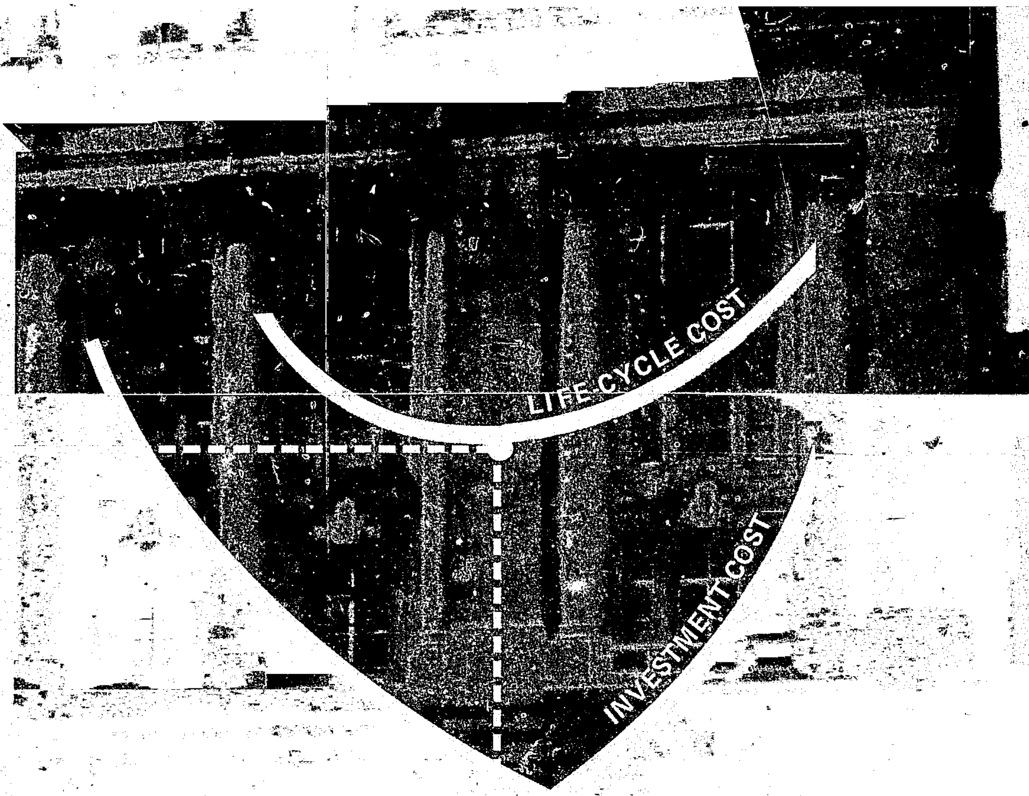

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NBS Building Science Series 113

Life-Cycle Costing

A Guide for Selecting Energy Conservation Projects for Public Buildings

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PREFACE

This report is addressed primarily to managers and operators of all types of buildings owned or leased by Federal, State, or local government, including office buildings, hospitals, schools, and residential buildings. It is also applicable to energy conservation investments in buildings operated by nonprofit, tax-exempt organizations. Because it does not include tax effects, the report will be less useful to the owners, managers, and operators of privately-owned buildings. However, aside from the treatment of taxes, the approach is generally applicable to the evaluation of energy conservation in privately owned buildings.

The report was prepared by the National Bureau of Standards and sponsored by the U.S. Department of Energy. It was developed from life-cycle costing guidelines for energy conservation in Federal buildings prepared by the National Bureau of Standards in support of the Federal Energy Management Program.

The preparation of guidelines for the Federal Energy Management Program was required by Executive Order 12003, "Relating to Energy Policy and Conservation," signed by President Carter on July 20, 1977. The Executive Order established goals for Federal agencies in energy conservation. The goals are to achieve by 1985, a reduction of 20 percent of the average annual energy use per gross square foot of floor area for the total of all Federally owned existing buildings, and a reduction of 45 percent, for the total of all Federally owned new buildings.

The Executive Order further directed Federal agencies to consider in their building plans only those energy conservation improvements which are cost effective based on a life-cycle cost approach, and to give the highest priority to the most cost effective projects. It requires that the determination of cost effectiveness be consistent with criteria established by U.S. Office of Management and Budget (OMB) Circular No. A-94, "Discount Rates to be used in Evaluating Time-Distributed Costs and Benefits," dated March 27, 1972. The Executive Order also required that the Department of Energy provide guidelines to Federal agencies for estimating life-cycle costs and savings of proposed energy conservation improvements, and for comparing their cost effectiveness in a uniform and consistent manner from agency to agency.

The life-cycle costing guidelines for Federal buildings — upon which this report is based — contain certain specific instructions for Federal agencies that are not necessarily applicable to the analysis of energy conservation in State and local buildings. In order to broaden the applicability of the material for analysis of State and local government buildings, a distinction is made in this report between the general requirements of an economic evaluation and the specific set of economic criteria that should be followed in selecting energy conservation projects in Federal buildings. The report also indicates to some extent the economic criterion that applies to the Department of Energy Grants Program for Technical Assistance Programs and Energy Conservation Projects in Schools, Hospitals, Local Government and Public Care Buildings, a program that is exempt from the requirements of OMB Circular A-94.

The guidelines for the Federal Energy Management Program and for the Federal Grant Program are, however, not final at the printing of this report. Therefore, analysts who need to comply with the specific requirements of these Federal programs should refer to the Department of Energy's Program Rules, expected to be released later this year. Information on the Federal Energy Management Program and on the Department of Energy Grants Program for Technical Assistance Programs and Energy Conservation Projects in Schools, Hospitals, Local Government and Public Care Buildings can be obtained from the Department of Energy, Office of Conservation and Solar Applications, Washington, D.C. 20461.

ACKNOWLEDGEMENTS

This report was prepared in the Applied Economics Program of the National Bureau of Standards under the leadership of Rosalie T. Ruegg, with the support of John S. McConnaughey, G. Thomas Sav, and Kimberly A. Hockenbery.

The authors which to thank Harold E. Marshall, Chief of the Applied Economics Program, Stephen Weber, and Phillip T. Chen, also of the Applied Economics Program, for their valuable comments and assistance. George E. Turner, Daniel H. Nall, Thomas P. Frazier, and William G. Hall, all of the National Bureau of Standards were helpful in reviewing the draft report.

Appreciation is also extended to the representatives of an interagency life-cycle cost task force, organized by the Department of Energy, for their advice on the preparation of the guidelines for Federal buildings that preceded this report. Representatives to the task force were Michael Walsh, Department of Energy; Virgil Ostrander, General Services Administration; John Williams, Department of the Navy; Frank Durso, National Aeronautics and Space Administration; Paul Neal, Department of the Air Force; Lawrence Schindler, Department of Defense; and R.R. Huber and John Sisty, Veterans Administration.

Special credit is due to John Anderson of the Department of Energy who coordinated the Task Force, oversaw the preparation of the Federal guidelines, and offered valuable comments on this report.

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ABSTRACT

This report provides a step-by-step guide for conducting life-cycle cost evaluations of energy conservation projects for public buildings. It explains the use of life-cycle costing analysis to evaluate and rank the cost effectiveness of alternative energy conservation retrofit projects to existing public buildings, and to select the most cost-effective design for new buildings. Worksheets, illustrated with a realistic example, and a computer program are provided.

This guide is compatible with a life-cycle costing guide prepared for the Department of Energy for use in the Federal Energy Management Program by Federal Agencies. The purpose of this report is to provide a guide to state and local governments for use in their energy conservation programs.

Key words: Building economics; economic analysis; energy conservation; engineering economics; investment analysis; life-cycle cost analysis.

1. INTRODUCTION

This report has been prepared to assist Federal, State, and local government officials in evaluating energy conservation projects in public buildings, including residential, commercial, and industrial buildings. It explains the basic concepts needed to understand the life-cycle costing (LCC) evaluation method, discusses the choice of basic assumptions and evaluation criteria, and provides computational aids in the form of worksheets, a nomogram, and a computer program for deriving cost effectiveness measures.

While most other books and reports on life-cycle costing[1] describe the general LCC methodology, this report

[1] An annotated list of selected references on life-cycle

focuses on the establishment of a technically correct, practical, standardized approach for evaluating proposed energy conservation improvements in public buildings. Its emphasis is on performing the LCC evaluation of energy conservation investments; it is not intended as a guide to identifying specific energy conservation projects, nor a guide to calculating energy consumption.[2]

Based on the evaluation approach presented here, the cost effectiveness of alternative projects can be compared in a uniform and consistent manner from agency to agency. This will assist agencies in selecting and giving highest priority to those projects which are most cost effective. (For a definition of economic terms used in this report, see Appendix A.)

1.1 BACKGROUND

The material from which this report was developed was prepared in support of the Federal Energy Management Program, as required by Executive Order 12003 [17]. In order to promote consistency and uniformity among Federal agencies in their use of LCC analysis for evaluating energy conservation projects in Federal buildings, the Executive Order called for the preparation of Federal guidelines for life-cycle costing. The basic material from that effort has been broadened here for application to State and local government buildings. State and local units of governments, like Federal agencies, require consistent LCC measures to allocate limited funds among competing energy conservation projects and to participate with other governmental units in State, regional, and Federal programs for energy conservation. For this reason, the specific evaluation guidelines that were developed to promote consistency among Federal agencies are contained in the following discussion of the general requirements for performing LCC analysis of energy conservation projects.

The State Energy Conservation Program, which was established by the Energy Policy and Conservation Act (EPCA) of 1975, has been instrumental in stimulating energy conservation efforts in the States [18]. Over a three-year period (FY 1976-78), $150 million was authorized to assist states in developing energy conservation programs. To be eligible for Federal funds, States were required to establish certain standards, requirements, and policies by January 1978, among which were

- lighting efficiency standards for public buildings,
- energy efficiency standards and policies to govern procurement practices, and
- thermal efficiency standards and insulation requirements for new and renovated buildings.

Virtually every State plan prepared under this program mentions the use of LCC or some other type of energy/cost performance criteria to be implemented as part of EPCA. In addition, these plans indicate a trend toward development of training programs, seminars, and workshops to encourage the use of LCC or other procurement techniques suitable for encouraging energy conservation in products purchased.[3]

Many States are utilizing LCC analysis in conjunction with their energy conservation programs for public buildings under state domain. The State of Washington, for example, is designing an LCC analysis technology transfer program to provide assistance to local governments in adopting State energy conservation procedures. The California Energy Commission was mandated by legislation to develop a life-cycle cost procedure for use by State agencies and the general public by July 1, 1978 [16].

During its more than 20 years of existence and application, life-cycle costing has become a generally accepted means, in both the public and private sectors, of recognizing the sum total of all costs (and benefits) associated with a project during its estimated lifetime. As experience has grown, the application of LCC techniques has become increasingly sophisticated, evolving from the use of simple manual calculations to complex computer programs that require vast data bases. Many government agencies are currently using LCC or other economic evaluation techniques, but differences exist in applications and in technical criteria. Thus, while the LCC technique is not new, there is a lack of uniformity and consistency in its use.

In order to facilitate a uniform LCC approach, this report provides basic ground rules, assumptions, definitions, and requirements for using the LCC methodology. It may be used in conjunction with existing calculation techniques or models for estimating specific LCC parameters such as initial investment costs, future energy costs, or maintenance costs, provided that these techniques or models satisfy the criteria included here.

1.2 THE LCC CONCEPT: AN OVERVIEW

LCC analysis is a method of economic evaluation of alternatives which considers all relevant costs (and

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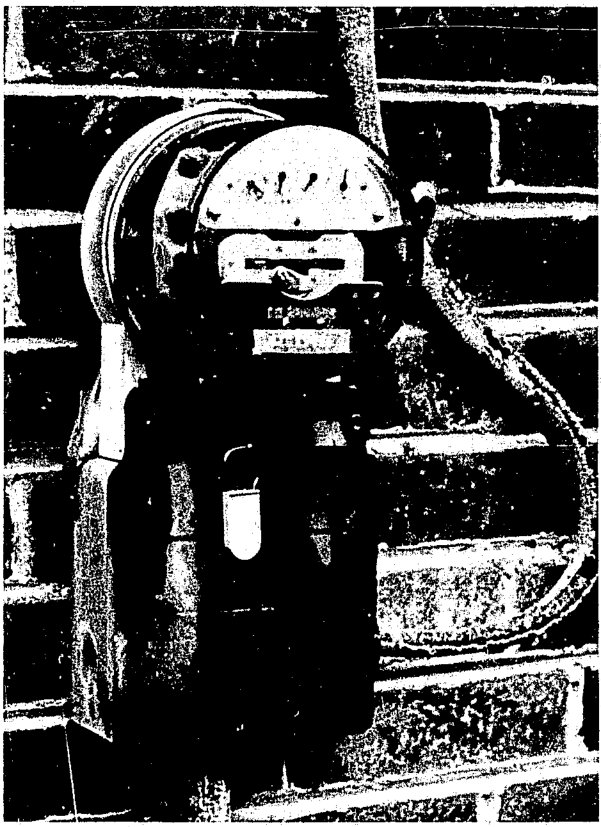
costing is provided in Appendix E. See references [1-7].

[2] For guidance in identifying potential energy conservation projects for public buildings, in calculating energy consumption, and in planning and carrying out energy conservation programs, the reader may consult references [8 through 16] in Appendix E.

[3] Background information on the current regulatory status and degree of implementation of building energy conservation projects at the State level are described in reference [19].



benefits)[4] associated with each alternative activity or project over its life. As applied to energy conservation projects in buildings, LCC analysis provides an evaluation of the net effect, over time, of reducing fuel costs by purchasing, installing, maintaining, operating, repairing, and replacing energy-conserving features.

LCC analysis is primarily suited for the economic comparison of alternatives. Its emphasis is on determining how to allocate a given budget among competing projects so as to maximize the overall net return from that budget. The LCC method is used to *select* energy conservation projects for which budget estimates must be made; however, the *LCC cost estimates are not appropriate as budget estimates,* because they are expressed in constant dollars (excluding inflation) and all dollar cash flows are converted to a common point in time. Hence, LCC estimates are not necessarily equivalent to the obligated amounts required in the funding years.

The results of LCC analyses are usually expressed in either present value dollars,[5] uniform annual value dollars,[6] as a ratio of present or annual value dollar savings to present or annual value dollar costs (referred to here as the savings-to-investment ratio or SIR), or as a percentage rate of return on the investment. Although it is not in a strict sense an LCC measure, the time until the initial investment is recouped (Payback) is another form that is sometimes used to report the results of an LCC analysis. To derive any of these measures, it is important to adjust for differences in the timing of expenditures and cost savings. This time adjustment can be accomplished by a technique called "discounting."

The major steps for performing an LCC analysis of energy conservation investments are the following:

(1) Identify the alternative approaches to achieve the objective of reducing consumption of nonrenewable energy, as well as any constraints that must be imposed such as the level of thermal comfort required.
(2) Establish a common time basis for expressing LCC values, a study period for the analysis, and the economic lives of major assets.
(3) Identify and estimate the cost (and benefit) parameters to be considered in the analysis.
(4) Convert costs and savings occurring at different times to a common time.
(5) Compare the investment alternatives in terms of their relative economic efficiencies in order to select the energy conservation projects that will result in the largest savings of nonrenewable energy costs possible for a given budget and constraints.
(6) Analyze the results for sensitivity to the initial assumptions.

1.3 ORGANIZATION

A more detailed description of the basic LCC procedures is given in the following section. The application of LCC

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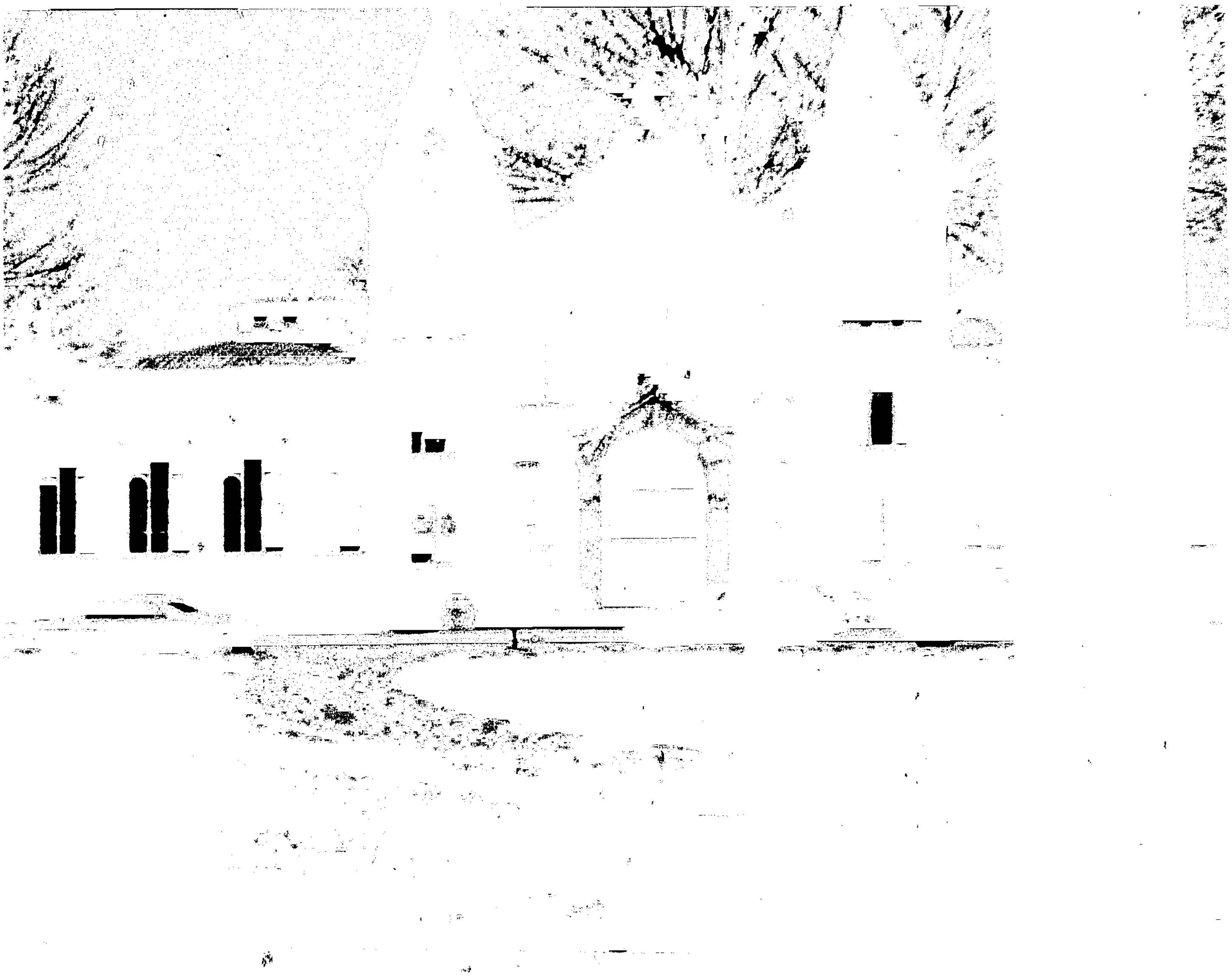
[4] In evaluating energy conservation investments, it is important to account for any significant differences in the benefits of alternatives, such as the effects on the comfort and productivity of a building's occupants.

[5] Expressing LCC estimates in present value dollars means converting all past and future cash flows associated with an investment to their equivalent value at the present time, taking into account the time value of money, and adding them to first costs, which are already expressed in present value terms. This process is explained in Section 2.4.

[6] Expressing LCC estimates in uniform annual value dollars means converting all past, present, and future cash flows to their equivalent value in terms of a series of level, annual amounts, taking into account the time value of money; e.g., mortgage loan payments are usually calculated using the uniform annual value method, except that the year is generally divided into 12 interest periods. The process of computing annual value is explained in Section 2.4.

procedures to the evaluation of retrofit projects for energy conservation in existing buildings is described in Section 3.0. Worksheets, instructions and a sample problem are provided for calculating the LCC ranking measure for retrofit projects. The application of LCC procedures to energy conservation designs for new buildings is described in Section 4.0, and worksheets and instructions for evaluating the life-cycle costs of new design alternatives are given. The use of LCC procedures to evaluate investments in solar energy is discussed in Section 5.0. The LCC evaluation of conservation actions for leased buildings is discussed in Section 6.0. A summary listing of selected LCC criteria to facilitate uniformity in evaluation measures is given in Section 7.0. Selected economic terms are defined in Appendix A to encourage consistent usage. Discount formulas and selected tables of discount factors are provided in Appendix B for the convenience of the analyst performing LCC evaluations. A complete set of blank worksheets for computing LCC measures are provided in Appendix C. A computer program for performing the same LCC calculations as provided by the worksheets is listed in Appendix D. An annotated list of selected references pertaining to LCC analysis and to energy conservation is given in Appendix E.



2. BASIC LCC PROCEDURES

2.1 IDENTIFYING THE ALTERNATIVES

For existing buildings, energy conserving modifications (retrofits) may be made to the building envelope, equipment, systems, and components. For example, alternative retrofits may include adding insulation to the exterior envelope, replacing existing windows with more energy conserving window systems, adding a solar energy system, or upgrading the efficiency of the existing heating and cooling system. Extensive retro-fitting may involve complete renovation of the building.

In the case of new buildings, it may be possible to use alternative designs, building sites, and materials to reduce energy consumption. For example, a building may be designed for passivc utilization of solar energy.

In either existing or new buildings, operation and maintenance practices may be altered to conserve energy. For example, an increased frequency of scheduled maintenance may be found to improve the efficiency of equipment and to reduce its energy usage.

2.2 TIME CONSIDERATIONS

To perform LCC analysis, it is necessary to establish a base time so that all present, past, and future costs can be converted to a common dollar measure at that base time. If LCC estimates are to be expressed in present value dollars, the base time is the present (the time at which the LCC analysis is being conducted). If LCC estimates are to be expressed in annual value dollars, the base time is actually a series of time periods of equal intervals (e.g., years) extending over the period of the analysis.

An LCC analysis requires the estimation of the economic life expectancies of the principal assets associated with each investment alternative. The economic life is that period over which the asset is expected to be retained in use as the lowest cost alternative for satisfying its intended purpose. The economic life of the building, equipment, systems or components is often difficult to determine. Generally, the facility engineer will determine life based on available technical manuals, information from manufacturers and distributors, expectations for obsolescense, and information of the average lives of generic types of plants and equipment.[7]

It is also necessary for the analyst to specify the length of time, or study period, over which an investment is to be evaluated. In specifying the study period, it is important that (1) all mutually exclusive alternatives[8] be evaluated on the basis of the same study period, (2) the study period not exceed the period of intended use of the facility in which the energy conservation investment is to be made, and (3) if alternatives are evaluated for a period shorter or longer than the estimated lives of the principal assets, any significant salvage values or replacement costs should be taken into account.

