NBS HANDBOOK 135

Life-Cycle Cost Manual for the Federal Energy Management Program

United States Department of Commerce
National Bureau of Standards

Prepared for

United States Department of Energy
Federal Energy Management Program

ENERGY EFFICIENCY
PRESIDENT'S PROGRAM FOR ENERGY EFFICIENCY

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NBS HANDBOOK 135

Life-Cycle Costing Manual for the Federal Energy Management Programs

A Guide for Evaluating the Cost Effectiveness of Energy Conservation and Renewable Energy Projects for New and Existing Federally Owned and Leased Buildings and Facilities

Prepared for

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PREFACE

This manual amplifies the methodology and procedures for life-cycle cost analysis established by the Department of Energy (DoE) in Subpart A of Part 436 of Title 10 of the Code of Federal Regulations (10 CFR Part 436), which is entitled "Federal Energy Management and Planning Programs" (FEMP). It incorporates proposed changes in the methodology and procedures made in response to recent amendments to the law. It is intended as an aid to implementing life-cycle cost evaluations of potential energy conservation and renewable energy investments in existing and new federally owned and leased buildings as required by Section 381(a)(2) of the Energy Policy and Conservation Act (EPCA), as amended, 42 U.S.C. 6361(a)(2); by Section 10 of Executive Order 11912, as amended by Executive Order 120003 (Executive Order); and by Title V of the National Energy Conservation Policy Act (NECPA), 92 Stat. 3275, as amended by Section 405 of the Energy Security Act, 94 Stat. 611.

Executive Order 12003, signed by President Carter in July 1977, amends Section 10 of Executive Order 11912 to establish 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, as compared to a base of 1975. The Executive Order further directs 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 the Department of Energy to provide methods and procedures to Federal agencies for estimating life-cycle costs and savings of proposed energy conservation and renewable energy projects and for comparing their cost effectiveness in a uniform and consistent manner from agency to agency. The guidelines are required to be consistent with criteria established by the 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. This circular requires, among other things, the use of a 10 percent real discount rate.

The National Energy Conservation Policy Act (NECPA), signed by President Carter in November 1978, also contains provisions for establishing methods and procedures for life-cycle costing. It calls upon the Secretary of the Department of Energy, in consultation with the Director of the Office of Management and Budget, the Director of the National Bureau of Standards, and the Administrator of the General Services Administration to (1) "establish practical and effective methods for estimating and comparing life-cycle costs for Federal buildings," and (2) "develop and prescribe the procedures to be followed in applying and implementing the methods so established. . . ." (Title V, Part 3, Sec. 545(a)). Section 405 of the Energy Security Act subsequently amended NECPA to require the use of a 7 percent discount rate, a study period equal to building system life not to exceed 25 years, and marginal fuel costs rather than average (market) prices. Revisions to the life-cycle costing methodology and procedures to reflect the recently legislated changes are now being proposed and are expected to become final for use in fiscal year 1981. This manual indicates those proposed changes.

The life-cycle costing methods and procedures set forth in Subpart A, Part 436, 10 CFR (as amended) are to be followed by all Federal agencies, unless specifically exempted, in evaluating the cost effectiveness of potential energy conservation and renewable energy investments in federally owned and leased buildings.

The National Bureau of Standards has provided technical assistance to the Department of Energy in formulating the life-cycle costing methods and procedures for the FEMP Rules and has developed this manual in support of applying the rules.

Further information on the Federal Energy Management Programs can be obtained from the Federal Programs Office, Office of the Assistant Secretary for Conservation and Solar Energy, U.S. Department of Energy, Washington, D.C. 20461. Further information on the Solar Federal Buildings Program can be obtained from the Federal Buildings Program/FA34, Huntsville, AL 35812 [Telephone (205) 453-1870 or (FTS) 872-1870].

ACKNOWLEDGMENTS

The author wishes to thank all of those persons who contributed to the preparation of this manual. Special credit is due to John McConnaughey, formerly of the National Bureau of Standards, for his valuable and extensive technical contributions to earlier drafts. Appreciation is also extended to Kimberly Barnes, who prepared the computer program in appendix E; Phillip Chen, who provided cost estimates for several of the sample problems in an earlier draft; Thomas Sav, who developed the computer program for calculating the tables of combined discounting and energy escalation factors in appendix B; and Jeanne Powell, who assisted with the solar example. Harold Marshall, Linde Fuller, Anne Bretzfield, Jacqueline Elder, Roy Clark, and Wayne Stieffel, also of the National Bureau of Standards, reviewed the draft manual and offered many helpful comments and suggestions.

Representatives to an interagency life-cycle cost task force also offered valuable contributions. The representatives to the task force were Mike Walsh, Department of Energy; Dave Eakin and 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; Larry Schindler, Department of Defense; and R. R. Huber and John Sisty, Veterans Administration. John Anderson of the Department of Energy coordinated the formation of the task force and oversaw the preparation of an early draft of the manual.

The author is also indebted to the many persons who attended the series of LCC workshops held around the country, for the valuable insight they provided in discussing energy issues and significant problems in implementing energy conservation and life-cycle cost analysis in Federal agencies. They provided field testing of an earlier draft of this manual.

Special acknowledgment and appreciation are extended to Jack Vitullo of the Office for Conservation and Solar Energy, U.S. Department of Energy, who guided the preparation of the methodology and procedures for life-cycle cost analyses published in Subpart A, Part 436, 10 CFR, and who oversaw the completion of this manual. Appreciation is also extended to William Rhodes of the Office for Conservation and Solar Energy and to Neal Strauss and Philip Yates of the Office of the General Counsel, Department of Energy, for their assistance.

ABSTRACT

This manual is a guide to understanding the life-cycle costing method and an aid to calculating the measures required for evaluating energy conservation and renewable energy investments in all Federal buildings. It expands upon the life-cycle costing criteria contained in the Program Rules of the Federal Energy Management Program (Subpart A of Part 436, Title 10, U.S. Code of Federal Regulations) and is consistent with those criteria. Its purpose is to facilitate the implementation of the Program Rules by explaining the life-cycle costing method, defining the measures, describing the assumptions and procedures to follow in performing evaluations, and giving examples. It provides worksheets, a computer program, and instructions for calculating the required measurements.

The life-cycle costing method and evaluation procedures set forth in the Federal Energy Management Program Rules and described in greater detail in this guide are to be followed by all Federal agencies for all energy conservation and renewable energy projects undertaken in new and existing buildings and facilities owned or leased by the Federal government, unless specifically exempted. The establishment of the methods and procedures and their use by Federal agencies to evaluate energy conservation and solar energy investments are required by Section 381(a)(2) of the Energy Policy and Conservation Act, as amended, 42 U.S.C. 6361(a)(2); by Section 10 of Presidential Executive Order 11912, amended; and by Title V of the National Energy Conservation Policy Act, 92 Stat. 3275.

Key words: Cost effectiveness; economic evaluations; energy conservation; Federal energy management program; life-cycle costing; public buildings; renewable energy; solar energy; solar photovoltaic.

Sprayed-on insulation reduces the heating and cooling energy needs of this corrugated metal building at the Brookhaven National Laboratory.

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EXECUTIVE SUMMARY

In response to Executive Order and legislation, the Department of Energy issued a final rule, effective January 23, 1980, to establish a methodology and procedures for all Federal agencies to follow in conducting life-cycle cost (LCC) analyses of energy conservation and renewable energy investments in Federal buildings. The LCC Rule, intended to promote consistency and rationality in the investment decisions of Federal agencies, is one of six subparts established in the Code of Federal Regulations under the title, "Federal Energy Management and Planning Programs."

This manual was prepared to assist Federal agencies to implement the new LCC rule. It explains LCC concepts, provides a common glossary of terms, lists assumptions, and guides the making of the required calculations through provision of worksheets, a computer program, and sample problems solved step by step. The following is a capsulized summary of the key LCC requirements:

PRINCIPAL APPLICATIONS

The LCC Rule applies to:

° Alternative building systems and designs for existing and new Federal buildings proposed under the 10-year building plans of Federal agencies to reduce their consumption of nonrenewable energy.

° Solar energy projects proposed under the Solar Federal Buildings Program.

° Federal photovoltaic utilization projects.

MAJOR REQUIREMENTS

° Alternative building systems for proposed retrofit to existing Federal buildings should be determined to be life-cycle cost effective.

° Cost-effective alternative retrofit systems should be ranked in descending order of their savings-to-investment ratios and given priority on the basis of that ranking.

° The alternative Federal building design or building system design estimated to result in the lowest total life-cycle costs of the building should be selected, other things being equal.

° A proposed Federal solar demonstration project will be rated in part on the basis of its relative economic performance as indicated by its estimated net savings or excess cost, its years to payback, and its savings-to-investment ratio, as formulated in Section III of Form A-2 of the Solar Federal Buildings Program.

° In leasing buildings for Federal use, preference should be given to the building that uses solar energy or is otherwise life-cycle cost effective.

° All Federal buildings should be retrofitted to assure their minimum life-cycle cost by 1990.

KEY ELEMENTS OF THE LCC RULE

° Life-cycle cost evaluations should account for those investment costs, nonfuel operation and maintenance costs, repair and replacement costs, salvage values, and energy costs that are important to the long-term cost effectiveness of a decision.

° All future dollar amounts must be estimated in constant dollars, i.e., excluding the effects of general price inflation.

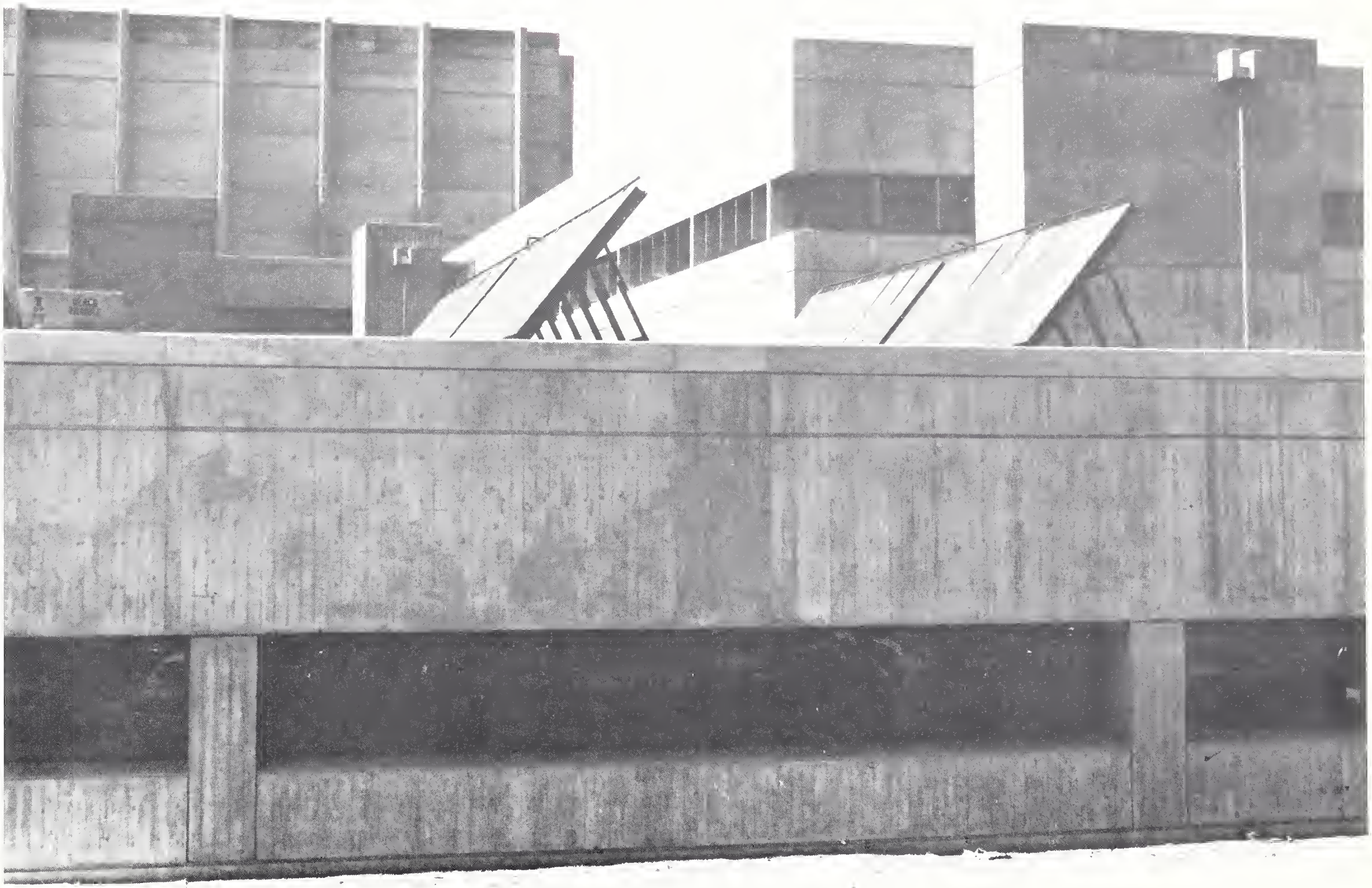
° A discount rate of 7 percent, also excluding inflation, must be used to adjust all dollar values to a present value in the year the analysis is made.

° As an interim adjustment for social benefits of saving nonrenewable energy, that are not fully reflected in the dollar savings, initial project investment costs must be reduced to 90 percent of the actual investment costs for the purpose of estimating life-cycle costs. (This requirement is subject to change.)

° The DoE-provided prices (published in tables C-1 and C-2 of the LCC Rule and in this manual and subject to periodic revision in the Federal Register) must be used to establish initial energy costs, with the specific exceptions noted.

° Energy price growth projections provided by DoE (published in tables C-6 through C-8 of the LCC Rule and in this manual and subject to periodic revision in the Federal Register) must be used in estimating life-cycle energy costs or savings. (This requirement can be met by using the modified discount factors given in appendix B.)

° The study period for a building system retrofit should be the lesser of 25 years or the expected life of the system; for a new building design, the lesser of 25 years or the period of intended use of that building; and for a leased building, the lesser of 25 years or the effective remaining term of the lease. For project design and/or sizing where choices are mutually exclusive, all choices should be evaluated based on an equivalent study period.



The cafeteria at DOE's Richland, Washington, Operations office uses an active solar energy system to meet part of its energy requirement.

PRINCIPAL DEFINITIONS

Because the function of this manual is to amplify the LCC Rule, terminology and definitions used in the Rule are also used here. Definitions of additional economic terms are also provided. Defined terms that appear in the definitions of other terms are capitalized.

Alternative Building System - An installation or modification of an installation in a building intended primarily to reduce energy consumption or allow the use of renewable energy sources, or a primarily energy-saving Building System, including a renewable energy system, for consideration as part of the design for a New Federal Building.

Annually Recurring Costs - Those costs which are incurred each year in an equal, constant dollar amount throughout the Study Period.

Annual Value (Annual Worth) - Project costs or benefits amortized over the Study Period, that is, expressed as an equivalent uniform annual amount, taking into account the Time Value of Money.

Annual Value (Annual Worth) Factor - The number by which a dollar amount may be multiplied to find its equivalent Annual Value, based on a given Discount Rate and a given period of time.

Base Year - The year in which the life-cycle cost analysis is conducted.

Base-Year Energy Costs - The quantity of energy delivered to the boundary of a Federal Building in the Base Year, multiplied by the base-year price of fuel (as given in the most recent edition of appendix C, table C-1 or C-2, for the appropriate type of fuel, sector, and region, or, if higher, the price actually charged the Government by the supplier in the Base Year).

Base-Year Energy Savings - For an Existing Federal Building, the positive difference between the existing building's Base-Year Energy Costs before the Retrofit and its estimated Base-Year Energy Costs after the Retrofit of a proposed Alternative Building System, taking into account all types of energy affected. For a New Federal Building, the positive difference between the estimated Base-Year Energy Cost of a building design or Building System design which is not primarily oriented towards energy conservation and the estimated Base-Year Energy Cost of an alternative building design or Building System design, taking into account all types of energy affected.

Building - Any structure with a roof and walls designed for storage or human use.

Building System - A portion of the structure of the Building or of any energy-using system in the Building.

Cash Flow - The stream of occurrence of a project's costs and benefits--expressed for the purpose of this requirement in Constant Dollars.

Constant Dollars - Values expressed in terms of the purchasing power of the dollar at the time the life-cycle cost analysis is conducted; constant dollars do not reflect future price Inflation.

Cost Effective - The condition whereby estimated life-cycle cost reductions (benefits) from an energy conservation project exceed the life-cycle costs of that project, where all Cash Flows are assessed in Constant Dollars over the relevant Study Period and discounted to reflect the Time Value of Money.

Current Dollars - Values expressed in terms of the actual prices of each year, including future price Inflation.

Demand Charge - That portion of the charge for electric service based on the plant and equipment costs associated with supplying the electricity consumed.

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

Differential Energy Price Escalation Rate - The expected difference between a general rate of Inflation and the rate of price increase assumed for energy.

Discount Factors - Multiplicative numbers for converting Cash Flows occurring at different times to correspondence at a common time. Discount factors are obtained by solving Discount Formulas based upon one dollar of value and an assumed Discount Rate and time.

Discount Formula - An expression of a mathematical relationship which enables the conversion of dollars at a given point in time to an equivalent amount at some other point in time.

Discount Rate - The rate of interest, reflecting the Time Value of Money, that is used in Discount Formulas, or to select Discount Factors which in turn are used to convert Cash Flows to a common time.

Discounted Payback Period - The time required for the cumulative savings, net of future costs, from an investment to pay back the Investment Costs, taking into account the Time Value of Money.

Discounting - A technique for converting Cash Flows occurring over time to time-equivalent values, adjusting for the Time Value of Money.

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

Energy Conservation Measure - An installation or modification of an installation in a Building which is primarily intended to reduce energy consumption energy cost, or allow the use of a renewable energy source.

