.30	22.27	21.86	18.60	23.90	27.44	22.68	19.76	18.68	24.10	27.94	23.91	19.74	22.98	27
28/a	21.23	22.95	22.94	22.51	19.06	24.64	28.40	23.38	20.26	19.15	24.86	28.94	24.68	20.28	23.66	28
29/a	21.80	23.59	23.59	23.14	19.50	25.38	29.34	24.07	20.75	19.62	25.61	29.93	25.44	20.80	24.34	29
30/a	22.35	24.22	24.23	23.77	19.92	26.11	30.29	24.75	21.24	20.07	26.35	30.92	26.19	21.32	25.01	30

[a] UPW* factors are reported for years 26-30 to accommodate a planning/construction period of up to 5 years.

Table E/Ba-2. UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type, for 1995.[a]
Discount Rate = 3.0 percent (DOE)

Census Region 2 (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)

	RESIDENTIAL				COMMERCIAL					INDUSTRIAL					TRANSPORT	
N	ELEC	DIST	LPG	NTGAS	ELEC	DIST	RESID	NTGAS	COAL	ELEC	DIST	RESID	NTGAS	COAL	GASLN	N
1	0.98	0.99	0.98	1.00	0.98	0.99	1.02	1.00	1.00	0.98	0.99	1.02	1.00	0.97	1.00	1
2	1.94	1.97	1.95	1.99	1.93	1.99	2.05	2.00	1.97	1.93	1.98	2.05	1.99	1.93	2.00	2
3	2.87	2.94	2.91	2.96	2.86	2.98	3.08	2.98	2.92	2.85	2.97	3.08	2.97	2.87	2.99	3
4	3.78	3.90	3.87	3.92	3.78	3.98	4.12	3.94	3.84	3.76	3.96	4.13	3.95	3.79	3.96	4
5	4.68	4.85	4.82	4.85	4.67	4.98	5.17	4.88	4.75	4.65	4.94	5.18	4.90	4.70	4.92	5
6	5.56	5.80	5.77	5.76	5.54	5.98	6.24	5.80	5.63	5.51	5.93	6.25	5.84	5.60	5.88	6
7	6.42	6.75	6.72	6.65	6.40	6.98	7.32	6.70	6.52	6.36	6.92	7.34	6.77	6.47	6.83	7
8	7.27	7.69	7.67	7.52	7.24	7.99	8.42	7.59	7.38	7.19	7.91	8.43	7.70	7.31	7.76	8
9	8.10	8.63	8.61	8.39	8.05	9.01	9.52	8.47	8.22	8.00	8.90	9.55	8.61	8.13	8.68	9
10	8.90	9.55	9.54	9.24	8.85	10.01	10.64	9.34	9.04	8.78	9.88	10.66	9.53	8.95	9.59	10
11	9.70	10.47	10.45	10.09	9.63	11.01	11.74	10.20	9.82	9.55	10.85	11.77	10.44	9.75	10.48	11
12	10.48	11.37	11.36	10.94	10.39	12.00	12.84	11.06	10.57	10.30	11.82	12.88	11.34	10.54	11.36	12
13	11.26	12.26	12.26	11.77	11.14	12.98	13.94	11.92	11.31	11.03	12.77	13.98	12.24	11.31	12.22	13
14	12.03	13.14	13.15	12.60	11.88	13.96	15.02	12.77	12.02	11.75	13.72	15.07	13.14	12.10	13.07	14
15	12.80	14.00	14.02	13.41	12.60	14.92	16.09	13.60	12.71	12.47	14.66	16.14	14.02	12.89	13.90	15
16	13.54	14.85	14.88	14.21	13.30	15.87	17.14	14.43	13.37	13.19	15.58	17.20	14.89	13.66	14.72	16
17	14.27	15.69	15.73	15.00	13.98	16.81	18.19	15.24	14.02	13.89	16.49	18.26	15.75	14.43	15.52	17
18	14.98	16.51	16.56	15.77	14.64	17.74	19.24	16.04	14.66	14.57	17.39	19.32	16.61	15.17	16.31	18
19	15.68	17.31	17.39	16.54	15.28	18.65	20.28	16.83	15.28	15.23	18.28	20.38	17.46	15.90	17.09	19
20	16.36	18.11	18.20	17.29	15.90	19.55	21.31	17.60	15.88	15.88	19.16	21.43	18.30	16.62	17.86	20
21	17.03	18.88	18.99	18.03	16.51	20.44	22.34	18.37	16.47	16.51	20.02	22.48	19.13	17.32	18.62	21
22	17.69	19.65	19.78	18.75	17.10	21.32	23.37	19.12	17.05	17.13	20.88	23.52	19.95	18.02	19.37	22
23	18.33	20.40	20.55	19.47	17.67	22.19	24.39	19.87	17.62	17.73	21.72	24.57	20.77	18.69	20.11	23
24	18.96	21.14	21.31	20.17	18.22	23.04	25.40	20.60	18.17	18.32	22.55	25.61	21.58	19.36	20.84	24
25	19.58	21.86	22.06	20.86	18.76	23.88	26.41	21.33	18.71	18.89	23.38	26.65	22.38	20.01	21.56	25
26/a	20.19	22.58	22.80	21.54	19.28	24.72	27.41	22.04	19.24	19.44	24.19	27.68	23.17	20.65	22.27	26
27/a	20.78	23.28	23.53	22.21	19.79	25.54	28.41	22.75	19.76	19.99	24.99	28.71	23.96	21.27	22.97	27
28/a	21.36	23.96	24.25	22.87	20.29	26.35	29.41	23.44	20.26	20.51	25.78	29.74	24.74	21.89	23.65	28
29/a	21.93	24.64	24.95	23.52	20.77	27.14	30.39	24.13	20.75	21.03	26.57	30.77	25.51	22.49	24.33	29
30/a	22.49	25.30	25.64	24.16	21.23	27.93	31.38	24.80	21.24	21.53	27.34	31.79	26.28	23.08	25.00	30

[a] UPW* factors are reported for years 26-30 to accommodate a planning/construction period of up to 5 years.

Table E/Ba-3. UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type, for 1995.[a]
Discount Rate = 3.0 percent (DOE)

Census Region 3 (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia)

	RESIDENTIAL				COMMERCIAL					INDUSTRIAL					TRANSPORT	
N	ELEC	DIST	LPG	NTGAS	ELEC	DIST	RESID	NTGAS	COAL	ELEC	DIST	RESID	NTGAS	COAL	GASLN	N
-	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-
1	0.99	0.98	0.98	0.99	0.98	0.98	1.02	1.00	1.00	0.98	0.98	1.02	1.00	1.02	1.00	1
2	1.96	1.94	1.94	1.97	1.93	1.95	2.05	1.98	1.98	1.92	1.95	2.04	1.99	2.04	2.00	2
3	2.91	2.88	2.89	2.93	2.85	2.91	3.08	2.95	2.93	2.83	2.91	3.07	2.98	3.01	2.99	3
4	3.83	3.82	3.83	3.87	3.74	3.88	4.12	3.90	3.87	3.71	3.87	4.10	3.96	3.96	3.97	4
5	4.74	4.75	4.76	4.79	4.60	4.84	5.17	4.84	4.79	4.58	4.82	5.14	4.92	4.87	4.94	5
6	5.63	5.67	5.68	5.69	5.46	5.81	6.24	5.75	5.67	5.42	5.79	6.20	5.86	5.77	5.90	6
7	6.51	6.58	6.59	6.57	6.30	6.79	7.32	6.65	6.54	6.25	6.75	7.27	6.81	6.66	6.85	7
8	7.36	7.49	7.50	7.45	7.11	7.76	8.41	7.54	7.40	7.05	7.71	8.35	7.75	7.54	7.79	8
9	8.19	8.39	8.39	8.30	7.90	8.73	9.52	8.41	8.25	7.82	8.67	9.44	8.67	8.42	8.71	9
10	9.01	9.28	9.28	9.14	8.66	9.70	10.63	9.27	9.07	8.58	9.62	10.53	9.60	9.28	9.63	10
11	9.81	10.15	10.15	9.97	9.40	10.66	11.74	10.13	9.85	9.30	10.56	11.61	10.52	10.12	10.52	11
12	10.60	11.01	11.00	10.79	10.11	11.61	12.84	10.97	10.61	10.01	11.49	12.69	11.43	10.94	11.40	12
13	11.38	11.85	11.85	11.61	10.80	12.55	13.93	11.82	11.34	10.69	12.41	13.76	12.35	11.73	12.26	13
14	12.14	12.69	12.67	12.42	11.47	13.49	15.01	12.66	12.05	11.36	13.33	14.83	13.27	12.51	13.12	14
15	12.89	13.51	13.49	13.22	12.12	14.41	16.08	13.49	12.75	12.02	14.23	15.87	14.17	13.28	13.95	15
16	13.62	14.31	14.29	14.01	12.76	15.32	17.14	14.32	13.44	12.66	15.12	16.91	15.07	14.01	14.77	16
17	14.34	15.11	15.08	14.78	13.38	16.22	18.19	15.13	14.11	13.29	16.00	17.94	15.96	14.74	15.58	17
18	15.04	15.88	15.86	15.54	13.98	17.11	19.23	15.92	14.77	13.90	16.87	18.97	16.84	15.45	16.37	18
19	15.73	16.65	16.63	16.29	14.56	17.99	20.28	16.71	15.41	14.50	17.73	20.00	17.72	16.15	17.16	19
20	16.40	17.40	17.38	17.03	15.13	18.85	21.31	17.49	16.04	15.08	18.57	21.02	18.58	16.83	17.93	20
21	17.06	18.14	18.12	17.75	15.68	19.70	22.34	18.25	16.66	15.64	19.41	22.04	19.44	17.50	18.70	21
22	17.71	18.86	18.85	18.47	16.21	20.54	23.37	19.01	17.26	16.20	20.23	23.06	20.29	18.16	19.45	22
23	18.34	19.58	19.57	19.17	16.73	21.37	24.39	19.75	17.85	16.73	21.05	24.08	21.13	18.80	20.19	23
24	18.96	20.28	20.28	19.86	17.23	22.19	25.40	20.49	18.42	17.26	21.85	25.09	21.96	19.43	20.93	24
25	19.57	20.96	20.98	20.54	17.72	23.00	26.41	21.21	18.98	17.77	22.65	26.10	22.79	20.05	21.65	25
26/a	20.17	21.64	21.67	21.21	18.20	23.80	27.41	21.92	19.53	18.27	23.43	27.11	23.61	20.66	22.36	26
27/a	20.75	22.30	22.35	21.87	18.66	24.58	28.41	22.63	20.07	18.76	24.21	28.11	24.42	21.26	23.06	27
28/a	21.32	22.95	23.01	22.52	19.11	25.36	29.41	23.32	20.59	19.23	24.97	29.11	25.22	21.84	23.75	28
29/a	21.88	23.60	23.67	23.16	19.55	26.12	30.40	24.00	21.11	19.69	25.73	30.11	26.02	22.42	24.44	29
30/a	22.43	24.22	24.32	23.78	19.97	26.88	31.38	24.68	21.61	20.14	26.47	31.11	26.80	22.98	25.11	30