One of the following four approaches is usually taken to establish the study period: (1) If it is assumed that the facility is to be used indefinitely, the study period can also be assumed to be infinite, and costs can be evaluated in annual value dollars based on the economic life of each alternative investment. For example, the annual cost of a 10-year life investment is calculated on the basis of 10 years and the annual cost of an alternative 15-year life investment is based on 15 years. Then it is assumed that either would be used indefinitely through a series of replacements. This approach can in some cases simplify calculations because it eliminates the need to consider replacements and salvage values. (2) The study period can be set equal to a period of time that allows coincidence of the expiration of alternative investments. For example, in comparing an investment with a 10-year life to one with a 15-year life, the study period would be set equal to 30 years, with three renewals of the first investment and two renewals of the second. This approach is often taken to evaluate alternatives over an equal period of time when results are to be measured in present value dollars. (3) The study period may be a finite period of time set to reflect the period of intended use of the investment or of the facility in which the investment is to be made. (4) Alternatively, the study period may be set equal to some other finite period to reflect other constraints, such as the time over which costs and benefits can be estimated with some degree of accuracy. Both the third and fourth approaches require the inclusion of any relevant replacements or salvage values when the study period does not coincide with the expected lives of the various alternatives. It is also important in both approaches that mutually exclusive alternatives to accomplish a given objective (e.g., solar screens of type A versus solar screens of type B) be evaluated for the same finite study period.

It is unnecessary, however, to evaluate retrofit projects that are not mutually exclusive on the basis of a common study period for purpose of comparing and ranking them. For example, alternative solar energy systems for application to Building A may be evaluated over a study period of, say, 25 years; alternative heat recovery systems also for Building A may be evaluated over a period of, say, 15 years; and alternative new plant control systems for Building B may be evaluated over a period of, say, 10 years. The economic ranking measure for each of the alternatives selected – each based on its respective study period – can then be compared without the need to convert all of the projects to the same study period.

Due to uncertainties in forecasting future energy prices and in order to promote consistency among agencies, an *upper limit* of 25 years is imposed on the study period for analyzing energy conservation projects in existing buildings in the Federal Energy Management Program.

2.3 IDENTIFYING THE LCC PARAMETERS

The costs of owning, operating and maintaining an asset over a period of time are traditionally separated into initial (investment) costs and future (operation, maintenance, repair, and replacement) costs. The investment costs include all first costs that arise directly from the project, including special site-specific studies, design, and installation or construction costs, i.e., all costs

[7] See, for example, reference [3], pp. B-1 to B-4.

[8] "Mutually exclusive" means that if one alternative is chosen, the other alternatives will not be chosen; e.g., if for a given window area, double-glazed windows are used, triple-glazed windows will not be used.

necessary to provide the finished project ready for use. All investment costs should be taken into account in evaluating alternatives. Sunk costs (that is, costs incurred prior to making the LCC analysis) should not be included. Those costs for studies, analyses, etc., which are not due directly to a specific project, such as costs for preliminary energy audits or energy surveys, should not be included as an investment cost for the purpose of evaluating a given project.

Future costs can be divided into energy and non-energy costs. Energy costs are defined here as the dollar cost of delivered energy at the building or facility boundary. Estimates of energy costs are a critical data input to the LCC evaluation. For an existing building, estimates will be needed of the building's energy requirements before it is retrofitted, and projections will be needed of its expected energy requirements after specific retrofit actions have been taken.[9] For new buildings, it will be necessary to estimate the expected energy requirements of alternative building and system designs.

Energy requirements may be estimated at varying levels of analytical detail, utilizing past records of energy usage, walk-through surveys of facilities, reviews of specifications and drawings, engineering test data and computer analysis of energy flows. Once the impact of a given energy conservation investment has been estimated, future dollar energy savings can be projected by first determining the value of the expected yearly energy savings in today's prices, and then adjusting yearly dollar savings to reflect expected increases in energy prices over the study period.

Guidelines for estimating the energy requirements of Federal buildings are provided in the Program Rules of the Federal Energy Management Program. Projections for estimating increases in energy prices are currently being developed by the Department of Energy.[10]

Non-energy costs are maintenance, repair, replacement, and future non-energy operating costs such as operating personnel costs. For new buildings, where LCC analysis is used to determine the basic building design, future non-energy costs may also include functional-use costs, i.e., non-maintenance costs associated with performing the intended function of the building. For example, the shape of a building may affect not only its energy requirements, but also its ability to serve its intended purpose.

The implementation of some energy conservation improvements may have little or no effect on maintenance, repair, or replacement costs (e.g., installing insulation in the roof of a building). If these costs are not significantly affected, they may be excluded from the analysis. Where non-energy cost changes are significant, they should be included in the analysis.

Differences in benefits from alternative investments in energy conservation should also be taken into account wherever they are significant. For example, an energy conserving lighting system may adversely affect the quality of lighting, and, thereby, affect worker productivity in a significant way. A comparison of alternative energy conservation investments based solely on their energy savings and direct costs is valid *only* if the investments have no other important consequences.

2.4 CONVERTING COSTS AND SAVINGS TO A COMMON TIME AND COMMON DOLLAR MEASURE

The costs and savings associated with investments in energy conservation are typically spread out over time. It is necessary to convert costs and savings to a common time and a common dollar measure to account for the time value (or opportunity cost) of money. The time value of money means that there is a difference between the value of a dollar today and its value at some future time. The time dependency of value reflects not only inflation, which may erode the buying power of the dollar, but also the fact that money currently in hand can be invested to earn a real return, i.e., it has a real opportunity cost.

[9] For guidance in identifying potential retrofit projects, see references [8 and 12 through 15]. For guidance in planning, managing, and implementing energy conservation projects and in determining energy requirements, see references [8 through 11 and 15 and 16].

[10] An example of previous projections of energy prices is the Department of Energy's (DOE) Project Independence Evaluation System (PIES) [20]. The PIES projects will be replaced by the new projections currently in preparation by DOE. PIES projections will not be used either for the Federal Energy Management Program or the Federal Grants Program.

Inflation. The adjustment of costs and savings to account for inflation and for the real opportunity cost of money can be accomplished in several ways. If future estimates of costs and savings include an inflation factor (expected price changes), it is necessary to remove the inflation factor so that all values are expressed in constant dollars. This is important, because an economic evaluation makes no sense if it is made in variable-value dollars.

Inflation may be eliminated from the evaluation in any of three ways: (1) One way is simply to state estimates of future prices in constant dollars at the outset. This may be done by assuming that inflationary effects will cancel out, leaving base year prices as good indicators of future constant dollar prices. Using this approach, any future prices that are expected to increase differently from general price inflation must be adjusted to include the amounts of the expected differential rates of change. For example, it may be assumed that the price of labor to perform a given maintenance service will remain at today's level in constant dollar terms, but that energy prices will rise above today's level in constant dollars, i.e., they will increase faster than general price inflation, say, 3 percent faster for purposes of illustration. Today's prices for labor could then be used without adjustment for the purpose of estimating future maintenance costs, but today's prices for energy would need to be escalated at a rate of 3 percent per year for use in measuring future energy costs. Future amounts that are fixed in base year dollars, for example, level mortgage payments, do not inflate with other costs and savings. Because they do not inflate, fixed payments decline in constant dollars as inflation occurs. To convert fixed amounts in future years to constant dollars requires the use of a constant dollar price deflator.[11] If future prices are given in constant dollars, the real opportunity cost of money can subsequently be taken into account by using a technique called "discounting." The technique will in this case employ a *real* discount rate that also excludes inflation. (Discounting is explained in more detail below.)

(2) A second way to eliminate inflation, used when the estimates of future costs and savings are not in constant dollars, is to apply a constant dollar price deflator to the estimates of all future costs and savings.[12] The deflator would be applied to fixed, as well as nonfixed, future amounts. In this case, the subsequent adjustment for the real opportunity cost of money is performed as above, employing a real discount rate (one that excludes inflation).

(3) A third way of dealing with inflation, also used when the estimates of future cash flows are not in constant dollars, is to combine the adjustment for inflation with the adjustment for the real opportunity cost of capital. This can be done by discounting future costs and savings stated in current dollars with a nominal discount rate, i.e. a rate that includes both the real opportunity cost of capital and the expected rate of inflation.

OMB Circular A-94 requires Federal agencies to express future cash flows in constant dollars, i.e., to remove inflation from the estimates of future costs and savings prior to discounting. Only those expected price changes over and above the general inflation rate (i.e., differential change) can be included in estimates of future cash flows. This is the first way of treating inflation listed above. This is the approach that is to be followed for the Federal Management Program and the Federal Grants Program, where differential price changes are generally allowable only in the case of projecting future energy prices. It is also the approach to be followed in the Federal Grants Program, although the Grants Program is exempt from OMB Circular A-94.

Discounting. Discounting is performed by applying interest (discount) formulas, or corresponding discount factors calculated from the formulas, to the estimated costs and savings resulting from a given investment. The application of the appropriate formula or factor to a cash flow will convert that cost or saving to its equivalent value at the selected point in time.

The commonly used discount formulas and corresponding tables of discount factors, calculated for specific time periods and interest (or discount) rates, are provided in Appendix B. The algebraic equation, notation, and intended use are given for each formula. The factors are more convenient to use and give the same results as the formulas.

The appropriate formula, or factor, to use depends on the timing of the cost or savings, and on the time basis selected by the analyst for the economic evaluation. It is often necessary to use several different discounting formulas or factors to evaluate a given investment.

Table 1 illustrates the use of four different discount formulas and factors to convert four different types of costs and savings to a common time. A past cost, a future recurring cost, a future non-recurring cost, and future energy savings are all expressed as though they were to be incurred now. The result obtained is called a present value.

The Federal Energy Management Program provides for the conversion of costs and savings to present values. Although the use of present value is emphasized in the descriptions and worksheets, agencies may also use annual values.

Discount Rates. As demonstrated in the examples of

[11] The derivation of a constant dollar price deflator and its use are demonstrated in reference [21] in Appendix E.

[12] Price indices and an explanation of their use can be found in reference [22] in Appendix E.

TABLE 1

Computing the Present Value of Cost and Savings Occurring at Different Times[a]

Type of Cash Flow	Description	Appropriate Discount Formula[b]	Computation by Discount Formula	Computation by Discount Factor	Source of Discount Factor[c]
(1) Past Cost (Design)	$100 cost incurred 2 years past	Single Compound Amount $P = T\,(1+i)^N$	$P = \$100\,(1+.10)^2$ $= \$121$	P = $100 (1.2100) = $121	Table B-4 Year 1, i=10%
(2) Future Recurring Cost (Maintenance)	$100 cost per year over 20 years	Uniform Present Value $P = A \cdot [\frac{(1+i)^N - 1}{i\,(1+i)^N}]$	$P = \$100\,\frac{(1+.10)^{20} - 1}{.10\,(1+.10)^{20}}$ $= \$851.35$	P = $100 (8.5135) = $851.35	Table B-3 Year 1, i=20% e=0%
(3) Future Non-Recurring Cost (Repair and Replacement)	$100 replacement cost incurred in the 10th year	Single Present Value $P = F\frac{1}{(1+i)^N}$	$P = \$100\,\frac{1}{(1+.10)^{10}}$ $= \$38.55$	P = $100 (0.3855) = $38.55	Table B-2 Year 10, i=10% e=0%
(4) Future Savings (Energy)	$100 energy savings priced in base period dollars, escalated at 5 percent yearly, over 20 years	Uniform Present Value, Modified $P = A \cdot \sum_{j=1}^{N} (\frac{1+e}{1+i})^j$ $= A \cdot (\frac{1+e}{i-e})(1 - \left(\frac{1+e}{1+i}\right)^N)$	$P = \$100\,(\frac{1+.05}{.10-.05})(1 - \left(\frac{1+.05}{1+.10}\right)^{20})$ $= \$1271.77$	P = $100 (12.7178) = $1271.78	Table B-3 Year 20, i=10% e=5%

[a] A 10 percent real discount rate, constant dollars, and end-of-period cash flows are assumed throughout.

[b] Notation: P = present value; T = past value; F = future value; A = end-of-year recurring value; i = discount rate; N = number of interest periods; e = price escalation rate

[c] Note that in both Tables B-2 and B-3, the "0%" column reflects a 10 percent discount rate without any offsetting price escalation. This column is used in conjunction with the Federal Energy Management Program and the Federal Grant Program to determine the present value factor for all non-energy items.

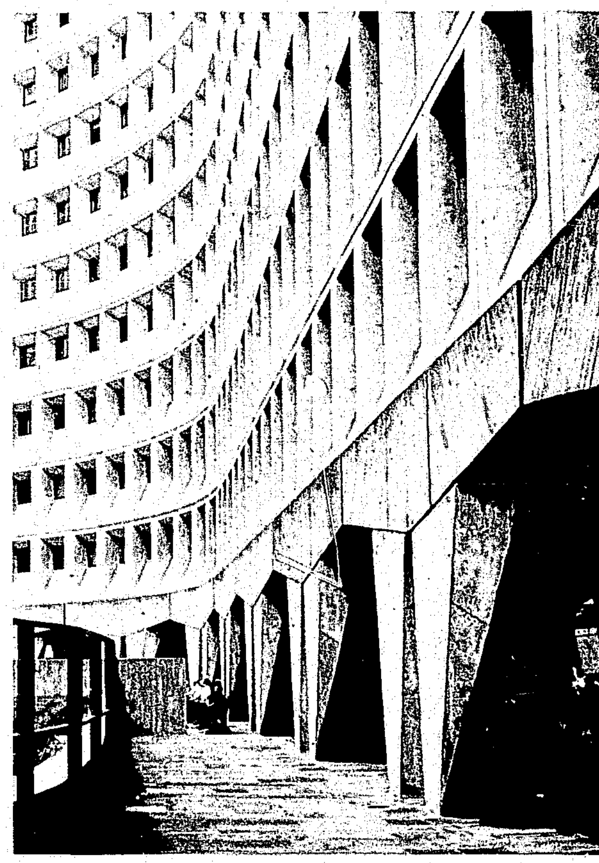
Table 1, it is necessary to select a discount rate to perform discounting. The purpose of the discount rate is to reflect the fact that money in hand can command resources that earn a return; i.e., to reflect the opportunity cost of money. The discount rate can be selected to include inflation, in addition to the real opportunity cost of money (i.e., a nominal discount rate), or it can be stated exclusive of inflation (i.e., a real discount rate).

In both the public and private sectors, a wide range of rates are used to discount cash flows. Discount rates typically range from rates as low as 2-3 percent to rates higher than 20 percent. The choice of rates can significantly affect the outcome of an evaluation. The higher the rate, the lower the value of future cash flows.

OMB Circular A-94 requires Federal agencies to use a real discount rate of 10 percent to evaluate most Federal investment decisions.[13] The real 10 percent rate is required for the purpose of both the Federal Management Program and the Federal Grants Program, although the latter program is not subject to Circular A-94.

Timing of Cash Flows. To discount, it is also necessary to make an assumption about the timing of cash flows within the year of occurrence. In practice, cash flows usually occur throughout the year, and may not be well described by any of the following four alternative assumptions that are usually made to simplify the discounting of cash flows: (1) lump-sum, end-of-year cash flows, (2) lump-sum, beginning-of-year cash flows, (3) lump-sum, middle-of-year cash flows, and (4) continuous cash flows throughout the year. However, to describe the timing of cash flows more accurately would generally require more effort than is warranted by the resulting improvement in the economic measures; therefore, one of the above four assumptions is usually adopted.

The discounting factors shown in Appendix B, Tables B-2 and B-3, can be used to discount cash flows on either a beginning-of-period or an end-of-period basis by designating the initial period as O or as 1, respectively. The discount factors in the tables can be averaged for two consecutive periods, or a conversion factor (see Table B-2) can be used to develop middle-of-period factors.



For consistency in the Federal Energy Management Program and the Federal Grants Program, cash flows should be treated as lump-sum, end-of-year amounts.

Energy Price Escalation. In escalating future energy savings, there may be differences in the price escalation of alternative energy sources and in the periods of time over which various escalation rates are assumed to prevail. The prices of coal, fuel oil, electricity, and natural gas are expected to rise at different rates, both relative to one another and over time. While energy prices are widely expected to increase faster than most other prices, it is not clear that very high price escalation rates will be sustained indefinitely. As was indicated earlier, one approach to dealing with the increasing uncertainty of energy prices over time in an economic evaluation is to impose a cut-off time on the study period. Another approach is to reduce the energy price escalation rate to zero or to a low level at some future point in time.

For the purpose of the Federal Energy Management Program a distinction is made between the "short-term" (defined as up to three years from

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[13] Some Federal investment decisions are guided by other rates. For example, OMB Circular A-104 prescribes a real discount rate of 7 percent to analyze Federal decisions to acquire additional space by building, renovating, or leasing, when the costs are estimated to be $500,000 or more. For the purpose of evaluating energy conservation in new, renovated, or leased facilities, however, Federal agencies are required to use a real discount rate of 10 percent.

the present) and the "long-term" (defined as the period beyond three years). For the short-term period, agencies can use their own escalation rates as obtained from local power companies, utility commissions, and their internal analysis, if these rates are likely to be more accurate than the rates provided nationwide by DOE. For the long-term period, agencies should use the escalation rates provided by DOE in order to provide greater consistency and comparability among agencies' LCC estimates.

2.5 DETERMINING THE MOST ECONOMICAL ALTERNATIVE

There are several economic evaluation methods that can be used to determine whether or not a project is cost effective; that is, whether life-cycle savings equal or exceed life-cycle costs. Cost effectiveness of an investment is indicated when any of the following conditions are met:[14] (1) the total life-cycle costs of the building is lower with the investment than without it; (2) the net present value or net annual value of the investment's life-cycle savings minus life-cycle costs is greater than zero; (3) the ratio of net life-cycle savings-to-investment cost is greater than 1; (4) the internal rate of return on the investment is greater than the minimum acceptable rate of return; (5) the discounted payback period on the investment is shorter than its expected life.[15]

However, economic evaluation methods can be used for more than simply identifying investments that satisfy a minimum cost-effectiveness criterion. Greater energy cost savings per conservation investment dollar spent can be achieved if: (1) projects are economically optimal in terms of their design and size, and (2) priority is given to the most economically efficient projects.

Sizing or determining the economically efficient scale of an energy conservation project is best accomplished by use of the total life-cycle cost method, the net present value of savings method, or the net annual value of savings method. As long as the total life-cycle costs of a building decline as the project is increased in scale, or as long as net life-cycle savings rise, it pays to expand the project.[16]

Sizing can also be done by using the savings-to-investment ratio method or the internal rate of return method, *provided* the methods are applied to evaluate each incremental change in an investment, rather than the total investment.

The Federal Energy Management Program and the Federal Grants Program do not require the use of a particular evaluation method for sizing projects.

To give priority to the most economically efficient projects from among those projects that are identified as potential candidates, requires a method for ranking projects. The ranking of retrofit projects is discussed in Section 3.0, and the ranking of energy conservation in new building designs is discussed in Section 4.0.

2.6 SENSITIVITY ANALYSIS

Prior to making a final investment decision, it is usually advisable to evaluate an investment's economic feasibility based on alternative values of key parameters about which there is uncertainty, e.g., life, energy price escalation rate, quantity of energy saved, and discount rate. This can be done by recomputing the LCC measure for minimum and maximum values of the parameters in question using a technique called "sensitivity analysis." The results of a sensitivity analysis enable the decision maker to consider the consequences associated with alternative parametric values. By examining the results together with estimates of the likelihood of the various values occurring, the decision maker is better able to decide if an investment should be undertaken.

OMB Circular A-94, which applies to the Federal Energy Management Program, but not to the Federal Grants Program, requires Federal agencies to conduct sensitivity analysis of proposed programs and projects, provided that there is a "reasonable basis to estimate the variability of future costs and benefits." It is further specifically required that the prescribed 10 percent discount rate be used to evaluate all alternatives and that different discount rates should not be used to reflect the relative uncertainty of alternatives.

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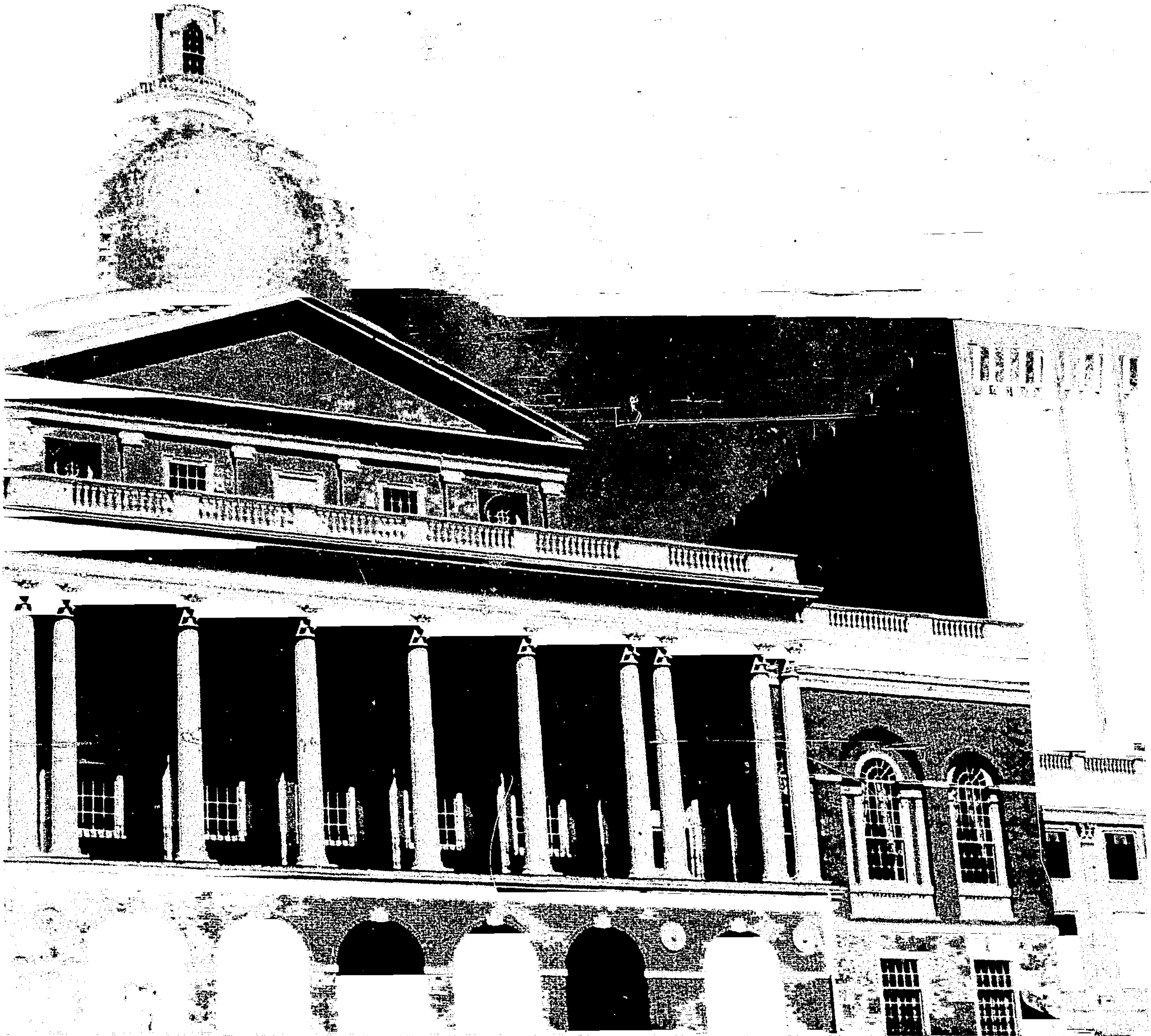
[14] The economic evaluation methods for deriving these results are defined in the Glossary, Appendix A.