Existing Federal Building - A Federal Building, the construction of which was complete by November 9, 1978, or the design of which cannot feasibly be modified after the effective date of Subpart C of Part 436, 10 CFR.

Facility - Any group of closely located Buildings, none of which is individually metered for all energy sources and for which the actual rate of use of all energy sources can be determined.

Federal Agency - An Executive agency under 5 U.S.C. 105 (1970), the United States Postal Service, and each entity specified in 5 U.S.C. 5721 (1)(B)-(H) (1970).

Federal Building - Any Building, structure, or facility which is constructed, renovated, leased or purchased in whole or in part for use by the United States, and which includes a heating system, or cooling system, or both.

Inflation - A rise in the general price level, or, put another way, a decline in the general purchasing power of the dollar.

Internal Rate of Return - The compound rate of interest which, when used to discount the life-cycle costs and savings of a project, will cause the two to be equal.

Investment Costs - The initial costs of design, engineering, purchase and installation, exclusive of "Sunk Costs," all of which are assumed to occur as a lump sum at the beginning of the Base Year for purposes of making the life-cycle cost analysis.

Life-Cycle Costing (LCC) - A general method of economic evaluation which takes into account all relevant costs of a building design, system, component, material, or practice over a given period of time, adjusting for differences in the timing of those costs. The LCC method encompasses several different economic evaluation techniques, or "Modes of Analysis," including Total Life-Cycle Cost Analysis, Net Benefits or Net Savings Analysis, Savings-to-Investment Ratio Analysis, and Internal Rate-of-Return Analysis.

Liquid Gas - Propane, butane, ethane, penetane, or natural gasoline.

Modes of Analysis - The various ways in which cost data of a project can be combined and presented to describe a measure of project cost effectiveness. The LCC Modes of Analysis used to evaluate FEMP projects are Total Life-Cycle Costs (TLCC), Net Savings (NS), and Savings-to-Investment Ratio (SIR). An additional Mode of Analysis--not fully consistent with the LCC method--used for evaluation in the Solar Federal Buildings Program is Simple Payback (SPB).

New Federal Building - A Federal Building for which construction was not completed prior to November 9, 1978, and the design of which can be feasibly modified after the effective data of Subpart C of Part 436, 10 CFR.

Nonrecurring Costs - Costs that are not uniformly incurred annually over the Study Period.

Nonfuel Operation and Maintenance Costs - Labor and material costs required for routine upkeep, repair and operation, exclusive of energy cost.

Present Value (Present Worth) - The time-equivalent value of past, present or future costs as of the beginning of the Base Year.

Present Value (Present Worth) Factor - The number by which a dollar amount may be multiplied to find its equivalent Present Value as of the beginning of the Base Year.

Replacement Costs - Future costs to replace a Building System or a component thereof.

Retrofit - The installation of an Alternative Building System in an Existing Federal Building.

Salvage Value - The residual value, net of any disposal costs, of any Building System removed or replaced during the Study Period, or remaining at the end of the Study Period, or recovered through resale at the end of the Study Period.

Savings-to-Investment Ratio (SIR) - The Present Value of future energy savings, net of future Nonfuel Operation and Maintenance Costs, as a ratio to Investment plus Replacement Costs, net of Salvage Value.

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

Simple Payback Period (SPB) - A measure of the length of time required for the cumulative savings, net of cumulative future costs, from an investment to pay back the Investment Cost, without taking into account the Time Value of Money nor the Differential Energy Price Escalation Rate.

Study Period - The time period covered by a life-cycle cost analysis.

Sunk Costs - Costs which have been incurred prior to the life-cycle cost analysis and which therefore should not be considered in making a current investment decision.

Time-of-Day Rate - The charge for service during periods of the day based on the cost of supplying the service at that particular time of the day.

Time Value of Money - The time dependent value of money that may stem both from price Inflation and from the real earning potential of investments over time.

Total Life-Cycle Cost (TLCC) - The total cost of owning, operating and maintaining a Building or Building System over the Study Period.

Useful Life - The time over which an investment continues to generate benefits or savings.

SYMBOLS AND ABBREVIATIONS

Btu - British Thermal Units

DoE - Department of Energy

DPB - Discounted Payback

FEMP - Federal Energy Management Programs

HVAC - Heating, Ventilation and Air Conditioning

IRR - Internal Rate of Return

kWh - Kilowatt Hours

LCC - Life-Cycle Costs or Life-Cycle Costing

MBtu - 10^6 x Btu or One Million Btu

NECPA - National Energy Conservation Policy Act

NS - Net Savings

O&M - Operation and Maintenance

OMB - Office of Management and Budget

PB - Payback Period

SFBP - Solar Federal Buildings Program

SIR - Savings-to-Investment Ratio

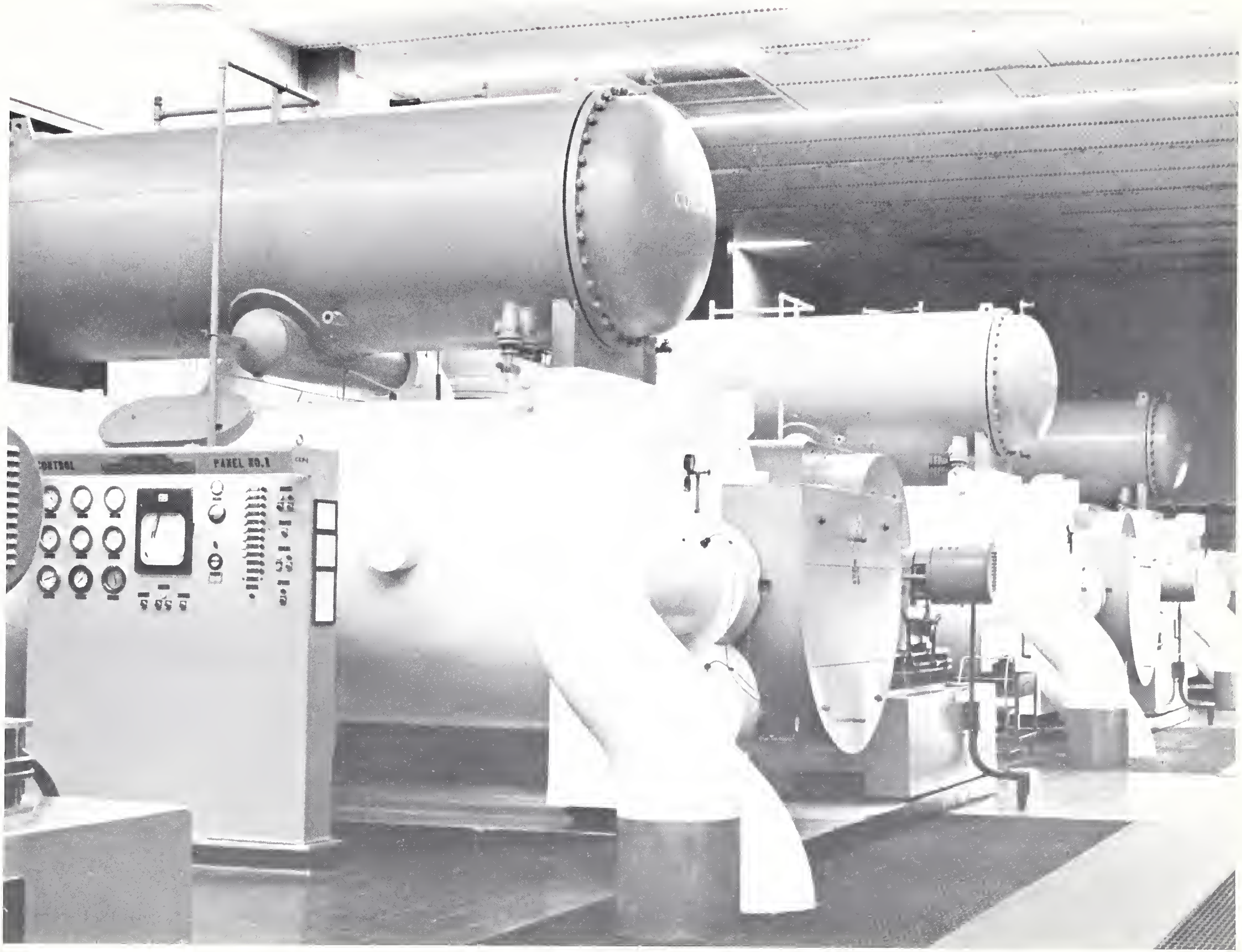
SPB - Simple Payback

SPW - Single Present Worth Factor

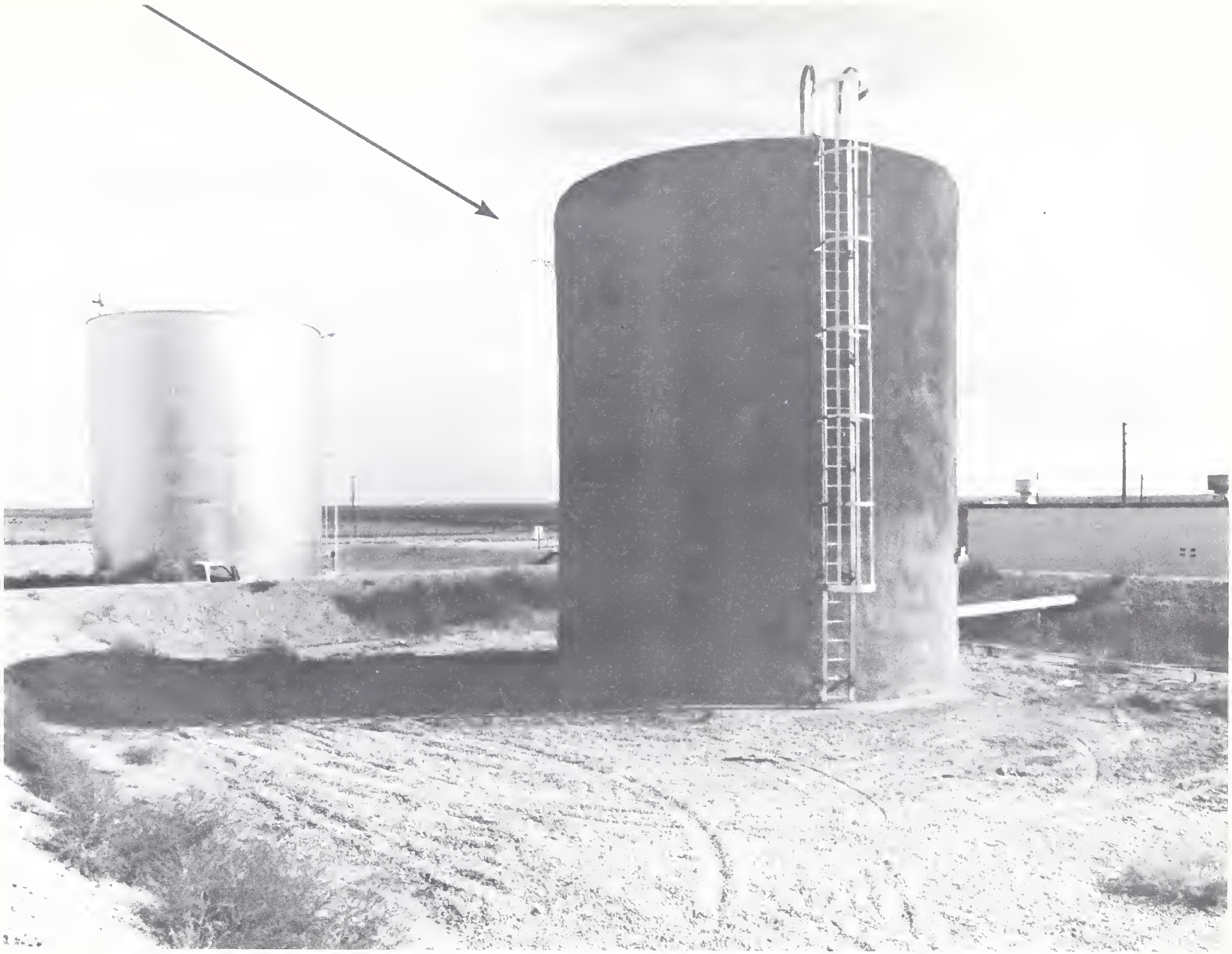
TLCC - Total Life-Cycle Costs

UPW - Uniform Present Worth Factor

UPW* - Modified Uniform Present Worth Factor



These 3,000 ton refrigeration units in the Steam and Chilled Water Generation Plant of the National Bureau of Standards are used to chill water. A feasibility study is being planned to determine whether these units should be retrofitted or replaced by smaller intermediate units to decrease electricity consumption.



This fuel oil tank at the Idaho National Engineering Laboratory has been insulated to reduce the amount of energy required to maintain the oil at the desired temperature. In addition to saving energy, this retrofit project has lowered the maintenance costs of the energy system.

1. INTRODUCTION

1.1 PURPOSE

This report is intended as a working manual for use by Federal agencies in performing economic evaluations of energy conservation and renewable energy projects required by legislation and executive order and guided by the Life-Cycle Cost Rule (LCC Rule) for the Federal Energy Management Programs (FEMP). It describes the method, outlines the procedures, defines the terms, gives basic assumptions, and provides instructions, worksheets, data tables, and a computer program for calculating the required measures.[1] The manual may be used in any or all of the following ways: (1) as a general reference for performing or understanding life-cycle costing, (2) as a specific guide to the FEMP economic evaluation requirements, and (3) as a tool for carrying out these requirements.[2]

The manual aims at assisting agencies to meet the following specific requirements (paraphrased) of Executive Order 11912, as amended by Executive Order 12003, and of the National Energy Conservation Policy Act (NECPA):

(1) In the construction or renovation of buildings, the cost of energy consumed over the building life must be considered.

(2) In the design of new Federal buildings, cost evaluations shall be made on the basis of life-cycle costs rather than initial costs.

(3) In designing new buildings, the lowest life-cycle cost design alternative that meets performance requirements of the building shall be selected.

(4) All energy conservation investments must be life-cycle cost effective.

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1 This manual draws upon a number of existing Federal agency documents pertaining to LCC analysis, such as Refs. [1]-[7], and aims at promoting uniformity of method and procedures among Federal agencies. Specific terminology used in the Federal Regulation is used here for consistency. Definitions are given in the front of the report.

2 The engineering and design of building retrofit and construction are not treated in the LCC Rule nor in this manual. For assistance in developing engineering costs and thermal data for energy conservation and solar projects, see Refs. [8]-[10].

(5) Energy conservation investments should be undertaken (ranked) in order of their life-cycle cost effectiveness, with priority given to the most cost-effective investments.

(6) On or before January 1, 1990, all cost-effective energy-conserving retrofits shall be implemented in Federal buildings.

(7) In leasing buildings, preference shall be given to buildings that utilize solar energy or otherwise minimize life-cycle costs to the Federal government over the remaining term of the lease.

(8) The life-cycle cost effectiveness of the system shall be one factor to consider in the use of solar energy in Federal buildings under the Solar Federal Buildings Program.

(9) Measures of present value costs and benefits, excess cost (if any), and payback shall be computed for solar energy investments under the Solar Federal Buildings Program.

1.2 ORGANIZATION

The remainder of this manual is organized into six sections and seven appendices. Section 2 provides a reference to basic concepts in life-cycle cost analysis for the convenience of the user who desires background. Section 3 gives the assumptions that are to be followed in evaluating Federal projects. Sections 4 through 7 describe the calculation procedures that are to be used for each of the following applications: (a) evaluating retrofit projects for existing buildings, (b) evaluating alternative designs for new buildings, (c) evaluating the life-cycle costs of leased buildings, and (d) evaluating solar energy systems for new and existing buildings. These sections provide instructions, worksheets, and sample problems that agencies may follow to calculate the required measures.

Supporting information is provided in the seven appendices. Appendix A contains discount factors for finding the present values of nonfuel future amounts. Appendix B contains discount factors for finding the present value of future energy costs. Appendix C gives current and future energy prices and the projected rates of change in future prices. Appendix D contains blank worksheets that can be used for calculating the required measures of cost effectiveness for each of the preceding four applications. Appendix E lists a computerized version of the calculation procedures contained in the worksheets. Appendix F contains a nomogram for converting a simple payback measure to a discounted payback measure. Appendix G provides a year-by-year, manual calculation method for evaluating life-cycle energy costs or savings that may be required under certain circumstances.

Replacement of the existing 1,000 watt mercury vapor lighting fixtures with these 400 watt high pressure sodium lights has more than halved the lighting energy requirements of this Brookhaven National Laboratory facility, while providing the same lighting level.

These buildings at DOE's Raff River site have been converted to geothermal space heating.

2. BASIC CONCEPTS

This section provides an overview of basic concepts in life-cycle cost analysis. It is offered as a reference for those who would like background on the method employed in sections 4 through 7, but it is not a prerequisite to carrying out the required evaluations. The computational aids -- the worksheets and the computer program -- are accompanied by step-by-step instructions as to procedure, and the specific requirements for data and assumptions are given in section 3. Hence, the user may choose to go directly to section 3 and refer to this section only as needed.

2.1 THE LIFE-CYCLE COSTING APPROACH

Life-cycle costing (LCC) is an evaluation method which takes into account relevant costs over time of a building's design, systems, components, materials, and operation. It incorporates initial investment costs, future replacement costs, operation and maintenance costs, and salvage and resale values, adjusting them to a consistent time basis and combining them in a single cost-effectiveness measure that makes it easy to compare alternative projects. Because it includes future amounts, it is a tool particularly suited for determining which energy conservation projects will save more than they cost (i.e., which are cost effective) and for selecting those projects that will provide the highest overall net return to the Federal energy conservation budget.

2.2 THE CHANGING VALUE OF MONEY OVER TIME: INFLATION AND OPPORTUNITY COSTS

An LCC approach requires that the cash amounts associated with a given project be put on a common time basis to make all dollars have the same value. This time adjustment is essential for a valid evaluation of a project's cost effectiveness, as well as for its comparison with other projects that involve differently timed cash amounts.