[a] UPW* factors are reported for years 26-30 to accommodate a planning/construction period of up to 5 years.

Table E/Ba-4. UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type, for 1995.[a]
Discount Rate = 3.0 percent (DOE)

Census Region 4 (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming)

	RESIDENTIAL				COMMERCIAL					INDUSTRIAL					TRANSPORT	
N	ELEC	DIST	LPG	NTGAS	ELEC	DIST	RESID	NTGAS	COAL	ELEC	DIST	RESID	NTGAS	COAL	GASLN	N
-	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-
1	0.98	0.98	0.97	0.99	0.98	0.99	1.00	1.00	0.98	0.98	0.98	1.02	1.00	1.02	1.00	1
2	1.95	1.95	1.92	1.99	1.93	1.96	2.00	2.01	1.93	1.92	1.95	2.04	1.99	2.04	2.00	2
3	2.89	2.91	2.86	2.98	2.87	2.94	3.02	3.01	2.87	2.83	2.91	3.07	2.98	3.01	2.99	3
4	3.82	3.86	3.78	3.94	3.79	3.91	4.04	3.99	3.79	3.71	3.87	4.10	3.96	3.96	3.97	4
5	4.74	4.80	4.70	4.89	4.69	4.89	5.07	4.95	4.69	4.58	4.82	5.14	4.92	4.87	4.94	5
6	5.64	5.73	5.61	5.81	5.58	5.86	6.11	5.90	5.57	5.42	5.79	6.20	5.86	5.77	5.90	6
7	6.53	6.66	6.50	6.72	6.45	6.85	7.16	6.83	6.41	6.25	6.75	7.27	6.81	6.66	6.85	7
8	7.40	7.58	7.39	7.62	7.30	7.83	8.21	7.75	7.25	7.05	7.71	8.35	7.75	7.54	7.79	8
9	8.25	8.50	8.26	8.52	8.15	8.82	9.28	8.67	8.06	7.82	8.67	9.44	8.67	8.42	8.71	9
10	9.10	9.41	9.13	9.40	8.97	9.81	10.34	9.58	8.84	8.58	9.62	10.53	9.60	9.28	9.63	10
11	9.92	10.30	10.00	10.27	9.77	10.78	11.41	10.47	9.63	9.30	10.56	11.61	10.52	10.12	10.52	11
12	10.73	11.18	10.87	11.13	10.57	11.75	12.47	11.37	10.43	10.01	11.49	12.69	11.43	10.94	11.40	12
13	11.53	12.06	11.75	11.98	11.35	12.72	13.54	12.25	11.19	10.69	12.41	13.76	12.35	11.73	12.26	13
14	12.32	12.93	12.62	12.82	12.11	13.69	14.59	13.12	11.90	11.36	13.33	14.83	13.27	12.51	13.12	14
15	13.09	13.79	13.48	13.64	12.85	14.65	15.65	13.98	12.59	12.02	14.23	15.87	14.17	13.28	13.95	15
16	13.86	14.64	14.33	14.46	13.58	15.60	16.70	14.83	13.27	12.66	15.12	16.91	15.07	14.01	14.77	16
17	14.60	15.47	15.17	15.25	14.29	16.54	17.75	15.66	13.94	13.29	16.00	17.94	15.96	14.74	15.58	17
18	15.33	16.29	16.00	16.04	14.98	17.46	18.79	16.48	14.58	13.90	16.87	18.97	16.84	15.45	16.37	18
19	16.05	17.09	16.81	16.81	15.64	18.38	19.83	17.30	15.22	14.50	17.73	20.00	17.72	16.15	17.16	19
20	16.75	17.88	17.62	17.57	16.29	19.28	20.86	18.10	15.84	15.08	18.57	21.02	18.58	16.83	17.93	20
21	17.43	18.66	18.41	18.32	16.92	20.17	21.89	18.88	16.44	15.64	19.41	22.04	19.44	17.50	18.70	21
22	18.11	19.42	19.18	19.05	17.53	21.04	22.91	19.66	17.03	16.20	20.23	23.06	20.29	18.16	19.45	22
23	18.77	20.17	19.95	19.78	18.13	21.91	23.93	20.43	17.61	16.73	21.05	24.08	21.13	18.80	20.19	23
24	19.41	20.91	20.70	20.49	18.71	22.76	24.94	21.19	18.18	17.26	21.85	25.09	21.96	19.43	20.93	24
25	20.05	21.63	21.44	21.19	19.27	23.60	25.94	21.93	18.73	17.77	22.65	26.10	22.79	20.05	21.65	25
26/a	20.67	22.34	22.17	21.88	19.81	24.43	26.94	22.67	19.27	18.27	23.43	27.11	23.61	20.66	22.36	26
27/a	21.27	23.04	22.89	22.56	20.34	25.25	27.94	23.39	19.80	18.76	24.21	28.11	24.42	21.26	23.06	27
28/a	21.87	23.73	23.60	23.23	20.86	26.06	28.93	24.11	20.31	19.23	24.97	29.11	25.22	21.84	23.75	28
29/a	22.45	24.40	24.30	23.89	21.36	26.86	29.92	24.81	20.82	19.69	25.73	30.11	26.02	22.42	24.44	29
30/a	23.02	25.06	24.99	24.53	21.84	27.65	30.90	25.51	21.31	20.14	26.47	31.11	26.80	22.98	25.11	30

[a] UPW* factors are reported for years 26-30 to accommodate a planning/construction period of up to 5 years.