[15] The payback is a reliable indicator of cost effectiveness only if it is calculated on the basis of discounted costs and savings and if there are no costs of sufficient magnitude after the point of payback to affect subsequent savings.

[16] Although this condition holds in theory only when there are no limitations on the budget, it is generally followed in practice whether there is or is not a budget constraint, because of the difficulty of simultaneously equating the marginal return on all energy conservation projects. With a budget constraint, the most economically efficient size of an energy conservation project is that size for which the ratio of savings to costs for the last increment in the investment is just equal to the ratio for the last increment on the next best available investment. For methods of finding the most efficient sizes of energy conservation projects with and without budget constraints, see reference [23] which treats the optimal level of insulation, and reference [24] which treats the optimal sizing of solar collectors.



3. RANKING ENERGY CONSERVATION PROJECTS FOR EXISTING BUILDINGS

A method is needed for selecting and giving highest priority to those retrofit projects in existing buildings which are most cost effective. With a limited budget for energy conservation projects, selection of projects on the basis of their comparative cost effectiveness will mean more savings per investment dollar. Ranking projects within an organization will help to ensure the economic efficiency of its expenditures, and ranking projects across groups of participating organizations will contribute to the overall goal of maximum savings for a given total budget.

3.1 ALTERNATIVE RANKING CRITERIA

There are a number of criteria that might be considered in evaluating the relative cost effectiveness of energy conservation projects for retrofitting existing buildings. Some possible criteria are the savings-to-investment ratio, the internal rate of return on investment, the net present value (or net annual value) of the investment, and the discounted payback period. Another possible criterion is the quantity of energy saved per investment dollar spent, e.g., the annual Btu savings per investment dollar, or some variation of this measure, such as the annual Btu savings per average investment dollar or the annual Btu savings per annualized investment dollar.

The following is a brief assessment and comparison of these alternative criteria that might be considered for ranking competing retrofit projects.

The Savings-to-Investment (SIR) Ratio as a Ranking Criterion. The Savings-to-Investment (SIR) Ratio is defined as the ratio of the net present value of savings to the present value of investment costs. The SIR provides a technically correct ranking criterion that meets the economic efficiency objective of saving the most energy dollars for a given energy conservation budget. It incorporates all present and future dollar savings and costs over the life of the project, including those from energy sources and non-energy sources such as labor and materials.

Selecting projects in descending order of their SIR's until the available budget is exhausted will result in the largest total dollar savings for a given budget. By treating energy savings in monetary terms, the SIR measure recognizes present and future differences in energy savings and costs from alternative sources of energy (e.g., fuel oil, electricity), as well as from regional variations in energy costs. For example, the SIR would reflect that a reduction in energy usage of a million Btu's of fuel oil may save $3.00, whereas a reduction of a million Btu's of electricity may save $8.00. Similarly, the SIR would reflect that electricity may cost $.06 per kilowatt hour in one region of the country and $.03 in another region.

Since it is based on dollar values, the SIR does not distinguish between dollar savings occurring from energy sources and dollar savings occurring from non-energy sources such as labor or materials. On the one hand, this feature may require the need for supplementary project selection criteria to ensure that an energy conservation program is indeed supporting energy conservation projects. On the other hand, it is important that significant non-energy savings be taken into account.

The Internal-Rate of Return (IRR) as a Ranking Criterion. The IRR method calculates the rate of return which an investment is expected to yield. The IRR is generally equivalent in technical accuracy to the SIR for ranking retrofit projects. Like the SIR, the IRR incorporates all present and future energy and non-energy dollar savings and costs over the project life. For situations in which the minimum acceptable rate of return of the organization is subject to change, the IRR method offers an advantage over the SIR. Because the SIR is computed using a particular discount rate, it would be necessary to recompute it if the applicable discount rate changed. In contrast, the IRR solves for the rate that equates costs and savings, and this rate can then be compared with the current discount rate. Because the 10 percent discount rate prescribed by OMB is not expected to change in the near future, this difference in the two methods does not appear relevant to the evaluation of Federal projects. The IRR has the disadvantage of often being more cumbersome to calculate than the SIR.[17]

The Net Present Value Savings (NPV) as a Ranking Criterion.[18] The NPV indicates whether a project will save more than it costs and is a particularly useful method for sizing a project; however, it does not serve well as a criterion for ranking projects within a limited budget. It does not distinguish, for example, between a large project that saves a given dollar amount of energy and a smaller project that results in the same dollar savings. Ranking projects in descending order of their net present value savings until the budget is exhausted will not guarantee the largest dollar savings per conservation budget.

The Discounted Payback as a Ranking Criterion. The discounted payback method evaluates energy and non-energy savings and costs in common dollar terms, but does not incorporate all relevant costs and savings in the measure. It thereby results in a partial measure of economic efficiency. A project with a shorter payback may yield lower net benefits than a project with a longer payback. Therefore, ranking projects in ascending order of their payback periods will not necessarily result in the largest dollar savings per investment dollar spent; it will favor the selection of short-lived projects. In some cases of uncertainty, or when there is a need to recover investment funds quickly, this feature may be deemed desirable. The payback method has the advantages of being an easy to understand concept and a method which many organizations are experienced in using. But when properly expressed in discounted terms, it offers no particular computational advantage over the other methods.

Btu per Investment Dollar as a Ranking Criterion. The Btu criterion gives weight to the annual quantity of energy saved, but does not take into account the relative scarcities of different types of energy, as reflected

[17] For a description of the computation of the IRR, see reference [1].

[18] The discussion of net present value as a ranking criterion would apply also to the net annual value savings method and the total-life-cycle cost method.

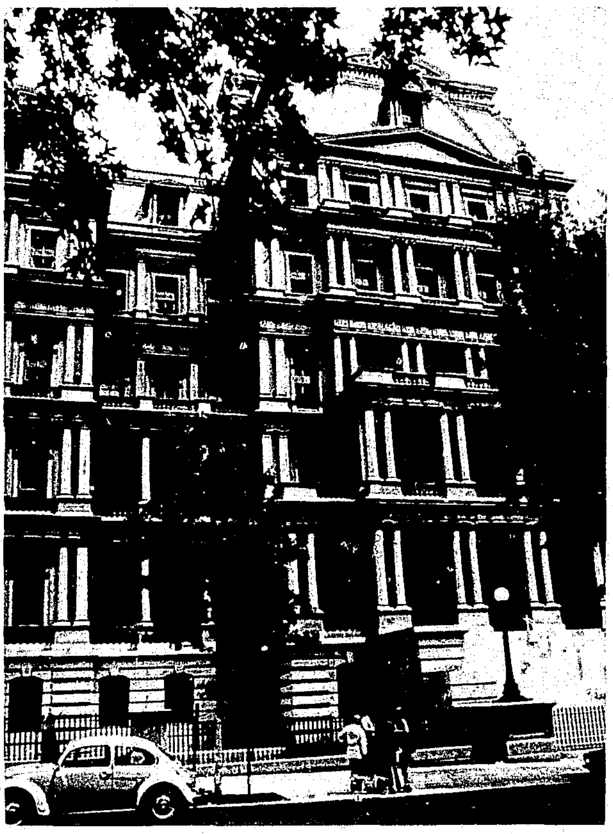
by their present prices or as can be accounted for by applying escalation rates; nor does it account for the expected life of the project or for the time value of money. Relating annual Btu savings to investment costs also neglects non-energy savings and costs.

This measure, used as a ranking criterion, cannot be relied upon to yield the largest dollar savings for a given conservation budget. In the short run, it will yield the largest Btu energy savings (if based on energy consumption at the source). However, it may not yield the largest Btu savings in the long run, because dollar savings foregone in the short run will not be available to purchase more energy conservation investments.

Selecting Ranking Criteria: Conclusion. All the measures except the last listed above provide for the evaluation and comparison of both investment costs and the resulting savings in economic terms, although the measures are not all equally effective as ranking criteria. The last measure listed (Btu criterion) allows for only the investment costs to be evaluated in economic terms, while the savings are evaluated in terms of quantity of energy, with no measure of economic value attached to that quantity.[19] The appeal of the latter type of measure is that by stating savings in terms of units of energy, the measure appears to focus more directly on the essence of an energy conservation program, i.e., saving energy. However, by failing to attach economic values to the savings, this type of measure fails to give priority to the most economically efficient projects.

If the objective of an energy conservation program is to reduce energy consumption in the most cost-effective way, either the savings-to-investment ratio method or the internal rate of return method is the most suitable criterion for ranking and selecting retrofit projects. Both methods provide a measure of the return on the dollar spent, and will result in a selection of projects that will yield the largest dollar savings for a given budget. In contrast, ranking projects in order of their net present values (or net annual values), their payback periods, or their ratios of quantity of energy saved to investment cost, cannot be relied upon to obtain the largest savings for a given budget.

However, the discounted payback method may be a useful ranking criterion in certain cases where uncertainty is great or where there is a particular need to recover investment funds quickly. Also, a measure of the quantity of energy saved in relation to the cost incurred may be a useful measure for distinguishing between projects that



save energy and those that save non-energy dollars, if this is important to the energy conservation program. But due to the significant economic inefficiencies that can result from sole reliance on either of three measures, they are not recommended as primary ranking devices. They may be helpful as supplements to either the savings-to-investment ratio or the internal rate of return method.

For the purpose of the Federal Energy Management Program, the savings-to-investment ratio method is required for ranking retrofit projects to determine funding priorities. The Btu and discounted payback measures are secondary criteria which are recommended for choosing between projects having identical SIR's. The Federal Grant Program, on the other hand, has several ranking criteria, the discounted payback method being one of the primary criteria.

For new buildings, where all energy-related cash flows are usually stated as costs, and the objective is to achieve the lowest overall total cost for the energy-related components of the building, the Federal Energy Management Program requires that the various costs be stated in present values and summed to derive the total life-cycle cost (TLCC). For a given building, priority is to be given to the design with the lowest TLCC, that meets the

[19] In considering the Btu measure for ranking projects, it would, therefore, be necessary to pre-screen the projects using some other measure in order to ensure that life-cycle savings exceed life-cycle costs and that the minimum cost-effectiveness criterion is met.

functional requirements of the building and other constraints.[20]

In the Section that follows, the SIR and the discounted payback methods are described in more detail. The calculation of both methods is explained, and computational aids are provided in the form of worksheets and a nomogram. The net present value method is described in Section 4.

3.2 CALCULATING THE SIR

The basic step-by-step procedure for calculating the SIR is as follows: (1) Compute the denominator of the SIR by finding the net present value of investment costs. (2) Compute the present value of future energy savings, where energy savings are defined as the difference between the cost of energy in the existing building situation and the expected cost of energy if the energy conservation investment were made. (3) Determine if the investment is expected to raise or lower future non-energy costs such as maintenance and repair, and compute the present value of the change.[21] (4) Compute the net present value of cost savings, the numerator of the SIR, by subtracting from (adding to) the present value of energy cost savings (Step 2), the increase (the decrease) in non-energy costs (Step 3). (5) Compute the SIR by dividing the present value of savings net of future non-energy costs (Step 4) by the net present value of project investment costs (Step 1).

This procedure can be performed manually using the worksheets provided in Appendix C (C-1 or C-2) and explained and illustrated below, or it can be performed using the computer program described in Appendix D.

3.2.1 Simple Investment Projects

Energy conservation projects are easy to evaluate if they (1) require a lump-sum initial investment, (2) are expected to result in a level quantity of yearly energy savings with a steadily escalating price, (3) do not significantly affect non-energy costs or benefits, and (4) have no significant salvage value at the end of the study period. The SIR for this type of project is simple to compute because there are no future non-energy costs or benefits to calculate, and the initial investment is already in present value terms. To compute the SIR in this case, it is necessary only to multiply the initial annual energy savings by the appropriate present value factor and to divide this product by the initial investment cost.

Table 2 illustrates with a sample problem the worksheet approach to evaluating the LCC of a simple investment project. (A blank copy of the worksheet, numbered C-1, is provided in Appendix C.) The sample investment problem is for a simple retrofit project to add insulation to buildings. For the purpose of this example, a 6 percent differential rate of escalation in energy prices is assumed. (The uniform present worth factor is taken from Table B-3, 6% Collumn, year 25.)

Items 1 through 7 of the worksheet provide information about the nature of the project, its location, and expected duration. Item 8 gives the investment cost. Item 9, A through F, tabulates the information required to compute the annual energy savings. Item 9A gives the annual quantity of energy saved, measured in units purchased at the building boundary. The annual quantity saved is then multiplied by Item 9B, the current price per unit of energy, to obtain Item 9C, the initial value of annual energy savings. Item 9D identifies the expected rate of energy price escalation. Item 9E, the uniform present worth factor (obtained from Table B-3) is multiplied by Item 9C to calculate Item 9F, the present value of savings. Item 10 gives the sum of entries in Item 9F. The SIR, Item 11, is calculated by dividing Item 10, the total present value of energy savings, by Item 8, the project investment cost.

Alternatively, to use the computer program (Appendix D) to calculate the SIR, it is necessary to enter the basic data from Items 1 through 9 of Table 1, into the computer. The computer then calculates the present value of the energy savings and divides this value by the investment cost to obtain the SIR.

3.2.2 Complex Investment Projects

Any of the following conditions mean a more complex investment project for which the worksheet in Table 2 may be inadequate:

(1) The proposed project may be expected to change future non-energy costs or benefits significantly.
(2) Investment costs (planning, design, and construction) may stretch significantly beyond the base year of the LCC analysis.
(3) The projected rate of price escalation for each type of energy may change in the future.

If any of these conditions exist, the calculation of the SIR requires more computations than are allowed for in

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[20] The TLCC should reflect any differences in the *expected* benefits of alternative designs.

[21] This instruction is based on the assumption that the retrofit project does not affect significantly the functional use or performance of the building. If it *is* expected to have a significant impact on the building, other than on its energy requirements, the positive or negative impacts on productivity or on other aspects of using the building should be assessed, and either quantitative measures should be developed for incorporation into the numerator of the SIR or qualitative measures should be developed for consideration.

TABLE 2

Worksheet for Calculating the SIR for a Simple Retrofit Project*

1. Name of Agency National Administration
2. Project Description Install Insulation
3. Location Suburban Washington, D.C.
4. Gross Floor Area Affected 140,000 square feet
5. Expected Life of Project 40 years
6. Expected Life of Building 30 years
7. Study Period 25 years
8. Project Investment Cost (Date 1 July 1978) S41,000
9. Value of Annual Energy Savings

(A) Units of Energy Saved at Bldg/Facility Boundary	(B) Current Unit Energy Price (Date 7 1 78)	(C) Initial Annual Energy Savings (Date 7/1/78) (C)=(A)x(B)	(D) Energy Escalation Rate	(E) Uniform Present Value Factor for Specified Energy Price Escalation Rate	(F) Present Value (Date 7/1/78) (F)=(C)x(E)
606060 kWh Electricity	033 S Per kWh	S20,000	6%	16.0026	$320,052
___ therms Natural Gas	___ S Per Therm				
___ gal. Fuel Oil	___ S Per Gal.				
___ Other	S Per ___				

10. Total Savings S320,052
11. SIR (Item 10 ÷ Item 8) 7.81

*This is Appendix Worksheet C-1.

Table 2. To handle these conditions, five worksheets numbered C-2.1 through C-2.5, are provided in Appendix C. Tables 3 through 7 illustrate the use of these worksheets to analyze a sample problem. The illustrative problem involves several types of energy, for which there are seasonal price differences.

Table 3 summarizes the results of the LCC analysis. It draws together key items of information developed in Tables 4 through 7, and computes the SIR. Instructions for completing Tables 4 through 7 follow.

Computing Energy Savings. Table 4 shows for a sample problem the estimates of the quantity of energy saved, and the value of these savings both in today's dollars and in present value life-cycle dollars by type of energy source. (A blank copy of this worksheet, numbered C-2-1, is provided in Appendix C.)

The worksheet in Table 4 is divided into three parts. The first part (Steps 1 through 5) calculates the initial value of a year's energy savings in base-year dollars. This part is needed to complete both the second and third parts of the Table. If constant price escalation rates are used over the entire study period, only the first and second parts need be completed. The first and second parts of Table 4 together (Steps 1 through 8) are comparable to the simple calculations of energy savings given in Table 2. If price escalation rates are to be changed during the study period, only the first and third parts of Table 4 need be completed.

After estimating the initial value of a year's energy savings in Steps 1 through 5, one proceeds either to Step 6 or to Step 9, depending on whether the energy price escalation rate is constant or changing. If it is constant, the constant price escalation rate for each type of energy is entered in Step 6. The uniform present value factors called for in Step 7 are based on the stated discount rate, price escalation rates and study period, and are obtained from Table B-3. The factors are for the purpose of converting the initial annual energy savings to a present value life-cycle equivalent. (The factors for the sample problem are for 25 years, a discount rate of 10 percent, and differential energy price escalation rates of 5 percent for electricity and 7 percent for natural gas.) The total present value of energy savings is obtained in Step 8 by multiplying the values in Step 5 by the factors in Step 7 for each energy/fuel type, and summing these present values in the total column. If constant energy escalation rates have been used for each type of energy over the project life, the third part (Steps 9 through 18) of Table 4 can be ignored, and the total present value of energy savings in Step 8 can be transferred to Item 8 of Table 3, the Summary Worksheet.

If price escalation rates are to be changed during the study period, it is necessary after completing Steps 1 through 5 of the first part of Table 4, to continue to the third part of the table (Steps 9 through 18).

The third part, developed for use by Federal agencies in conjunction with the Federal Energy Management Program, allows for the use of both short term and long-term energy escalation rates. Steps 9 through 11 compute the present value of energy savings during the short-term period. Step 9 requires that two parameters be specified: (a) the number of years to which the short-term rate is to apply (in the example, the short-term rate is applied for 2 years); and (b) the short-term energy escalation rate for each energy type. (In the example, the rate is 10 percent for electricity and 6 percent for natural gas.) In Step 10 the uniform present value factors for finding the present value of energy savings in the short-term period are obtained from Table B-3, for year 2, and for energy price escalation rates of 10 percent and 6 percent.[22] In Step 11 the factors from Step 10 are multiplied by initial dollar energy savings from Step 5 to obtain the present value of short-term energy savings. The values for each type of energy are then summed in the total column.

Steps 12 through 17 compute the present value of energy savings during the long-term period. Step 12 obtains the expected price of energy at the end of the short-term period by multiplying the short-term price (Step 4) by an adjustment factor. The adjustment factor for each type of energy is the single compound amount factor for the appropriate discount rate, the short-term energy escalation rate and the time period. In this example, the adjustment factors for electricity and gas are obtained from Table B-4, row 2, for 10 percent and 6 percent. In the example, the expected price of \$.04 per kWh for electricity for heating at the end of year 2, is obtained by multiplying the initial price of \$.033 (from Step 4), by the single compound amount adjustment factor for 2 years and 10 percent, i.e., 1.21.

In Step 13, the expected dollar value of yearly energy savings just prior to the change in the energy price escalation rate is calculated by multiplying the quantity of energy saved (Step 3) by the expected price at the end of year 2 (Step 12). In Step 14, the uniform present value factor to reflect both the remaining period of time and the long-term energy price escalation rate is obtained from Table B-3. In the example, the period of years for which the long-term analysis applies is 23 (i.e., 25 – 2 = 23 years), and the long-term escalation rate is assumed to be 5 percent for electricity and 7 percent for natural gas.

In Step 15, the uniform present value factors (Step 14) are multiplied by the value of yearly savings just prior

[22] Note that the Single Present Value and Uniform Present Value factors given in Appendix Tables B-2 and B-3 are appropriate only if the discount rate is 10 percent.

TABLE 3

Worksheet for Calculating the SIR for a Retrofit Project when Cash Flows are Complex*

(Project Summary Sheet)

1. Name of Agency: National Administration
2. Project Description: Installation of a Central Automatic Environmental Control System to serve the Entire Building Facility
3. Location: Suburban Washington, D.C.
4. Gross Floor Area Affected: 2.3 million square feet
5. Expected Life of System: 40 years
6. Expected Life of Building: 30 years
7. Study Period: 25 years

ENERGY SAVINGS

8. Total Present Value of Energy Savings (Item 18, Table 4): $22,774,758

INVESTMENT COST

9. Present Value of Investment Cost Less Salvage (Item 9, Table 5): $1,384,915

NON-ENERGY COSTS (or SAVINGS)

10. Present Value of Non-Energy Costs for the Retrofitted Building (Item 10, Table 6): $739,836
11. Present Value of Non-Energy Costs for Existing Building or System (Worksheet C-2.5): NA
12. Present Value of Change in Non-Energy Costs (Line 10 minus Line 11, or (difference method) Line 10): $739,836

SIR NUMERATOR

13. Total Present Value of Energy Savings Minus Non-Energy Costs (Line 8 minus Line 12): $22,034,922

LIFE-CYCLE COST MEASURES

14. SIR (Line 13 ÷ Line 9): 15.91
15. Net Savings in Present Value (Line 13 − Line 9): $20,650,007

*This is Appendix Worksheet C-2.1.
NA = Not Applicable

TABLE 4

Worksheet for Calculating the Present Value of Energy Savings from a Retrofit Project when Short-Term and Long-Term Energy Escalation Rates are Used*

Step	Electricity: Heating	Electricity: Cooling	Natural Gas	Fuel Oil
CALCULATION OF BASE YEAR ENERGY COSTS				
(1) Annual Consumption, Existing System	71,489,000 kWh	28,330,000 kWh	43,360,000Therms	
(2) Annual Consumption, Proposed Alternative	66,500,000 kWh	25,400,000 kWh	38,680,000Therms	
(3) Annual Quantity Saved (3) = (1) – (2)	4,980,000 kWh	2,930,000 kWh	4,680,000Therms	
(4) Today's Local Price/Unit	$.033/kWh	$.038/kWh	$.225/Therm	
(5) Today's Annual $ Savings (5) = (3) x (4)	$164,340	$111,340	$1,053,000	
CONSTANT PRICE ESCALATION ADJUSTMENT				
(6) Constant Price Escalation Rate	5%	5%	7%	
(7) Uniform Present Value Factor**	14.4367	14.4367	17.7998	
(8) Present Value Energy Savings (8) = (5) x (7)	$2,372,527	$1,607,382	$18,743,189	
SHORT-TERM/LONG-TERM PRICE ESCALATION ADJUSTMENT				
(9) Expected Real Short-Term Price Escalation from End of Year 0 to End of Year 2	10%	10%	6%	
(10) Uniform Present Value Factor for Short-Term Price Escalation	2.0	2.0	1.8921	
(11) Present Value of Short-Term Energy Savings (11) = (5) x (10)	$328,680	$222,680	$1,992,381	
(12) Expected Price End of Year 2 (See Instructions)	$.040	$.046	$.253	
(13) Value of Annual Savings in Year 3 (13) = (3) x (12)	$199,200	$134,780	$1,184,040	
(14) Uniform Present Value Factor for Long-Term (See Instructions)	13.7968	13.7968	16.7841	
(15) Discounted Value of Savings in Year 3 (15) = (13) x (14)	$2,748,323	$1,859,533	$19,873,046	
(16) Single Present Value Factor (See Instructions)	.8264	.8264	.8264	
(17) Present Value of Long-Term Energy Savings (17) = (15) x (16)	$2,271,214	$1,536,718	$16,423,085	
(18) Present Value of Total Energy Savings (18) = (11) + (17)	$2,599,894	$1,759,398	$18,415,466	

*This is Appendix Worksheet C-2.2.