The value of money depends on when that money is expended or received because of two factors: inflation and the "opportunity cost of money." Inflation erodes the buying power of money over time. The opportunity cost of money reflects the fact that money in hand can be invested or used for some purpose to yield a return over time apart from inflation.

2.2.1 Inflation

Federal agencies are directed by Office of Management and Budget (OMB) Circular A-94 to state future prices in "constant dollars" (i.e., dollars having the same purchasing power).[1] This means that those future prices which are expected to change at about the same rate as general price inflation should be assumed to remain unchanged in terms of "constant dollars." Those future prices which are expected to remain fixed in amount, for example by contract, should be estimated to decline at the rate of general price inflation, when expressed as constant dollars.[2] The constant dollar equivalent of those future prices which are expected to increase more quickly or more slowly than the rate of general price inflation should reflect the amount of the difference between the rate of general price inflation and the expected future rate of change in the particular prices in question.

2.2.2 Opportunity Cost and Discounting

With future amounts expressed in constant dollars, it remains necessary to adjust them for the opportunity cost of money--the additional factor that changes the value of money over time. This time adjustment can be accomplished by applying appropriate "discount formulas," or multiplicative "discount factors" derived from the formulas, to the future amounts. This operation is called "discounting".

2.2.2.1 Discount Formulas

The more commonly used discount formulas are shown in table 2.1, with graphic depictions of their use. Of these seven formulas, the following are the ones that will be most used in evaluating the cost effectiveness of energy conservation and renewable energy projects: (1) the Single Present Worth (or Value) Formula (SPW), used to find the present-time equivalent value of a single future amount, such as a replacement cost or a salvage value; (2) the Uniform Present Worth Formula (UPW), used to find the present-time equivalent value of an annually recurring amount, such as routine maintenance cost; (3) and the Uniform Present Worth Formula Modified (UPW*), used to find the present-time equivalent value of a future amount projected to increase at some rate over time, such as energy costs.

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1 See Ref. [11].

2 For directions in adjusting fixed current dollars to their constant dollar equivalent see Ref. [12].

TABLE 2.1. DISCOUNT FORMULAS

Formula Name			
Single Compound Amount Formula (SCA)	P → F?	To find F when P is known	$F = P\ (1+d)^N$
Single Present Worth Formula (SPW)	P? ← F	To find P when F is known	$P = F\ \frac{1}{(1+d)^N}$
Uniform Sinking Fund Formula (USF)	A? + A? · · A? → F	To find A when F is known	$A = F\ \frac{1}{(1+d)^N - 1}$
Uniform Capital Recovery Formula (UCR)	P → A? + A? · · · · A?	To find A when P is known	$A = P\ \frac{d(1+d)^N}{(1+d)^N - 1}$
Uniform Compound Amount Formula (UCA)	A + A · · A → F?	To find F when A is known	$F = A\ \frac{(1+d)^N - 1}{d}$
Uniform Present Worth Formula (UPW)	P? ← A + A · · · · A	To find P when A is known	$P = A\ \frac{(1+d)^N - 1}{d(1+d)^N}$
Uniform Present Worth Formula Modified (UPW*)	P? ← $\bar{A}$ + $\bar{A}$ · · $\bar{A}$	To find P when A is escalating at rate e[a]	$\bar{P} = \bar{A}_o\ \frac{(1+e)}{(d-e)}\left[1 - \left(\frac{1+e}{1+d}\right)^N\right]$

Where:

P = a present sum of money, or the present value of a sum of money occurring at some other time.

F = a future sum of money, or the future value of a sum of money occurring at some other time.

d = an interest or discount rate for the period being considered.

N = the number of interest or discounting periods.

A = an end-of-period payment (or savings or receipt) in a uniform series over N periods, or the uniform time-equivalent of a sum of money occuring at some other time.

$\bar{A}$ = an end-of-period payment (or savings or receipt) in a series over N periods, escalating at a given rate in each period.

$\bar{A}_o$ = $\bar{A}$ evaluated at the beginning of the study period and used to calculate the present value, (P), of $\bar{A}$.

e = rate of escalation of A in each of $\bar{N}$ periods.

F? = a future value to be found.
P? = a present value to be found.
A? = an annual value to be found.

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a To find P when $\bar{A}$ is escalating at a different rate over each of k escalation periods,

$$P = \bar{A}_o \Bigg[\sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \dots + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j \Bigg],$$

where n = the length of the period for a given escalation rate, and the subscript k indicates the escalation period; e = rate of escalation in a given escalation period; and

$$\sum_{j=1}^{n} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left[1 - \left(\frac{1+e}{1+d}\right)^n\right].$$

2.2.2.2 Discount Factors

Discounting is simplified by the use of discount factors, simple multipliers precalculated from the formulas in table 2.1. The factors, which are more convenient to use and give the same results (aside from possible rounding errors) as the formulas, are emphasized in the LCC Rule.

Appendix tables A-1 and A-2 give the Single Present Worth (SPW) and Uniform Present Worth (UPW) discount factors for years 1 through 25, based on the 7 percent discount rate now required for Federal building decisions. These discount factors are to be used to find the present value of nonfuel costs or savings in energy-related investments.

Appendix tables B-1 through B-11 give the Uniform Present Worth Modified (UPW*) discount factors for years 1 through 25, based on a 7 percent discount rate. These UPW* factors incorporate the official DoE-projected energy price escalation rates which Federal agencies are directed to use in making their LCC evaluations. Because the projected energy price escalation rates vary by the 10 DoE regions of the country, by fuel type, and by sector, a set of 10 tables are necessary to provide these discount factors. (Table B-11, which incorporates the U.S. average energy price projections, is given for general reference.) Appendix B discount factors are to be used to find the present value of energy costs or savings.

2.2.2.3 Discount Rate

Discount factors are based on a "discount rate" which is a rate of interest to reflect the investor's opportunity cost of money. As a general rule, the opportunity cost is best indicated by the rate of return that could be realized if the funds were used for the best available alternative investment to the project being considered.

For evaluating most investments of the Federal government, the Office of Management and Budget (OMB) has specified that a real rate of 10 percent (not including inflation) be used[1] and, Executive Order 12003 stated that the Federal LCC methodology should be consistent with OMB Circular No. A-94. Hence, the appendix A and B data tables published in the January 23, 1980 Federal Register, as part of the final LCC Rule, were based on a 10 percent discount rate.

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[1] The 10 percent rate is dictated by the Office of Management and Budget in Circular A-94, Ref. [11]. 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, Ref. [12].

On June 30, 1980, however, President Carter signed the Energy Security Act which requires a discount rate of 7 percent per year.[1] (This rate, like the 10 percent rate, is interpreted as a real discount rate, not including the rate of inflation.) The changeover to the 7 percent discount rate for the Federal Energy Management Program is scheduled for October 1, 1980.

All of the tables of discounting factors in appendices A and B are based on a 7 percent discount rate. Because it is a "real discount rate" that does not include an estimate of the rate of inflation, it is lower than a comparable "nominal discount rate" that includes inflation. A real discount rate is appropriate for discounting future cash amounts that do not include inflation, i.e., that are given in constant dollars.

The effect of discounting is to reduce the present value of future cash amounts. The higher the discount rate, the lower the present value equivalent of a future amount; the farther into the future the cash amount, the lower its present value equivalent.

2.2.2.4 Present Values

As indicated above, cash amounts that occur at different times should be adjusted to a common time basis for a valid economic analysis. In general, that common time might be (1) the present, whereby all cash amounts are converted to an equivalent value occurring now; (2) annually, whereby all cash amounts are converted to an equivalent value occurring in a uniform amount each year over the study period; and (3) the future, whereby all cash amounts are converted to an equivalent value occurring at some common time in the future, although future time bases are not often used.

For uniformity, all Federal agencies are required to use a present value basis for evaluating energy conservation and renewable energy projects for their 10-year building plans and Solar Federal Buildings proposals. Present values are being used in preference to annual values because the present value conversions are needed in any case to incorporate the future escalation of energy prices. The need to include energy price escalation results in the loss of the computational advantages usually associated with the annual value basis.

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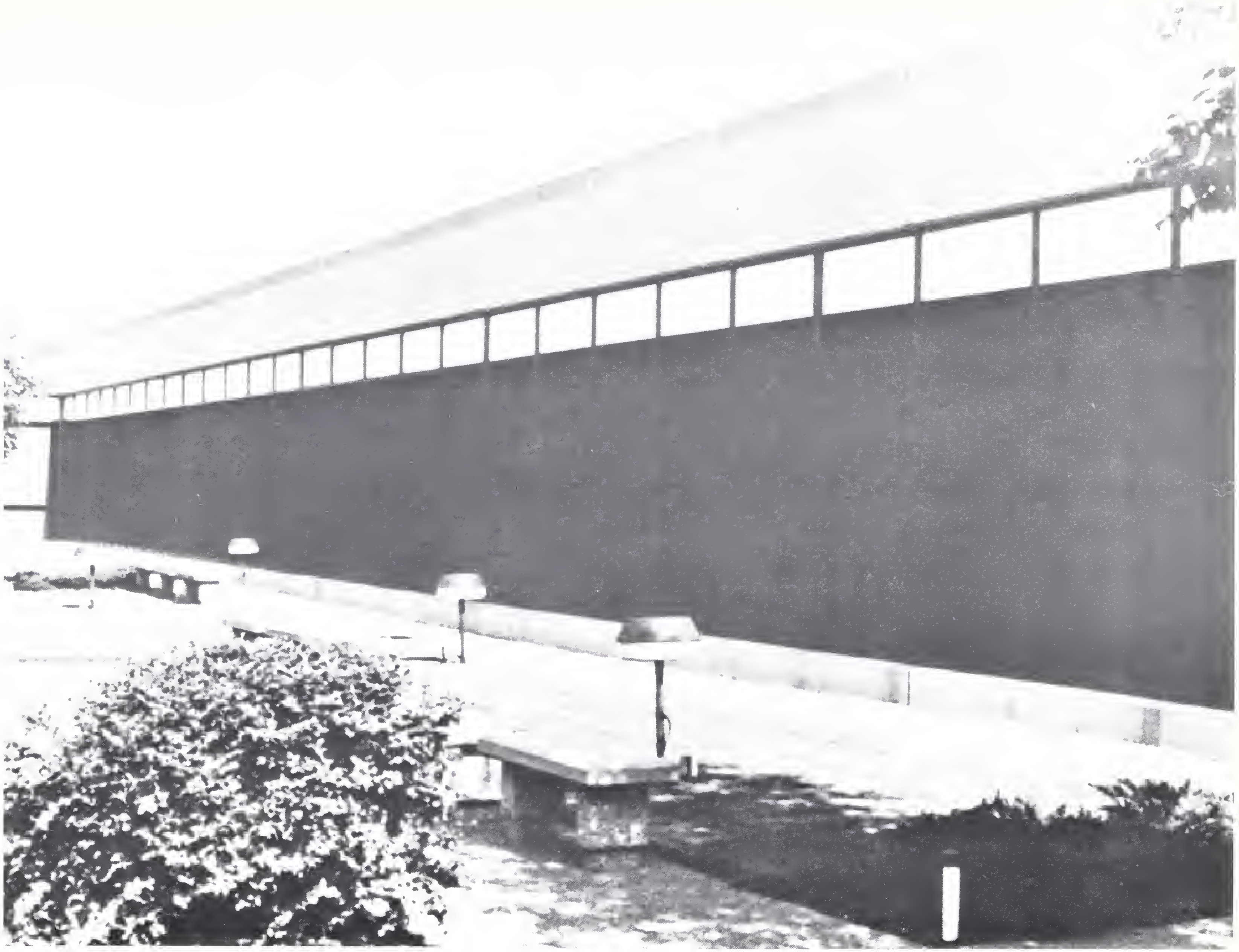
1 See Ref. [13].



Solar screens installed at the Internal Revenue Service Center in Memphis reduce air conditioning requirements by an estimated 53,500 BTU each year.

2.2.2.5 Using Discount Factors to Find the Present Value of Maintenance, Replacement, Salvage Value, and Energy Costs[1]

Finding the Present Value of Annually Recurring Routine Maintenance Costs:

If a future constant dollar amount is expected to recur annually--as is typical of routine maintenance cost--its present value (P) over N years can be found by multiplying the UPW factor for N years by the annually recurring amount (A), i.e.,

$$P = A \times UPW. \tag{2.1}$$

For evaluating a Federal energy conservation or renewable energy project, UPW factors based on a 7 percent discount rate (given in appendix table A-2), should be used.

For example, to find the present value of 15 years of annual maintenance costs of \$100, multiply \$100 by 9.11 (the UPW discount factor for 15 years and a 7 percent discount rate found in table A-2), obtaining \$911, i.e.,

$$P = \$100 \times 9.11 = \$911. \tag{2.2}$$

This means that a Federal agency should regard the spending of \$100 for maintenance in each of 15 years as the economic equivalent to spending \$911 in a lump sum now. This kind of equivalency measure can be useful in guiding cost tradeoffs, such as a tradeoff between initial investment costs and future maintenance costs.

Finding the Present Value of Nonannually Recurring Replacement Costs and Salvage Values:

The present value (P) of a future amount that does not recur annually--such as a major system replacement or a salvage (resale) value--can be found by multiplying each future amount (F) by the SPW factor for the year in which it occurs, i.e.,

$$P = F \times SPW. \tag{2.3}$$

For a Federal energy conservation or renewable energy project, SPW factors based on a 7 percent discount rate (given in appendix table A-1) should be used.

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[1] Initial investment costs can be assumed to be already in present value dollars and to require no discounting operation. (See sections 3.6 and 3.7 for further discussion of this assumption.)

For example, to find the present value of a replacement cost estimated at \$1000 in the 10th year in constant dollars, multiply \$1000 by 0.51 (the SPW discount factor for the 10th year and 7 percent found in table A-1), obtaining \$510, i.e.,

$$P = \$1000 \times 0.51 = \$510. \tag{2.4}$$

This time equivalency measure can also be used to evaluate cost tradeoff; for example, it would be worth raising initial investment costs by up to \$510 to avoid this future replacement.

In the same way, the present value of a future salvage or resale value can be found. For example, the present value of a salvage of \$600 expected to be received in the 25th year can be estimated by multiplying \$600 by 0.18 (the SPW discount factor for the 25th year and 7 percent found in table A-1), as follows:

$$P = \$600 \times 0.18 = \$108. \tag{2.5}$$

As may be seen, the future salvage value is reduced substantially when translated into today's equivalent value, taking into account the federally prescribed 7 percent opportunity cost of money.

Finding the Present Value of Energy Costs:

If the price of a material or commodity is expected to rise in amount over time faster than general price inflation--as is widely expected of energy--the present value (P) of its cost over N years can be found by multiplying the appropriate UPW* factor by a year's energy cost evaluated at today's ("base-year") prices ($\overline{A}_o$), i.e.,

$$P = \overline{A}_o \times \text{UPW*}. \tag{2.6}$$

For evaluating a Federal energy conservation or renewable energy project, UPW* factors based on a 7 percent discount rate and on DoE-projected differential energy price escalation rates should be used. (These are given in appendix tables B-1 through B-10 and are subject to periodic revision in the Federal Register.)

For example, to find the present value of energy costs over 20 years for a Federal office building in Wisconsin (DoE Region 5), which uses the equivalent of 5000 x 10^6 Btu of distillate oil annually, priced today at \$6.78 per 10^6 Btu (the DoE price in mid-1980 for DoE Region 5, Commercial Sector, Distillate Oil, as given in appendix table C-1), first find $\overline{A}_o$, the base-year energy costs, by multiplying 5000 x 10^6 Btu x \$6.78/10^6 Btu. Then multiply the resulting amount, \$33,900, by 14.31 (the UPW* discount factor for DoE Region 5, Commercial Sector, Distillate, for 20 years found in table B-5), obtaining \$485,109, i.e.,

$$P = 5000 \times 10^6 \text{ Btu} \times \$6.78/10^6 \text{ Btu} \times 14.31 = \$485{,}109. \tag{2.7}$$

Replacement of old windows with well fitting, insulated windows has lowered the heating and cooling requirements of this Federal facility through reduced conductance and infiltration.

A reduction in the present value of energy costs can be compared with the present value costs of achieving the reduction. For example, an energy conservation project that would reduce the present value energy costs of the example building by, say, one-third, from $485,109 to $325,023--a savings of $160,086--would be cost effective if its present value costs were less than $160,086.

2.3 MODES OF ANALYSIS

There are several different ways of combining the data on cost and savings from a project to evaluate its economic performance. The different measures of economic performance are referred to in the LCC Rule as "modes of analysis." For making evaluations of potential FEMP projects, the required modes of analysis are: (1) Total Life-Cycle Costs (TLCC), (2) Net Life-Cycle Savings (NS), (3) Savings-to-Investment Ratio (SIR), and (4) Payback Period (PB).[1] The first three of these are fully consistent with an LCC approach, in that they take into account all relevant values over the entire study period and discount them to a common time basis. The fourth, the payback period, is not fully consistent with an LCC approach because it may not include all values and, in its simple version, does not adjust values for time differences. It is used in the LCC Rule only as a supplementary measure to the life-cycle costing measures.

The above modes of analysis treat energy in monetary terms and take into account the present differences in prices of alternative sources of energy in the various regions of the U.S. For example, each of the LCC modes reflects that a reduction in energy usage in 1980 of a million Btu's of fuel oil would save an average of $6.91 (commercial prices) per year in 1980 dollars, whereas a reduction of a million Btu's of electricity would save an average of $18.06 (commercial prices), and a million Btu's of coal, only $1.46 (industrial prices). Similarly, the LCC modes reflect that in 1980, electricity costs more than $0.09 (residential prices) per kilowatt hour in one region of the country and less than $0.03 (residential prices) in another region.[2] Modes (1) through (3) also take into account the projected future escalation of energy prices.