Table E/Ba-5. UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type, for 1995.[a]
Discount Rate = 3.0 percent (DOE)

United States Average

N	RESIDENTIAL ELEC	RESIDENTIAL DIST	RESIDENTIAL LPG	RESIDENTIAL NTGAS	COMMERCIAL ELEC	COMMERCIAL DIST	COMMERCIAL RESID	COMMERCIAL NTGAS	COMMERCIAL COAL	INDUSTRIAL ELEC	INDUSTRIAL DIST	INDUSTRIAL RESID	INDUSTRIAL NTGAS	INDUSTRIAL COAL	TRANSPORT GASLN	N
1	0.98	0.98	0.98	0.99	0.97	0.98	1.01	1.00	0.99	0.97	0.98	0.99	1.00	1.00	1.00	1
2	1.95	1.94	1.94	1.98	1.92	1.95	2.04	1.99	1.97	1.91	1.95	1.99	2.02	1.98	2.00	2
3	2.89	2.89	2.89	2.95	2.84	2.91	3.07	2.97	2.91	2.83	2.91	3.00	3.02	2.93	2.99	3
4	3.81	3.83	3.84	3.90	3.74	3.88	4.10	3.94	3.84	3.73	3.87	4.02	4.02	3.91	3.97	4
5	4.71	4.76	4.77	4.83	4.62	4.84	5.13	4.88	4.75	4.61	4.83	5.06	5.00	4.89	4.94	5
6	5.60	5.69	5.70	5.74	5.48	5.80	6.17	5.80	5.63	5.47	5.80	6.11	5.98	5.86	5.90	6
7	6.47	6.61	6.62	6.63	6.33	6.76	7.22	6.71	6.50	6.31	6.76	7.16	6.95	6.81	6.85	7
8	7.32	7.52	7.53	7.51	7.15	7.73	8.28	7.61	7.36	7.13	7.73	8.22	7.92	7.74	7.79	8
9	8.16	8.42	8.43	8.38	7.95	8.69	9.35	8.49	8.19	7.93	8.70	9.29	8.89	8.64	8.71	9
10	8.98	9.32	9.33	9.24	8.73	9.65	10.42	9.37	9.00	8.72	9.66	10.36	9.86	9.51	9.63	10
11	9.78	10.20	10.21	10.09	9.49	10.59	11.48	10.24	9.79	9.49	10.61	11.44	10.83	10.40	10.52	11
12	10.57	11.06	11.09	10.93	10.24	11.53	12.55	11.10	10.56	10.24	11.56	12.52	11.81	11.34	11.40	12
13	11.36	11.92	11.95	11.76	10.97	12.46	13.62	11.97	11.31	10.98	12.49	13.59	12.78	12.22	12.26	13
14	12.13	12.76	12.81	12.58	11.68	13.38	14.67	12.82	12.04	11.71	13.43	14.67	13.75	13.06	13.12	14
15	12.89	13.59	13.65	13.39	12.37	14.29	15.70	13.66	12.75	12.43	14.35	15.74	14.70	13.88	13.95	15
16	13.63	14.40	14.48	14.19	13.05	15.19	16.72	14.49	13.44	13.13	15.27	16.80	15.65	14.68	14.77	16
17	14.36	15.20	15.30	14.98	13.71	16.08	17.73	15.30	14.12	13.81	16.17	17.87	16.60	15.46	15.58	17
18	15.07	15.98	16.11	15.75	14.35	16.95	18.74	16.11	14.78	14.47	17.06	18.93	17.53	16.23	16.37	18
19	15.77	16.75	16.91	16.51	14.97	17.81	19.75	16.91	15.43	15.12	17.94	19.99	18.46	16.98	17.16	19
20	16.45	17.51	17.69	17.26	15.57	18.67	20.75	17.69	16.06	15.75	18.81	21.04	19.37	17.71	17.93	20
21	17.12	18.26	18.46	17.99	16.16	19.50	21.74	18.46	16.68	16.37	19.67	22.10	20.28	18.44	18.70	21
22	17.78	18.99	19.22	18.72	16.72	20.33	22.73	19.22	17.29	16.97	20.52	23.15	21.18	19.15	19.45	22
23	18.42	19.71	19.96	19.43	17.28	21.15	23.72	19.97	17.88	17.56	21.36	24.19	22.07	19.84	20.19	23
24	19.05	20.41	20.70	20.13	17.81	21.96	24.70	20.72	18.45	18.13	22.18	25.24	22.96	20.52	20.93	24
25	19.67	21.11	21.42	20.82	18.33	22.75	25.67	21.45	19.02	18.69	23.00	26.28	23.83	21.19	21.65	25
26/a	20.27	21.79	22.14	21.50	18.84	23.54	26.64	22.17	19.57	19.23	23.80	27.32	24.70	21.85	22.36	26
27/a	20.87	22.46	22.84	22.17	19.33	24.31	27.61	22.88	20.11	19.76	24.60	28.35	25.56	22.49	23.06	27
28/a	21.45	23.12	23.53	22.82	19.81	25.08	28.57	23.58	20.64	20.27	25.38	29.38	26.41	23.12	23.75	28
29/a	22.01	23.76	24.21	23.47	20.28	25.83	29.52	24.27	21.16	20.78	26.16	30.41	27.25	23.74	24.44	29
30/a	22.57	24.40	24.88	24.11	20.73	26.57	30.47	24.95	21.66	21.27	26.93	31.44	28.08	24.34	25.11	30

[a] UPW* factors are reported for years 26-30 to accommodate a planning/construction period of up to 5 years.

Table E/Ca-1. **Projected fuel price indices (excluding general inflation), by end-use sector and fuel type, for 1995.**

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

Sector and Fuel	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Projected End-of-Year Fuel Price Indices (Beginning of Year 1995 = 1.00)														
Residential															
Electricity	1.01	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.13	1.15	1.17
Distillate Oil	1.01	1.02	1.04	1.06	1.07	1.10	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.28
LPG	1.01	1.03	1.04	1.06	1.08	1.10	1.13	1.15	1.17	1.18	1.20	1.21	1.23	1.24	1.26
Natural Gas	1.02	1.03	1.05	1.06	1.06	1.07	1.09	1.10	1.11	1.13	1.15	1.16	1.20	1.23	1.25
Commercial															
Electricity	0.99	0.99	0.99	0.99	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.03	1.04	1.03
Distillate Oil	1.01	1.02	1.05	1.08	1.10	1.14	1.17	1.21	1.24	1.27	1.29	1.31	1.34	1.36	1.39
Residual Oil	1.04	1.08	1.13	1.16	1.19	1.23	1.28	1.34	1.39	1.42	1.46	1.51	1.57	1.58	1.59
Natural Gas	1.03	1.04	1.06	1.07	1.08	1.09	1.11	1.13	1.13	1.17	1.19	1.20	1.25	1.28	1.30
Steam Coal	1.03	1.04	1.03	1.04	1.05	1.05	1.09	1.10	1.09	1.10	1.08	1.07	1.07	1.08	1.07
Industrial															
Electricity	0.99	0.98	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.03	1.03
Distillate Oil	1.01	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.28	1.30	1.32	1.35	1.37	1.40
Residual Oil	1.04	1.09	1.14	1.17	1.20	1.25	1.29	1.35	1.41	1.44	1.47	1.53	1.59	1.61	1.61
Natural Gas	1.03	1.05	1.07	1.09	1.10	1.12	1.15	1.17	1.19	1.22	1.25	1.27	1.32	1.36	1.38
Steam Coal	0.98	0.98	0.99	1.08	1.10	1.05	1.04	1.03	1.05	1.06	1.05	1.05	1.06	1.07	1.08
Transportation															
Motor Gasoline	1.04	1.07	1.09	1.10	1.12	1.15	1.17	1.18	1.20	1.22	1.23	1.24	1.26	1.28	1.29
	Projected world oil price indices (Beginning of year 1995 = 1.00)														
Oil Price Assumption	1.04	1.08	1.12	1.17	1.22	1.27	1.32	1.38	1.43	1.47	1.51	1.55	1.59	1.64	1.67

Table E/Ca-1, continued. Projected fu el price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Residential															
Electricity	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.28	1.29	1.30	1.31	1.32	1.33	1.35
Distillate Oil	1.29	1.31	1.32	1.34	1.35	1.37	1.39	1.40	1.42	1.44	1.46	1.47	1.49	1.51	1.53
LPG	1.28	1.30	1.31	1.33	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.54	1.56
Natural Gas	1.26	1.28	1.30	1.32	1.33	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.48	1.50	1.53
Commercial															
Electricity	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.04
Distillate Oil	1.41	1.43	1.45	1.48	1.50	1.52	1.55	1.57	1.60	1.63	1.65	1.68	1.71	1.73	1.76
Residual Oil	1.62	1.66	1.71	1.75	1.79	1.84	1.88	1.93	1.98	2.02	2.07	2.13	2.18	2.23	2.29
Natural Gas	1.33	1.35	1.37	1.39	1.41	1.43	1.45	1.48	1.50	1.52	1.55	1.57	1.60	1.62	1.65
Steam Coal	1.07	1.07	1.08	1.09	1.09	1.10	1.11	1.12	1.12	1.13	1.14	1.15	1.15	1.16	1.17
Industrial															
Electricity	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.07	1.07	1.08	1.08	1.09	1.09	1.10
Distillate Oil	1.42	1.44	1.47	1.49	1.52	1.54	1.57	1.60	1.62	1.65	1.68	1.71	1.74	1.77	1.80
Residual Oil	1.65	1.70	1.74	1.79	1.84	1.89	1.94	1.99	2.05	2.10	2.16	2.22	2.28	2.34	2.40
Natural Gas	1.41	1.44	1.47	1.50	1.53	1.56	1.58	1.61	1.64	1.67	1.70	1.72	1.75	1.78	1.81
Steam Coal	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.17	1.18	1.19	1.20	1.21	1.23	1.24	1.25
Transportation															
Motor Gasoline	1.30	1.32	1.35	1.37	1.39	1.41	1.43	1.45	1.48	1.50	1.52	1.55	1.57	1.60	1.62