**Sample problem based on the assumption of a discount rate of 10 percent and a study period of 25 years.

Total
$22,723,098
$2,543,741
$1,518,020
$20,231,017
$22,774,758

to the change in escalation rates (Step 13), to obtain the value of energy savings over the remaining years, discounted back to the year the escalation rate changed. In the example, the factors are multiplied by the value of savings in the third year to obtain the value of savings over the remaining 23 years discounted to the third year. In Step 16, the single present value factor for converting total savings from the year the escalation rate changed to the base year is obtained from Table B-2. In the example, the factor of .8264 is obtained from Table B-2, row 2, column 0 percent.

In Step 17, the value of savings over the long-term are converted back to the base year by multiplying the single present value factor (Step 16) by the discounted value of savings in the third year (Step 15). The long-term energy savings are summed across the different energy types and given in the total column for Step 17.

Finally, in Step 18, the short-term energy savings (Step 11) and the long-term energy savings (Step 17) are summed. The total savings from Item 18 are entered as Item 8 on the Worksheet in Table 3 if both short-term and long-term energy escalation rates are used.

Computing the Net Present Value of Investment Costs. Table 5 demonstrates the use of the worksheet for computing the net present value of investment costs when the investment occurs in more than one year, when there are substantial replacement costs, and/or when a significant residual or salvage value is expected to remain at the end of the study period. Investment costs in the base year are already in present value terms. Thus, for the sample problem, the $725,000 incurred in the base year (year 0, column 2) is entered unchanged in the present value column (year 0, column 6). Investment in subsequent years must be discounted to a present value using single present value factors from Table B-2. For the sample problem, the $725,000 incurred at the end of the first year is discounted to an equivalent value of $659,100 in column 6 by applying the single present value factor of .9091 (from Table B-2, year 1, 0 percent escalation). In the sample problem an additional major replacement investment in year 10 is made of $50,000, which is discounted to an equivalent value of $19,275 in column 6 by applying the single present value factor of .3855 from Table B-2, year 10, 0 percent escalation. The residual or salvage value (column 3) is the net sum which could be expected to be realized from disposal of the investment at the end of the study period. For the sample problem, the estimate of $200,000 of residual value evaluated in constant dollars is placed in column 3 in the final year of the study period. The $200,000 residual value is discounted to a present value of $18,460 (column 5) by use of the single present value factor of .0923 (from Table B-2, year 25, 0 percent escalation).

The net present value of investment costs (Item 9) is then obtained by summing the present values of investments in column 6 and subtracting the present value of the residual in column 5. The net present value of investment costs ($1,384,915) is entered as Item 9 on the worksheet in Table 3.

Alternatively, replacement costs and salvage values could be combined in the numerator with other future cash flows, rather than combined with investment costs in the denominator as provided in Table 5. While this change in the method of computing the SIR will change its numerical value, it often will not change the relative order of ranking projects. However, under conditions where projects with large salvage values and/or replacement costs are being compared with projects with little or no salvage and/or placement costs, it is possible for the relative ranking of projects also to be changed slightly. If the objective is the largest return on the present year's investment dollars, future investment costs will usually be put in the numerator. If the objective is the largest return on the long-run budget, future investment costs will usually be put in the denominator. If the SIR is greater than 1, having subtracted future investment costs from the numerator, other things equal, would have resulted in a higher SIR than having added these costs to the denominator. Thus a project with significant future investment costs will look better relative to a project without significant future investment costs if the future costs for the first project are put into the numerator of the SIR. Placing the present value of future investment costs in the denominator of the SIR gives as much weight to these costs as to the initial investment costs.

For the purpose of the Federal Energy Management Program, future investment costs are put in the denominator of the SIR.

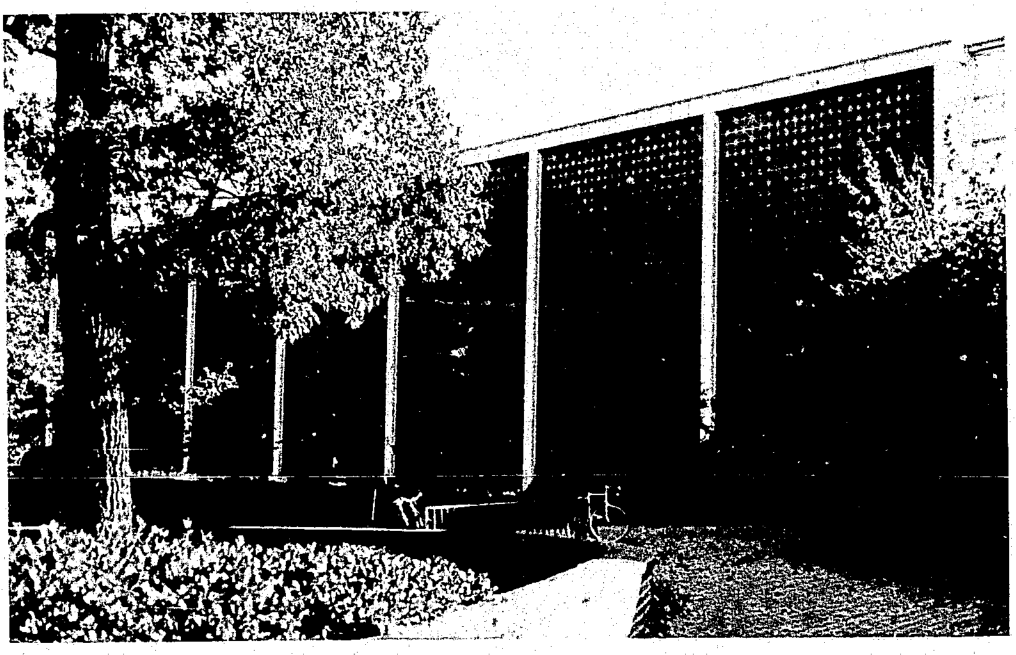


TABLE 5

Worksheet for Calculating the Net Present Value of Capital Investment Costs when Costs are Spread Over Time and There is Salvage Value*

Year (1)	Investment Cost in Constant $ (Planning, Design, Construction, Replacement) (2)	Salvage Value at End of Study Period in Constant $ (3)	Single Present Value Factor for Year Indicated (from Table B-1) (4)	Present Value of Salvage (5)=(3)x(4)	Present Value of Investment for Year Indicated (6)=(2)x(4)
0	$725,000		1.0		$725,000
1	725,000		.9091		659,100
3			.8264		
4			.7513		
5					
•					
10	50,000		.3855		19,275
•					
•					
25		$200,000	.0923	$18,460	
Totals				$18,460	$1,403,375

(7) Present Value of Investment Costs, (Sum of Column 6): $1,403,375

(8) (minus) Present Value of Salvage Value (Sum of Column 5): $18,460

(9) (equals) Net Present Value of Investment Costs: $1,384,915

*This is Appendix Worksheet C-2.3

Computing the Present Value of Future Non-Energy Costs. Table 6 illustrates the use of a worksheet to compute the present value of future non-energy costs. These calculations are necessary only if it is expected that non-energy costs will be significantly affected by the retrofit project. The changes in non-energy costs attributable to the retrofit may be entered directly on the worksheet in Table 6.

If the changes in non-energy costs are entered directly on Table 6, a *negative sign* can be assigned to the values if the retrofit project results in lowered non-energy costs, i.e., if it results in non-energy cost savings. A *positive value* means that the proposed retrofit raises non-energy costs.

In the sample problem, the proposed retrofit is expected to raise annual recurring non-energy costs by $60,000 per year (column 2) and other non-energy costs by $140,000 every 5 years (column 5). To convert the annual recurring costs to present value, the uniform present value factor is obtained from Table B-3, year 25, 0 percent escalation, and entered in Column 3. The factor is then applied to the annual recurring costs in column 2 to derive the present value equivalent in column 4. To convert the other non-energy costs to present value, the single present value factors are obtained from Table B-2, 0 percent escalation, for each appropriate year and are entered in column 6. The factors are then multiplied by the other costs (in column 5) to derive the present value equivalent in column 7. The total present value of annual recurring and other non-energy costs are then summed at the bottom of Table 6 to obtain a present value of non-energy costs of $739,836.

Duplicates of this worksheet are provided in Appendix C. When the amounts and timing of non-recurring costs are expected to be substantially different before and after the retrofit, it may be helpful to complete one worksheet for the non-energy costs before the retrofit, and another worksheet for non-energy costs after the retrofit, and then find the differences.

Before computing the SIR, it is important to assess the possible positive or negative impacts of the retrofit project on the usefulness of the building, e.g., on user productivity. If there are thought to be significant impacts that can be quantified, it may be feasible to consider them in calculating the SIR. Any improvement in productivity can be treated as a benefit. The present value of the benefit may be added as a saving to the numerator of the SIR. Any decrease in productivity can be treated as a functional use cost. The present value of the functional use cost may be subtracted from the numerator of the SIR. Significant impacts affecting the usefulness of the building which cannot be quantified may be described verbally.

For the purpose of the sample problem, it is assumed that the retrofit project does not affect the benefits of using the building.

At this point, the necessary information for computing the SIR can be entered on the summary worksheet in Table 3. The SIR is computed by simple division for the sample problem to be 15.91. The net present value of savings is also computed by subtracting life-cycle costs from life-cycle savings; it is found to be $20,650,007 for the sample problem.

As in the case of the simple investment problem, the SIR can alternatively be computed by using the computer program in Appendix D. To use the program, it would be necessary to enter as data inputs, the short-term and long-term price escalation rates, the additional investment costs, and the expected non-energy cost differences, in addition to the basic inputs required for the simple problem.

TABLE 6

Worksheet for Calculating the Present Value of Non-Energy (Maintenance and Repair) Costs After the Retrofit*

Year	Annual Recurring Costs in Constant $	Uniform Present Value Factor (from Table B-2)	Present Value of Recurring Costs	Other Costs in Constant $	Single Present Value Factor for Year Indicated (from Table B-1)	Present Value of Other Costs
(1)	(2)	(3)	(4)=(2)x(3)	(5)	(6)	(7)=(5)x(6)
1	$60,000	9.077 factor	$544,620			
2						
3						
4						
5				$140,000	.6209	$86,926
6						
7						
8						
9						
10				140,000	.3855	53,970
11						
12						
13						
14						
15				140,000	.2394	33,516
16						
17						
18						
19						
20				140,000	.1486	20,804
21						
22						
23						
24						
25						
Totals			$544,620			$195,216

(8) Total Present Value of Recurring Costs $544,620

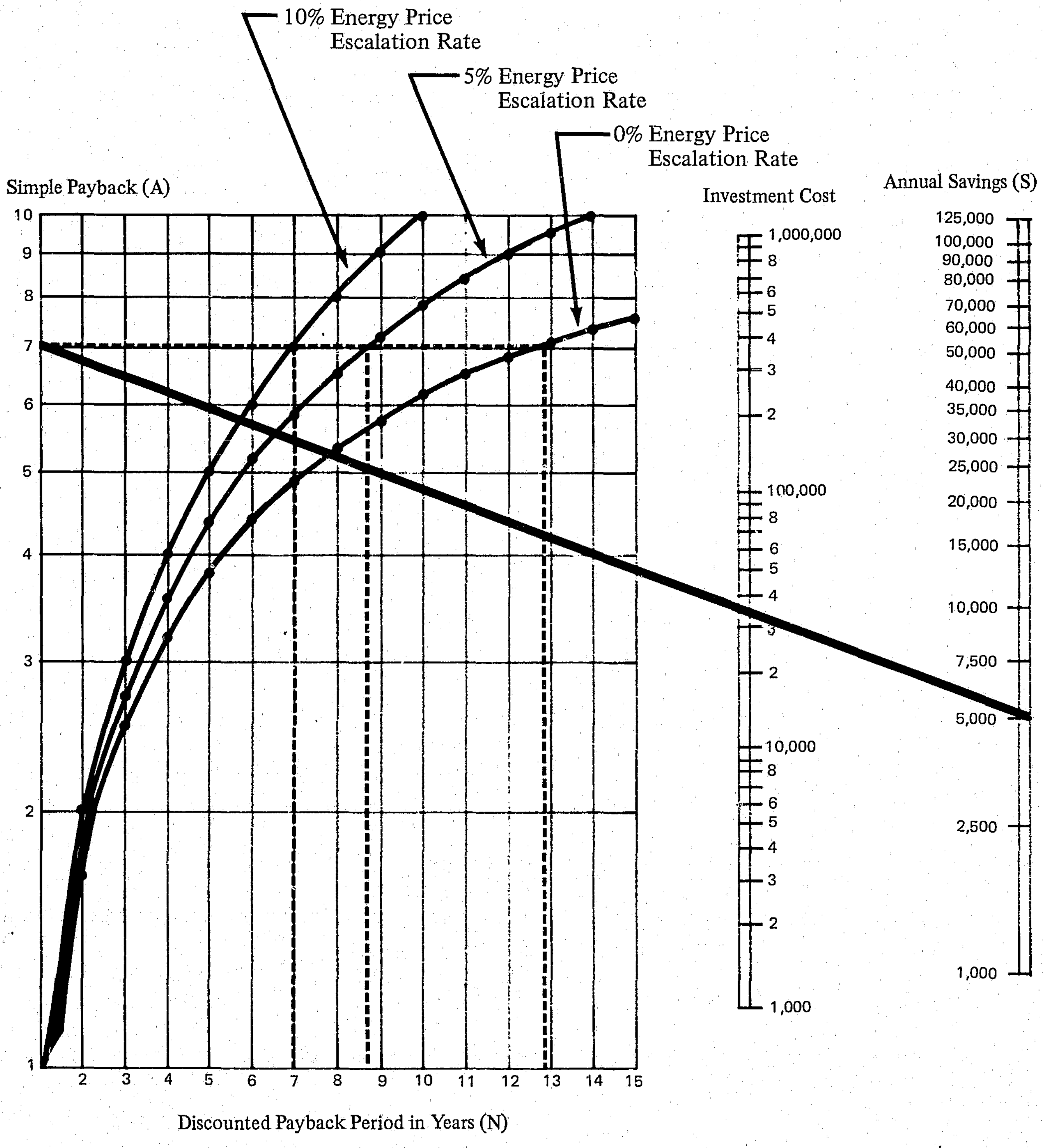
(9) (plus) Total Present Value of Other Costs $195,216

(10) (equals) Present Value of Non-Energy Costs $739,836

*This is Appendix Worksheet C-2.4, used to report the changes in non-energy costs attributable to the retrofit. (See Appendix Worksheet C-2.5 for computing non-energy costs before the retrofit, in order to calculate changes from the before and after-retrofit total cost figures.)

FIGURE 1

Discounted Payback Nomogram

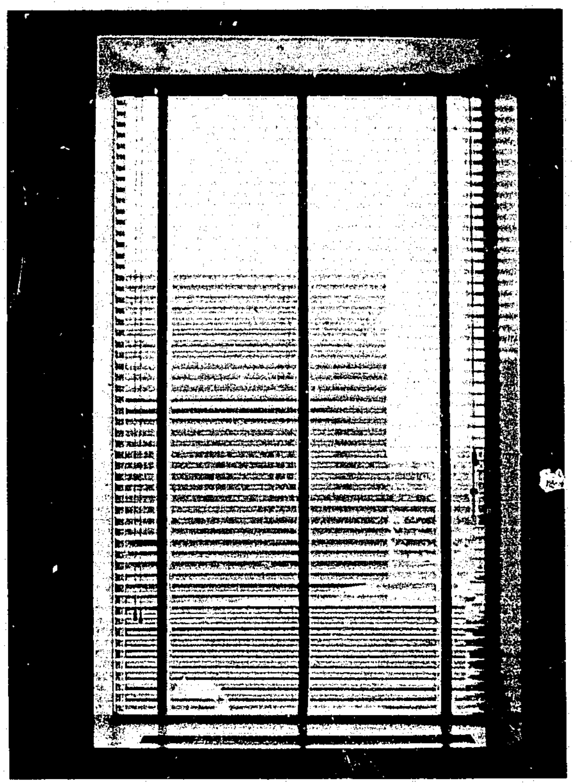


3.3 CALCULATING THE DISCOUNTED PAYBACK

The payback period is the time required for the annual net cost savings produced by an energy conservation investment to equal the original investment outlay. However, simply dividing the dollar value of the energy conservation investment by the annual net cost savings produced by the investment, as is done in a "simple payback" measure, neglects the time value of money and results in an incorrect determination of the payback period. Use of simple payback can lead to decisions which are not cost effective, and its use does not satisfy the OMB Circular A-94 requirements. The "discounted payback" corrects the above disadvantage by incorporating the time value of money. The discounted payback is the time required for the annual net cost savings produced by an energy conservation investment to equal the original investment, taking into consideration the time value of money. The discounted payback also facilitates the incorporation of differential rates of price escalation for energy.

The measure can be calculated by an iterative approach or from formulas.[23] For simple investment projects, it can also be calculated using the nomogram shown in Figure 1.[24]

The discounted payback period for a simple investment project can be calculated from Figure 1 as follows: Assume that the initial conservation investment is $35,000, and the annual energy savings is $5,000. To use the nomogram, a line connecting the annual savings and the investment costs (located on the two vertical scales to right of the nomogram) is projected to the vertical axis of the graph labeled "Simple Payback." For this example, the projected line indicates a simple payback of 7 years. Next, a line is projected from the point on the vertical axis, horizontally to the appropriate discount rate/energy price escalation rate curve. The nomogram has three discount rate/energy price escalation rate curves: (1) the curve labeled "0%" is for a 10 percent discount rate and a 0 percent energy price escalation rate, (2) the curve labeled "5%" is for a 10 percent discount rate and a 5 percent energy price escalation rate, and (3) the curve labeled "10%" is for a 10 percent discount rate and a 10 percent energy price escalation rate. A third line is then projected from the point of intersection with the appropriate curve to the horizontal axis of the graph labeled "Discounted Payback." This intersection will give the discounted payback period for the investment. For the example, the



discounted payback is 7 years if a 10 percent energy price escalation rate is used. It is 8.7 years if a 5 percent escalation rate is used, and it is 12.9 years if a 0 percent escalation rate is used. The values for other energy price escalation rates must be interpolated from the three curves shown.[25]

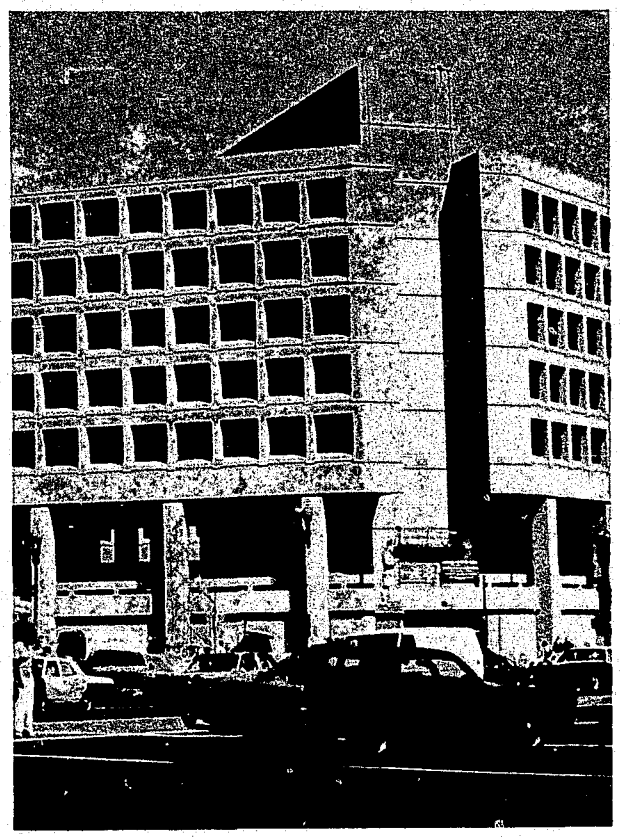
The example illustrates the importance both of discounting to account for the time value of money and of the choice of energy price escalation rates. In the example, a simple payback of 7 years is equivalent to a discounted payback of 12.9 years, based on a 10 percent discount rate and no real energy price escalation. If the investment were expected to have an economic life of, say, 10 years, the simple payback measure indicates that the investment is cost effective, while this discounted measure indicates that it is not.

There is little difference between the simple and the discounted payback periods for investments having extremely short paybacks (less than 2 years simple payback). The rate of escalation in energy prices also has little impact in the very short run. Both factors, however, become very significant in determining the payback period for longer periods.

[23] See references [1] and [7].

[24] "Simple" investment projects suitable for evaluation by the nomogram are those which generate only energy savings and involve no significant non-energy costs after the initial investment.

[25] Alternatively, the nomogram could be expanded to show other curves.



3.4 RANKING INTERDEPENDENT PROJECTS

In evaluating candidate projects for a particular building or facility, the problem of interdependency among projects may arise; that is, undertaking one project may affect the relative life-cycle costs and savings of remaining projects. For example, the value of adding an automatic environmental control system will be different depending on the level of insulation in the building envelope and vice versa. Undertaking one will tend to diminish the value of the other. When sufficiently few projects are under consideration, a practical approach to this problem is to evaluate each of the candidate projects independently of one another, first select the one with the highest SIR value, and then adjust the SIR value of any remaining projects that are expected to be substantially altered by the first, higher priority, selection. The selection process would then be continued, with necessary adjustments to remaining projects being made as each project is chosen.[26]

[26]For a description of a more sophisticated and detailed approach to the problem of ranking interdependent projects, see reference [25].

For the purpose of the Federal Energy Management Program, participants are directed to recompute the SIR's for interdependencies among projects when there is reason to expect that the problem is significant. The Federal Grant Program also requires that significant interdependencies be taken into account.

3.5 SELECTING PROJECTS FOR FUNDING

From the project summary worksheets (Tables 2 and 3), and with adjustments for any independencies among projects, an agency can prepare a plan which lists projects in descending order of their priority ranking until their energy conservation budget dollars have been exhausted.