Since they are based on dollar values, the LCC modes do not distinguish between dollar savings occurring from energy sources and dollar savings occurring from nonenergy sources such as labor or materials. On the one hand, this feature may in some cases mean the need for supplementary project selection criteria to

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1 A mode of analysis, consistent with an LCC approach, but not used for evaluating FEMP projects, is the Internal Rate of Return (IRR) Method. For a simplified description of the modes of analysis and the discounting technique, see Ref. [14]. For a more detailed treatment of the IRR or additional description of the modes of analysis, see an engineering economics or cost-benefit text, such as Refs. [15] and [16].

2 Based on DoE 1980 estimated prices given in appendix tables C-1 and C-2.

ensure that the energy conservation program is indeed supporting energy conservation projects. On the other hand, it is a strength of the LCC modes of analysis that significant nonenergy savings are taken into account.

Each of the four modes of analysis used in FEMP evaluations is described below.

2.3.1 Total Life-Cycle Costs

ABBREVIATION: TLCC

DESCRIPTION: TLCC is the sum of all significant dollar costs of a project, discounted to present values. A building design or system that lowers the TLCC of the building while meeting performance requirements can generally be held to be cost effective.[1]

GENERAL FORMULA:

Total Life-Cycle Costs
Investment Costs
Salvage Value
Nonfuel Operation & Maintenance Costs
Replacement Costs
Energy Costs

$$TLCC = I - S + M + R + E, \tag{2.8}$$

where all amounts are expressed as present values.

FEMP USE: (1) Comparison of new building designs.

(2) Comparison of alternatives for a given building system in a given application, e.g., alternative thicknesses of insulation for a given wall.

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[1] This is true unless there are substantial costs which are nonquantified that alter the cost effectiveness of the design or system.

2.3.2. Net Life-Cycle Savings

ABBREVIATION: NS

DESCRIPTION: NS is the decrease in the TLCC of a building or building system which is attributable to an energy conservation or renewable energy project. It is found by subtracting the TLCC of the building or building system with the energy-conserving or renewable energy project (as calculated by equation 2.8), from the TLCC without the project (also calculated by equation 2.8).

An equivalent way of defining NS is "the difference between the decrease in energy costs attributable to a project and the increase in other costs attributable to it." A positive NS can generally be held to mean the project is cost effective.[1]

GENERAL FORMULAS:

$$\overset{\text{Net Life-Cycle Savings}}{NS} = \overset{\text{TLCC Without the Energy-Conserving or Renewable Energy Project}}{TLCC_{WO}} - \overset{\text{TLCC With the Project}}{TLCC_{W}}, \qquad (2.9)$$

or

$$\overset{\text{Net Life-Cycle Savings}}{NS} = \overset{\text{Reduction in Energy Costs}}{\Delta E} - [\overset{\text{Differential Investment Costs}}{\Delta I} - \overset{\text{Differential Salvage Values}}{\Delta S} + \overset{\text{Differential Nonfuel Operation \& Maintenance Costs}}{\Delta M} + \overset{\text{Differential Replacement Costs}}{\Delta R}], \qquad (2.10)$$

where all amounts are expressed as present values.

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1 See footnote 1 on page 25.

The Δ values used in the above formula for NS and below in the formula for the SIR are calculated by taking the difference in present value costs between the proposed energy conservation or renewable energy system and its alternative which may be an existing system or a new system without energy conserving or renewable energy features. Where the subscript w designates the amounts with the proposed energy conservation or renewable energy system and the subscript wo designates the amounts without the proposed system, the Δ values are defined as follows:

$$\Delta E = (E_e - E_r) \tag{2.11}$$

$$\Delta I = (I_r - I_e) \tag{2.12}$$

$$\Delta S = (S_r - S_e) \tag{2.13}$$

$$\Delta M = (M_r - M_e) \tag{2.14}$$

$$\Delta R = (R_r - R_e) \tag{2.15}$$

FEMP USE: (1) Comparison of alternatives for a given building system in a given application, e.g., alternative thicknesses of insulation for a given wall, or alternative sizes of a solar energy system (i.e., same as FEMP use #2 for TLCC).

(2) Evaluation of solar energy systems proposed under the Solar Federal Buildings Program, as required by Title V, Part 2 of NECPA.

2.3.3 Savings-to-Investment Ratio

ABBREVIATION: SIR

DESCRIPTION: The SIR is a numerical ratio calculated with the reduction in energy costs, net of increased nonfuel operation and maintenance costs, as the numerator, and the increase in investment cost, minus increased salvage values, plus increased replacement costs, as the denominator. An SIR greater than one means the investment is cost effective; the higher the ratio, the greater the dollar savings per dollar spent.

GENERAL FORMULA:

Savings-to-Investment Ratio
Reduction in Energy Costs
Differential Nonfuel Operation & Maintenance Costs
Differential Investment Costs
Differential Salvage Value
Differential Replacement Costs

$$SIR = [\Delta E - \Delta M] \div [\Delta I - \Delta S + \Delta R], \qquad (2.16)$$

FEMP USE: (1) Comparison and ranking of retrofit projects for existing buildings to determine their relative priorities.

(2) Comparison and ranking of proposed solar energy systems under the Solar Federal Buildings Program.

2.3.4 Payback Period

ABBREVIATION: PB

DESCRIPTION: The PB is the elapsed time between the initial investment and the time at which cumulative savings in energy costs, net of other future costs, are just sufficient to offset the initial investment costs. If differences in the timing of the cash flows are taken into account, the mode is called "discounted payback" (DPB). If timing differences are not taken into account, the mode is called "simple payback" (SPB).[1]

The shorter the time until the investment is paid back, generally the more attractive the investment is considered. However, this preference is not always justified from the standpoint of cost effectiveness, and an investment with a longer payback period may be more cost effective than an investment with a shorter payback. For example, a project that costs $10,000, saves $4,000 a year, lasts 4 years, and therefore has a simple payback of 2 1/2 years, will be less cost effective than a project that costs $10,000, saves $3,000 a year, lasts 6 years, and therefore has a simple payback of 3 1/3 years. Ignoring price escalation and using the 7 percent discount rate, the net present value savings of the first project is $3,560, while that of the second is $4,310. The discounted payback of the first project occurs in the third year. The discounted payback of the second project occurs in the fourth year--later than the first, but a year before the end of its expected life. Hence, the payback mode of analysis has the disadvantage of not always indicating the

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1 A nomogram for converting from SPB to DPB is provided in appendix F.

most cost-effective projects; the simple version of payback has the added disadvantage of not indicating the correct time to payback including the cost of money.[1]

GENERAL FORMULA:

Years to Payback
Sum of Values for Years 1 to Y
Reduction in Energy Costs
Differential Non-fuel Operation & Maintenance Costs
Differential Replacement Costs
Differential Initial Investment Costs

$$\text{Find } y, \text{ such that } \sum_{j=1}^{y} (\Delta E_j - \Delta M_j - \Delta R_j) = \Delta I, \tag{2.17}$$

where, for DPB, E, M, and R are yearly amounts, in constant dollars which reflect any differential price changes, converted to present values; and, for SPB, they are base-year amounts which do not reflect any differential price changes and are not discounted.

SIMPLIFIED SPB FORMULA: If future changes in energy or other prices are not taken into account, and if future costs and savings are estimated to occur in even yearly amounts, the following simple formula can be used to determine SPB:

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1 A primary advantage that usually exists for the PB mode is that it indicates to a speculative investor the length of time before returns enable a loan to be paid off. This feature, however, does not appear critical to Federal investment decisions. Other advantages of PB--which may be important to the Federal government--are its widespread familiarity and its usefulness for testing the sensitivity of estimated system life.

$$\overset{\text{Simple Payback Time}}{\mathrm{SPB}} = \overset{\text{Differential Investment Costs}}{\Delta I} \div (\overset{\text{Reduction in Energy Costs}}{\Delta E_O} - \overset{\text{Differential Nonfuel Operation \& Maintenance Costs}}{\Delta M_O} - \overset{\text{Differential Replacement Costs}}{\Delta R_O}), \tag{2.18}$$

where ΔE_O, ΔM_O, and ΔR_O are base-year amounts and not discounted.

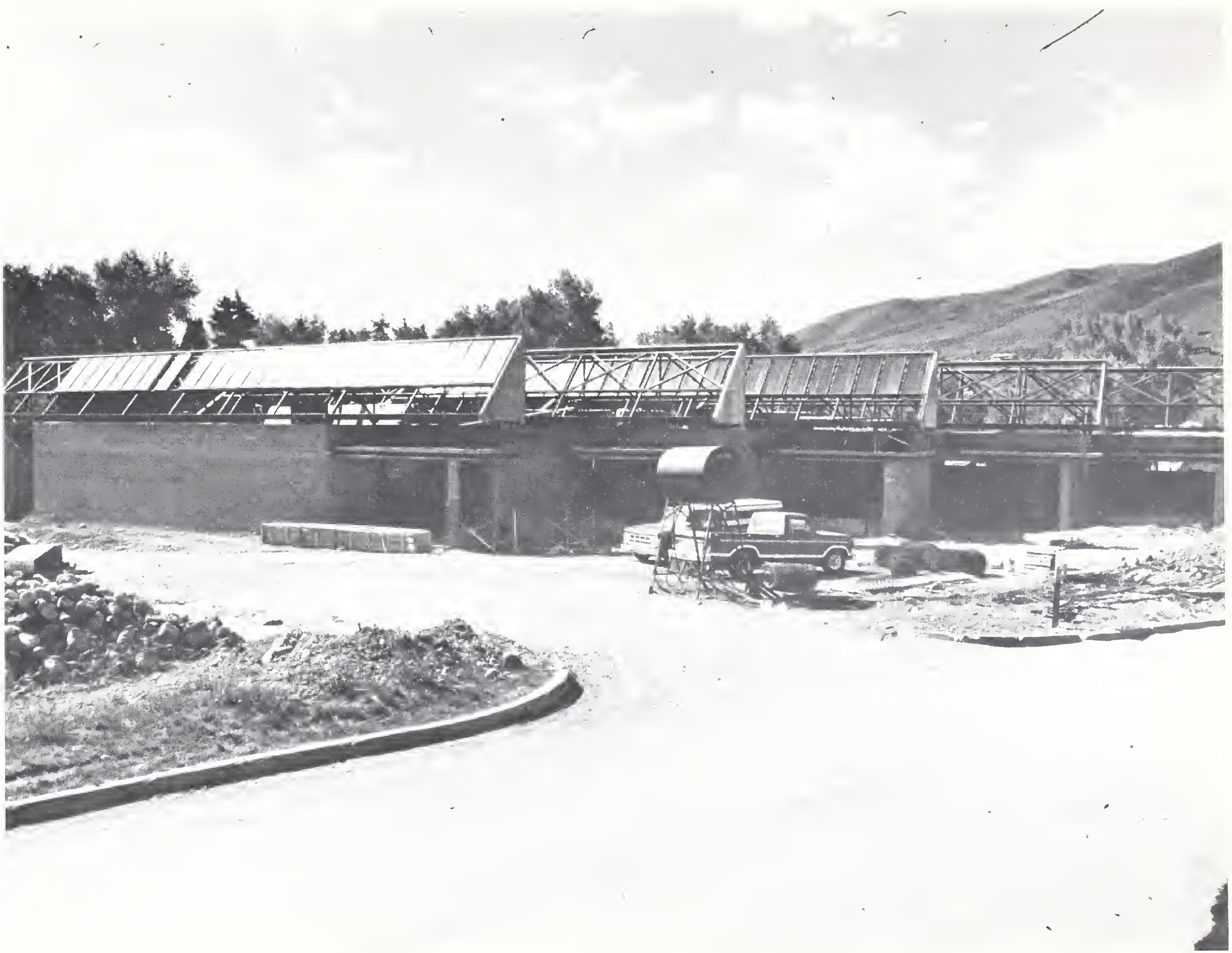
FEMP USE: A measure of payback is required by Title V, Part 2 of NECPA for the evaluation of solar energy systems in the Solar Federal Buildings Program, in supplement to the NS measure. To meet this requirement, the SPB mode is used with energy and other costs evaluated in base-year prices, without differential price escalation or discounting. This should be viewed as only a rough, approximate measure of economic performance and should not be relied upon as the primary measure for most project decisions.

2.4 APPLICATIONS

2.4.1 Determining Cost Effectiveness -- TLCC, NS, SIR, and SPB

Provided the SPB measure is used with caution, any of the four above modes of analysis can usually be used to determine whether or not a project is cost effective; that is, whether the reduction in energy and other costs caused by a project exceed the increases in investment and other costs attributable to it. The cost effectiveness of a project is indicated when any of the following conditions are met: (1) The TLCC of the building is lower with the project than without it; (2) the NS from the project is greater than zero; (3) the SIR is greater than one; or (4) the payback period for the project is shorter than its expected life. In using the SPB to determine cost effectiveness, it is important to remember that the SPB is a rough measure of cost effectiveness which tends to understate the payback period. When the SPB time is close to the expected life, the project will probably not be cost effective, taking into account the 7 percent cost of money.

It is not enough, however, simply to identify projects that are cost effective in terms of saving more than they cost. It is possible to increase energy cost savings per investment dollar spent if: (1) projects are designed and sized



The U.S. Postal Service is relying on solar energy for part of the heating requirements in both new and existing post offices around the country, such as this new post office in Colorado.

for the greatest possible economic efficiency, and (2) for a limited budget, priority is given to the most economically efficient projects. The four modes of analysis listed above are not equally suitable for choosing among alternative new building designs, for designing and sizing projects for new and existing buildings, nor for ranking available retrofit projects in terms of their relative cost effectiveness.

Additionally, the economic efficiency of energy-related projects can be improved by the optimal timing of investment decisions. This means developing replacement schedules for building systems on the basis of their economic lives. It means timing the investment in new building systems so as to capture the largest possible long-run net benefits or savings from those systems in the face of technological and other changes. Ideally, determining the choice of timing--the "when"--of investment planning is integrated with the choice of project type, design, size, and mix--the "what" of investment planning--to develop an investment strategy that accounts for both. This generally requires a dynamic programming approach which goes beyond the scope of this Manual. The emphasis of the LCC Rule and of this Manual is on providing a simplified, practical tool which can be used for general project development, evaluation, and ranking.[1]

2.4.2 Choosing Among Alternative Building Designs--TLCC

TLCC is generally the mode best suited for choosing among alternative designs for a new building. The design with the lowest TLCC for the energy-related components of the building will be preferred, other things being equal. To use the other modes, it is necessary to find the dollar differences between the various features of one design and its alternatives. While this can be done and should lead to the same design decision, the TLCC mode will usually tend to be somewhat more convenient for comparing alternatives for the building's basic configuration and overall design.

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1 For guidance in determining economically efficient replacement and retirement policies, see Ref. [15]. For a landmark work on dynamic investment planning, see Ref. [17].

2.4.3 Designing and Sizing Projects--TLCC and NS

Choosing between alternatives for a given building system in a given application (i.e., mutually exclusive[2] projects), such as determining the economically efficient design and size of an energy conservation project or of a solar energy system, is best accomplished by either the TLCC or the NS mode of analysis. As long as the TLCC of a building declines as a project is changed in design and/or increased in scale--which is the same thing as saying as long as NS rises--it pays to expand the project.[2]

Although it is also possible to use the SIR to choose among alternative designs and sizes of a project, the SIR is more likely to be misapplied than the TLCC and the NS. The SIR may be misapplied because its value tends to fall before the optimal investment design or size is reached. For example, the SIR computed for the addition to a solar collector array may be lower than the SIR on the total of the rest of the investment, thereby causing the SIR on the total investment to fall with the increase in size. Yet the larger size collector may be more cost effective than the smaller size, provided the return on the

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1 Alternatives are "mutually exclusive" if choosing one alternative precludes choosing the other; e.g., double and triple glazing are mutually exclusive alternatives for a given window. Projects are "nonmutually exclusive" if doing one does not necessarily preclude doing the other; e.g., it may be cost effective to replace both the furnace and the windows in a building if the budget permits, although one project may be more cost effective than the other. (Although the projects in this last example are not mutually exclusive, they are interdependent. See section 4.4 for a discussion of project interdepencies.)

2 Although this condition holds in theory only if 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 projects. Furthermore, this guideline of improving the design or increasing the size of a project as long as TLCC declines or NS increases, seems particularly appropriate for the Federal program which requires by 1990 that all Federal buildings be life-cycle cost effective in their design and retrofit. Stopping projects short of their lowest cost design and size might well result in a need within the 1980-1990 time frame for the retrofitting of previously accomplished retrofit projects and also of new building designs, which would likely entail high attendant administrative and other costs; that is, the "moving target" phenomenon that may in any case result from changes in energy price forecasts and technological developments would probably be considerably worsened by not adopting this guideline of choosing the project design and/or size that minimizes the TLCC or maximizes the NS of that project.

increment to the investment is greater than its cost.[1] To avoid this kind of error, the TLCC and NS are recommended for choosing among mutually exclusive projects.

2.4.4 Assigning Project Priorities--SIR

Ranking nonmutually exclusive retrofit projects to give priority to the most cost-effective projects is best accomplished by the use of the SIR.[2] Because it relates the size of the savings to the size of the investment, it provides a measure of the return on an investment dollar--a measure which the TLCC, the NS, and the PB modes do not provide. The TLCC and the NS modes do not, for example, distinguish between a project costing $9,000 and saving $10,000 and one costing $4,000 and saving $5,000 (assuming comparable time considerations).

Selecting projects in descending order of their SIR's until the available budget is exhausted can be expected to result in a larger return per investment dollar and, hence, a greater total dollar savings for a given budget than selecting projects according to their TLCC, their NS, or their PB.[3]

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1 The optimal size occurs when the cost of an additional increment in the investment is just matched by the resulting increment in savings.

2 The Internal Rate of Return (IRR), a mode of analysis not discussed here, is generally equivalent in technical accuracy to the SIR for ranking retrofit projects. However, it is not used for FEMP evaluations for the following reasons: it is more cumbersome to calculate than the SIR; (b) it is subject under certain conditions to problems in computation; and (c) its principal advantage of accommodating a changing required rate of return is lost, because the Federal discount rate is set.