Projected world oil price indices
(Beginning of year 1995 = 1.00)

Oil Price Assumption	1.70	1.72	1.75	1.77	1.80	1.82	1.84	1.87	1.89	1.92	1.94	1.96	1.99	2.01	2.03

Table E/Ca-2. Projected fuel price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

Census Region 2 (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Residential															
Electricity	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.12	1.14	1.17	1.19
Distillate Oil	1.02	1.04	1.06	1.08	1.11	1.14	1.17	1.19	1.22	1.25	1.26	1.28	1.31	1.33	1.35
LPG	1.01	1.03	1.05	1.08	1.10	1.14	1.17	1.20	1.23	1.25	1.27	1.30	1.32	1.34	1.36
Natural Gas	1.03	1.05	1.07	1.07	1.08	1.09	1.10	1.11	1.13	1.15	1.17	1.20	1.23	1.25	1.27
Commercial															
Electricity	1.01	1.01	1.02	1.03	1.04	1.04	1.05	1.06	1.07	1.07	1.08	1.09	1.10	1.11	1.12
Distillate Oil	1.02	1.06	1.09	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.38	1.41	1.44	1.48	1.50
Residual Oil	1.05	1.09	1.13	1.17	1.22	1.27	1.33	1.39	1.44	1.50	1.53	1.56	1.61	1.64	1.66
Natural Gas	1.03	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.14	1.17	1.20	1.23	1.26	1.28	1.30
Steam Coal	1.03	1.04	1.03	1.04	1.05	1.05	1.09	1.10	1.09	1.10	1.08	1.07	1.07	1.08	1.07
Industrial															
Electricity	1.01	1.01	1.01	1.02	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.12
Distillate Oil	1.02	1.05	1.08	1.11	1.14	1.18	1.22	1.25	1.29	1.32	1.35	1.37	1.40	1.43	1.46
Residual Oil	1.05	1.09	1.13	1.18	1.22	1.28	1.34	1.39	1.45	1.50	1.54	1.57	1.62	1.65	1.67
Natural Gas	1.03	1.05	1.08	1.09	1.11	1.12	1.14	1.17	1.20	1.23	1.26	1.29	1.33	1.35	1.37
Steam Coal	1.00	1.02	1.02	1.04	1.06	1.07	1.07	1.06	1.07	1.10	1.12	1.12	1.14	1.19	1.23
Transportation															
Motor Gasoline	1.03	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.23	1.25	1.27	1.28	1.30

Projected world oil price indices
(Beginning of year 1995 = 1.00)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Oil Price Assumption	1.04	1.08	1.12	1.17	1.22	1.27	1.32	1.38	1.43	1.47	1.51	1.55	1.59	1.64	1.67

Table E/Ca-2, continued. Projected fu el price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

Census Region 2 (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Residential															
Electricity	1.19	1.20	1.21	1.22	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.32	1.33	1.34	1.35
Distillate Oil	1.36	1.38	1.40	1.41	1.43	1.45	1.46	1.48	1.50	1.52	1.54	1.55	1.57	1.59	1.61
LPG	1.38	1.40	1.42	1.44	1.46	1.48	1.50	1.53	1.55	1.57	1.59	1.62	1.64	1.66	1.69
Natural Gas	1.28	1.30	1.32	1.34	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.53	1.55
Commercial															
Electricity	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Distillate Oil	1.53	1.55	1.58	1.60	1.63	1.65	1.68	1.71	1.74	1.76	1.79	1.82	1.85	1.88	1.91
Residual Oil	1.69	1.74	1.78	1.82	1.87	1.91	1.96	2.01	2.06	2.11	2.16	2.22	2.27	2.33	2.39
Natural Gas	1.32	1.34	1.36	1.38	1.40	1.43	1.45	1.47	1.49	1.52	1.54	1.56	1.59	1.61	1.64
Steam Coal	1.07	1.07	1.08	1.09	1.09	1.10	1.11	1.12	1.12	1.13	1.14	1.15	1.15	1.16	1.17
Industrial															
Electricity	1.15	1.16	1.16	1.17	1.17	1.18	1.18	1.19	1.19	1.20	1.20	1.21	1.21	1.22	1.22
Distillate Oil	1.48	1.51	1.53	1.56	1.58	1.61	1.64	1.67	1.69	1.72	1.75	1.78	1.81	1.84	1.87
Residual Oil	1.71	1.75	1.80	1.85	1.90	1.95	2.00	2.06	2.11	2.17	2.23	2.29	2.35	2.42	2.49
Natural Gas	1.40	1.43	1.46	1.49	1.52	1.55	1.58	1.61	1.64	1.68	1.71	1.75	1.78	1.82	1.86
Steam Coal	1.25	1.26	1.27	1.28	1.30	1.31	1.32	1.34	1.35	1.37	1.38	1.39	1.40	1.42	1.43
Transportation															
Motor Gasoline	1.31	1.33	1.35	1.37	1.39	1.41	1.44	1.46	1.48	1.50	1.53	1.55	1.58	1.60	1.63

Projected world oil price indices
(Beginning of year 1995 = 1.00)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Oil Price Assumption	1.70	1.72	1.75	1.77	1.80	1.82	1.84	1.87	1.89	1.92	1.94	1.96	1.99	2.01	2.03

Table E/Ca-3. Projected fuel price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

Census Region 3 (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Residential															
Electricity	1.02	1.03	1.03	1.04	1.05	1.07	1.08	1.08	1.08	1.10	1.11	1.12	1.14	1.16	1.17
Distillate Oil	1.01	1.02	1.03	1.05	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.22	1.24	1.26	1.28
LPG	1.01	1.02	1.04	1.06	1.08	1.10	1.12	1.15	1.17	1.19	1.20	1.22	1.24	1.25	1.27
Natural Gas	1.02	1.04	1.05	1.06	1.06	1.07	1.09	1.10	1.11	1.13	1.15	1.16	1.20	1.23	1.25
Commercial															
Electricity	1.01	1.01	1.00	1.00	1.01	1.02	1.03	1.03	1.03	1.03	1.02	1.01	1.01	1.02	1.02
Distillate Oil	1.01	1.03	1.05	1.09	1.12	1.16	1.20	1.23	1.27	1.30	1.33	1.35	1.38	1.41	1.44
Residual Oil	1.05	1.09	1.13	1.17	1.22	1.27	1.33	1.39	1.44	1.50	1.53	1.56	1.61	1.64	1.66
Natural Gas	1.03	1.04	1.06	1.07	1.08	1.09	1.11	1.13	1.13	1.16	1.19	1.20	1.24	1.28	1.30
Steam Coal	1.03	1.04	1.04	1.05	1.07	1.06	1.07	1.09	1.10	1.10	1.09	1.08	1.07	1.08	1.09
Industrial															
Electricity	1.00	1.00	1.00	0.99	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.01	1.01	1.02
Distillate Oil	1.01	1.02	1.05	1.08	1.11	1.15	1.18	1.22	1.25	1.28	1.30	1.33	1.36	1.38	1.41
Residual Oil	1.05	1.08	1.12	1.16	1.21	1.26	1.32	1.37	1.42	1.47	1.50	1.53	1.58	1.61	1.63
Natural Gas	1.03	1.05	1.08	1.10	1.11	1.13	1.16	1.19	1.21	1.25	1.27	1.30	1.35	1.39	1.41
Steam Coal	1.05	1.08	1.07	1.06	1.06	1.07	1.10	1.12	1.14	1.16	1.16	1.17	1.17	1.18	1.19
Transportation															
Motor Gasoline	1.03	1.06	1.08	1.10	1.12	1.15	1.17	1.19	1.21	1.23	1.24	1.25	1.27	1.29	1.30
	Projected world oil price indices (Beginning of year 1995 = 1.00)														
Oil Price Assumption	1.04	1.08	1.12	1.17	1.22	1.27	1.32	1.38	1.43	1.47	1.51	1.55	1.59	1.64	1.67

Table E/Ca-3, continued. Projected fu el price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