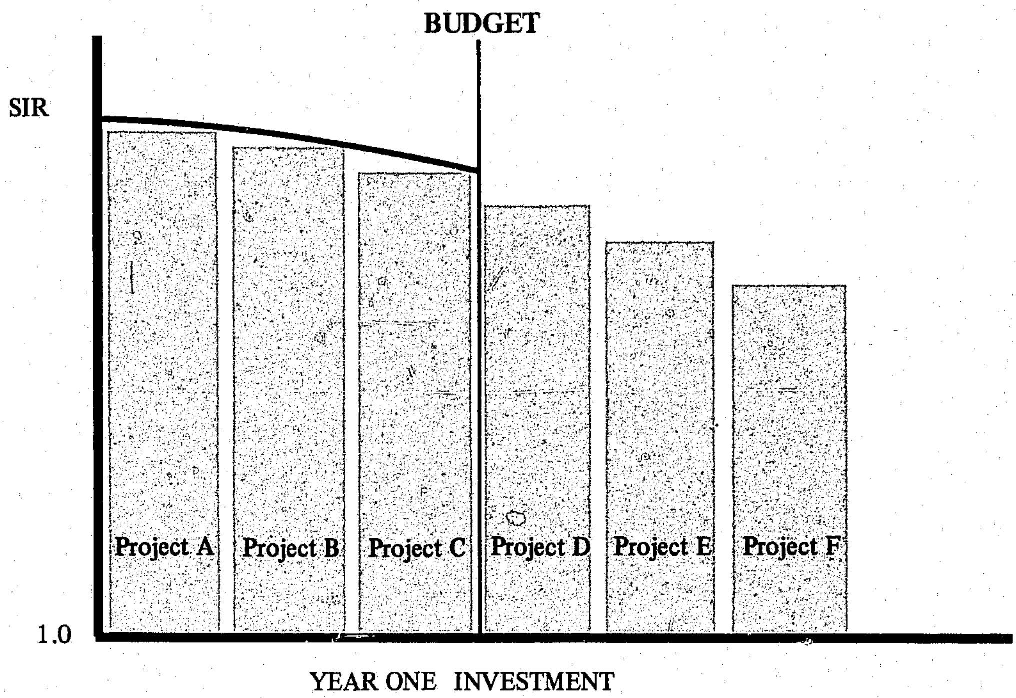
During the initial round of funding, all projects should be analyzed as though their implementation were to start in the present year. All evaluated projects which satisfy the cost-effectiveness criterion and which together exhaust the first year's budget would be selected. In the second year, all projects not previously selected should be reanalyzed if their SIR's are expected to have changed. They can then be ranked together with any new projects which have been identified.

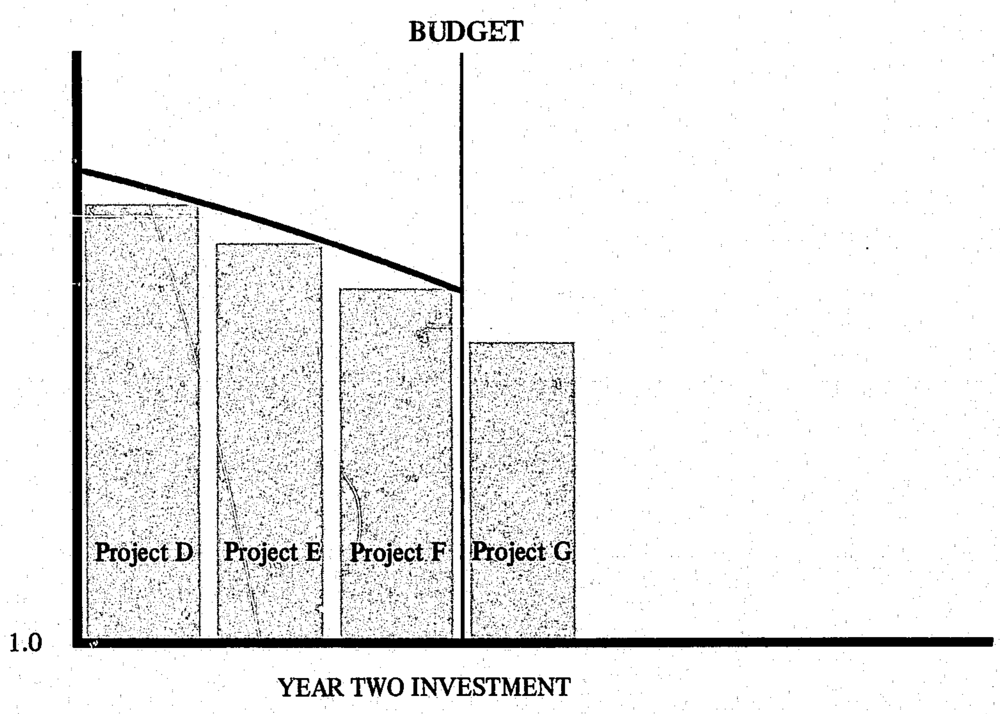
Graphically, the ranking and selection procedure can be illustrated as shown in Figure 2 in which projects are arrayed in order of their priority ranking and a selection of projects is made in accordance with a limited budget. There are six candidate projects depicted in the first year as meeting the minimum cost-effectiveness criterion by having an SIR of one or greater. However, the budget in that year only allows for the first three to be done. In the second year the budget allows for the remaining three projects. A fourth new candidate project in that year is omitted because of the budget constraint.

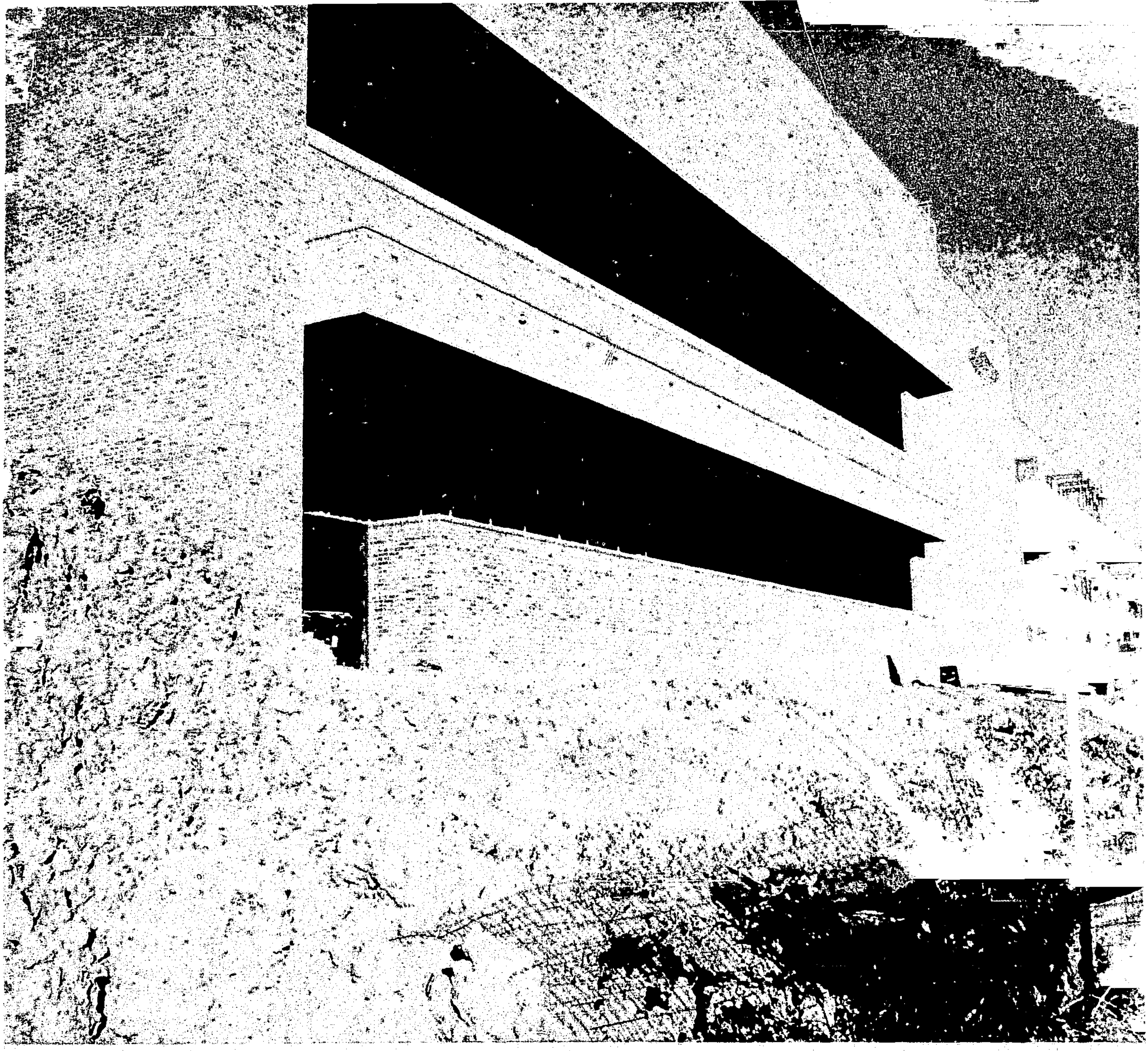
Allocating a single energy conservation budget among different agencies based on the comparative values of their SIR rankings could be expected to result in uneven energy conservation efforts among agencies. Other things being equal, those agencies whose buildings are relatively inefficient in their energy usage would be expected to have higher SIR rankings than agencies which have already achieved relatively energy-conserving buildings. Concentrating the energy conservation effort on buildings that are currently most inefficient and have the greatest room for improvement, however, will result in the most energy conservation at lowest life-cycle costs.

FIGURE 2

Allocating the Budget Among Alternative Projects Ranked by SIR







4. EVALUATING ENERGY CONSERVATION DESIGNS FOR NEW BUILDINGS

In evaluating and choosing among new building designs, the overriding factor is the functional use of the building. Economic evaluation of energy conservation in new building designs is useful for determining the most cost effective of alternative designs for a given building. It will generally *not* be used to rank and select among independent new buildings.

An economic evaluation method is needed for identifying the design option with the lowest total life-cycle costs. This can be best accomplished by summing: (a) the net present value investment costs, (b) the present value future non-energy costs, such as maintenance, repair, replacement, and functional-use costs, and (c) the present value energy costs for each alternative design. The design with the lowest total LCC for the energy-related components of the building will be preferred, other things being equal.[27]

A set of worksheets are provided in Tables 7 through 10 for evaluating the total LCC of alternative building designs. The first (Table 7) is a Project Summary Sheet for new buildings. Like the summary worksheet shown in Table 2 for the existing building case, it draws together key information developed in the 3 supporting worksheets (Tables 8, 9, and 10) in order to compute the total LCC of a given design. The worksheets given in Tables 7 through 10 are simply modified versions of the worksheets for the existing buildings given in Tables 2 through 6, and follow similar instructions.

Table 8 provides for short-term and long-term energy escalation in the calculation of life-cycle energy costs. Table 9 provides for the calculation of investment and replacement costs, net of salvage values. Table 10 allows for the computation of non-energy costs.

For the purpose of the Federal Energy Management Program, agencies are directed to use the total LCC method for choosing among alternative designs for a given building. The Federal Grants Program is a retrofit program and does not address this situation.

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[27] Again it is important that any significant differences in the benefits associated with alternative new building designs be taken into account. If quantificable, these differences can be incorporated into the total LCC measure as negative costs.

TABLE 7

Summary Worksheet for Calculating the Total Life-Cycle Costs of the Energy Components of a New Building Project*

(Design ______________________)

1. Name of Agency ______________________

2. Project Description ______________________

3. Location ______________________

4. Gross Floor Area Affected ______________________

5. Expected Economic Life of Building Design ______________________

6. Study Period ______________________

7. Present Value of Investment Cost ______________________
   (Item 9, Table 9)

8. Present Value of Future Non-Energy Costs ______________________
   (Item 10, Table 10)

9. Total Present Value of Energy Costs ______________________
   (Item 6 or 16, Table 8)

10. Total Life-Cycle Costs in Present Value $ ______________________
    (line (10) = lines (7) + (8) + (9))

* This is Appendix Worksheet C-3.1.

TABLE 8

Worksheet for Calculating the Present Value of Energy Costs in a New Building Design*

Step	Electricity: Heating	Electricity: Cooling	Natural Gas	Fuel Oil	Total
CALCULATION OF BASE YEAR ENERGY COSTS					
(1) Annual Energy Consumption					
(2) Today's Local Price/Unit					
(3) Today's Annual $ Costs (3) = (1) x (2)					
CONSTANT PRICE ESCALATION ADJUSTMENT					
(4) Constant Price Escalation Rate					
(5) Uniform Present Value Factor					
(6) Present Value Energy Costs (6) = (3) x (5)					
SHORT-TERM/LONG-TERM PRICE ESCALATION ADJUSTMENT					
(7) Expected Real Short-Term Price Escalation from End of Year 0 to End of Year ____					
(8) Uniform Present Value Factor for Short-Term Price Escalation					
(9) Present Value of Short-Term Energy Costs (9) = (3) x (8)					
(10) Expected Price End of Year ____ (See Instructions)					
(11) Value of Annual Costs in Year ____ (11) = (1) x (10)					
(12) Uniform Present Value Factor for Long-Term (See Instructions)					
(13) Discounted Value of Costs in Year ____ (13) = (11) x (12)					
(14) Single Present Value Factor (See Instructions)					
(15) Present Value Adjustment of Long-Term Energy Costs (15) = (13) x (14)					
(16) Present Value of Total Energy Costs (16) = (9) + (15)					

*This is Appendix Worksheet C-3.2.

TABLE 9

Worksheet for Calculating the Present Value of Capital Investment Costs in a New Building Design*

Year (1)	Investment Cost in Constant $ (Planning, Design, Construction, Replacement) (2)	Salvage Value at End of Study Period in Constant $ (3)	Single Present Value Factor for Year Indicated (from Table B-1) (4)	Present Value of Salvage (5)=(3)x(4)	Present Value of Investment for Year Indicated (6)=(2)x(4)
0	______	______	______	______	______
1	______	______	______	______	______
3	______	______	______	______	______
4	______	______	______	______	______
5	______	______	______	______	______
•	______	______	______	______	______
10	______	______	______	______	______
•	______	______	______	______	______
•	______	______	______	______	______
25	______	______	______	______	______
Totals				______	______

(7) Present Value of Investment Costs, (Sum of Column 6): ______________________

(8) (minus) Present Value of Salvage Value (Sum of Column 5): ______________________

(9) (equals) Net Present Value of Investment Costs: ______________________

*This is Appendix Worksheet C-3.3.

TABLE 10

Worksheet for Calculating Non-Energy (Maintenance and Repair) Costs for a New Building Design*

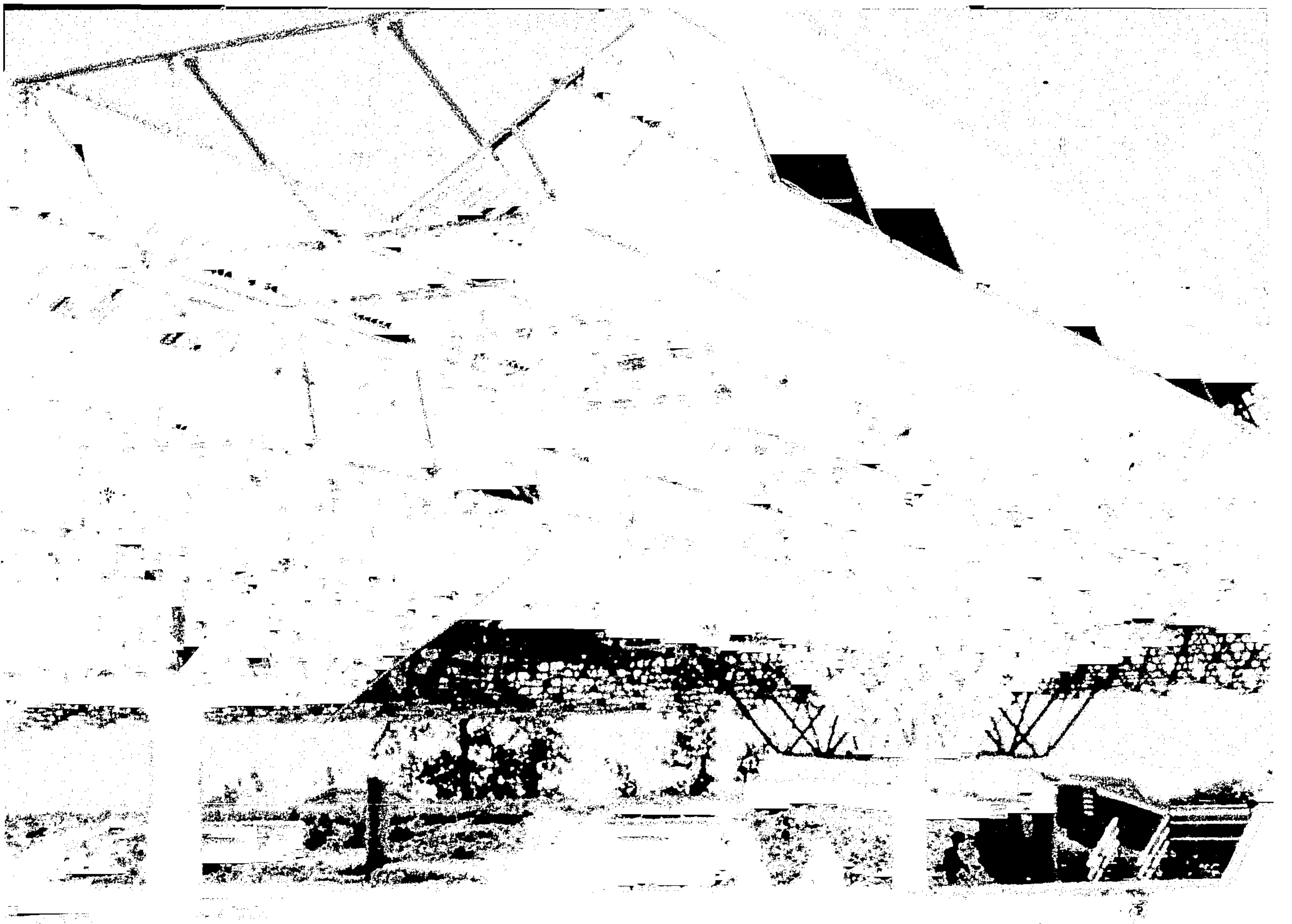
Year	Annual Recurring Costs in Constant $	Uniform Present Value Factor (from Table B-2)	Present Value of Recurring Costs	Other Costs in Constant $	Single Present Value Factor for Year Indicated (from Table B-1)	Present Value of Other Costs
(1)	(2)	(3)	(4)=(2)x(3)	(5)	(6)	(7)=(5)x(6)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Totals						

(8) Total Present Value of Recurring Costs ______

(9) (plus) Total Present Value of Other Costs ______

(10) (equals) Present Value of Non-Energy Costs ______

*This is Appendix Worksheet C-3.4.



5. EVALUATING INVESTMENTS IN SOLAR ENERGY

Investments in solar energy systems are regarded as energy conserving in that they substitute renewable energy for non-renewable energy. Investments in solar energy systems may be evaluated using the LCC methods specified in this guide in essentially the same way as for other energy conservation investments.

For solar retrofit projects to existing buildings, the SIR can be calculated using the same procedures outlined in Section 3.0, and these projects can then be ranked together with the non-solar investments in energy conservation. For new buildings, solar building designs can be compared to alternative non-solar designs based on the total LCC of each design as outlined in Section 4.0.

Sensitivity analysis is particularly recommended for solar energy applications because of the lack of experience and uncertainty associated with some of the LCC parameters.[28]

Participants in the Federal Energy Management Program and in the Federal Grant Program are directed to follow the same basic procedures for evaluating solar energy investments as for other energy conservation investments.

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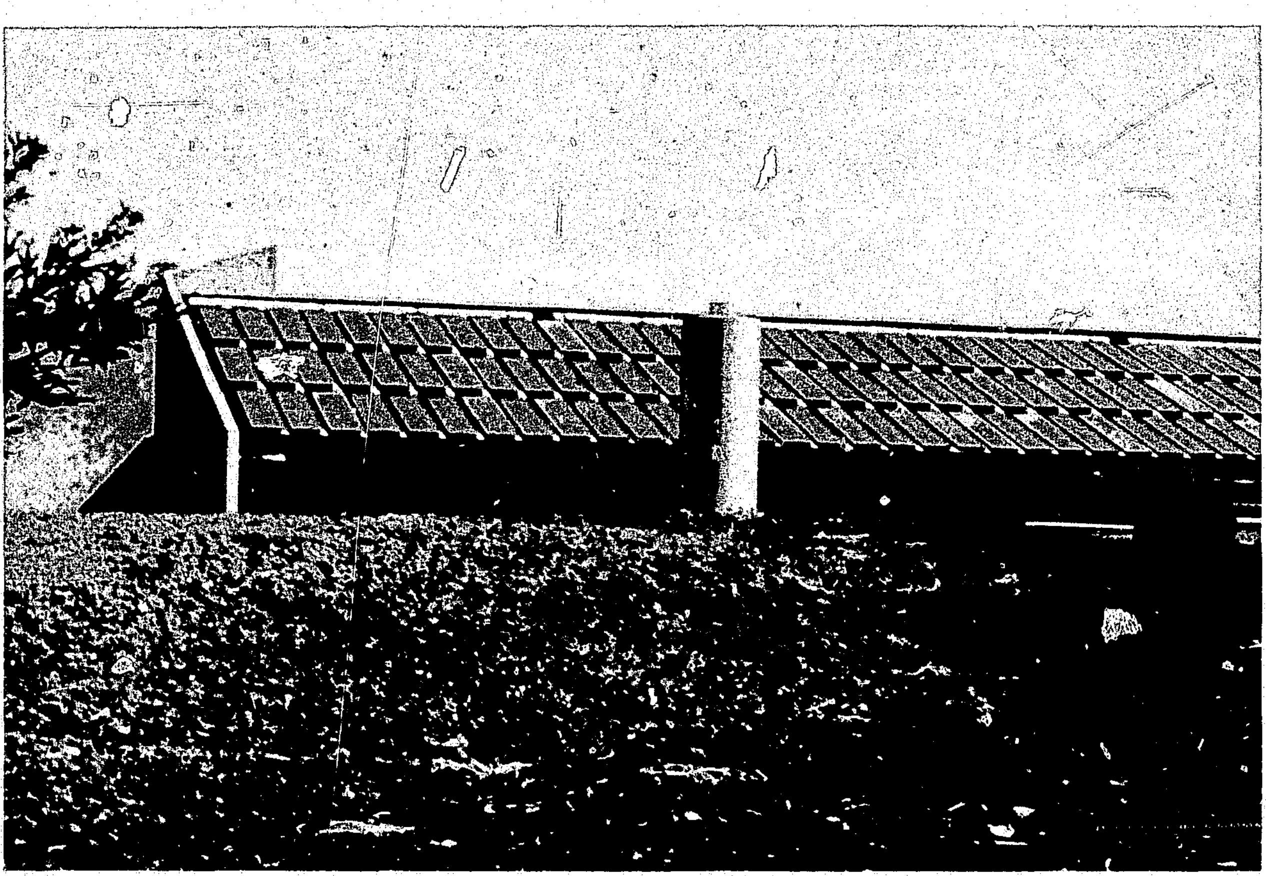
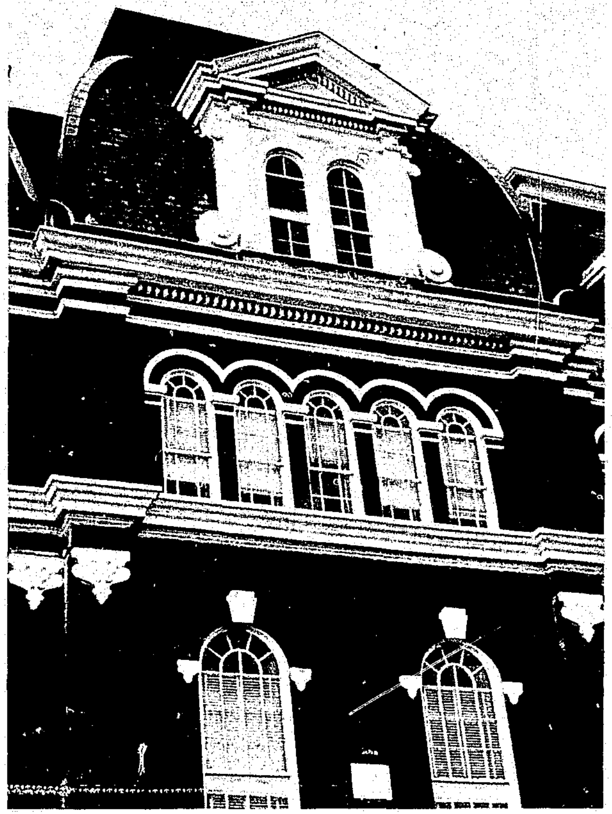
[28] For an indepth treatment of the economic evaluation of solar energy systems, including determination of the optimally sized system, see reference [24].