3 Another possible criterion for ranking retrofit projects that was considered for use in this program is a measure of Btu per investment dollar. However, it is not being used because it does not appear consistent with the requirements of the NECPA and the Executive Order for a life-cycle cost approach. It 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 by their present prices or as can be accounted for by applying the special UPW* factors to adjust for projected energy prices changes. It does not, for example, distinguish between savings of coal and savings of oil, nor between savings of electricity in the northeast and in the northwest. Nor does the Btu per investment dollar measure account for the expected life of the project, the time value of money, and future nonenergy savings and costs. In the short run, it will yield the largest Btu energy savings (if based on energy consumption at the source) though probably not the largest dollar energy savings. But in the long run, it may not even yield the largest Btu savings, because of lower program efficiency and smaller dollar savings.

2.5 SENSITIVITY ANALYSIS

Sensitivity analysis is a technique for evaluating a project when there is considerable uncertainty about the appropriate values to use in performing the evaluation. For example, uncertainty about the life of a project, the quantity of energy it will save, and/or its future replacement costs may raise doubts about its cost effectiveness. To assess the likely range of possible outcomes, several evaluations of the project can be made, based on alternative values of the parameters in question. By evaluating the outcome for upper and lower estimated values of the parameters, such as the minimum and maximum estimated life and the minimum and maximum estimated energy savings, sensitivity analysis can be used to bracket the range of likely outcomes and to give a clearer estimate of a project's potential cost effectiveness.[1]

While there are no explicit requirements in the LCC Rule for sensitivity analysis, it is encouraged whenever substantial uncertainties cast doubt on project cost effectiveness. OMB Circular A-94 requires Federal agencies to conduct sensitivity analyses of proposed programs and projects if there is a "reasonable basis to estimate the variability of future costs and benefits."

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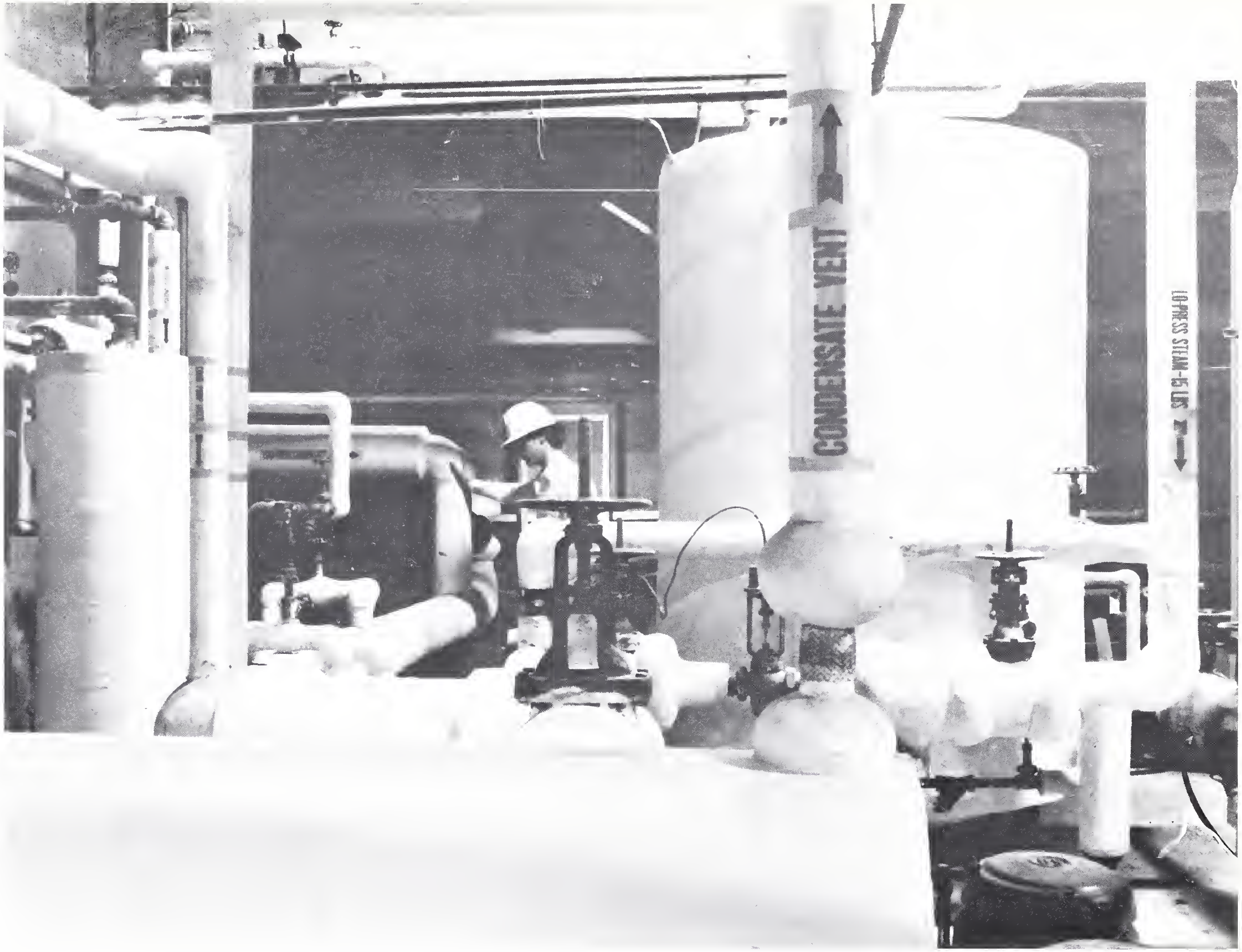
[1] A related technique, probability analysis, may be used to evaluate a project under conditions of uncertainty when the probability of different occurrences can be estimated. For a description of how to perform probability analysis, see Ref. [16]; for a more detailed treatment, see Ref. [18].



Additional insulation for hot water convertors, the steam station, and steam and hot water lines was included in the energy reduction modification of one of the buildings of the Brookhaven National Laboratory.

3. DATA AND ASSUMPTIONS

The following is a list of requirements of the LCC Rule for establishing economic data and assumptions:[1]

3.1 CONSTANT DOLLARS

ESTIMATE ALL FUTURE AMOUNTS IN CONSTANT DOLLARS

Consistent with OMB Circular A-94, all monetary amounts should be stated in constant dollars in terms of the purchasing power of the dollar at the time the evaluation is being made, i.e., in the base year. For example, if an LCC evaluation were being made in 1980, a future cost expected to occur in 1990 should be stated in 1980 dollars without an estimate for the purely inflationary trends that may cause the general level of prices in the economy to rise between 1980 and 1990.

This approach allows for the inclusion in data estimates of "differential price changes," i.e., changes that are faster or slower than the rate of general price inflation. The constant dollar value of future energy costs should incorporate DoE-projected differential price changes (See section 3.4).[2]

3.2 QUANTITY OF ENERGY

ESTIMATE THE QUANTITY OF ENERGY AT THE BUILDING BOUNDARY

The life-cycle cost approach uses energy prices to evaluate the cost effectiveness of an investment. Because these prices already tend to reflect the relationship of "boundary energy" to "source energy," the measure of the physical quantity of energy associated with a building or building system should be based on the quantity of energy delivered to the boundary of the Federal building for the purpose of making the LCC evalaution.

A possible exception is when fuel is used to generate electricity on site. If, in the case of on-site generation of electricity, the agency estimates the value of the electricity on the basis of the DoE-provided electricity price

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1 These requirements reflect amendments to subpart A of Part 436, 10 CFR, made in response the Energy Security Act (Ref. [13]). These revisions are expected to become final in the fall of 1980.

2 For guidance in estimating the constant dollar value of a future amount which is fixed in amount (for example, by contract), and which declines in constant dollar value in response to inflation, see Ref. [12].

data (appendix table C-1), the quantity of electricity generated should be used in the LCC evaluations, not the boundary purchases of fuel to produce the electricity. If, however, the agency estimates the value of on-site electricity/steam/hot water on the basis of the input fuel plus generating and distributing costs, the quantity of the input energy should be based on the boundary purchases of the fuel. (See section 3.3)

3.3 BASE-YEAR ENERGY PRICES

USE DoE BASE-YEAR ENERGY PRICES TO ESTIMATE INITIAL ENERGY COSTS OR SAVINGS UNLESS ACTUAL PRICES TO THE AGENCY ARE HIGHER

Federal agencies should use the higher of (1) the estimated base-year energy prices developed by DoE and given in appendix table C-1 and C-2 (these are subject to periodic revision in the Federal Register[1]), or (2) the agencies' own base-year energy prices.

An exception exists when fuel is purchased by a Federal agency to produce its own electricity, steam, or hot water on site. In this case, the base-year price of energy used to make LCC evaluations should be (a) the price of the input fuel to the agency plus the costs incurred by the agency in generating and distributing the electricity/steam/hot water, or (b) for electricity only, the DoE regional price of electricity indicated in appendix table C-1 (subject to periodic revision), whichever is higher.

3.4 FUTURE ENERGY PRICES

TO ACCOUNT FOR ANTICIPATED RISE IN FUTURE ENERGY PRICES, USE DoE PROJECTED ENERGY PRICE ESCALATION RATES

DoE projects the future prices of coal, fuel oil, electricity, and natural gas to rise at rates different from the rate of change in the general level of prices. These "differential energy price escalation rates" are projected to

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[1] The energy prices provided in appendix C of this manual are average retail prices proposed for use beginning October 1980. (See Ref. [19].) DoE plans at a future time, however, to substitute for these average retail prices, adjusted marginal costs. The adjusted marginal costs will be based on the private and social costs of producing and delivering additional supplies of energy. They will be intended to more accurately reflect the costs of energy to the nation than do the average retail prices. Public notice will be given prior to a change to marginal cost pricing. The guideline of using the higher of the (1) DoE-provided price in appendix table C-1 or (2) the actual agency price will continue to apply unless specifically changed in an amendment to the LCC Rule.

vary by DoE region, by sector, by fuel type, and over time, as indicated by appendix tables C-6 through C-8 (subject to periodic revision in the Federal Register).[1]

There are three alternative recommended ways of using the DoE-projected energy price escalation rates to estimate future energy costs or savings: (1) Using a manual calculation approach, the simplest way to incorporate the escalation rates is to apply the approrpriate UPW* discount factor from appendix table B-1 through B-10 (subject to revision whenever the DoE price projections are revised) to the base-year energy cost or savings to find the equivalent present value over the study period. (The UPW* factors already incorporate the DoE-projected energy price escalation rates, as well as the 7 percent discount rate.) (2) using a lengthier, step-by-step manual calculation approach, the future year-by-year prices of energy can be determined by applying the appropriate compound annual escalation rates for energy prices, given in appendix tables C-6 through C-8, to the price of energy in each preceding year, using the single compound amount (SCA) interest formula. Each future year's energy cost or savings should then be discounted to present value. (See appendix G for a further description of this procedure.) (3) Using a computer program which incorporates the LCC calculation formulas, such as the LCC computer program in appendix E, the appropriate energy price escalation rates from appendix tables C-6 through C-8 may be merely entered into the program, together with other data.

3.5 DISCOUNTING

DISCOUNT FUTURE AMOUNTS TO PRESENT VALUE USING A 7 PERCENT "REAL" DISCOUNT RATE

Consistent with OMB Circular A-94, Federal agencies should use a discount rate of 7 percent, not including inflation, to find the present value equivalents of future cash amounts which are estimated without inflation. The use of the discounting factors given in appendices A and B, all of which are based on a 7 percent rate, will meet this requirement.

3.6 INVESTMENT COSTS

TREAT INVESTMENT COSTS, INCLUDING COSTS OF DESIGN, ENGINEERING, PURCHASE, AND INSTALLATION (EXCLUSIVE OF SUNK COSTS), AS A LUMP-SUM PRESENT VALUE AMOUNT OCCURRING AT THE BEGINNING OF THE BASE YEAR AND CONSTITUTING 90 PERCENT OF ACTUAL INVESTMENT COSTS

Treating investment costs as occurring at the beginning of the base year is a simplification which allows these costs to be considered already in present value dollars without discounting.

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1 See footnote 1, on page 38.

To assume that the initial investment costs, for all projects to be evaluated in a given year occur at the beginning of that year is, of course, a simplification that gives somewhat less accurate results than a detailed analysis of actual estimated cash flows. Furthermore, it should be recognized that a detailed scheduling and accounting of costs is an important aspect of project management. However, for the purpose of making FEMP investment decisions, the difference in the results of a detailed cash flow analysis and of the simplified approach is expected generally not to be great. If a more detailed analysis is made, it is, in any case, necessary to convert all amounts to present value dollars as of the base year in order to compare alternative projects. A delay of project construction costs into the future generally means a corresponding delay in the commencing of energy savings. The discounted values of future investment costs, energy savings, and other costs will be reduced by delays in project completion. The reductions in costs and savings will tend to be somewhat offsetting, resulting in an LCC measure that tends to be quite close to that obtained by this simplified approach used for FEMP evaluation. (For a numerical example, see section 3.7.)

Reducing actual investment costs by 10 percent for use in the LCC evaluation is an adjustment designed to encourage Federal energy conservation. It is an interim adjustment intended to compensate for the use of average retail energy prices which likely do not reflect the full value to the nation of conserving nonrenewable energy resources. The 10 percent reduction was modeled after the 10 percent tax credit allowed to business for energy conservation and renewable energy investments at the time this adjustment was designed.[1]

3.7 ENERGY AND ANNUALLY RECURRING NONFUEL OPERATION AND MAINTENANCE COSTS

ASSUME THAT ENERGY AND ANNUALLY RECURRING NONFUEL OPERATION AND MAINTENANCE COSTS BEGIN TO ACCRUE AT THE BEGINNING OF THE BASE YEAR, AND ARE EVALUATED AS LUMP-SUM AMOUNTS AT THE END OF EACH YEAR OVER THE STUDY PERIOD, STARTING WITH THE END OF THE BASE YEAR

To correspond with the treatment of investment costs as initially incurred expenses, energy and nonfuel annually recurring amounts are evaluated first at the end of the base year and thereafter at the end of each year following. Again, this is a simplifying assumption adopted to promote uniformity and practicality in the LCC Rule.

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[1] It is recognized that applying the 10 percent adjustment factor to investment costs is only a very rough proxy for the true value of social externalities not reflected in energy prices. For one thing, a more accurate adjustment would be linked to the type and amount of energy affected, not to the size of the investment cost. DoE plans in the future to eliminate this investment adjustment factor and to substitute for it improved energy cost data that more fully incorporate social costs.

These photovoltaic cells, supported on station roofs, supply power for the mobile telephone communication stations of the U.S. Department of Defense.

As explained above, this simplified approach, though less accurate than a detailed analysis, is not expected to result in serious errors in investment decision. For the purpose of illustration, there follows for a simple, hypothetical problem a comparison of the LCC evaluation using, first, the simplified evaluation approach adopted in the LCC Rule and, second, a more detailed approach which takes into account the expected actual scheduling of project installation and energy savings:

GIVEN ASSUMPTIONS:

Total Project Investment Cost = $100,000 (Constant 1980 Dollars)
Annual Energy Savings = $15,000 (mid-1980 prices, Natural Gas, Commercial, U.S. Average)
Project Life = 20 years
Time of LCC Evaluation: mid-1980
Expected Investment Schedule:
- mid-1981 - $5,000 Design
- late-1981 - $5,000 Engineering
- mid-1982 - $20,000 Engineering
- mid-1983 - $70,000 Installation

Expected Onset of Energy Savings: Mid-1983

SOLUTION BY LCC RULE, SIMPLIFIED METHOD:

$PV_{1980\$}$ Investment = $100,000
$PV_{1980\$}$ Energy Savings = $15,000 x 12.78 = $191,700
NS = $191,700 - $100,000 = $91,700
SIR = $191,700/100,000 = 1.92

SOLUTION BY DETAILED METHOD, TAKING INTO ACCOUNT EXPECTED TIMING OF INVESTMENT COSTS AND ENERGY SAVINGS:

<u>Investment Costs</u>

PV Investment Design	= $ 5,000	x .93	=	$ 4,650
PV Investment Engineering	= $ 5,000	x .90	=	$ 4,500
PV Investment Engineering	= $20,000	x .87	=	$17,400
PV Investment Installation	= $70,000	x .82	=	$57,400
$PV_{1980\$}$ Total Investment			=	$83,950

<u>Energy Savings</u>

Annual Energy Savings Evaluated in mid-1983 = $\$15{,}000\ (1 + .0175)^3 = \$15{,}801$

$PV_{1980\$}$ of Energy Savings from 1983 to 1985 =

$$15{,}801\left(\frac{1 + .0175}{.07 - .0175}\right)\left[1 - \left(\frac{1 + .0175}{1 + .07}\right)^2\right](0.82) = \$24{,}038$$

Annual Energy Savings Evaluated in mid-1985 = \$15,801 $(1 + .0175)^2$ = \$16,359

$PV_{1980\$}$ of Energy Savings from mid-1985 to mid-1990 =

$$16,359\left(\frac{1 + .0349}{.07 - .0349}\right)\left[1 - \left(\frac{1 + .0349}{1 + .07}\right)^5\right](0.71) = \$52,603$$

Annual Energy Savings Evaluated in mid-1990 = \$16,359 $(1 + .0349)^5$ = \$19,420

$PV_{1980\$}$ of Energy Savings from mid-1990 through mid-2003 =

$$19,420\left(\frac{1 + .0139}{.07 - .0139}\right)\left[1 - \left(\frac{1 + .0139}{1 + .07}\right)^{13}\right](0.51) = \$90,120$$

$PV_{1980\$}$ of Total Energy Savings from mid-1983 through mid-2002 = \$166,761

Net Savings

NS = \$166,761 - \$83,950 = \$82,811

Savings-to-Investment Ratio

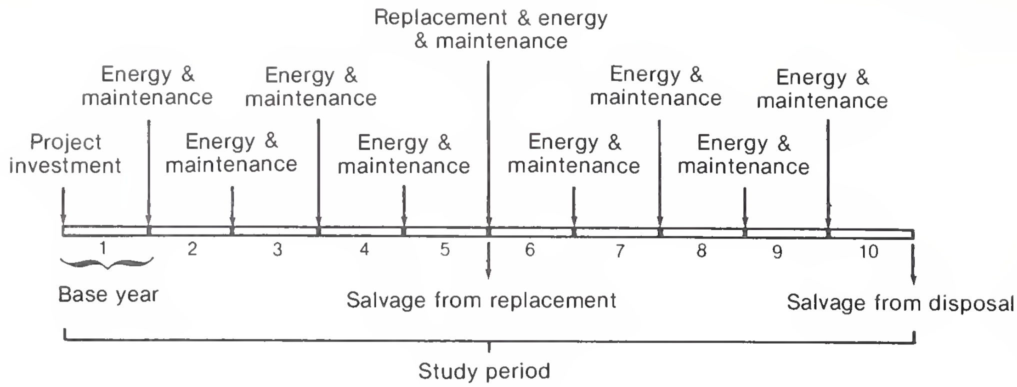
SIR = \$166,761/\$83,950 = 1.99

Note that NS and SIR calculated by this more detailed approach will vary relative to the NS and SIR calculated by the simplified approach depending on the exact scheduling of investment, the onset of energy savings, and the rate of escalation assumed in the price of energy. For example, if the \$70,000 installation cost in this example had occurred in mid-1982 and the \$20,000 engineering cost in mid-1983, the NS would have been calculated to be \$80,311 and the SIR 1.93, other things remaining the same.