Census Region 3 (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Residential															
Electricity	1.17	1.18	1.19	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.30	1.31	1.32	1.33
Distillate Oil	1.29	1.31	1.32	1.34	1.36	1.37	1.39	1.41	1.42	1.44	1.46	1.47	1.49	1.51	1.53
LPG	1.29	1.31	1.32	1.34	1.36	1.38	1.40	1.42	1.44	1.46	1.48	1.50	1.53	1.55	1.57
Natural Gas	1.26	1.28	1.30	1.31	1.33	1.35	1.37	1.39	1.41	1.42	1.44	1.46	1.48	1.50	1.52
Commercial															
Electricity	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Distillate Oil	1.46	1.49	1.51	1.54	1.56	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.77	1.80	1.83
Residual Oil	1.70	1.74	1.78	1.82	1.87	1.92	1.96	2.01	2.06	2.11	2.17	2.22	2.28	2.33	2.39
Natural Gas	1.32	1.34	1.36	1.38	1.40	1.42	1.45	1.47	1.49	1.51	1.54	1.56	1.59	1.61	1.64
Steam Coal	1.11	1.11	1.12	1.13	1.14	1.14	1.15	1.16	1.17	1.18	1.18	1.19	1.20	1.21	1.22
Industrial															
Electricity	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07	1.08	1.08	1.08	1.09	1.09
Distillate Oil	1.43	1.45	1.48	1.50	1.53	1.55	1.58	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81
Residual Oil	1.66	1.71	1.75	1.80	1.85	1.90	1.95	2.01	2.06	2.12	2.17	2.23	2.29	2.36	2.42
Natural Gas	1.44	1.47	1.50	1.53	1.56	1.59	1.63	1.66	1.69	1.73	1.76	1.80	1.84	1.87	1.91
Steam Coal	1.19	1.20	1.21	1.22	1.23	1.25	1.26	1.27	1.29	1.30	1.31	1.32	1.34	1.35	1.36
Transportation															
Motor Gasoline	1.31	1.33	1.36	1.38	1.40	1.42	1.44	1.47	1.49	1.51	1.54	1.56	1.58	1.61	1.63

Projected world oil price indices
(Beginning of year 1995 = 1.00)

Oil Price Assumption	1.70	1.72	1.75	1.77	1.80	1.82	1.84	1.87	1.89	1.92	1.94	1.96	1.99	2.01	2.03

Table E/Ca-4. **Projected fuel price indices (excluding general inflation), by end-use sector and fuel type, for 1995.**

Census Region 4 (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Residential															
Electricity	1.01	1.02	1.03	1.05	1.06	1.08	1.09	1.10	1.12	1.13	1.14	1.16	1.17	1.19	1.21
Distillate Oil	1.01	1.03	1.05	1.07	1.09	1.11	1.14	1.17	1.20	1.22	1.23	1.26	1.29	1.31	1.34
LPG	1.00	1.01	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.20	1.25	1.28	1.32	1.35
Natural Gas	1.02	1.06	1.08	1.09	1.09	1.11	1.12	1.14	1.17	1.19	1.21	1.23	1.25	1.27	1.28
Commercial															
Electricity	1.01	1.01	1.02	1.04	1.05	1.06	1.07	1.09	1.10	1.10	1.11	1.14	1.14	1.15	1.16
Distillate Oil	1.01	1.04	1.06	1.10	1.13	1.17	1.21	1.25	1.29	1.32	1.35	1.39	1.42	1.46	1.50
Residual Oil	1.03	1.07	1.11	1.15	1.20	1.24	1.29	1.33	1.39	1.44	1.48	1.52	1.56	1.60	1.64
Natural Gas	1.03	1.07	1.09	1.10	1.11	1.13	1.15	1.17	1.20	1.22	1.24	1.27	1.30	1.32	1.33
Steam Coal	1.01	1.01	1.02	1.04	1.05	1.04	1.04	1.05	1.06	1.05	1.09	1.14	1.11	1.08	1.08
Industrial															
Electricity	1.00	1.00	1.00	0.99	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.01	1.01	1.02
Distillate Oil	1.01	1.02	1.05	1.08	1.11	1.15	1.18	1.22	1.25	1.28	1.30	1.33	1.36	1.38	1.41
Residual Oil	1.05	1.08	1.12	1.16	1.21	1.26	1.32	1.37	1.42	1.47	1.50	1.53	1.58	1.61	1.63
Natural Gas	1.03	1.05	1.08	1.10	1.11	1.13	1.16	1.19	1.21	1.25	1.27	1.30	1.35	1.39	1.41
Steam Coal	1.05	1.08	1.07	1.06	1.06	1.07	1.10	1.12	1.14	1.16	1.16	1.17	1.17	1.18	1.19
Transportation															
Motor Gasoline	1.03	1.06	1.08	1.10	1.12	1.15	1.17	1.19	1.21	1.23	1.24	1.25	1.27	1.29	1.30

Projected world oil price indices
(Beginning of year 1995 = 1.00)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Oil Price Assumption	1.04	1.08	1.12	1.17	1.22	1.27	1.32	1.38	1.43	1.47	1.51	1.55	1.59	1.64	1.67

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Table E/Ca-4, continued. Projected fu el price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

Census Region 4 (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming)

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Residential															
Electricity	1.22	1.23	1.24	1.25	1.27	1.28	1.29	1.30	1.31	1.32	1.34	1.35	1.36	1.37	1.39
Distillate Oil	1.36	1.38	1.39	1.41	1.43	1.44	1.46	1.48	1.50	1.52	1.53	1.55	1.57	1.59	1.61
LPG	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.62	1.64	1.67
Natural Gas	1.30	1.32	1.34	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.53	1.55	1.57
Commercial															
Electricity	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.18
Distillate Oil	1.53	1.55	1.58	1.60	1.63	1.65	1.68	1.71	1.73	1.76	1.79	1.82	1.85	1.88	1.91
Residual Oil	1.69	1.73	1.78	1.82	1.86	1.91	1.96	2.01	2.06	2.11	2.16	2.21	2.27	2.32	2.38
Natural Gas	1.36	1.38	1.40	1.42	1.44	1.47	1.49	1.51	1.54	1.56	1.59	1.61	1.64	1.66	1.69
Steam Coal	1.09	1.10	1.10	1.11	1.12	1.12	1.13	1.14	1.15	1.16	1.16	1.17	1.18	1.19	1.20
Industrial															
Electricity	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07	1.08	1.08	1.08	1.09	1.09
Distillate Oil	1.43	1.45	1.48	1.50	1.53	1.55	1.58	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81
Residual Oil	1.66	1.71	1.75	1.80	1.85	1.90	1.95	2.01	2.06	2.12	2.17	2.23	2.29	2.36	2.42
Natural Gas	1.44	1.47	1.50	1.53	1.56	1.59	1.63	1.66	1.69	1.73	1.76	1.80	1.84	1.87	1.91
Steam Coal	1.19	1.20	1.21	1.22	1.23	1.25	1.26	1.27	1.29	1.30	1.31	1.32	1.34	1.35	1.36
Transportation															
Motor Gasoline	1.31	1.33	1.36	1.38	1.40	1.42	1.44	1.47	1.49	1.51	1.54	1.56	1.58	1.61	1.63

Projected world oil price indices
(Beginning of year 1995 = 1.00)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Oil Price Assumption	1.70	1.72	1.75	1.77	1.80	1.82	1.84	1.87	1.89	1.92	1.94	1.96	1.99	2.01	2.03

Table E/Ca-5. Projected fuel price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

United States Average

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Residential															
Electricity	1.01	1.02	1.03	1.03	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.15	1.17	1.18
Distillate Oil	1.01	1.02	1.04	1.06	1.08	1.10	1.13	1.16	1.18	1.20	1.22	1.23	1.25	1.27	1.29
LPG	1.01	1.02	1.04	1.06	1.08	1.11	1.13	1.16	1.18	1.20	1.22	1.25	1.27	1.29	1.32
Natural Gas	1.02	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.15	1.17	1.20	1.23	1.25	1.26
Commercial															
Electricity	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.04	1.05	1.05	1.05	1.06	1.07	1.08	1.08
Distillate Oil	1.01	1.03	1.05	1.08	1.11	1.15	1.19	1.22	1.26	1.29	1.31	1.34	1.36	1.39	1.42
Residual Oil	1.04	1.08	1.13	1.16	1.19	1.24	1.29	1.35	1.40	1.43	1.47	1.52	1.57	1.59	1.60
Natural Gas	1.03	1.05	1.07	1.08	1.09	1.10	1.12	1.14	1.15	1.18	1.21	1.23	1.26	1.29	1.31
Steam Coal	1.02	1.03	1.03	1.04	1.06	1.05	1.07	1.08	1.08	1.09	1.09	1.10	1.10	1.10	1.11
Industrial															
Electricity	1.00	1.00	1.00	1.01	1.02	1.03	1.03	1.04	1.05	1.05	1.06	1.08	1.09	1.10	1.11
Distillate Oil	1.01	1.03	1.05	1.08	1.11	1.15	1.19	1.22	1.26	1.29	1.32	1.35	1.38	1.41	1.44
Residual Oil	1.02	1.06	1.10	1.15	1.20	1.25	1.29	1.34	1.40	1.44	1.49	1.54	1.58	1.62	1.67
Natural Gas	1.04	1.07	1.10	1.12	1.14	1.17	1.20	1.23	1.27	1.30	1.34	1.39	1.43	1.46	1.49
Steam Coal	1.03	1.04	1.04	1.10	1.14	1.16	1.18	1.17	1.17	1.16	1.24	1.33	1.29	1.27	1.29
Transportation															
Motor Gasoline	1.03	1.06	1.08	1.10	1.12	1.15	1.17	1.19	1.21	1.23	1.24	1.25	1.27	1.29	1.30