6. DETERMINING ENERGY CONSERVATION REQUIREMENTS FOR EXISTING LEASED BUILDINGS

In principle, the LCC procedures described for existing owned buildings can also be applied to evaluate energy conservation investments for existing buildings that are leased. SIR measures can be computed for each potential retrofit project for an existing leased building. The SIR can be computed using the same assumptions about economic life and study period that would be used if the building were publicly owned, or the study period may be set to coincide with the term of the lease. A ranking of retrofit projects for leased buildings by SIR can then be compiled.

Private ownership of leased buildings, however, will generally preclude the expenditure of public investment funds for energy conservation in the leased buildings.



The SIR ranking can nevertheless be used to identify those projects which may be potentially sound investments in energy conservation for the building owners. Thus, the use of SIR rankings for potential energy conservation projects may be beneficial for both the government and the building owners at the time of lease negotiation/renegotiation. However, because private building owners must also consider the effects of local and Federal taxes and incentives, retrofit investments may have a different level of benefits to a private building owner than to the public lessee. In general, leases in which the building owner is required to pay energy costs should provide greater incentive to a private owner to invest in energy conservation projects.

Lease negotiations may be considered unsatisfactory if the SIR for potential retrofit projects for a leased building is larger than the SIR of retrofit projects which are being funded for publicly-owned buildings. Unsatisfactory negotiation/renegotiation regarding energy conservation may be cause for an agency to consider leasing space elsewhere, or for an agency to consider construction of a publicly owned building.

7. UNIFORM LCC CRITERIA

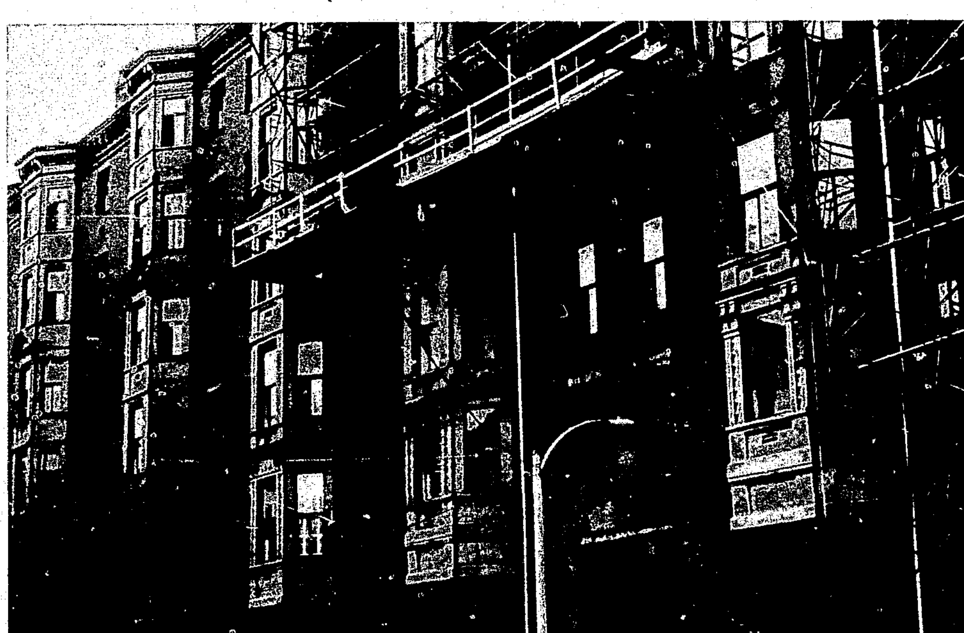
As indicated throughout this report, there are many choices that an analyst must make among alternative assumptions, procedures, and methods — alternatives which may be equally valid, but which are different. The use of different assumptions, procedures, and methods leads to results that are not comparable among projects or agencies.

Based on the view that it is often useful and desirable to have comparability of results, this report concludes by proposing a list of uniform LCC criteria that might be adopted by public agencies and organizations. The purpose of providing this list is to facilitate uniform and consistent practices among public agencies in determining the relative cost effectiveness of energy conservation projects.

Again, it should be noted that participants in the Federal Energy Management Program and the Federal Grants Program for Technical Assistance Programs and Energy Conservation Projects in Schools, Hospitals, Local Government and Public Care Buildings, are subject to specific sets of guidelines for performing economic analysis for each of these programs. Those requirements, as given by current draft program guidelines, have been noted in this report in conjunction with the general descriptions of alternative methods, procedures, and assumptions. However, the reader is reminded that the requirements for the Federal Programs are not final at the printing of this report and may change. The following list of uniform LCC criteria does not reflect completely the requirements of either of the Federal Programs, although many of the specific requirements of the Federal Energy Management Program are included in the list. An example of a requirement for the Federal program that is not included in the list of uniform LCC criteria, is the use of a 10 percent real discount rate. It is not included because States and localities may be legally subject to a different discount rate, or may have concluded that a different rate is more appropriate to their situation.

Adoption of the following criteria will lead to the use of more consistent methods, assumptions, and results in the evaluation of energy conservation in public buildings:

(1) Measure all costs and savings in either present value or annual value dollars.
(2) Make evaluations in constant dollars, adjusted to remove inflation, and use a real discount rate (also without inflation) to account for the time value of money.
(3) Compute the SIR for retrofit projects, based on either present value or annual value dollars, and use it as the principal economic measure for ranking and giving priority to projects.
(4) Compute the total LCC for alternative new building designs, based on either present value or annual value dollars, and use it to select the optimal design for each new building under consideration.
(5) Measure energy costs and savings in dollars, based on the local price at the margin of energy and the quantity of energy delivered to the building or facility boundary.
(6) To estimate future energy prices, include only the differential change in energy prices in excess of general price inflation.
(7) To estimate future non-energy costs (e.g., labor and materials), assume that these costs will increase at about the same rate as general price inflation, and do not escalate future prices.
(8) For the estimation of long-term future energy prices, use the most recent available projections of energy prices developed or endorsed by the Department of Energy.
(9) Include in the evaluation of a project those project-specific investment costs not already incurred, such as for special studies, design, installation, and replacement, but exclude costs for preliminary energy audits and surveys.



APPENDIX A

GLOSSARY OF SELECTED ECONOMIC TERMS

Annual Recurring Costs. Those costs which are incurred each year in an equal amount or in an amount that is increasing at a constant rate throughout the study period.

Annual Value. Past or future costs or benefits expressed as an equivalent uniform annual amount, taking into account the *Time Value of Money.*

Annual Value Factor. The number by which a benefit or cost may be multiplied to find its *Annual Value,* based on a given *Discount Rate* and a given period of time.

Base Year. The year to which all future and past costs are converted when a *Present Value* method is used.

Constant Dollars. Values expressed in terms of the purchasing power of the dollar in the base year; i.e., constant dollars do not reflect price inflation.

Cost Effective. Estimated benefits (savings) from an energy conservation investment project are equal to or exceed the costs of the investment, where both are assessed over the life of the project.

Current Dollars. Values expressed in terms of the actual prices of each year; i.e., current dollars reflect inflation.

Differential Cost. The difference in the total cost of two alternatives.

Differential Energy Price Escalation Rate. The expected difference between a general rate of inflation and the rate of cost increases assumed for energy.

Discount Factor. A multiplicative number for converting costs and benefits occurring at different times to a common basis. Discount factors are obtained by solving a discount formula based upon one dollar of costs or benefits and the assumed *Discount Rate.*

Discount Rate. The rate of interest reflecting the *Time Value of Money* that is used to convert benefits and costs occurring at different times to a common time. OMB Circular A-94 specifies that the discount rate for evaluating government projects be 10 percent. This 10 percent represents the rate of interest after inflation is removed.

Discounted Payback Period. The time required for the cumulative savings, net of future costs, from an investment to pay back the *Investment Cost,* considering the *Time Value of Money.*

Discounting. A technique for converting costs and benefits occurring over time to equivalent amounts at a common point in time.

Economic Life. That period of time over which an investment is considered to be the lowest cost alternative for satisfying a particular need.

Future Non-Energy Costs. Recurring and nonrecurring maintenance and repair costs that may be spread throughout the life of the project.

Initial Annual Energy Cost. For each type of energy, the product of the quantity of energy consumed in a year (measured at the building or facility boundary) times the current unit energy price at the margin, in the *Base Year.*

Initial Annual Energy Savings. In existing buildings, for each type of energy, the positive difference between the existing building's *Initial Annual Energy Cost* and its projected initial annual energy cost with the proposed energy conservation retrofit in place.

Initial Investment or First Cost. The sum of the planning, design, and construction costs necessary to provide a finished building or project ready for use.

Internal Rate of Return. The calculated rate of return which an investment is expected to yield, determined by taking into account the *Time Value of Money.* It is the compound rate of interest which when used to discount life-cycle costs and savings will cause the two to be equal.

Life-Cycle Costing (LCC). A method of economic evaluation of alternatives which considers all relevant costs associated with each alternative activity or project during the time it is in use. For buildings, life-cycle costs include all costs of owning, operating, and maintaining a building over its *Economic Life,* including its energy costs.

Maintenance and Repair Cost. The total of labor, material, transportation, and other related costs incurred in conducting corrective and preventative maintenance and repair on a building and/or its systems, components, and equipment.

Major Replacement Investment. Any significant future component replacement, included in the capital budget, which must be incurred during the study period in order to maintain the investment at a functional level.

Net Annual Value of Savings. The *Annual Value* of life-cycle energy savings minus (or plus) the annual value of the related increase (or decrease) in life-cycle costs.

Net Present Value of Investment Costs. The *Present Value* of the *Initial Investment Cost* plus the present value of *Major Replacement Investments* less the present value of *Salvage Values.*

Net Present Value of Savings. The present value of life-cycle energy savings minus (or plus) the present value of the related increase (or decrease) in life-cycle costs.

Operating Cost. The expenses incurred during the normal operation of a building or a building system, component, or equipment, including costs of labor, materials, and utilities.

Present Value. Past, present and future costs or benefits expressed as an equivalent amount in the *Base Year,* taking into account the *Time Value of Money.*

Present Value Factor. The number by which a future value may be multiplied to find its value in the *Base Year,* given a *Discount Rate.*

Recurring Costs. Those costs which recur on a periodic basis throughout the life of a project.

Salvage Value. The net sum to be realized from disposal of an asset at the end of its *Economic Life,* at the end of the study period, or whenever it is no longer to be used.

Savings-to-Investment Ratio (SIR). Either the ratio of *Present Value* savings to present value investment costs, or the ratio of *Annual Value* savings to annual value investment costs.

Sensitivity Analysis. Testing the outcome of an evaluation by altering one or more system parameters from the initially assumed values.

Simple Payback Period. A measure of the length of time required for the cumulative savings, net of future costs, from an investment to pay back the *Initial Investment Cost,* without taking into account the *Time Value of Money.*

Study Period. The length of time over which an investment is analyzed.

Sunk Cost. A cost which has already been incurred and should not be considered in making a current investment decision.

Time Value of Money. The time-dependent value of money that may stem both from changes in the purchasing power of money and from the earning potential of alternative investments over time. The time value of money is indicated by the difference between the value of a dollar received today and its value if received at some future time, when it can be invested today at a stated rate of interest.

Total Life-Cycle Cost. The sum of the costs of the *Initial Investment* (less *Salvage Value*), the *Major Replacement Investments,* maintenance and repair, and energy, over the life-cycle of an investment.

APPENDIX B

DISCOUNT FORMULAS AND FACTOR TABLES

TABLE B-1

Discount Formulas

Nomenclature	Use When	Algebraic Form
Single Compound Amount Formula	Given P; to find F, and Given T; to find P	$F = P\ (1+i)^N$ $P = T\ (1+i)^N$
Single Present Value Formula	Given F; to find P	$P = F \frac{1}{(1+i)^N}$
Uniform Compound Amount Formula	Given A; to find F	$F = A \frac{(1+i)^N - 1}{i}$
Uniform Sinking Fund Formula	Given F; to find A	$A = F \frac{i}{(1+i)^N - 1}$
Uniform Capital Recovery Formula	Given P; to find A	$A = P \frac{i(1+i)^N}{(1+i)^N - 1}$
Uniform Present Value Formula*	Given A; to find P	$P = A \frac{(1+i)^N - 1}{i(1+i)^N}$

Where:

P = a present sum of money.
T = a past sum of money.
F = a future sum of money.
i = an interest rate.
N = number of interest periods.
A = an end-of-period payment (or receipt) in a uniform series of payments (or receipts), usually annually.

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*A variation of the uniform present value formula that can be used to find the present value of an annual amount that is increasing at a constant rate is the following (i.e., Given A, escalating at rate e; to find P):

$$P = A \cdot \sum_{j=1}^{N} \left(\frac{1+e}{1+i}\right)^j = \left(\frac{1+e}{i-e}\right)\left(1 - \left(\frac{1+e}{1+i}\right)^N\right) A$$

Source: Gerald W. Smith, *Engineering Economy: Principles of Capital Expenditures,* 2nd Ed. (Ames, Iowa: The Iowa State University Press, 1973), p. 47.

TABLE B-2
Single Present Value Discount Factors for Energy Price Escalation Rates from 0% to 10%
(Based Upon a 10% Discount Rate)

	Energy Price Escalation Rates										
Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	0.9091	0.9182	0.9273	0.9364	0.9455	0.9546	0.9636	0.9727	0.9818	0.9909	1.0000
2	0.8264	0.8430	0.8598	0.8767	0.8938	0.9111	0.9285	0.9461	0.9639	0.9818	1.0000
3	0.7513	0.7741	0.7973	0.8209	0.8451	0.8697	0.8948	0.9203	0.9464	0.9729	1.0000
4	0.6830	0.7107	0.7393	0.7687	0.7990	0.8302	0.8623	0.8953	0.9292	0.9641	1.0000
5	0.6209	0.6526	0.6855	0.7198	0.7554	0.7925	0.8309	0.8709	0.9123	0.9553	1.0000
6	0.5645	0.5992	0.6357	0.6741	0.7143	0.7565	0.8007	0.8471	0.8958	0.9467	1.0000
7	0.5132	0.5502	0.5895	0.6312	0.6753	0.7221	0.7716	0.8241	0.8795	0.9381	1.0000
8	0.4665	0.5041	0.5466	0.5910	0.6385	0.6893	0.7435	0.8015	0.8634	0.9295	1.0000
9	0.4241	0.4638	0.5068	0.5534	0.6036	0.6579	0.7165	0.7797	0.8478	0.9211	1.0000
10	0.3855	0.4258	0.4699	0.5181	0.5706	0.6279	0.6904	0.7584	0.8323	0.9126	1.0000
11	0.3505	0.3911	0.4358	0.4852	0.5396	0.5995	0.6654	0.7378	0.8172	0.9044	1.0000
12	0.3187	0.3591	0.4042	0.4544	0.5102	0.5724	0.6413	0.7178	0.8026	0.8964	1.0000
13	0.2897	0.3297	0.3748	0.4254	0.4824	0.5463	0.6179	0.6981	0.7879	0.8882	1.0000
14	0.2633	0.3027	0.3474	0.3983	0.4560	0.5213	0.5953	0.6789	0.7734	0.8799	1.0000
15	0.2394	0.2779	0.3222	0.3730	0.4311	0.4977	0.5737	0.6605	0.7594	0.8720	1.0000
16	0.2176	0.2552	0.2987	0.3492	0.4076	0.4750	0.5528	0.6424	0.7455	0.8639	1.0000
17	0.1979	0.2344	0.2771	0.3271	0.3855	0.4536	0.5329	0.6251	0.7322	0.8564	1.0000
18	0.1798	0.2151	0.2568	0.3061	0.3642	0.4327	0.5132	0.6077	0.7185	0.8481	1.0000
19	0.1635	0.1975	0.2382	0.2867	0.3445	0.4132	0.4947	0.5913	0.7056	0.8407	1.0000
20	0.1486	0.1813	0.2208	0.2684	0.3256	0.3943	0.4766	0.5750	0.6926	0.8328	1.0000
21	0.1351	0.1665	0.2048	0.2513	0.3079	0.3764	0.4593	0.5594	0.6801	0.8253	1.0000
22	0.1229	0.1530	0.1900	0.2355	0.2913	0.3595	0.4429	0.5445	0.6681	0.8183	1.0000
23	0.1117	0.1404	0.1761	0.2205	0.2753	0.3431	0.4267	0.5295	0.6558	0.8107	1.0000
24	0.1015	0.1289	0.1633	0.2063	0.2602	0.3273	0.4110	0.5148	0.6436	0.8030	1.0000
25	0.0923	0.1184	0.1514	0.1933	0.2461	0.3126	0.3961	0.5009	0.6321	0.7959	1.0000

NOTES: The discount factors in the 0% column of this table can be converted to a mid-year discounting basis by multiplying them by the factor 1.0488.

Factors for intermediate values of energy price escalation rates, e.g., 7.5%, may be obtained by interpolation.

If the 10% discount rate on which the factors are based is defined as a real rate, excluding inflation, then the energy escalation rates should also be defined as real rates, i.e., as differential rates in excess of general price inflation.

Inclusion of energy escalation rates ranging from 0% to 10% is not intended to indicate anything about the appropriate projections of energy prices.

TABLE B-3

Uniform Present Value Discount Factors for Energy Price Escalation Rates from 0% to 10%
(Based Upon a 10% Discount Rate)

	Energy Price Escalation Rates										
Year	**0%**	**1%**	**2%**	**3%**	**4%**	**5%**	**6%**	**7%**	**8%**	**9%**	**10%**
1	0.9091	0.9182	0.9273	0.9364	0.9455	0.9546	0.9636	0.9727	0.9818	0.9909	1.0000
2	1.7355	1.7612	1.7871	1.8131	1.8393	1.8657	1.8921	1.9188	1.9457	1.9727	2.0000
3	2.4868	2.5353	2.5844	2.6340	2.6844	2.7354	2.7869	2.8391	2.8921	2.9456	3.0000
4	3.1698	3.2460	3.3237	3.4027	3.4834	3.5656	3.6492	3.7344	3.8213	3.9097	4.0000
5	3.7907	3.8986	4.0092	4.1225	4.2388	4.3581	4.4801	4.6053	4.7336	4.8650	5.0000
6	4.3552	4.4978	4.6449	4.7966	4.9531	5.1146	5.2808	5.4524	5.6294	5.8117	6.0000
7	4.8684	5.0480	5.2344	5.4278	5.6284	5.8367	6.0524	6.2765	6.5089	6.7498	7.0000
8	5.3449	5.5521	5.7810	6.0188	6.2669	6.5260	6.7959	7.0780	7.3723	7.6793	8.0000
9	5.7590	6.0159	6.2878	6.5722	6.8705	7.1839	7.5124	7.8577	8.2201	8.6004	9.0000
10	6.1445	6.4417	6.7577	7.0903	7.4411	7.8118	8.2028	8.6161	9.0524	9.5130	10.0000
11	6.4930	6.8328	7.1935	7.5755	7.9807	8.4113	8.8682	9.3539	9.8696	10.4174	11.0000
12	6.8137	7.1919	7.5977	8.0299	8.4909	8.9837	9.5095	10.0717	10.6722	11.3138	12.0000
13	7.1034	7.5216	7.9725	8.4553	8.9733	9.5300	10.1274	10.7698	11.4601	12.2020	13.0000
14	7.3667	7.8243	8.3199	8.8536	9.4293	10.0513	10.7227	11.4487	12.2335	13.0819	14.0000
15	7.6061	8.1022	8.6421	9.2266	9.8604	10.5490	11.2964	12.1092	12.9929	13.9539	15.0000
16	7.8238	8.3574	8.9408	9.5758	10.2680	11.0240	11.8492	12.7516	13.7384	14.8178	16.0000
17	8.0216	8.5918	9.2179	9.9029	10.6535	11.4776	12.3821	13.3767	14.4706	15.6742	17.0000
18	8.2014	8.8069	9.4747	10.2090	11.0177	11.9103	12.8953	13.9844	15.1891	16.5223	18.0000
19	8.3649	9.0044	9.7129	10.4957	11.3622	12.3235	13.3900	14.5757	15.8947	17.3630	19.0000
20	8.5135	9.1857	9.9337	10.7641	11.6878	12.7178	13.8666	15.1507	16.5873	18.1958	20.0000
21	8.6486	9.3512	10.1385	11.0154	11.9957	13.0942	14.3259	15.7101	17.2674	19.0211	21.0000
22	8.7715	9.5042	10.3285	11.2509	12.2870	13.4537	14.7688	16.2546	17.9355	19.8394	22.0000
23	8.8832	9.6446	10.5046	11.4714	12.5623	13.7968	15.1955	16.7841	18.5913	20.6501	23.0000
24	8.9847	9.7735	10.6679	11.6777	12.8225	14.1241	15.6065	17.2989	19.2349	21.4531	24.0000
25	9.0770	9.8919	10.8193	11.8710	13.0686	14.4367	16.0026	17.7998	19.8670	22.2490	25.0000

NOTE: See Table B-2, "Notes".