3.8 NONANNUALLY RECURRING REPAIR AND REPLACEMENT COSTS AND SALVAGE VALUES

ASSUME THAT FUTURE AMOUNTS NOT RECURRING ANNUALLY, SUCH AS REPAIR AND REPLACEMENT COSTS AND SALVAGE VALUES, OCCUR IN A LUMP SUM AT THE END OF THE YEAR IN WHICH THEY ARE ESTIMATED TO OCCUR

The following cash-flow diagram illustrates the assumptions for the timing of investment costs, energy costs, annually recurring nonfuel operation and maintenance costs, nonannually recurring replacement costs (shown to occur in the 5th year for illustrative purposes), and salvage values (shown to occur at the time of the replacement in the 5th year and also at the end of the assumed 10 year study period, also for illustrative purposes).



3.9 RETROFIT STUDY PERIOD

FOR EVALUATING OR RANKING AN ALTERNATIVE BUILDING SYSTEM RETROFIT FOR A FEDERALLY OWNED BUILDING, CHOOSE A STUDY PERIOD THAT IS THE LESSER OF (A) 25 YEARS OR (B) THE ESTIMATED LIFE OF THE ALTERNATIVE BUILDING SYSTEM[1]

Note that the proposed amendment to the LCC Rule states that the period of service of a building system shall not be assumed to exceed the expected life of the building. See Ref. [19]. Also note that in selecting among mutually exclusive choices for a given retrofit project, it is important to use an equivalent study period for evaluating all choices. (See section 3.10.)

3.10 STUDY PERIOD FOR DESIGNING AND SIZING NEW BUILDINGS AND BUILDING SYSTEMS

FOR SELECTING AMONG MUTUALLY EXCLUSIVE DESIGNS AND/OR SIZES FOR A GIVEN BUILDING OR BUILDING SYSTEM, USE THE SAME STUDY PERIOD TO EVALUATE ALL OF THE CHOICES, NOT TO EXCEED 25 YEARS

When present values are used, it is important to evaluate mutually exclusive choices--such as alternative designs for a given building, alternative layers of glazing in windows, alternative solar collector designs and sizes, or alternative levels of thermal insulation--using the same study period. Choosing

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1 An arbitrary cut-off for the study period of 30 years was originally adopted in Sec. A of Subpart 436, CFR 10, because of the great uncertainties regarding energy prices in the distant future. This limit is lowered from 30 years to 25 years by the provisions of the Energy Security Act of 1980. See Ref. [13].

different study periods will automatically cause one choice to have a different life-cycle cost or net savings than another, because its cash flows will be examined over a longer time period. Mutually exclusive choices such as those mentioned above tend to arise early in the project identification and design phase.[1]

The common study period for evaluating mutually exclusive choices may be either:

(a) the estimated life of the mutually exclusive alternative having the longest life, not to exceed 25 years, with appropriate replacements and/or salvage values for each of the shorter-lived alternatives; or

(b) the lowest common multiple of the estimated lives of the mutually exclusive alternatives, not to exceed 25 years, with appropriate replacements and salvage values for each alternative.

For example, consider that the problem is to decide whether it is more cost effective to retrofit a building with a heat reflecting window film that costs $\$4.00/ft^2$ to purchase and install and is estimated to last an estimated 5 years or one that costs $\$10.00/ft^2$ and is estimated to last an estimated 15 years. In this case, a study period of 15 years could be chosen, with the first alternative replaced twice and the second alternative installed just once.

3.11 LEASED BUILDING STUDY PERIOD

FOR EVALUATING ENERGY USE AND RELATED INVESTMENTS IN A LEASED FEDERAL BUILDING, CHOOSE A STUDY PERIOD THAT IS THE LESSER OF 25 YEARS OR THE EFFECTIVE REMAINING TERM OF THE LEASE (INCLUDING RENEWAL OPTIONS LIKELY TO BE EXERCISED)

Since Federal agencies are required to consider only those costs that accrue to the Federal government in evaluating projects for leased buildings, the study period should be the effective remaining term of the lease, not in excess of the 25-year limit. Renewal options may be taken into account, if appropriate, in setting the study period.

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1 See section 2.4.3 for a discussion of project designing and sizing prior to project ranking.

3.12 SOLAR ENERGY SYSTEM STUDY PERIOD

TO PROPOSE A SOLAR ENERGY PROJECT UNDER THE SOLAR FEDERAL BUILDINGS PROGRAM, ASSUME A LIFE OF 20 YEARS UNLESS A DIFFERENT NUMBER (NOT TO EXCEED 25 YEARS) CAN BE SUPPORTED.

This guideline has been adopted by the Solar Federal Buildings Program and is reflected in item A.(4) of section III of the A-2 Solar Proposal Form. (See appendix D-3.)

3.13 SOLAR PROJECT PROPOSALS

FORMAT THE LCC EVALUATION OF SOLAR ENERGY PROJECTS PROPOSED UNDER THE SOLAR FEDERAL BUILDINGS PROGRAM USING SECTION III OF FORM A-2 OF THE OFFICIAL SOLAR FEDERAL BUILDINGS PROGRAM APPLICATION FORMS. (See section 7 and appendix D-3 of this Manual.)

3.14 PRESUMING COST EFFECTIVENESS

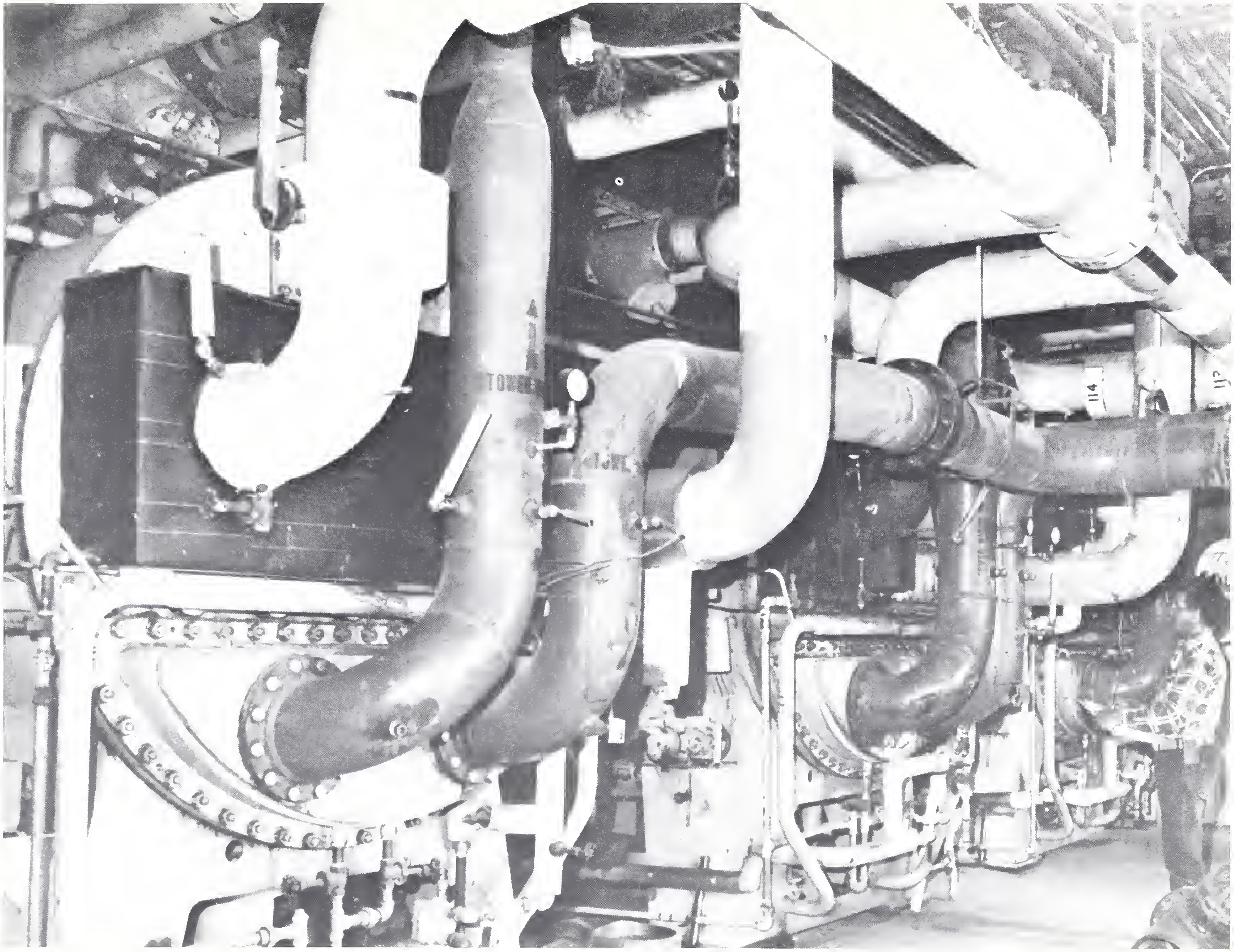
PRESUME THAT AN ALTERNATIVE BUILDING SYSTEM <u>IS</u> COST EFFECTIVE IF ITS INVESTMENT AND OTHER COSTS ARE INSIGNIFICANT.

Investment and other costs may be considered insignificant when their total is less than the cost of performing the LCC evaluation. In other cases, the application of this guideline requires responsible judgment. It should be interpreted in a strict sense, and is intended to exempt from evaluation only those projects whose costs are actually trivial in an absolute sense.

3.15 PRESUMING COST INEFFECTIVENESS

PRESUME THAT AN ALTERNATIVE BUILDING SYSTEM <u>IS NOT</u> COST EFFECTIVE IF THE BUILDING IS (A) OCCUPIED UNDER A SHORT-TERM LEASE WITHOUT RENEWAL OPTION OR WITH A RENEWAL OPTION THAT IS NOT LIKELY TO BE EXERCISED, (B) OCCUPIED UNDER A LEASE THAT INCLUDES THE COST OF UTILITIES IN THE RENT, WITH NO PASS THROUGH TO THE GOVERNMENT OF ENERGY SAVINGS, OR (C) SCHEDULED FOR DEMOLITION OR RETIREMENT WITHIN 3 YEARS.

Deteriorated piping in the steam supply system at Sandia Laboratories is a candidate for partial replacement and renewal of insulation to reduce energy requirements. Areas of extensive heat loss from the piping were identified by infrared aerial surveys.



This absorption liquid chiller at Sandia Laboratories was retrofitted with an economizer valve, a demand limiter, a storage sump, and other energy-saving devices, resulting in a substantial savings in steam consumption.

4. EVALUATING RETROFIT PROJECTS FOR EXISTING BUILDINGS

4.1 OBJECTIVES AND APPROACHES

There are three main economic objectives to be achieved by an LCC evaluation of retrofit projects:

(1) to identify cost-effective projects;

(2) to design and size candidate projects for maximum cost effectiveness; and

(3) to assign highest priority to those candidate retrofit projects that will result in the greatest return to the Federal budget.

As is explained in section 2.4, "Applications," any of the four modes of analysis covered in part 2--TLCC, NS, SIR, or PB--can generally be used to meet the first objective by determining whether or not a project is estimated to save more than it costs. To meet the second objective of finding the most cost-effective choice of design and/or size for a given project, the TLCC or the NS are the recommended modes of analysis. The third objective, assigning priority among candidate retrofit projects, requires a means of ranking projects on the basis of their return per dollar invested, and this can be accomplished by calculating their SIR's.

To assist the Federal facilities analyst in making the required evaluations for retrofit projects, two tools are provided in this manual: (1) a set of worksheets, entitled "RETROFIT WORKSHEETS" (appendix D-1), which guide the formatting of data and the operational computations for a hand calculation procedure, and (2) an LCC computer program written in BASIC language (appendix E) which, in an interactive mode, requests the necessary data, carries out the operations, and prints the required measures.

Either of those tools can be used--or, if desired, an agency can develop or adopt its own forms and/or computer program--for evaluating retrofit projects. It is required, however, that Federal agencies adhere to the specific LCC methodology and assumptions set forth in the LCC Rule and in this manual.

To help explain the LCC evaluation procedures for retrofit projects, two sample problems are solved below in sections 4.2 and 4.3, step by step, using the RETROFIT WORKSHEETS from appendix D-1. The first illustrative problem is quite simple, involving the addition of insulation to bare hot water pipes. The only costs involved are the purchase and installation costs for the insulation; the savings result from a lower heat loss rate from the pipes. The second, slightly more complex illustrative problem--replacement of an existing manual seasonal control system with an automatic control system--involves additional elements of cost.[1] (The use of the computer program is described in appendix E.)

[1] Both problems are hypothetical and are intended to demonstrate the method rather than to suggest generalizable data or results.

4.2 SAMPLE RETROFIT PROBLEM #1: MODIFYING AN EXISTING BUILDING SYSTEM

4.2.1 Problem Statement

Approximately 100 ft of hot water pipes running through the basements of each of 10 buildings of a Federal laboratory facility in Massachusetts have been found to be uninsulated. Data and assumptions are as follows:[1]

Quantity of Uninsulated Pipe: 100 ft/Bldg x 10 Bldgs = 1,000 ft
Required Water Temperature: 180°
Pipe Size: 1 1/2" Diameter
Operation: 4 hr/day x 260 days/yr = 1,040 hrs/yr
Type of Energy: Distillate Oil
Agency Base-Year Price of Distillate: $\$6.12/10^6$ Btu
DoE-Provided Base-Year Price of Distillate: $\$6.94/10^6$ Btu
Plant Efficiency: .55
Remaining Building Life: Indefinitely
Insulation Life: Indefinitely
Available Insulation Choices: 1" or 2" of Fibrous Material
Heat Loss Rates[2]--Uninsulated 1 1/2" Pipe: 150 Btu/hr/ft
1" Insulated 1 1/2" Pipe: 20 Btu/hr/ft
2" Insulated 1 1/2" Pipe: 12.5 Btu/hr/ft
Pipe Insulation Costs[3]--1" Insulation: \$2.50/ft installed cost
2" Insulation: \$4.55/ft installed cost

The following questions are to be answered:

(1) Would it be cost-effective to add insulation?
(2) How much insulation should be added?
(3) What priority should this project receive relative to other projects?

4.2.2 Problem Solution

This problem can be solved by (1) first calculating the NS for 1" and 2" of pipe insulation to see if the NS is in either case positive and, further, to see which thickness is estimated to result in the highest NS; and (2) then calculating the SIR for the thickness with the highest positive NS to provide a priority ranking of this project relative to other candidate projects.

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1 For the purpose of demonstrating the basic procedures, this sample problem is kept simple. In actual practice, there would likely be other considerations than those included here, such as the possibility of reducing the water temperature and the type of pipe used.

2 Estimated from the Heat Loss Rate Nomogram, figure H-1 of Ref. [9].

3 Estimated from table H-1, "Cost for Insulating Various Pipe Sizes," Ref. [9].

The RETROFIT WORKSHEETS from appendix D-1 can be used to make these calculations. Section I of the worksheets describes the project and helps to organize background information necessary for the LCC evaluation. Section II, Parts A through E can be used to calculate the estimated TLCC of the building or building system without the retrofit project, to provide a basis of comparison. Parts F through J can be used to calculate the TLCC of the building or building system with the retrofit project, Part K to calculate the NS, and Part L, the SIR. When alternative design and/or size choices for a given project--such as 1" versus 2" of pipe insulation--are being considered, it is necessary to repeat the calculations in Parts F through K for each choice.

A set of RETROFIT WORKSHEETS completed for this problem is given in exhibit 4.1. The calculations of NS for both choices of insulation thickness are shown on a single set of worksheets, with the calculations for the 2" thickness given in parentheses. Since this project entails no cost effects other than the estimated reduction in fuel cost and the cost of the insulation, not all of the parts of the worksheets are needed to solve the problem. [Note that instructions for completing each part of the worksheets are provided on the pages facing the worksheets.]