Projected world oil price indices
(Beginning of year 1995 = 1.00)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Oil Price Assumption	1.04	1.08	1.12	1.17	1.22	1.27	1.32	1.38	1.43	1.47	1.51	1.55	1.59	1.64	1.67

Table E/Ca-5, continued. Projected fu el price indices (excluding general inflation), by end-use sector and fuel type, for 1995.

United States Average

Projected End-of-Year Fuel Price Indices
(Beginning of Year 1995 = 1.00)

Sector and Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Residential															
Electricity	1.19	1.20	1.21	1.22	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.32	1.33	1.34	1.35
Distillate Oil	1.31	1.32	1.34	1.35	1.37	1.39	1.40	1.42	1.44	1.45	1.47	1.49	1.51	1.52	1.54
LPG	1.34	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.50	1.52	1.54	1.56	1.58	1.61	1.63
Natural Gas	1.28	1.30	1.31	1.33	1.35	1.37	1.39	1.41	1.43	1.44	1.46	1.48	1.50	1.52	1.55
Commercial															
Electricity	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.10
Distillate Oil	1.44	1.47	1.49	1.51	1.54	1.56	1.59	1.61	1.64	1.67	1.69	1.72	1.75	1.78	1.80
Residual Oil	1.64	1.68	1.72	1.76	1.81	1.85	1.90	1.94	1.99	2.04	2.09	2.14	2.20	2.25	2.31
Natural Gas	1.33	1.35	1.37	1.39	1.42	1.44	1.46	1.48	1.51	1.53	1.55	1.58	1.60	1.63	1.65
Steam Coal	1.11	1.12	1.13	1.14	1.14	1.15	1.16	1.17	1.17	1.18	1.19	1.20	1.21	1.22	1.22
Industrial															
Electricity	1.12	1.13	1.13	1.14	1.14	1.15	1.15	1.16	1.16	1.17	1.17	1.18	1.18	1.19	1.19
Distillate Oil	1.47	1.49	1.52	1.54	1.57	1.60	1.62	1.65	1.68	1.71	1.74	1.77	1.80	1.83	1.86
Residual Oil	1.71	1.76	1.81	1.86	1.91	1.96	2.01	2.07	2.12	2.18	2.24	2.30	2.36	2.43	2.49
Natural Gas	1.53	1.56	1.59	1.62	1.66	1.69	1.72	1.76	1.80	1.83	1.87	1.91	1.95	1.99	2.03
Steam Coal	1.28	1.29	1.30	1.32	1.33	1.35	1.36	1.37	1.38	1.40	1.41	1.43	1.44	1.46	1.47
Transportation															
Motor Gasoline	1.31	1.33	1.36	1.38	1.40	1.42	1.44	1.47	1.49	1.51	1.54	1.56	1.58	1.61	1.63

Projected world oil price indices
(Beginning of year 1995 = 1.00)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Oil Price Assumption	1.70	1.72	1.75	1.77	1.80	1.82	1.84	1.87	1.89	1.92	1.94	1.96	1.99	2.01	2.03

APPENDIX F

EVALUATING ENERGY SAVINGS PERFORMANCE CONTRACTS

CONTENTS

Appendix F
EVALUATING ENERGY SAVINGS PERFORMANCE CONTRACTS

F.1 BACKGROUND

The National Energy Conservation Policy Act (NECPA) is the primary legislative authority directing federal agencies to improve energy management in their facilities and operations. The Energy Policy Act of 1992 (EPACT) amended NECPA to include additional provisions regarding energy management requirements, budget treatment for energy conservation measures, incentives for federal agencies, reporting requirements, new technology demonstrations, and agency surveys of energy-saving potential. Executive Order 12902 of March 8, 1994 mandates additional requirements for federal energy and water efficiency beyond the provisions of EPACT. These requirements include a 30 percent reduction in energy consumption in federal buildings by the year 2005 from the FY 1985 baseline, in Btu per gross square foot, and a 20 percent increase in energy efficiency in federal agency industrial facilities by 2005 compared to FY 1990.

To meet these ambitious requirements of federal energy management legislation, federal agencies can access four sources of financing to fund energy efficiency projects:

(1) Agency Capital Funds (Direct Appropriations)

(2) FEMP's Federal Energy Efficiency Fund

(3) Utility Demand Side Management Incentives

(4) Energy Savings Performance Contracts

This appendix provides a short overview of the economic requirements of Energy Savings Performance Contracts (ESPC), formerly known as "Shared Energy Savings" contracts. In addition, this appendix contains an example of the comparative economic evaluation of an ESPC project with a similar project using agency funding. The information in this appendix, other than this example, is based primarily on FEMP's Energy Savings Performance Contracting Guidance Manual, version 2.0 [15]. That manual should be consulted before attempting to establish or evaluate an ESPC.

In an ESPC, the Energy Service Company (ESCO) incurs all costs of implementing energy savings measures, including: performing the audit, designing the project, acquiring and installing the equipment, training personnel, and operating and maintaining equipment. In exchange, the ESCO receives a share of any energy cost savings directly resulting from implementation of energy conservation measures during the term of the contract. EPACT and the Executive Order strongly recommend this method of financing for energy efficiency projects. Specific provisions of EPACT provide that

- Agencies are allowed to enter into contracts for 25 years without funding of cancellation charges,
- Congress is notified 30 days before awarding contracts in excess of $750,000,
- Funds are available to cover ESPC payments in the first fiscal year,
- ESCOs incur costs of conservation measures for a share of the savings,

- Payments are to be made from the agency's utility and related operation and maintenance funds, and
- ESCOs guarantee savings to agencies.

F.2 ECONOMIC ANALYSIS REQUIREMENTS

In developing an ESPC, the government agency must conduct an economic viability analysis, including an economic analysis of the proposed project, an examination of issues that affect project viability, and a review of financing alternatives. The economic analysis should include

- current utility rates for the federal facility,
- a cost estimate for the retrofit measures, including the cost to the government of evaluating these measures,
- the energy consumption of the existing system(s), based on an assessment of actual operating conditions,
- the operating and maintenance (O&M) costs of the existing and new systems,
- an estimate of the annual energy consumption for the proposed systems, and
- an estimate of the annual energy savings, net of O&M cost differences between the existing and new systems.

Annual energy cost savings should include both energy consumption savings and power demand savings (if applicable), based on current, local, utility rates.

There are two "Rules of Thumb" for evaluating the economic viability of an ESPC:

Rule 1: The annual savings potential should be greater than $25,000 per year.

Rule 2: The ESPC project term is typically two times the "simple payback" of the entire project. The simple payback is the period of time it would take the government to recover its investment (from the anticipated annual savings) if the project were paid for with appropriated funds.

For the purpose of evaluating an ESPC, simple payback is computed by dividing the project cost by the annual savings at current prices. This simple payback does not include price escalation rates, a discount rate, or general inflation. The project term of two times the simple payback period allows the ESCO to recoup costs for capital equipment, cost of financing, labor, handling of hazardous material, maintenance, and profits, and the Government to realize its share of the savings. However, the project term is negotiable, depending on the Government's needs. For example, when dealing with sophisticated equipment, such as energy management and control systems, a highly trained ESCO may be desired to maintain the system over a longer period of time, so that the Government may want to consider a longer contract period.

There is no rule of thumb with regard to how the energy savings are shared between the ESCO and the Government. This is a matter of negotiation in setting up the contract.

To get the maximum benefit for a federal agency, retrofit measures with short and long term paybacks may be combined or "bundled" into a single ESPC contract. The purpose is to make short payback measures pay for needed measures with long-term paybacks. Even projects in different buildings can be bundled into a single ESPC.