TABLE B-4
Single Compound Amount Factors for Alternative Discount Rates

	Discount Rates									
Year	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	1.0100	1.0200	1.0300	1.0400	1.0500	1.0600	1.0700	1.0800	1.0900	1.1000
2	1.0201	1.0404	1.0609	1.0816	1.1025	1.1236	1.1449	1.1664	1.1881	1.2100
3	1.0303	1.0612	1.0927	1.1249	1.1576	1.1910	1.2250	1.2597	1.2950	1.3310
4	1.0406	1.0824	1.1255	1.1699	1.2155	1.2625	1.3108	1.3605	1.4115	1.4641
5	1.0510	1.1041	1.1593	1.2167	1.2763	1.3382	1.4026	1.4693	1.5386	1.6105
6	1.0615	1.1262	1.1941	1.2653	1.3401	1.4185	1.5007	1.5869	1.6771	1.7716
7	1.0721	1.1487	1.2299	1.3159	1.4071	1.5036	1.6058	1.7138	1.8280	1.9487
8	1.0829	1.1717	1.2668	1.3686	1.4775	1.5938	1.7182	1.8509	1.9925	2.1436
9	1.0937	1.1951	1.3048	1.4233	1.5513	1.6895	1.8385	1.9990	2.1718	2.3579
10	1.1046	1.2190	1.3439	1.4802	1.6289	1.7908	1.9672	2.1589	2.3673	2.5937
11	1.1157	1.2434	1.3842	1.5395	1.7103	1.8983	2.1049	2.3316	2.5804	2.8531
12	1.1268	1.2682	1.4258	1.6010	1.7959	2.0122	2.2522	2.5182	2.8126	3.1384
13	1.1381	1.2936	1.4685	1.6651	1.8856	2.1329	2.4098	2.7196	3.0658	3.4523
14	1.1495	1.3195	1.5126	1.7317	1.9800	2.2609	2.5785	2.9372	3.3417	3.7975
15	1.1610	1.3459	1.5580	1.8009	2.0789	2.3966	2.7590	3.1722	3.6424	4.1772
16	1.1726	1.3728	1.6047	1.8730	2.1829	2.5404	2.9522	3.4259	3.9703	4.5950
17	1.1843	1.4002	1.6528	1.9479	2.2920	2.6928	3.1588	3.7000	4.3276	5.0545
18	1.1961	1.4282	1.7024	2.0258	2.4066	2.8543	3.3799	3.9960	4.7171	5.5599
19	1.2081	1.4568	1.7535	2.1068	2.5270	3.0256	3.6165	4.3157	5.1416	6.1159
20	1.2202	1.4859	1.8061	2.1911	2.6533	3.2071	3.8697	4.6610	5.6044	6.7275
21	1.2324	1.5157	1.8603	2.2788	2.7860	3.3996	4.1406	5.0338	6.1088	7.4002
22	1.2447	1.5460	1.9161	2.3699	2.9253	3.6035	4.4304	5.4365	6.6586	8.1403
23	1.2572	1.5769	1.9736	2.4647	3.0715	3.8197	4.7405	5.8715	7.2578	8.9543
24	1.2697	1.6084	2.0328	2.5633	3.2251	4.0489	5.0724	6.3412	7.9110	9.8497
25	1.2824	1.6406	2.0938	2.6658	3.3864	4.2919	5.4274	6.8485	8.6230	10.8347
26	1.2953	1.6734	2.1566	2.7725	3.5557	4.5494	5.8074	7.3964	9.3991	11.9182
27	1.3082	1.7069	2.2213	2.8834	3.7335	4.8223	6.2139	7.9881	10.2450	13.1100
28	1.3213	1.7410	2.2879	2.9987	3.9201	5.1117	6.6488	8.6271	11.1671	14.4210
29	1.3345	1.7758	2.3566	3.1187	4.1161	5.4184	7.1143	9.3173	12.1721	15.8631
30	1.3478	1.8114	2.4273	3.2434	4.3219	5.7435	7.6123	10.0627	13.2676	17.4494
31	1.3613	1.8476	2.5001	3.3731	4.5380	6.0881	8.1451	10.8677	14.4617	19.1943
32	1.3749	1.8845	2.5751	3.5081	4.7649	6.4534	8.7153	11.7371	15.7633	21.1138
33	1.3887	1.9222	2.6523	3.6484	5.0032	6.8406	9.3253	12.6760	17.1820	23.2252
34	1.4026	1.9607	2.7319	3.7943	5.2533	7.2510	9.9781	13.6901	18.7284	25.5477
35	1.4166	1.9999	2.8139	3.9461	5.5160	7.6861	10.6766	14.7853	20.4139	28.1024
40	1.4889	2.2080	3.2620	4.8010	7.0400	10.2857	14.9745	21.7245	31.4094	45.2593

APPENDIX C
WORKSHEETS FOR DERIVING ECONOMIC RANKING

WORKSHEET C-1

Calculating the SIR for a Simple Retrofit Project

1. Name of Agency ______________________________

2. Project Description ______________________________

3. Location ______________________________

4. Gross Floor Area Affected ______________________________

5. Expected Life of Project ______________________________

6. Expected Life of Building ______________________________

7. Study Period ______________________________

8. Project Investment Cost ______________________________
(Date____________)

9. Value of Annual Energy Savings

(A) Units of Energy Saved at Bldg/Facility Boundary	(B) Current Unit Energy Price (Date ________)	(C) Initial Annual Energy Savings (Date ________) (C)=(A)x(B)	(D) Energy Escalation Rate	(E) Uniform Present Value Factor for Specified Energy Price Escalation Rate	(F) Present Value (Date ________) (F)=(C)x(E)
________ kWh Electricity	________ $ Per kWh	________	________	________	________
________ therms Natural Gas	________ $ Per Therm	________	________	________	________
________ gal. Fuel Oil	________ $ Per Gal.	________	________	________	________
________ Other	________ $ Per ______	________	________	________	________

10. Total Savings ______________________________

11. SIR (Item 10 ÷ Item 8) ______________________________

WORKSHEET C-2.1

Calculating the SIR for a Retrofit Project when Cash Flows are Complex

(Project Summary Sheet)

1. Name of Agency ____________________

2. Project Description ____________________

3. Location ____________________

4. Gross Floor Area Affected ____________________

5. Expected Life of System ____________________

6. Expected Life of Building ____________________

7. Study Period ____________________

ENERGY SAVINGS

8. Total Present Value of Energy Savings ____________________
   (Item 18, Worksheet C-2.2)

INVESTMENT COST

9. Present Value of Investment Cost Less Salvage ____________________
   (Item 9, Worksheet C-2.3)

NON-ENERGY COSTS (or SAVINGS)

10. Present Value of Non-Energy Costs for the Retrofitted Building ____________________
    (Item 10, Worksheet C-2.4)

11. Present Value of Non-Energy Costs for Existing Building or System ____________________
    (Item 10, Worksheet C-2.5)

12. Present Value of Change in Non-Energy Costs ____________________
    (Line 10 minus Line 11, or (difference method) Line 10)

SIR NUMERATOR

13. Total Present Value of Energy Savings Minus Non-Energy Costs ____________________
    (Line 8 minus Line 12)

LIFE-CYCLE COST MEASURES

14. SIR ____________________
    (Line 13 ÷ Line 9)

15. Net Savings in Present Value ____________________
    (Line 13 − Line 9)

WORKSHEET C-2.2

Calculating the Present Value of Energy Savings from a Retrofit Project when Short-Term and Long-Term Energy Escalation Rates are Used

Step	Electricity		Natural Gas	Fuel Oil	Total
	Heating	Cooling			
CALCULATION OF BASE YEAR ENERGY COSTS					
(1) Annual Consumption, Existing System					
(2) Annual Consumption, Proposed Alternative					
(3) Annual Quantity Saved (3) = (1) – (2)					
(4) Today's Local Price/Unit					
(5) Today's Annual $ Savings (5) = (3) x (4)					
CONSTANT PRICE ESCALATION ADJUSTMENT					
(6) Constant Price Escalation Rate					
(7) Uniform Present Value Factor**					
(8) Present Value Energy Savings (8) = (5) x (7)					
SHORT-TERM/LONG-TERM PRICE ESCALATION ADJUSTMENT					
(9) Expected Real Short-Term Price Escalation from End of Year 0 to End of Year ______					
(10) Uniform Present Value Factor for Short-Term Price Escalation					
(11) Present Value of Short-Term Energy Savings (11) = (5) x (10)					
(12) Expected Price End of Year _____ (See Instructions)					
(13) Value of Annual Savings in Year _____ (13) = (3) x (12)					
(14) Uniform Present Value Factor for Long-Term (See Instructions)					
(15) Discounted Value of Savings in Year _____ (15) = (13) x (14)					
(16) Single Present Value Factor (See Instructions)					
(17) Present Value of Long-Term Energy Savings (17) = (15) x (16)					
(18) Present Value of Total Energy Savings (18) = (11) + (17)					

WORKSHEET C-2.3

Calculating the Net Present Value of Capital Investment Costs when Costs are Spread Over Time and There is Salvage Value

Year (1)	Investment Cost in Constant $ (Planning, Design, Construction, Replacement) (2)	Salvage Value at End of Study Period in Constant $ (3)	Single Present Value Factor for Year Indicated (from Table B-1) (4)	Present Value of Salvage (5)=(3)x(4)	Present Value of Investment for Year Indicated (6)=(2)x(4)
0	______	______	______	______	______
1	______	______	______	______	______
3	______	______	______	______	______
4	______	______	______	______	______
5	______	______	______	______	______
•	______	______	______	______	______
10	______	______	______	______	______
•	______	______	______	______	______
•	______	______	______	______	______
25	______	______	______	______	______
Totals				______	______

(7) Present Value of Investment Costs, (Sum of Column 6): ______________________

(8) (minus) Present Value of Salvage Value (Sum of Column 5): ______________________

(9) (equals) Net Present Value of Investment Costs: ______________________

WORKSHEET C-2.4

Calculating the Present Value of Non-Energy (Maintenance and Repair) Costs After the Retrofit

Year (1)	Annual Recurring Costs in Constant $ (2)	Uniform Present Value Factor (from Table B-2) (3)	Present Value of Recurring Costs (4)=(2)x(3)	Other Costs in Constant $ (5)	Single Present Value Factor for Year Indicated (from Table B-1) (6)	Present Value of Other Costs (7)=(5)x(6)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Totals						

(8) Total Present Value of Recurring Costs __________

(9) (plus) Total Present Value of Other Costs __________

(10) (equals) Present Value of Non-Energy Costs __________

WORKSHEET C-2.5

Calculating the Present Value of Non-Energy (Maintenance and Repair) Cost Before the Retrofit

Year	Annual Recurring Costs in Constant $	Uniform Present Value Factor (from Table B-2)	Present Value of Recurring Costs	Other Costs in Constant $	Single Present Value Factor for Year Indicated (from Table B-1)	Present Value of Other Costs
(1)	(2)	(3)	(4)=(2)x(3)	(5)	(6)	(7)=(5)x(6)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Totals						

(8) Total Present Value of Recurring Costs __________

(9) (plus) Total Present Value of Other Costs __________

(10) (equals) Present Value of Non-Energy Costs __________

SUMMARY WORKSHEET C-3.1

Calculating the Total Life-Cycle Costs of the Energy Components of a New Building Project

(Design ______________________________)

1. Name of Agency ______________________________

2. Project Description ______________________________

3. Location ______________________________

4. Gross Floor Area Affected ______________________________

5. Expected Economic Life of Building Design ______________________________

6. Study Period ______________________________

7. Present Value of Investment Cost ______________________________
   (Item 9, Worksheet C-3.3)

8. Present Value of Future Non-Energy Costs ______________________________
   (Item 10, Worksheet C-3.4)

9. Total Present Value of Energy Costs ______________________________
   (Item 6 or 16, Worksheet C-3.2)

10. Total Life-Cycle Costs in Present Value $ ______________________________
    (line (10) = lines (7) + (8) + (9))

WORKSHEET C-3.2

Calculating the Present Value of Energy Costs in a New Building Design

Step	Electricity		Natural Gas	Fuel Oil	Total
	Heating	Cooling			
CALCULATION OF BASE YEAR ENERGY COSTS					
(1) Annual Energy Consumption					
(2) Today's Local Price/Unit					
(3) Today's Annual $ Costs (3) = (1) x (2)					
CONSTANT PRICE ESCALATION ADJUSTMENT					
(4) Constant Price Escalation Rate					
(5) Uniform Present Value Factor					
(6) Present Value Energy Costs (6) = (3) x (5)					
SHORT-TERM/LONG-TERM PRICE ESCALATION ADJUSTMENT					
(7) Expected Real Short-Term Price Escalation from End of Year 0 to End of Year ____					
(8) Uniform Present Value Factor for Short-Term Price Escalation					
(9) Present Value of Short-Term Energy Costs (9) = (3) x (8)					
(10) Expected Price End of Year ____ (See Instructions)					
(11) Value of Annual Costs in Year ____ (11) = (1) x (10)					
(12) Uniform Present Value Factor for Long-Term (See Instructions)					
(13) Discounted Value of Costs in Year ____ (13) = (11) x (12)					
(14) Single Present Value Factor (See Instructions)					
(15) Present Value Adjustment of Long-Term Energy Costs (15) = (13) x (14)					
(16) Present Value of Total Energy Costs (16) = (9) + (15)					

WORKSHEET C-3.3

Calculating the Present Value of Capital Investment Costs in a New Building Design

Year	Investment Cost in Constant $ (Planning, Design, Construction, Replacement)	Salvage Value at End of Study Period in Constant $	Single Present Value Factor for Year Indicated (from Table B-1)	Present Value of Salvage	Present Value of Investment for Year Indicated
(1)	(2)	(3)	(4)	(5)=(3)x(4)	(6)=(2)x(4)
0	________	________	________	________	________
1	________	________	________	________	________
3	________	________	________	________	________
4	________	________	________	________	________
5	________	________	________	________	________
•	________	________	________	________	________
10	________	________	________	________	________
•	________	________	________	________	________
•	________	________	________	________	________
25	________	________	________	________	________
Totals				________	________

(7) Present Value of Investment Costs, (Sum of Column 6): ________________

(8) (minus) Present Value of Salvage Value (Sum of Column 5): ________________

(9) (equals) Net Present Value of Investment Costs: ________________

WORKSHEET C-3.4

Calculating Non-Energy (Maintenance and Repair) Costs for a New Building Design

Year	Annual Recurring Costs in Constant $	Uniform Present Value Factor (from Table B-2)	Present Value of Recurring Costs	Other Costs in Constant $	Single Present Value Factor for Year Indicated (from Table B-1)	Present Value of Other Costs
(1)	(2)	(3)	(4)=(2)x(3)	(5)	(6)	(7)=(5)x(6)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Totals						

(8) Total Present Value of Recurring Costs ____________

(9) (plus) Total Present Value of Other Costs ____________

(10) (equals) Present Value of Non-Energy Costs ____________

APPENDIX D
COMPUTER PROGRAM

This Appendix contains a computer program written in BASIC* language for performing the life-cycle cost calculations presented in the guide. The program format is interactive, allowing the analyst maximum flexibility in specifying the values of the parameters. This same program can be used to calculate the SIR for retrofit projects on existing buildings (see Section 3) or to calculate the total life-cycle costs of the energy-related components of a new building design (see Section 4).

The following is a listing of the program input statements:

```
LCCEO

5 DIM E(8,6),E$(6),Q$(5),I(3,8),R(4,8),M(2,8)
10 DIM U$(6)
12 REM SINGLE PRESENT VALUE DISCOUNT FORMULA
15 DEF FNP(X,Z)=1/(1+X)↑Z
17 REM UNIFORM PRESENT VALUE DISCOUNT FORMULA INCLUDING ENERGY
 . ESCALATION RATE
20 DEF FNU(X,Y,Z)=(1+Y)/(X-Y)*(1-((1+Y)/(1+X))↑Z)
25 PRINT "INPUT NAME OF AGENCY"
30 INPUT Q$(1)
35 PRINT "INPUT PROJECT NAME"
40 INPUT Q$(2)
45 PRINT "INPUT LOCATION OF AGENCY"
50 INPUT Q$(3)
55 PRINT "TYPE 1 IF PROJECT IS FOR AN EXISTING BUILDING, 2 IF"
60 PRINT "IT IS FOR A NEW BUILDING"
65 INPUT Q
70 PRINT "INPUT GROSS FLOOR AREA AFFECTED (IN SQUARE FEET)"
75 INPUT Q$(4)
80 PRINT "INPUT EXPECTED LIFE OF SYSTEM"
85 INPUT N1
90 PRINT "INPUT EXPECTED LIFE OF BUILDING"
95 INPUT Q$(5)
100 PRINT "INPUT STUDY PERIOD"
105 INPUT N2
110 IF Q<>1 THEN 135
115 LET B$="SAVINGS"
120 LET C$="SAVED"
125 LET D$="EXISTING"
130 GO TO 150
135 LET B$="COSTS"
```

*BASIC is an acronym for Beginners All-purpose Symbolic Instruction Code. For a description of the use of BASIC see *BASIC Language,* Honeywell Information Systems Inc., August 1971.

```
140 LET C$="CONSUMED"
145 LET D$="NEW"
150 PRINT "INPUT DISCOUNT RATE"
155 INPUT D
160 LET V=0
165 LET R1=0
170 LET M1=0
175 PRINT
180 PRINT "ENERGY "B$
185 PRINT
190 PRINT "INPUT NUMBER OF ENERGY SOURCES USED"
195 INPUT N4
200 MAT E=ZER(8,N4)
205 FOR J=1 TO N4
210 PRINT "INPUT ENERGY TYPE "J" AND UNIT (E.G. ELECTRICITY
    (HEATING),KWH)"
215 PRINT "NOTE: SEPARATE TYPE AND UNIT BY A COMMA"
220 INPUT E$(J),U$(J)
225 PRINT "INPUT ANNUAL AMOUNT OF "E$(J)" "C$" BY THIS SYSTEM"
230 INPUT E(1,J)
235 PRINT "INPUT LOCAL PRICE/"U$(J)
240 INPUT E(2,J)
245 PRINT "INPUT LONG TERM ENERGY ESCALATION RATE"
250 INPUT E(3,J)
255 PRINT "TYPE 1 IF YOU HAVE A SEPARATE SHORT TERM ENERGY"
260 PRINT "ESCALATION RATE, 0 IF NOT"
265 INPUT S
270 IF S=0 THEN 295
275 PRINT "INPUT SHORT TERM ENERGY ESCALATION RATE"
280 INPUT E(4,J)
285 PRINT "INPUT EXPECTED NUMBER OF YEARS THAT THIS RATE CAN BE USED
290 INPUT E(5,J)
295 PRINT
300 NEXT J
305 REM COMPUTE PRESENT VALUE ENERGY SAVINGS/COSTS
310 FOR J=1 TO N4
315 LET E(6,J)=E(1,J)*E(2,J)
320 IF S=0 THEN 415
325 IF D<>E(4,J) THEN 340
330 LET E(7,J)=E(6,J)*E(5,J)
335 GO TO 345
340 LET E(7,J)=E(6,J)*FNU(D,E(4,J),E(5,J))
345 LET E(8,J)=E(2,J)
350 FOR K=1 TO E(5,J)
355 LET E(8,J)=E(8,J)+E(8,J)*E(4,J)
360 NEXT K
365 IF D<>E(3,J) THEN 380
370 LET S(J)=E(1,J)*E(8,J)*(N2-E(5,J))
375 GO TO 390
380 LET S(J)=E(1,J)*E(8,J)*FNU(D,E(3,J),N2-E(5,J))
385 LET S(J)=S(J)*FNP(D,E(5,J))
390 LET S(J)=S(J)+E(7,J)
395 GO TO 425
400 IF D<>E(3,J) THEN 415
405 LET S(J)=E(6,J)*N2
410 GO TO 420
415 LET S(J)=E(6,J)*FNU(D,E(3,J),N2)
```

```
420 REM S(J)=PRESENT VALUE OF ENERGY SAVINGS
425 LET V=V+S(J)
430 NEXT J
435 PRINT
440 PRINT "INVESTMENT COST"
445 PRINT
450 PRINT "INPUT INITIAL INVESTMENT COST (BASE YEAR)"
455 INPUT I
460 PRINT "INPUT NUMBER OF ADDITIONAL INVESTMENTS OR REPLACEMENTS"
465 PRINT "OVER THE STUDY PERIOD"
470 INPUT N5
475 FOR K=1 TO N5
480 PRINT "INPUT YEAR THAT COST OF ADDITIONAL INVESTMENT/REPLACEMENT # "K
485 PRINT "IS TO BE INCURRED"
490 INPUT I(1,K)
495 PRINT "INPUT COST IN TODAY'S DOLLARS"
500 INPUT I(2,K)
505 PRINT "INPUT SCRAP VALUE OF EQUIPMENT BEING REPLACED (IF NONE OR"
510 PRINT "NOT APPLICABLE, TYPE 0)"
515 INPUT I(3,K)
520 LET I=I+I(2,K)*FNP(D,I(1,K))-I(3,K)*FNP(D,I(1,K))
525 NEXT K
530 PRINT "INPUT RESIDUAL VALUE OF INVESTMENT AT END OF STUDY PERIOD"
535 INPUT I9
540 LET I9=I9*FNP(D,N2)
545 LET I=I-I9
550 REM I IS PRESENT VALUE OF INVESTMENT COST
555 PRINT
560 PRINT "NON-ENERGY COSTS"
565 PRINT
570 LET R$=D$
575 IF Q=1 THEN 585
580 GO TO 590
585 PRINT "CALCULATIONS FOR "R$" SYSTEM"
590 PRINT
595 PRINT "INPUT TOTAL YEARLY AMOUNT OF ANNUAL RECURRING COSTS IN TODAY'S $"
600 INPUT R
605 LET R=R*FNU(D,0,N2)
610 PRINT "INPUT NUMBER OF OTHER MAINTENANCE OR REPAIR COSTS THAT OCCUR"
615 PRINT "ON A PERIODIC BASIS"
620 INPUT N6
625 FOR J=1 TO N6
630 PRINT "INPUT AMOUNT OF RECURRING COST "J
635 INPUT R(1,J)
640 PRINT "INPUT FIRST YEAR THAT THIS COST IS INCURRED AND THE PERIOD"
645 PRINT "OVER WHICH IT WILL RECUR (EXAMPLE: FOR A RECURRING COST"
650 PRINT "BEGINNING IN YEAR 5 AND OCCURING EVERY 5 YEARS TYPE: 5,5 )"
655 INPUT R(2,J),R(3,J)
660 LET R(4,J)=R(1,J)*FNP(D,R(2,J))
665 FOR K=1 TO INT((N2-R(2,J))/R(3,J))
670 IF R(2,J)+K*R(3,J)=N2 THEN 685
675 REM DON'T ADD RECURRING COSTS THAT OCCUR LAST YEAR OF STUDY PERIOD
680 LET R(4,J)=R(4,J)+R(1,J)*FNP(D,R(2,J)+K*R(3,J))
685 NEXT K
690 LET R1=R1+R(4,J)
695 NEXT J
```

```
700 LET R1=R1+R
705 REM NON-RECURRING COSTS
710 PRINT
715 PRINT "INPUT TOTAL NUMBER OF NON-RECURRING MAINTENANCE OR REPAIR"
720 PRINT "COSTS THAT YOU HAVE TO MAKE"
725 INPUT N7
730 IF N7=0 THEN 770
735 FOR J=1 TO N7
740 PRINT "INPUT COST IN TODAY'S DOLLARS AND YEAR OF OCCURRENCE FOR"
745 PRINT "NON-RECURRING COST "J"  (EXAMPLE: FOR A COST OF $500 IN "
750 PRINT "YEAR 15, TYPE: 500,15 )"
755 INPUT M(1,J),M(2,J)
760 LET M1=M1+M(1,J)*FNP(D,M(2,J))
765 NEXT J
770 IF R$="NEW" THEN 805
775 LET R$="NEW"
780 LET P=R1+M1
785 LET R1=0
790 LET M1=0
795 PRINT
800 GO TO 585
805 IF Q=2 THEN 825
810 LET W=R1+M1
815 LET X=P-W
820 GO TO 840
825 LET X=R1+M1
830 PRINT
835 PRINT
840 PRINT "                        PROJECT SUMMARY REPORT",
845 PRINT
850 PRINT
855 PRINT "    NAME OF AGENCY                              "Q$(1)
860 PRINT
865 PRINT "    PROJECT                                     "Q$(2)
870 PRINT
875 PRINT "    LOCATION OF AGENCY                          "Q$(3)
880 PRINT
885 PRINT "    GROSS FLOOR AREA AFFECTED                   "Q$(4)" SQUARE FEET"
890 PRINT
895 PRINT "    EXPECTED LIFE OF SYSTEM                    "N1" YEARS"
900 PRINT
905 PRINT "    EXPECTED LIFE OF BUILDING                   "Q$(5)"  YEARS"
910 PRINT
915 PRINT "    STUDY PERIOD                               "N2" YEARS"
920 PRINT
925 PRINT "    DISCOUNT RATE                               "D
930 PRINT
935 PRINT "                        *         *          *"
940 PRINT
945 PRINT "                                               (IN THOUSANDS $)"
950 PRINT
955 PRINT "    TOTAL PRESENT VALUE OF ENERGY "B$
960 PRINT
965 FOR K=1 TO N4
970 LET S(K)=S(K)/1000
975 PRINT "                  "E$(K)"      "S(K)
980 NEXT K
```

```
985 PRINT
990 LET V=V/1000
995 PRINT "                    TOTAL                                  "V
1000 PRINT
1005 LET I=I/1000
1010 PRINT "       TOTAL PRESENT VALUE OF INVESTMENT COST  "I
1015 PRINT
1020 IF Q=2 THEN 1150
1025 LET P=P/1000
1030 PRINT "       PRESENT VALUE OF NON-ENERGY COSTS FOR   "
1035 PRINT "       EXISTING SYSTEM                         "P
1040 PRINT
1045 LET W=W/1000
1050 PRINT "       PRESENT VALUE OF NON-ENERGY COSTS FOR   "
1055 PRINT "       PROPOSED ALTERNATIVE                    "W
1060 PRINT
1065 LET X=X/1000
1070 PRINT "       PRESENT VALUE OF CHANGE IN NON-ENERGY   "
1075 PRINT "       COSTS                                   "X
1080 PRINT
1085 LET Z1=V+X
1090 PRINT "       TOTAL PRESENT VALUE SAVINGS             "Z1
1095 PRINT
1100 PRINT
1105 PRINT "                      LIFE-CYCLE COST MEASURES"
1110 PRINT
1115 LET Z2=Z1/I
1120 PRINT "       SAVINGS TO INVESTMENT RATIO             "Z2
1125 PRINT
1130 LET Z3=Z1-I
1135 PRINT "       NET SAVINGS IN PRESENT VALUE            "
1140 PRINT "       DOLLARS (IN THOUSANDS $)                "Z3
1145 GO TO 1190
1150 LET X=X/1000
1155 PRINT "       PRESENT VALUE OF NON-ENERGY COSTS       "X
1160 PRINT
1165 PRINT
1170 PRINT
1175 LET Z8=V+X+I
1180 PRINT "       TOTAL LIFE-CYCLE COSTS IN PRESENT       "
1185 PRINT "       VALUE DOLLARS (IN THOUSANDS $)          "Z8
1190 END
```