Exhibit 4.1 RETROFIT LCC WORKSHEETS -- Completed for Problem 4.2

PROJECT DESCRIPTION (Hypothetical Example)

AGENCY: Federal Science Agency

ADDRESS: STREET
CITY/COUNTY Boston
STATE Massachusetts
DoE REGION 1

PROJECT CONTACT PERSON: NAME L.C.C. Analyst
POSITION Facilities Engineer
TELEPHONE

BUILDING OR FACILITY DESCRIPTION: FUNCTIONAL USE Laboratory and Office Space

CLASSIFICATION FOR ENERGY CHARGES
___ Residential
X Commercial
___ Industrial

EXPECTED LIFE Indefinitely

PROJECT DESCRIPTION: Insulation of Hot Base Water Pipes in Basements of 10 Laboratory Buildings

EXPECTED PROJECT LIFE: Indefinitely

	1" Insulation	2" Insulation
Estimated Project Investment Cost[1]:	$2,500	$4,550

Energy Information: (Complete for Each Type of Energy Affected by the Retrofit Project)

	Energy Type: Distillate Oil			Energy Type:		
	Annual Quantity	Actual Agency Price/Unit	DoE Price/Unit (Table C-1 or C-2)	Annual Quantity	Actual Agency Price/Unit	DoE Price/Unit (Table C-1 or C-2)
Without Retrofit	*283.6 x 10^6 Btu* [2]	*$6.12/$10^6$ Btu*	*$6.94/$10^6$ Btu*			
With Retrofit	*37.8 x 10^6 Btu* [3] *(23.6 x 10^6 Btu)* [4]	*$6.12/$10^6$ Btu*	*$6.94/$10^6$ Btu*			

Study Period: From ______ (Base Year) To ______ (End Year)

Number of Years Covered: 25 (Not to exceed 25)

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1 Worksheet format is expanded to show comparison of two choices.

2 [(150 Btu/hr/ft)(1,040 hrs)(1,000 ft)] ÷ .55 = 283.6 x 10^6 Btu

3 [(20 Btu/hr/ft)(1,040 hrs)(1,000 ft)] ÷ .55 = 37.8 x 10^6 Btu for 1" of insulation

4 [(12.5 Btu/hr/ft)(1,040 hrs)(1,000 ft)] ÷ .55 = 23.6 x 10^6 Btu for 2" of insulation

Parts A through E calculate TLCC of the existing building or building system without the retrofit project:

A. This part calculates the present value of energy costs without the retrofit. It is appropriate to use when (1) the annual physical quantity of energy used with or by the existing building or building system is expected to remain about constant over the study period, and (2) the type of energy used is not expected to change over the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sale s units, e.g. gallons, kWh, etc.

(2) Price per unit purchased. Use the estimated base-year[1] energy prices indicated in tables C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge is Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the modified uniform present worth (UPW*) factor, see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs without the retrofit.

B. This part calculates the equivalent of investment costs for the existing building or building system without the retrofit. It may be omitted if the existing system is to be left in place either "as is" or renovated at about the same cost whether or not the retrofit project is implemented.[6]

(1) If the existing system will be sold, scrapped, or redirected to a new use if the retrofit project is implemented, enter in (1) the estimated resale, salvage, or reuse value of the existing system in the base year.

(2) If the existing system is to be left in place, but will require an initial renovation or repair cost that will be different in amount without the retrofit project than with it, enter in (2) the amount of the initial repair or renovation cost in base-year dollars that will be required if the retrofit project is not implemented.

C. This part calculates the present value of annually recurring nonfuel operating and maintenance costs for the existing building or building system without the retrofit. If this category of cost is expected to be the same whether or not the retrofit project is implemented, this part may be omitted.[7]

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs for the existing building or building system, such as for routine maintenance, that is expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

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1 The base year is the year the life-cycle cost evaluation is made.

2 Table C-2 is in terms of typical sales units and it can be used in lieu of table C-1, provided the quantity of energy in item (1) is also given in the same sales unit.

3 Revised energy price data and UPW* factors for use in the LCC evaluations will be published as available in the Federal Register as an amendment to the LCC Rule. The most current data should be used.

4 For projects using electricity as the energy source and which have separate charge components that may be affected by the retrofit project, the price to the agency should be used, since the prices in tables C-1 and C-2 do not take into account the separate charge components.

5 See footnote 3.

6 Only those costs that will be affected by an investment decision need be considered in making that decision.

7 See footnote 6.

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL	*283.6 x 10^6 Btu*	*\$6.94/10^6 Btu*	*\$ 1968.18*	*16.65*	*\$ 32,770*
GAS					
OTHER ____					
TOTAL					*\$ 32,770*

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ *0*

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ *0*

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ *0*	-	$ *0*

D. This part calculates the present value of nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values for the existing building or building system without the retrofit. If these costs are expected to be the same whether or not the retrofit project is implemented, this part may be omitted.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs for the existing building or system.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the existing building or system.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the existing building or system.

E. This Part calculates the total life-cycle cost (TLCC) without the retrofit.

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (1) or (2).

(3) Transcribe from Part C, Column (3).

(4) Transcribe from Part D, Column (6) Total.

(5) Transcribe from Part D, Column (7) Total.

(6) Transcribe from Part D, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL					0	0	0

E. Calculating TLCC Without the Retrofit

(1)	Present Value of Energy Costs		$ 32,770
(2)	Present Value of Investment Costs	+	$ 0
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ 0
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ 0
(5)	Present Value of Replacement Costs	+	$ 0
(6)	Present Value of Salvage	-	$ 0
(7)	TLCC Without the Retrofit	=	$ 32,770

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1990 costs in 1980 dollars, i.e., without future inflation.

Parts F through J calculate TLCC with the Retrofit

F. This part calculates the present value of energy costs with the retrofit. It is appropriate to use when (1) the annual physical quantity of energy required after the retrofit is expected to remain about constant over the study period, and (2) the type of energy required after the retrofit is not expected to change over the remainder of the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sales units, e.g., gallons, or kWh, etc.

(2) Price per unit purchased. Use the estimated base-year[1] energy prices indicated in table C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge is Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the UPW* factor see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs with the retrofit.

G. This part calculates the investment costs with the retrofit project.

(1) Costs of initial planning, design, engineering, purchase and installation, all in base-year prices.

(2) Special interim adjustment factor to reflect estimated societal benefits from reducing the use of nonrenewable energy resources, not adequately reflected by market energy prices. (The adjustment factor, set presently at .9 in the LCC Rule, is subject to future modification or deletion.)

(3) Line (3) = Line (1) x Line (2).

(4) If the existing system is to be left in place, but will require an initial renovation or repair cost that will be different in amount with the retrofit project than without it, enter in item (4) the amount of the initial renovation or repair cost in base-year dollars that will be required if the retrofit is performed. This part may be omitted if nothing was entered in Part B, item (2).

(5) Line (5) = Line (3) + Line (4).

[1] See footnote 1 on page 54 for explanation.

[2] See footnote 2 on page 54 for explanation.

[3] See footnote 3 on page 54 for explanation.

[4] See footnote 4 on page 54 for explanation.

[5] See footnote 5 on page 54 for explanation.

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL	*37.8 x 10^6 Btu* *(23.6 x 10^6 Btu)*[1]	*\$6.94/10^6 Btu*	*\$ 262.33* *\$ (163.78)*	*16.65*	*\$ 4,368* *\$ (2,727)*
GAS					
OTHER ____					
TOTAL					*\$ 4,368* *\$ (2,727)*

G. Calculating Investment Costs with the Retrofit

			(1" insulation)	(2" insulation)
(1)	Estimated Actual Investment Costs for the Retrofit Project		$ *2,500*	*(4,550)*
(2)	Investment Cost Adjustment Factor	x	*.9*	*.9*
(3)	Adjusted Investment Costs for the Retrofit Project	=	$ *2,250*	*(4,095)*
(4)	Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented	+	*0*	*(0)*
(5)	Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project	=	$ *2,250*	*(4,095)*

[1] Energy data based on 2" of pipe insulation are shown in parentheses.

H. This part gives the annually recurring (nonfuel) operating and maintenance costs with the retrofit.

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs, such as for routine maintenance, that is expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

I. This part gives the present value of these nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values for the building or building system after the retrofit. <u>If these costs are expected to be the same whether or not the retrofit project is implemented, and have not been included in part D, this part can be omitted</u>.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from the LCC MANUAL or the LCC Rule, table A-1.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs for the building or building system after the retrofit.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the building or building system after the retrofit.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the building or building system after the retrofit.

J. This part calculates the TLCC with the retrofit.

(1) Transcribe from Part F, Column (5) Total.

(2) Transcribe from Part G, item (5).

(3) Transcribe from Part H, item (3).

(4) Transcribe from Part I, Column (6) Total.

(5) Transcribe from Part I, Column (7) Total.

(6) Transcribe from Part I, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ 0	-	$ 0

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL					0	0	0

J. Calculating TLCC With the Retrofit Project

			(1" Insulation)	(2" Insulation)[2]
(1)	Present Value of Energy Costs		$ 4,368	(2,727)
(2)	Present Value of Adjusted Investment Costs	+	$ 2,250	(4,095)
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ 0	(0)
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ 0	(0)
(5)	Present Value of Replacement Costs	+	$ 0	(0)
(6)	Present Value of Salvage	-	$ 0	(0)
(7)	TLCC With the Retrofit Project	=	$ 6,618	(6,822)

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

K. This part calculates the Net Savings (NS) (or Excess Cost (-NS)) from the retrofit project.

(1) Transcribe from Part E, item (7).

(2) Transcribe from Part J, item (7).

(3) Line (3) = Line (1) - Line (2).

L. This part describes the Savings-to-Investment Ratio (SIR) calculation.

(1) (a) Line (a) = (Part E, item (1)) - (Part J, item (1)).

(b) Line (b) = (Part J, lines (3) plus (4)) - (Part E, lines (3) plus (4)). (Note that this will be a negative value if nonfuel O&M costs are lower with the retrofit project than without it.)

(c) Line (c) = Line (a) - Line (b).

(2) (a) Line (a) = (Part J, Line (2)) - (Part E, Line (2)).

(b) Line (b) = (Part J, Line (5)) - (Part E, Line (5)).

(c) Line (c) = (Part J, Line (6)) - (Part E, Line (6)).

(d) Line (d) = Line (a) + Line (b) - Line (c).

(3) Line (3) = Line (1)(c) ÷ Line (2)(d).

K. Net Savings or Excess Cost of the Retrofit Project

		(1" Insulation)	(2" Insulation)
(1) TLCC without the Retrofit			$ 32,770
(2) TLCC with the Retrofit	-	$ 6,618	$ (6,822)
(3) Net Savings (+) or net losses (-)	=	$ 26,152	$ (25,948)

L. SIR Calculation

(1) SIR Numerator		
(a) Energy Cost Savings from the Retrofit		$ 28,402[1]
(b) Change in Nonfuel O&M Costs	-	$ 0
(c) SIR Numerator	=	$ 28,402
(2) SIR Denominator		
(a) Adjusted Differential Investment Cost		$ 2,250
(b) Change in Replacement Costs	+	$ 0
(c) Change in Salvage Value	-	$ 0
(d) SIR Denominator	=	$ 2,250
(3) SIR for Ranking the Retrofit Project		12.62

[1] Based on a comparison of Net Savings, 1" of pipe insulation is a more cost-effective choice than 2" of insulation. The SIR need be calculated only for the project choice selected, i.e., for 1" of insulation.

This fuel oil storage tank at the Brookhaven National Laboratory was painted black to absorb solar heat. Warming the fuel oil reduces the amount of energy needed to preheat the oil for combustion.

4.3 SAMPLE RETROFIT PROBLEM #2: REPLACING AN EXISTING BUILDING SYSTEM

4.3.1 Problem Statement

A new automatic seasonal control system is being considered for replacing the existing manual control system in a Federal office complex located in Washington, D.C. The Federal complex has an indefinite life, and the facilities manager estimates that the new system would last at least 25 years. Would the replacement be cost effective? What priority should this retrofit project receive relative to other candidate projects?

Data and assumptions are as follows:

Existing System

Current (Immediate) Salvage Value (Base-Year $): $260,000
Expected Remaining Life without Major Replacements: 10 years
Expected Salvage Value in 10 years without Major Replacements: 0
Salvage Value in 25 years with Necessary Replacements: 0
Annually Recurring (Nonfuel) O&M Costs (Base-Year $): $120,000
Nonannually Recurring (Nonfuel) O&M Costs (Base-Year $):

Year	Amount
5	$25,000
15	$25,000
20	$25,000

Replacement Cost (Base-Year $):

Year	Amount
10	$150,000

Energy Data:

Quantity Electricity[1]	9,982,200 kWh
Quantity Natural Gas	433,600 x 10^6 Btu
Actual Agency Price of Electricity[2]	0.065/kWh
DoE Price of Electricity	0.063/kWh
Actual Agency Price of Natural Gas	$3.40/$10^6$ Btu
DoE Price of Natural Gas	$3.43/$10^6$ Btu

---

1 In this example, the quantity of electricity is given in terms of its typical sales unit, kWh, rather than 10^6 Btu. Therefore, the electricity price from table C-2 is the appropriate base-year price reference rather than the price per 10^6 Btu from table C-1.

2 In this example, it is assumed that the agency base-year price of electricity is higher than the published DoE price from table C-2, and is therefore used in the LCC evaluation in lieu of the DoE price.

Retrofit System

Initial Investment Cost: $1,500,000
Expected Life: 25 years or longer
Annually Recurring (Nonfuel) O&M Costs (Base-Year $): $145,000
Nonannually Recurring (Nonfuel) O&M Costs (Base-Year $):

Year	Amount
10	$40,000
20	40,000

Replacement Costs (Base-Year $): 0
Salvage Value at End of 25 Years (Base-Year $): 0

Energy Data:		
	Quantity Electricity[1]	9,190,000 kWh
	Quantity Natural Gas	$386,800 \times 10^6$ Btu
	Actual Agency Price of Electricity[2]	0.065/kWh
	DoE Price of Electricity	0.063/kWh
	Actual Agency Price of Natural Gas	$\$3.40/10^6$ Btu
	DoE Price of Natural Gas	$\$3.43/10^6$ Btu

4.3.2 Problem Solution

Since only one alternative control system is being considered, this problem does not entail a design or sizing element. It could be solved simply by calculating the SIR on the investment, which will both indicate cost effectiveness and establish project priority. However, since management often desires a dollar measure of net savings, both the NS and the SIR are shown calculated in the RETROFIT WORKSHEETS in exhibit 4.2.

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1 In this example, the quantity of electricity is given in terms of its typical sales unit, kWh, rather than 10^6 Btu. Therefore, the electricity price from table C-2 is the appropriate base-year price reference rather than the price per 10^6 Btu from table C-1.

2 In this example, it is assumed that the agency base-year price of electricity is higher than the published DoE price from table C-2, and is therefore used in the LCC evaluation in lieu of the DoE price.

Exhibit 4.2 RETROFIT LCC WORKSHEETS -- Completed for Problem 4.3

I. PROJECT DESCRIPTION (Hypothetical Example)

AGENCY: National Administration

ADDRESS: STREET
CITY/COUNTY Washington, D.C.
STATE
DoE REGION 3

PROJECT CONTACT PERSON: NAME L.C.C. Analyst
POSITION Facilities Engineer
TELEPHONE

BUILDING OR FACILITY DESCRIPTION: FUNCTIONAL USE Offices

CLASSIFICATION FOR ENERGY CHARGES
___ Residential
X Commercial
___ Industrial

EXPECTED LIFE Indefinitely

PROJECT DESCRIPTION: Replacement of manual seasonal control system with automatic control system.

EXPECTED SYSTEM LIFE: 25 years or more

Estimated Project Investment Cost: $ 1.5 million

Energy Information: (Complete for Each Type of Energy Affected by the Retrofit Project)

	Energy Type Electricity			Energy Type Natural Gas		
	Annual Quantity	Actual Agency Price/Unit	DoE Price/Unit (Table C-1 or C-2)	Annual Quantity	Actual Agency Price/Unit	DoE Price/Unit (Table C-1 or C-2)
Without Retrofit	*9,982,200 kWh*	*0.065/kWh*	*0.063/kWh*	*433,600 x 10^6 Btu*	*\$3.40/10^6 Btu*	*\$3.43/10^6 Btu*
With Retrofit	*9,190,000 kWh*	"	"	*386,800 x 10^6 Btu*	"	"

Study Period: From ________ (Base Year) To ________ (End Year)

Number of Years Covered: 25 (Not to exceed 25)

[1] Worksheet format is expanded to show comparison of two choices.

[2] [(150 Btu/hr/ft)(1,040 hrs)(1,000 ft)] ÷ .55 = 283.6 x 10^6 Btu

[3] [(20 Btu/hr/ft)(1,040 hrs)(1,000 ft)] ÷ .55 = 37.8 x 10^6 Btu for 1" of insulation

[4] [(12.5 Btu/hr/ft)(1,040 hrs)(1,000 ft)] ÷ .55 = 23.6 x 10^6 Btu for 2" of insulation

Parts A through E calculate TLCC of the existing building or building system without the retrofit project:

A. This part calculates the present value of energy costs without the retrofit. It is appropriate to use when (1) the annual physical quantity of energy used with or by the existing building or building system is expected to remain about constant over the study period, and (2) the type of energy used is not expected to change over the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sale s units, e.g. gallons, kWh, etc.

(2) Price per unit purchased. Use the estimated base-year[1] energy prices indicated in tables C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge is Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the modified uniform present worth (UPW*) factor, see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs without the retrofit.

B. This part calculates the equivalent of investment costs for the existing building or building system without the retrofit. It may be omitted if the existing system is to be left in place either "as is" or renovated at about the same cost whether or not the retrofit project is implemented.[6]

(1) If the existing system will be sold, scrapped, or redirected to a new use if the retrofit project is implemented, enter in (1) the estimated resale, salvage, or reuse value of the existing system in the base year.

(2) If the existing system is to be left in place, but will require an initial renovation or repair cost that will be different in amount without the retrofit project than with it, enter in (2) the amount of the initial repair or renovation cost in base-year dollars that will be required if the retrofit project is not implemented.