Life-cycle cost analysis is not explicitly included in the requirements for developing and evaluating an energy savings performance contract. Since there is no initial investment on the part of the Government, an LCC analysis is not needed to demonstrate that the ESPC is economically justified. The ESCO may undertake an LCC analysis to evaluate its own investment in the project. In doing so it is under no obligation to follow the LCC methods and evaluation criteria required for federal investments under either 10 CRF 436 or OBM Circular A-94.

However, the federal agency should seek to determine the most advantageous method of financing the package of conservation measures proposed in the ESPC. The agency should consider financing alternatives, such as appropriated funds, the Federal Energy Efficiency Fund, utility demand-side management incentives, or some combination of these alternatives in developing a final plan. In doing so, the agency should compare the estimated Net Savings to the government from each alternative financing plan. This comparison should take into consideration any differences in the expected timing with which the different approaches could be implemented. For example, if the ESPC could be implemented immediately but the in-house funding would be delayed for several years, this difference in timing should be reflected in the comparative analysis. The Net Savings approach is outlined in section 6.1 of this handbook.

The following two case examples are provided to demonstrate how ESCO funding can be compared to agency funding for the same project. The first case is based on the assumption that the project will be implemented at the same time whether it is funded as an ESPC or paid for with agency funds. The second case is based on the assumption that the project can be implemented immediately if it is funded by an ESCO, but the project will be delayed by two years if the Government finances the project.

F.2.1 Example: Net Savings Computation for ESPC Versus Agency Funding of an Energy Conservation Retrofit Package in a Federal Facility

ESPC package proposed:

Required investment:	$100,000
Annual energy savings:	$25,000 (at base-date energy prices)
Annual O&M cost:	$5,000 for existing system (at base-date prices), paid by Government $4,000 for new system (at base-date prices), to be paid by ESCO
ESPC contract duration:	8 years
Expected equipment life:	approximately 20 years
Shared savings plan:	90% of energy savings go to ESCO for 8 years, O&M costs paid; 10% of energy savings go to Government for 8 years, O&M costs avoided; after 8 years, all savings go to Government, plus O&M costs incurred
Escalation rates for analysis:	Energy: electricity, region 1, commercial, implicit in table F/Ba-1 in appendix F O&M: same as general inflation (0% differential escalation) DOE discount rate for energy-related projects (d) = 3% (real)

F.2.1.1 Case I. Immediate project implementation

Note: Evaluation of alternatives only needs to be made for the eight year contract life since the savings to the Government in all subsequent years will be the same in either case.

Net Savings with ESPC:

Initial Investment	0
PV energy savings:	$17,500
($2,500, 8 years, UPV*= 7.00)	
PV O&M savings:	$35,100
($5,000, 8 years, UPV = 7.02)	
Net Savings to Government	$52,600

Net Savings with agency funding:

Initial Investment	($100,000)
PV energy savings:	$175,000
($25,000, 8 years, UPV*= 7.00)	
PV O&M savings:	$7,020
($1,000, 8 years, UPV = 7.02)	
Net Savings to Government	$82,020

While the ESPC provides a present-value Net Savings to the Government of $52,600, the use of agency funding for the same project would generate a present-value Net Savings of $82,020. Thus, if agency funding is available, it is the more economic method of financing.

F.2.1.2 Case II. Two-year project implementation delay with agency funding

For the second case, assume that the ESPC can be implemented immediately but that agency funding is not currently available and project implementation would be delayed by two years if agency funding were to be used. Approximately $50,000 in potential energy savings will be foregone if the agency delays project implementation for those two years, although the agency share of those savings would be much smaller.

The Net Savings for each alternative can be compared over a 10-year period since the savings to the Government over years 11-20 will be the same in either case. However, in the case of the two-year delay in implementation, the package will still have two years of life left at the end of 20 years. This remaining life is better handled by assigning a residual value to the package than extending the study period to 22 years, since the latter would require a replacement of the retrofit package at the end of year 20 to force the same study period for both cases. (Net Savings for mutually exclusive project alternatives must be based on the same study period length.) In this example, the residual value at the end of 18 years of service is estimated, based on the straight-line depreciation method, to be 10 percent ($10,000) of its initial cost ((20-18)/20 = 10%). (There is no required method for estimating residual values.) The residual must be discounted to present value over the 20 year study period (SPV = .554 when d = 3 percent).

Net Savings over 10 years with ESPC:

Initial Investment	0
PV energy savings:	$55,750
($2,500, years 1-8, UPV*= 7.00) +	
$25,000, years 9-10, UPV*=(8.53-7.00=1.53)	
PV O&M savings:	36,610
($5,000, years 1-8, UPV=7.02)	
$(1,000, years 9-10, UPV=(8.53-7.02=1.51)	
Net Savings to Government	$92,360

Net Savings over 10 years with agency funding:

PV Initial Investment ($100,000, SPV (2 years)=0.943)	($94,300)
PV residual value at end of year 20 ($10,000, SPV (20 years)=0.554	5,540
PV energy savings: ($25,000, years 3-10, UPV*=(8.53-1.90=6.63)	165,750
PV O&M savings: ($1,000, years 3-10, UPV=(8.53-1.91=6.62)	6,620
Net Savings to Government	$83,610

In this second example, the Net Savings to the Government are greater by implementing the project immediately using an ESPC than by delaying implementation by two years and using agency funding.

GLOSSARY

Because the function of this handbook is to explain and help implement the FEMP LCC Rules, terminology and definitions used in the Rules are presented here. Definitions of additional economic terms used in this handbook are also provided. These terms are defined from the perspective of implementing the FEMP LCC Rules. Defined terms that appear in the definitions of other terms are capitalized.

Adjusted Internal Rate of Return (AIRR) — Annual yield from a project over the Study Period, taking into account reinvestment of interim returns.

Alternative Building System — The installation or modification of a building system intended primarily to reduce operating-related costs, including energy and/or water costs.

Annually Recurring Costs — Those costs which are incurred each year in an equal amount throughout the Study Period, or which change from year to year at a known rate.

Annual Value (Annual Worth) — The time-equivalent value of past, present, or future cash flows expressed as an Annually Recurring Uniform amount over the Study Period.

Annual Value (Annual Worth or Uniform Capital Recovery) Factor — A discount factor by which a present dollar amount may be multiplied to find its equivalent Annual Value, based on a given Discount Rate and a given period of time.

Base Case — The building system against which an Alternative Building System is compared.

Base Date — The beginning of the first year of the Study Period, generally the date on which the Life-Cycle-Cost analysis is conducted.

Base Year — The first year of the Study Period, generally the year in which the Life-Cycle-Cost Analysis is conducted.

Base-Date Price — The price of a good or service as of the Base Date.

Capital Investment Costs — Costs which are paid from capital funding accounts rather than from agency operating funds. For projects subject to the FEMP Rules, these include initial investment, capital replacements, and residual values.

Cash Flow — The stream of costs and savings (expressed for the purpose of this requirement in Constant Dollars) resulting from a project investment.

Compound Interest Factors or Formulas — See Discount Factors or Formulas.

Constant Dollars — Dollars of uniform purchasing power tied to a reference year (usually the Base Year) and exclusive of general price inflation or deflation.

Cost Effective — The condition in which an Alternative Building System saves more than it costs over the Study Period, where all Cash Flows are Discounted to their equivalent value at a common point in time.

Current Dollars — Dollars of nonuniform purchasing power, including general price inflation or deflation, in which actual prices are stated. (With zero inflation or deflation, current dollars are identical to constant dollars.)

Demand Charge — That portion of the charge for electric service based on fixed plant, equipment, and transmission costs associated with providing maximum required capacity.

Differential Cost — The difference in the costs of an Alternative Building System and the Base Case.

Differential Escalation Rate — See Real Escalation Rate

Discount Factor — A multiplicative number used to convert a Cash Flow occurring at a given point in time (usually in the future) to its equivalent value at a common point in time (usually the Base Date).

Discount Formula — An expression of a mathematical relationship which enables the conversion of dollars at a given point in time to their equivalent amount at some other point in time.

Discount Rate — The rate of interest, reflecting the investor's Time Value of Money (or opportunity cost), that is used in Discount Formulas or to select Discount Factors which in turn are used to convert ("discount") Cash Flows to a common time. *Real Discount Rates* reflect Time Value of Money apart from changes in the purchasing power of the dollar and are used to discount Constant Dollar Cash Flows; *Nominal Discount Rates* include changes in the purchasing power of the dollar and are used to discount Current Dollar Cash Flows.

Discounted Payback (DPB) Period — The time required for the cumulative savings from an investment to pay back the Investment Costs and other accrued costs, taking into account the Time Value of Money.