The above computer program is illustrated in the following example of an energy conservation retrofit to an existing building. This example is the same as that shown in the worksheets in Section 3.

```
INPUT NAME OF AGENCY
 ? NATIONAL ADMINISTRATION
INPUT PROJECT NAME
 ? ECS
INPUT LOCATION OF AGENCY
 ? WASHINGTON DC
```

```
TYPE 1 IF PROJECT IS FOR AN EXISTING BUILDING, 2 IF IT IS FOR A
NEW BUILDING
 ? 1
INPUT GROSS FLOOR AREA AFFECTED (IN SQUARE FEET)
 ? 2.3 MILLION
INPUT EXPECTED LIFE OF SYSTEM
 ? 40
INPUT EXPECTED LIFE OF BUILDING
 ? 30
INPUT STUDY PERIOD
 ? 25
INPUT DISCOUNT RATE
 ? .10

ENERGY SAVINGS

INPUT NUMBER OF ENERGY SOURCES USED
 ? 3
INPUT ENERGY TYPE  1  AND UNIT (E.G. ELECTRICITY (HEATING),KWH)
NOTE: SEPARATE TYPE AND UNIT BY A COMMA
 ? ELECTRICITY (HEATING),KWH
INPUT ANNUAL AMOUNT OF ELECTRICITY (HEATING) SAVED BY THIS SYSTEM
 ? 4980000
INPUT LOCAL PRICE/KWH
 ? .033
INPUT LONG TERM ENERGY ESCALATION RATE
 ? .05
TYPE 1 IF YOU HAVE A SEPARATE SHORT TERM ENERGY ESCALATION
RATE, 0 IF NOT
 ? 1
INPUT SHORT TERM ENERGY ESCALATION RATE
 ? .10
INPUT EXPECTED NUMBER OF YEARS THAT THIS RATE CAN BE USED
 ? 2

INPUT ENERGY TYPE  2  AND UNIT (E.G. ELECTRICITY (HEATING),KWH)
NOTE: SEPARATE TYPE AND UNIT BY A COMMA
 ? ELECTRICITY (COOLING),KWH
INPUT ANNUAL AMOUNT OF ELECTRICITY (COOLING) SAVED BY THIS SYSTEM
 ? 2930000
INPUT LOCAL PRICE/KWH
 ? .038
INPUT LONG TERM ENERGY ESCALATION RATE
 ? .05
TYPE 1 IF YOU HAVE A SEPARATE SHORT TERM ENERGY ESCALATION
RATE, 0 IF NOT
 ? 1
INPUT SHORT TERM ENERGY ESCALATION RATE
 ? .10
INPUT EXPECTED NUMBER OF YEARS THAT THIS RATE CAN BE USED
 ? 2

INPUT ENERGY TYPE  3  AND UNIT (E.G. ELECTRICITY (HEATING),KWH)
NOTE: SEPARATE TYPE AND UNIT BY A COMMA
 ? NATURAL GAS,THERM
INPUT ANNUAL AMOUNT OF NATURAL GAS SAVED BY THIS SYSTEM
 ? 4680000
```

```
INPUT LOCAL PRICE/THERM
 ? .225
INPUT LONG TERM ENERGY ESCALATION RATE
 ? .07
TYPE 1 IF YOU HAVE A SEPARATE SHORT TERM ENERGY ESCALATION
RATE, 0 IF NOT
 ? 1
INPUT SHORT TERM ENERGY ESCALATION RATE
 ? .06
INPUT EXPECTED NUMBER OF YEARS THAT THIS RATE CAN BE USED
 ? 2

INVESTMENT COST

INPUT INITIAL INVESTMENT COST (BASE YEAR)
 ? 725000
INPUT NUMBER OF ADDITIONAL INVESTMENTS OR REPLACEMENTS
OVER THE STUDY PERIOD
 ? 2
INPUT YEAR THAT COST OF ADDITIONAL INVESTMENT/REPLACEMENT #  1
IS TO BE INCURRED
 ? 1
INPUT COST IN TODAY'S DOLLARS
 ? 725000
INPUT SCRAP VALUE OF EQUIPMENT BEING REPLACED (IF NONE OR
NOT APPLICABLE, TYPE 0)
 ? 0
INPUT YEAR THAT COST OF ADDITIONAL INVESTMENT/REPLACEMENT #  2
IS TO BE INCURRED
 ? 10
INPUT COST IN TODAY'S DOLLARS
 ? 50000
INPUT SCRAP VALUE OF EQUIPMENT BEING REPLACED (IF NONE OR
NOT APPLICABLE, TYPE 0)
 ? 0
INPUT RESIDUAL VALUE OF INVESTMENT AT END OF STUDY PERIOD
 ? 200000

NON-ENERGY COSTS

CALCULATIONS FOR EXISTING SYSTEM

INPUT TOTAL YEARLY AMOUNT OF ANNUAL RECURRING COSTS IN TODAY'S $
 ? 120000
INPUT NUMBER OF OTHER MAINTENANCE OR REPAIR COSTS THAT OCCUR
ON A PERIODIC BASIS
 ? 1
INPUT AMOUNT OF RECURRING COST  1
 ? 140000
INPUT FIRST YEAR THAT THIS COST IS INCURRED AND THE PERIOD
OVER WHICH IT WILL RECUR (EXAMPLE: FOR A RECURRING COST
BEGINNING IN YEAR 5 AND OCCURING EVERY 5 YEARS TYPE: 5,5 )
 ? 5,5

INPUT TOTAL NUMBER OF NON-RECURRING MAINTENANCE OR REPAIR
COSTS THAT YOU HAVE TO MAKE
 ? 0
```

```
CALCULATIONS FOR NEW SYSTEM

INPUT TOTAL YEARLY AMOUNT OF ANNUAL RECURRING COSTS IN TODAY'S $
 ? 180000
INPUT NUMBER OF OTHER MAINTENANCE OR REPAIR COSTS THAT OCCUR
ON A PERIODIC BASIS
 ? 1
INPUT AMOUNT OF RECURRING COST  1
 ? 280000
INPUT FIRST YEAR THAT THIS COST IS INCURRED AND THE PERIOD
OVER WHICH IT WILL RECUR (EXAMPLE: FOR A RECURRING COST
BEGINNING IN YEAR 5 AND OCCURING EVERY 5 YEARS TYPE: 5,5 )
 ? 5,5

INPUT TOTAL NUMBER OF NON-RECURRING MAINTENANCE OR REPAIR
COSTS THAT YOU HAVE TO MAKE
 ? 0
                         PROJECT SUMMARY REPORT

    NAME OF AGENCY                            NATIONAL ADMINISTRATION

    PROJECT                                   ECS

    LOCATION OF AGENCY                        WASHINGTON DC

    GROSS FLOOR AREA AFFECTED                 2.3 MILLION SQUARE FEET

    EXPECTED LIFE OF SYSTEM                   40  YEARS

    EXPECTED LIFE OF BUILDING                 30 YEARS

    STUDY PERIOD                              25  YEARS

    DISCOUNT RATE                              .1

                          *          *         *

                                            (IN THOUSANDS $)

    TOTAL PRESENT VALUE OF ENERGY SAVINGS

         ELECTRICITY (HEATING)       2596.
         ELECTRICITY (COOLING)       1758.79
         NATURAL GAS         18404.3

         TOTAL                                 22759.1

    TOTAL PRESENT VALUE OF INVESTMENT COST     1384.91

    PRESENT VALUE OF NON-ENERGY COSTS FOR
    EXISTING SYSTEM                            1284.47

    PRESENT VALUE OF NON-ENERGY COSTS FOR
    PROPOSED ALTERNATIVE                       2024.33
```

PRESENT VALUE OF CHANGE IN NON-ENERGY COSTS	-739.852
TOTAL PRESENT VALUE SAVINGS	22019.3

LIFE-CYCLE COST MEASURES

SAVINGS TO INVESTMENT RATIO	15.8994
NET SAVINGS IN PRESENT VALUE DOLLARS (IN THOUSANDS $)	20634.4

RUNNING TIME: 6.6 SECS I/O TIME : 37.3 SECS

APPENDIX E

SELECTED ANNOTATED REFERENCES

1. Grant, Eugene L. and Ireson, W. Grant. *Principles of Engineering Economy.* New York: Ronald Press, 5th Edition, 1970.

A widely used textbook on engineering economics. Contains a comprehensive description of discounting with emphasis on investment analysis. Provides tables of discounting formulas and factors.

2. The American Institute of Architects. *Life Cycle Cost Analysis: A Guide for Architects.* Washington, D.C., 1977.

An easy-to-understand guide to fundamental LCC principles, directed primarily at architects who are not experienced in LCC analysis.

3. Reynolds, Smith & Hills, Architects —Engineers, Planners. *Life-Cycle Costing Emphasizing Energy Conservation; Guidelines for Investment Analysis.* Energy Research Development Administration Manual 76/130, Revised May, 1977.

A detailed LCC analysis handbook for ERDA, focusing on the retrofitting of existing facilities for energy conservation. Describes procedures to use and provides forms to complete for conducting investment analysis of energy conservation projects.

4. Booz-Allen and Hamilton, Inc. *Life-Cycle Costing in the Public Building Service.* Prepared for the General Services Administration, Vol. I, 1976, and Vol. II, 1977.

A comprehensive manual aimed primarily at evaluating alternative new building designs, that outlines LCC procedures for the Public Building Service of GSA. Vol II lists selected computer programs for simulating the energy loads of buildings.

5. Office of the Chief of Engineers, Department of the Army. *Engineering Instructions for Preparation of Feasibility Studies for Total Energy, Selective Energy, and Heat Pumps.* July 1, 1977.

Contains life-cycle costing instructions in a 10-page appendix that provides a step-by-step illustration of the computation of the present values of alternative energy systems for a building with the base period defined as the midpoint of the construction period. Provides a glossary of terms and instructions for determining heating and cooling loads, initial costs, and maintenance costs.

6. Richard S. Brown, *et. al.. Economic Analysis Handbook.* Prepared for the Department of the Navy, June, 1975.

Explains the concepts and techniques of economic analysis for the purpose of providing official guidance for the preparation of economic evaluation of investment decisions. Includes a discussion of the selection of a 10% discount rate for evaluating government investments; a section on cost analysis that describes the treatment of such items as residual values and personnel costs, using three techniques for estimating costs; a chapter on the treatment of inflation and conversion of cost estimates to budgetary amounts; and provides illustrations of techniques throughout.

7. Harold E. Marshall and Rosalie T. Ruegg. "Life-Cycle Costing Guide for Energy Conservation in Buildings." *Energy Conservation Through Building Design.* McGraw-Hill Architectural Record Books, In press.

Provides an overview of the state-of-the-art of life-cycle costing applied to energy conservation in buildings. Describes selected applications of LCC analysis, including (1) determining the optimal amount of insulation in existing houses; (2) the selection and use of windows in houses; (3) the choice between solar and alternative heating systems; and (4) the development of standards for efficient energy conservation in buildings.

8. Public Technology, Incorporated. *Energy Conservation Retrofit for Existing Public and Institutional Facilities.* Prepared for National Science Foundation (RANN), Washington, D.C., 1977.

Devoted primarily to providing assistance to public officials considering energy conservation in existing public buildings. Provides assistance in making management decisions for implementation of energy conservation programs, including development of a plan, establishment of schedules, selection of buildings, preliminary estimation of energy savings, development of work statements, and estimation of fees and construction costs. Describes four phases in the management of energy conservation: (1) the study of current energy consumption, (2) building survey and engineering analysis, (3) implementation, and (4) monitoring. Does not provide the details necessary for conducting engineering analysis nor life-cycle cost analysis. Emphasizes fast-payback retrofit projects. Appendices include lists of retrofit options by climate zones, sample forms for studies of energy consumption, and a list of computer programs for energy conservation analysis. The bibliography gives a number of references to guides for reducing energy consumption of buildings through retrofit and initial design.

9. National Bureau of Standards. *Technical Guidelines for Energy Conservation.* Prepared for the Air Force Civil Engineering Center, NBSIR 77-1238, AFCEC-TR-77-12, June, 1977.

Provides detailed technical material on various energy conservation actions for existing Air Force facilities and utility systems. Intended to serve as a working document for engineers and technical personnel. Includes coverage of equipment for providing hot water, space heating and cooling, lighting and humidification; central plant systems for hot water, steam, and chilled water. Discusses energy conservation measures for exterior building envelopes and for mechanical systems; describes the building energy survey and measurements for identifying energy conservation potential; and explains in brief the economic analysis. Appendices provide information on heat transfer, solar energy systems, distribution systems, and computer programs.

10. Hittle, D.C. *The Building Loads Analysis and System Thermodynamics (BLAST) Program, Volume I: Users Manual.* U.S. Army Construction Engineering Research Laboratory (CERL), Technical Report E-119, September, 1977.

Provides detailed user instructions for the BLAST program for the analysis of building energy loads.

11. Kusuda, Tamami. *NBSLD, the Computer Program for Heating and Cooling Loads in Buildings.* National Bureau of Standards, BSS 69, July, 1976.

Describes the methodological basis of the NBSLD program for the analysis of building energy loads.

12. Federal Energy Administration. *Identifying Retrofit Projects for Buildings.* FEA/D-76-467, GPO 041-018-00129-8, September, 1976.

Handbook designed to be used by building owners, managers, operators, and occupants to identify quick payback retrofit projects in existing buildings. Provides tools for coordinating the energy savings, cost savings, capital costs, and simple payback periods for the options identified. Suggests a format for writing up the options, energy qualifications, and reporting the overall surveys for one or several buildings.

13. Federal Energy Administration. *Guidelines for Saving Energy in Existing Buildings, ECM1.* FEA/D-75-359, GPO 041-018-000-79-8, June 16, 1975.

A manual for building owners and operators for conserving and managing energy use in buildings (including office buildings, retail stores, hospitals, schools, libraries, houses, and apartments) with relatively small investments.

14. Federal Energy Administration. *Manual for Engineers, Architects, and Operators, ECM2.* FEA/D-75-358, GPO 041-018-000-80-1.

A Guide intended for engineers, architects, and skilled building operators who are responsible for administering, advising, and implementing energy conservation programs which involve additional and more complex measures than those included in ECM1. Includes many conservation measures which can result in energy savings of 15-25% with an investment cost that can be recovered within 10 years through reduced operational cost.

15. Department of Energy. *Energy Conservation Compendium.* DOE Manual in Preparation to support implementation of Executive Order 12003.

A compendium which includes those publications designed specifically for use in planning and carrying out energy conservation programs. Purpose is to provide energy coordinators, planners, and related managing professionals with tools they may require to successfully plan, implement, and manage energy conservation programs. Contains abstracts of publications by many Federal and state agencies and information on where particular tools may be obtained.

16. State of California, Energy Resources Conservation and Development Commission Conservation Division. *Energy Conservation Design Manual for New Nonresidential Buildings.* October, 1977.

Describes the procedures, calculations, and documentation regarding energy conservation that are required prior to the application for a building permit in California. Describes calculation procedures for various energy analyses and provides documentation forms. Provides a brief description of life-cycle costing calculations as related to meeting the requirements of the California Energy Conservation Standards for New Nonresidential Buildings.

17. Executive Office of the President. "Relating to Energy Policy and Conservation." *Executive Order 12003.* July 20, 1977.

Amended Executive Order No. 11912, dated April 13, 1976, to require each executive agency that now maintains buildings to submit to the Administrator of the FEA a ten-year plan designed "to the maximum extent practicable" to meet specified goals for energy conservation in Federal buildings. Calls for the establishment of a "practical and effective "method for estimating and comparing life-cycle capital and operating costs for Federal residential, commercial, and industrial buildings. Requires the use of this method by Federal agencies in developing their ten-year plans, annual reports, and budget estimates for meeting the goals of reduced energy usage.

18. Laughlin, Qonnie B.Q. *Energy Conservation, The State of the States.* National Governors' Association, Center for Policy Research. Washington, D.C.

Provides an overview of the proposed plans for energy conservation programs prepared by States in response to the 1975 Energy Policy and Conservation Act (EPCA). Includes detailed descriptions of the initiatives of selected States.

19. Cooke, Patrick W. and Eisenhard, Robert M. *Building Energy Conservation Programs – A Preliminary Examination of Regulatory Activities at the State Level.* National Bureau of Standards, NBSIR 77-1259, June, 1977.

Describes the current regulatory status and degree of implementation of building energy conservation programs at the State level, including those programs that deal with solar energy. Based on a survey of 21 selected States, reports common problems experienced at the State level in the promulgation and implementation of building energy conservation regulations.

20. "Project Independence Evaluation Series," *Federal Register.* Vol. 42, No. 73, April 15, 1977.

Gives FEA's projected energy prices developed from March 30, 1977 Reference Case results of the Project Independence Evaluation System (PIES), an integrated model of the domestic energy system. Prices of oil, gas, coal, and electricity are projected by region, by year, to 1991.

21. Executive Office of the President, Office of Management and Budget. "Comparative Cost Analysis for Decisions to Lease or Purchase General Purpose Real Property." Circular No. A-104, June 14, 1972, Attachment.

22. U.S. Department of Labor, Bureau of Labor Statistics. *Monthly Labor Review.*

Provides price indices that can be used to convert current dollars to constant dollars.

23. Petersen, Stephen R. *Retrofitting Existing Housing for Energy Conservation An Economic Analysis.* National Bureau of Standards, BSS 64, 1974.

A technical study which develops an economic model for determining the optimal combination and level of energy conservation retrofit techniques in existing houses.

24. Ruegg, Rosalie T. and Sav, G. Thomas. *Microeconomics of Solar Energy.* National Bureau of Standards, BSS, In Press.

A comprehensive reference report that explains how alternative economic evaluation methods may be used to evaluate the economic efficiency of solar energy systems for residential, commercial, and institutional buildings. Describes the major components of costs and savings associated with solar energy systems, including the various types of system costs, energy costs and savings, taxes, and government incentives. Explains and illustrates the optimization of a solar energy system for maximum net savings.

25. Energy Resource Center, University of Illinois. *Selection and Assessment Methodology of Weatherization Retrofit Options for Multi-Family Buildings.* Prepared for the National Bureau of Standards, December 1977.

Describes a detailed approach to the problem of ranking interdependent projects.

CONTINUED

1 OF 2

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report provides a step-by-step guide for conducting life-cycle cost evaluations of energy conservation projects for public buildings. It explains the use of life-cycle costing analysis to evaluate and rank the cost effectiveness of alternative energy conservation retrofit projects to existing public buildings, and to select the most cost-effective design for new buildings. Worksheets, illustrated with a realistic example, and a computer program are provided.

This guide is compatible with a life-cycle costing guide prepared for the Department of Energy for use in the Federal Energy Management Program by Federal Agencies. The purpose of this report is to provide a guide to state and local governments for use in their energy conservation programs.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Building economics; economic analysis; energy conservation; engineering economics; investment analysis; life-cycle cost analysis

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