Discounting — A technique for converting Cash Flows occurring over time to time-equivalent values, at a common point in time, adjusting for the Time Value of Money.

Disposal Cost — See Residual Value

Economic Life — That period of time over which a Building or Building System is considered to be the lowest-cost alternative for satisfying a particular need.

Energy Conservation Measure — An installation or modification of an installation in a Building which is primarily intended to reduce energy consumption cost, or allow the use of a renewable energy source.

Energy Cost — The annual cost of fuel or energy used to operate a building or building system, as billed by the utility or supplier (including Demand Charges, if any). Energy Costs are incurred during the Service Period only. Energy consumed in the construction or installation of a new building or building system is not included in this cost.

Escalation Rate — The rate of change in price for a particular good or service (as contrasted with the Inflation Rate, which is for all goods and services). See Real Escalation Rate and Nominal Escalation Rate.

Federal Government — The U.S. Government.

Future Value — The time-equivalent value of past, present, or future Cash Flows expressed as of some future point in time.

Inflation — A rise in the general price level, i.e., the price level for all goods and services. (A negative change in the general price level is called "Deflation.")

Initial Investment Costs — The initial costs of design, engineering, purchase and installation, exclusive of "Sunk Costs," all of which are assumed to occur as a lump sum at the beginning of the Base Year or phased in during the Planning/Construction Period.

Internal Rate of Return — Annual yield from a project over the Study Period, i.e., the compound rate of interest which, when used to discount Cash Flows of an Alternative Building System, will result in zero Net Savings (Net Benefits).

Investment Costs — The Initial Investment Cost of a building or building system and capital Replacement Costs, less Residual Value, plus Disposal Cost, if any.

Life-Cycle Cost (LCC) — The total discounted dollar costs of owning, operating, maintaining, and disposing of a building or building system over the appropriate Study Period (see Life-Cycle Cost Analysis).

Life-Cycle Cost Analysis (LCCA) — A general approach to economic evaluation that encompasses several related economic evaluation measures, including Life-Cycle Cost (LCC), Net Benefits (NB) or Net Savings (NS), Savings-to-Investment Ratio (SIR), and Adjusted Internal Rate of Return (AIRR), all of which take into account all dollar costs related to owning, operating, maintaining, and disposing of a project over the appropriate Study Period.

Liquid Petroleum Gas (LPG) — Propane, butane, ethane, pentane, or natural gasoline.

Measures of Economic Evaluation — The various ways in which project cash flows can be combined and presented to describe a measure of project cost effectiveness. The measures used to evaluate FEMP projects are Life-Cycle Cost (LCC), Net Savings (NS), Savings-to-Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR). Discounted Payback (DPB) and Simple Payback (SPB) are measures of evaluation not fully consistent with the LCCA but are used as supplementary measures in some federal programs.

Modified Uniform Present Value (Worth) (UPV* or UPW*) Factor — A discount factor used to convert an annual amount, changing from year to year at a given escalation rate, to a time-equivalent Present Value. The FEMP UPV* Factor indicates a discount factor published in the Annual Supplement to Handbook 135 for use in computing present-value energy costs, based on energy price escalation rates provided for this purpose by DOE's Energy Information Administration.

Mutually Exclusive Projects — Projects where the acceptance of one precludes acceptance of the others. Examples are whether to use single-glazing, double glazing or triple-glazing for a window; or R11, R19, or R30 levels of insulation in an attic.

Net Savings (NS) or Net Benefits (NB) — Time-adjusted savings or benefits less time-adjusted differential costs taken over the Study Period, for an Alternative Building System relative to the Base Case.

Nominal Discount Rate — The rate of interest (market interest rate) reflecting the time value of money stemming from both inflation and the real earning power of money over time.

Nominal Escalation Rate — The projected annual rate of change in actual (market) prices for a particular good or service.

Operational Costs — See Operating, Maintenance, and Repair Costs

Operating, Maintenance, and Repair (OM&R) Costs — Non-investment costs related to the use of a building or building system, including energy and water costs.

Planning/Construction (P/C) Period — The period beginning with the Base Date and continuing up to the Service Date during which only Initial Investment Costs are incurred.

Present Value (Present Worth) — The time-equivalent value of past, present or future Cash Flows as of the beginning of the Base Year.

Present Value (Present Worth) Factor — A discount factor by which a future dollar amount may be multiplied to find its equivalent Present Value as of the Base Date. Single Present Value Factors are used to convert single future amounts to Present Values. Uniform Present Value Factors and Modified Present Value Factors are used to convert Annually Recurring amounts to Present Values.

Real Discount Rate — The rate of interest reflecting the portion of the time value of money attributable to the real earning power of money over time and not to general price inflation.

Real Escalation Rate — The difference between the rate of annual price change for a particular good or service and the rate of general Inflation.

Renewable Energy — Energy obtained from sources that are essentially inexhaustible (unlike, for instance, fossil fuels of which there is a limited supply). Renewable sources of energy include wind energy, geothermal energy, hydroelectric energy, photovoltaic and solar energy, biomass, and waste.

Replacement Costs — Capital costs incurred to replace the project during the Study Period. Sometimes referred to as Capital Replacement Costs. Replacement costs as used in this handbook do not include the cost of replacing system components that are paid out of current operating budgets; these are considered to be Operation-Related Costs.

Resale Value — See Residual Value

Residual Value — The estimated value, net of any Disposal Costs, of any building or building system removed or replaced during the Study Period, or remaining at the end of the Study Period, or recovered through resale or reuse at the end of the Study Period (also called Resale Value, Salvage Value, or Retention Value).

Retention Value — See Residual Value

Retrofit — The installation of an Alternative Building System into an existing building.

Risk Attitude — The willingness of decision makers to take chances or to gamble on investments of uncertain outcome. Risk attitudes are generally classified as *risk-averse, risk-neutral,* or *risk-taking*.

Risk Exposure — The probability of investing in a project whose economic outcome is less favorable than what is economically acceptable.

Salvage Value — See Residual Value

Savings-to-Investment Ratio (SIR) — A ratio of economic performance computed from a numerator of discounted energy and/or water savings, plus (less) savings (increases) in other operation-related costs, and a denominator of increased Initial Investment Costs plus (less) increased (decreased) Replacement Costs, net of Residual Value (all in present-value terms), for an Alternative Building System as compared with a Base Case.

Sensitivity Analysis — Testing the outcome of an evaluation to changes in the values of one or more system parameters from the initially assumed values.

Service Date — The point in time during the Study Period when a building or building system is put into use, and operation-related costs (including energy and water costs) begin to be incurred.

Service Period — The period of time starting with the Service Date and continuing through the end of the Study Period.

Simple Payback (SPB) Period — A measure of the length of time required for the cumulative savings from a project to recover its Initial Investment Cost and other accrued costs, without taking into account the Time Value of Money. SPB is usually measured from the Service Date of a project.

Single Present Value (Worth) (SPV or SPW) Factor — The discount factor used to convert single future benefit and cost amounts to Present Value.

Study Period — The length of the time period covered by the economic evaluation. This includes both the Planning/Construction Period and the Service Period.

Sunk Costs — Costs which have been incurred or committed to prior to the Life-Cycle Cost analysis. These costs should not be considered in making a current project decision.

Time-of-Use Rate — Charges for service (usually electricity) that vary from period to period, based on the cost of supplying the service during that period.

Time-Value of Money — The time-dependent value of money, reflecting the opportunity cost of capital to the investor during that time period. See Discount Rate.

Uniform Present Value (Worth) (UPV or UPW) Factor — The discount factor used to convert uniform annual values to a time-equivalent Present Value.

Useful Life — The period of time over which a Building or Building System continues to generate benefits or savings.

SYMBOLS AND ABBREVIATIONS

AIRR — Adjusted Internal Rate of Return

ASEAM — A Simplified Energy Analysis Method Computer Program

BLCC — The Building Life-Cycle Cost Computer Program

Btu — British Thermal Units

DoD — Department of Defense

DOE — Department of Energy

DPB — Discounted Payback

ESCO — Energy Service Company

ESCP — Energy Savings Performance Contract

FEMP — Federal Energy Management Program

HVAC — Heating, Ventilation and Air Conditioning

GJ — Gigajoule (10^9 joules)

kWh — Kilowatt Hours

LCC — Life-Cycle Costs or Life-Cycle Costing

MBtu — 10^6 x Btu

NS — Net Savings

OM&R — Operation, Maintenance, and (Routine) Repairs

OMB — Office of Management and Budget

PB — Payback

SIR — Savings-to-Investment Ratio

SPB — Simple Payback

SPV — Single Present Value (Factor)

TLCC — Total Life-Cycle Costs

UPV — Uniform Present Value (Factor)

UPV* — Modified Uniform Present Value (Factor)

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