C. This part calculates the present value of annually recurring nonfuel operating and maintenance costs for the existing building or building system without the retrofit. If this category of cost is expected to be the same whether or not the retrofit project is implemented, this part may be omitted.[7]

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs for the existing building or building system, such as for routine maintenance, that is expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

---

1 The base year is the year the life-cycle cost evaluation is made.

2 Table C-2 is in terms of typical sales units and it can be used in lieu of table C-1, provided the quantity of energy in item (1) is also given in the same sales unit.

3 Revised energy price data and UPW* factors for use in the LCC evaluations will be published as available in the Federal Register as an amendment to the LCC Rule. The most current data should be used.

4 For projects using electricity as the energy source and which have separate charge components that may be affected by the retrofit project, the price to the agency should be used, since the prices in tables C-1 and C-2 do not take into account the separate charge components.

5 See footnote 3.

6 Only those costs that will be affected by an investment decision need be considered in making that decision.

7 See footnote 6.

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	9,982,200 kWh	$ 0.065 kWh	$ 648,843 BASE CHARGE	11.81	$ 7,662,836
			$ ____ DEMAND CHARGE		$ ____
			$ ____ TIME OF DAY CHARGE		$ ____
			$ ____ CONTRACT CAPACITY CHARGE		$ ____
			$ ____ OTHER CHARGE COMPONENT		$ ____
OIL					
GAS	$433,600 \times 10^6$ Btu	$3.43/$10^6$ Btu	$ 1,487,248	14.66	$ 21,803,055
OTHER ____					
TOTAL					$ 29,465,891

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ 260,000

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ 0

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ 120,000	11.65	$ 1,398,000

D. This part calculates the present value of nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values for the existing building or building system without the retrofit. <u>If these costs are expected to be the same whether or not the retrofit project is implemented, this part may be omitted</u>.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs for the existing building or system.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the existing building or system.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the existing building or system.

E. This Part calculates the total life-cycle cost (TLCC) without the retrofit.

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (1) or (2).

(3) Transcribe from Part C, Column (3).

(4) Transcribe from Part D, Column (6) Total.

(5) Transcribe from Part D, Column (7) Total.

(6) Transcribe from Part D, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

D. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COST (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
5	*$25,000*			*0.71*	*$17,750*		
10		*$150,000*		*0.51*		*$76,500*	
15	*$25,000*			*0.36*	*$ 9,000*		
20	*$25,000*			*0.26*	*$ 6,500*		
TOTAL					*$33,250*	*$76,500*	*$ 0*

E. Calculating TLCC Without the Retrofit

(1)	Present Value of Energy Costs		$ *29,465,891*
(2)	Present Value of Investment Costs	+	$ *260,000*
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ *1,398,000*
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ *33,250*
(5)	Present Value of Replacement Costs	+	$ *76,500*
(6)	Present Value of Salvage	-	$ *0*
(7)	TLCC Without the Retrofit	=	$ *31,233,641*

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1990 costs in 1980 dollars, i.e., without future inflation.

Parts F through J calculate TLCC with the Retrofit

F. This part calculates the present value of energy costs with the retrofit. It is appropriate to use when (1) the annual physical quantity of energy required after the retrofit is expected to remain about constant over the study period, and (2) the type of energy required after the retrofit is not expected to change over the remainder of the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sales units, e.g., gallons, kWh, etc.

(2) Price per unit purchased. Use the estimated base-year[1] energy prices indicated in table C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge is Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the UPW* factor see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs with the retrofit.

G. This part calculates the investment costs with the retrofit project.

(1) Costs of initial planning, design, engineering, purchase and installation, all in base-year prices.

(2) Special interim adjustment factor to reflect estimated societal benefits from reducing the use of nonrenewable energy resources, not adequately reflected by market energy prices. (The adjustment factor, set at .9 in the LCC Rule, is subject to future modification or deletion.)

(3) Line (3) = Line (1) x Line (2).

(4) If the existing system is to be left in place, but will require an initial renovation or repair cost that will be different in amount with the retrofit project than without it, enter in item (4) the amount of the initial renovation or repair cost in base-year dollars that will be required if the retrofit is performed. This part may be omitted if nothing was entered in Part B, item (2).

(5) Line (5) = Line (3) + Line (4).

[1] See footnote 1 on page 68 for explanation.

[2] See footnote 2 on page 68 for explanation.

[3] See footnote 3 on page 68 for explanation.

[4] See footnote 4 on page 68 for explanation.

[5] See footnote 5 on page 68 for explanation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	9,190,000 kWh	$ 0.065/kWh	$ 597,350 BASE CHARGE	11.81	$ 7,054,704
			$ ____ DEMAND CHARGE		$ ____
			$ ____ TIME OF DAY CHARGE		$ ____
			$ ____ CONTRACT CAPACITY CHARGE		$ ____
			$ ____ OTHER CHARGE COMPONENT		$ ____
OIL					
GAS	$386,800 \times 10^6$ Btu	$\$ 3.43/10^6$ Btu	$ 1,326,724	14.66	19,449,773
OTHER ____					
TOTAL					26,504,477

G. Calculating Investment Costs with the Retrofit

(1)	Estimated Actual Investment Costs for the Retrofit Project		$ 1,500,000
(2)	Investment Cost Adjustment Factor	x	.9
(3)	Adjusted Investment Costs for the Retrofit Project	=	$ 1,350,000
(4)	Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented	+	0
(5)	Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project	=	$ 1,350,000

H. This part gives the annually recurring (nonfuel) operating and maintenance costs with the retrofit.

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs, such as for routine maintenance, that is expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

I. This part gives the present value of these nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values for the building or building system after the retrofit. <u>If these costs are expected to be the same whether or not the retrofit project is implemented, and have not been included in part D, this can be ommitted</u>.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from the LCC MANUAL or the LCC Rule, table A-1.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs for the building or building system after the retrofit.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the building or building system after the retrofit.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the building or building system after the retrofit.

J. This part calculates the TLCC with the retrofit.

(1) Transcribe from Part F, Column (5) Total.

(2) Transcribe from Part G, item (5).

(3) Transcribe from Part H, item (3).

(4) Transcribe from Part I, Column (6) Total.

(5) Transcribe from Part I, Column (7) Total.

(6) Transcribe from Part I, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ *145,000*	*11.65*	$ *1,689,250*

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
10	*$40,000*			*0.51*	*20,400*		
20	*$40,000*			*0.26*	*10,400*		
TOTAL					*30,800*	*0*	*0*

J. Calculating TLCC With the Retrofit Project

(1)	Present Value of Energy Costs		$ *26,504,477*
(2)	Present Value of Adjusted Investment Costs	+	$ *1,350,000*
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ *1,689,250*
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ *30,800*
(5)	Present Value of Replacement Costs	+	$ *0*
(6)	Total Present Value of Salvage	-	$ *0*
(7)	TLCC With the Retrofit Project	=	$ *24,574,527*

[1] See footnote on page 57 for explanation.

K. This part calculates the Net Savings (NS) (or Excess Cost (-NS)) from the retrofit project.

(1) Transcribe from Part E, item (7).

(2) Transcribe from Part J, item (7).

(3) Line (3) = Line (1) - Line (2).

L. This part describes the Savings-to-Investment Ratio (SIR) calculation.

(1) (a) Line (a) = (Part E, item (1)) - (Part J, item (1)).

(b) Line (b) = (Part J, lines (3) plus (4)) - (Part E, lines (3) plus (4)). (Note that this will be a negative value if (nonfuel) O&M costs are lower with the retrofit project than without it.)

(c) Line (c) = Line (a) - Line (b).

(2) (a) Line (a) = (Part J, line (2)) - (Part E, line (2)).

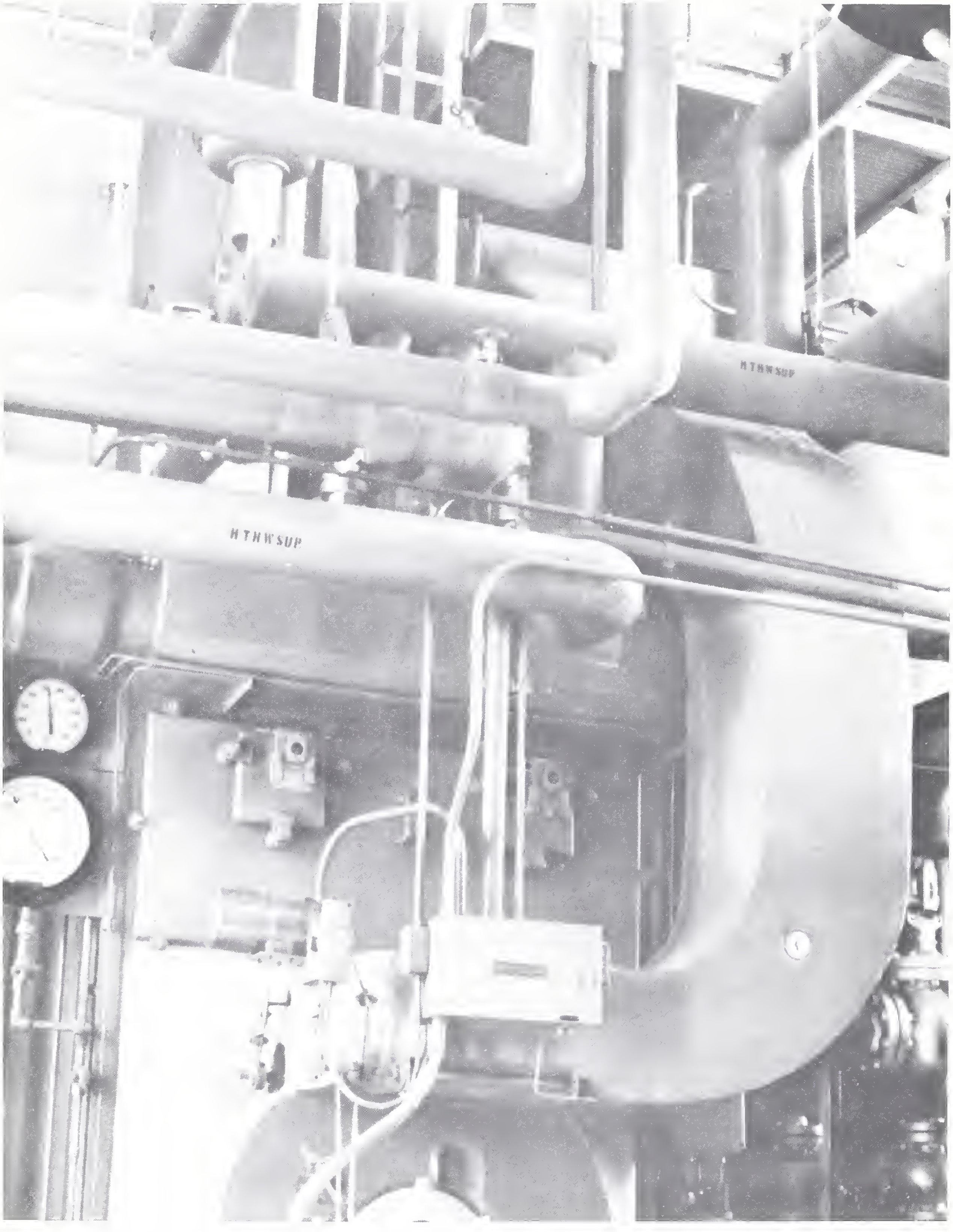
(b) Line (b) = (Part J, line (5)) - (Part E, line (5)).

(c) Line (c) = (Part J, line (6)) - (Part E, line (6)).

(d) Line (d) = Line (a) + Line (b) - Line (c).

(3) Line (3) = Line (1)(c) ÷ Line (2)(d).

K.	**Net Savings or Excess Cost of the Retrofit Project**		
(1)	TLCC without the Retrofit	-	$ 31,270,641
(2)	TLCC with the Retrofit	-	$ 29,574,527
(3)	Net Savings (+) or net losses (-)	=	$ 1,659,114
L.	**SIR Calculation**		
(1)	SIR Numerator		
	(a) Energy Cost Savings from the Retrofit		$ 2,961,414
	(b) Change in Non-Fuel O&M Costs	-	$ 288,800
	(c) SIR Numerator	=	$ 2,672,614
(2)	SIR Denominator		
	(a) Adjusted Differential Investment Cost		$ 1,090,000
	(b) Change in Replacement Costs	+	$ -76,500
	(c) Change in Salvage Value	-	$ 0
	(d) SIR Denominator	=	$ 1,013,500
(3)	SIR for Ranking the Retrofit Project		2.64



A waste heat recovery system has been retrofitted to the Bartlesville Energy Technology Center to preheat combustion air by drawing it through a heat exchanger energized by stack gases from the generator furnace,

4.4 ADJUSTING FOR PROJECT INTERDEPENDENCIES

Sometimes retrofitting one building system in an existing Federal building will affect the potential energy savings of another building system also being considered for retrofit in the same building. When this occurs, energy savings of the projects are interdependent. The total energy savings will be overestimated if calculated independently for each project instead of jointly. For example, the predicted energy savings from retrofitting a furnace to make it more efficient will be lowered by adding insulation to reduce the overall energy requirements of the building. Undertaking one retrofit project will diminish the value of the other. It is necessary to account for interdependencies to avoid "double counting" energy savings.

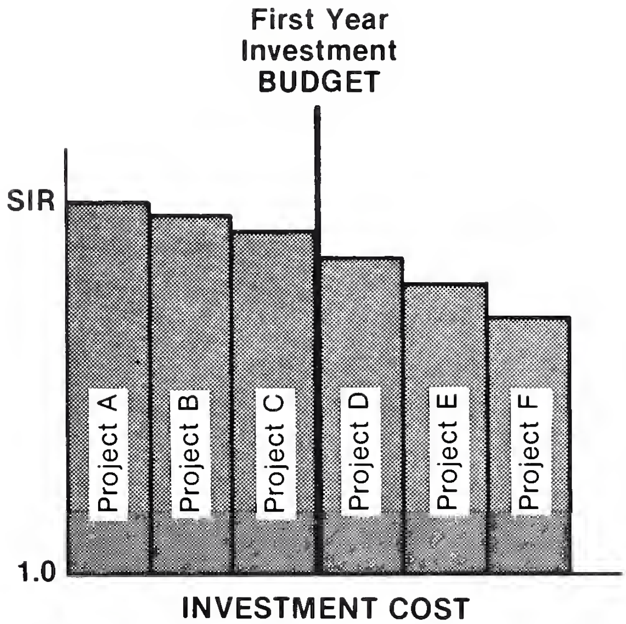
The amount of energy savings attributed to each of two or more interdependent building systems will depend upon the order in which the building systems are assumed to be retrofitted. To calculate their SIR's, it is necessary to establish the order in which they are to be retrofitted. A practical approach to establishing this order is to calculate the SIR of each alternative building system as though it were <u>in</u>dependent. Then select the retrofit project with the highest SIR value and recalculate the SIR's of the remaining projects which are estimated to be interdependent, adjusting for any changes in energy savings that result from the selection of the project with the highest priority. It may be necessary to have several iterations of the energy load calculations to repeat this process for a whole group of interdependent projects. When retrofit projects are interdependent, the SIR's should be adjusted for the interdependencies prior to establishing cost-effectiveness rankings among all of the projects.

4.5 SELECTING PROJECTS FOR FUNDING

From the SIR measures--adjusted for any interdependencies among projects--an agency can prepare a plan which ranks projects in descending order of their cost effectiveness. For example, the first sample retrofit project given in section 4.2 would be given higher priority than the second sample project given in section 4.3.

During the initial round of funding, the projects with the highest SIR's which together exhaust the first year's budget should be selected. In the second year, all projects not previously selected should be reevaluated if their SIR's are expected to have changed significantly. Then they can be ranked together with any new projects which have been identified.

Graphically, the ranking and selection procedure can be illustrated as shown in figure 4.1. It shows projects arrayed in order of their priority ranking with the selection of projects made in accordance with a limited budget. For illustrative purposes, 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



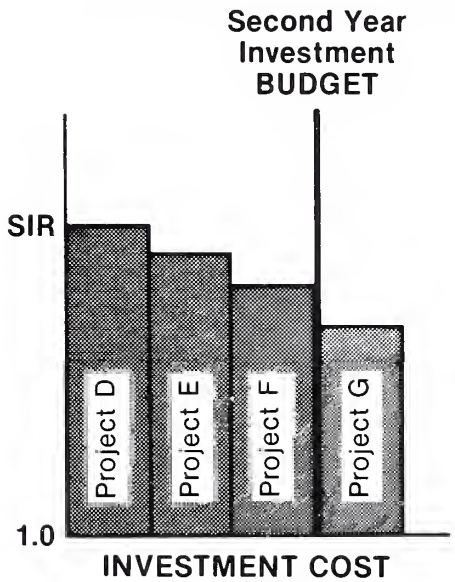


Figure 4.1 Allocating the Budget Among Alternative Projects Ranked by SIR

projects. A fourth new candidate project in that year is omitted because of the budget constraint and the fact that its SIR is lower than that of the three previously identified candidates.

Allocating an agency's energy conservation budget among candidate projects for that agency's buildings on the basis of SIR rankings can be expected to result in the greatest dollar savings from the agency's budget.

Allocating a single Federal energy conservation budget among different agencies based on the comparative values of SIR rankings can 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 can be expected to have higher SIR rankings for their projects than agencies which have already achieved buildings that are relatively energy conserving. Concentrating the energy conservation effort on buildings that are currently most inefficient and have the greatest room for improvement, however, is necessary to obtain the maximum amount of energy conservation in Federal buildings from the available funding.

These geothermal pipes are being readied to provide space heating for a new building at DOE's Raff River site.

5. EVALUATING ALTERNATIVE BUILDING DESIGNS AND SYSTEMS FOR NEW FEDERAL BUILDINGS

5.1 OBJECTIVE AND APPROACH

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 <u>alternative designs for a given building</u> that will satisfy the functional use requirements.

An economic evaluation method is needed to identify the design that will meet the functional and other requirements of a building at the lowest total life-cycle costs, emphasizing in this program the life-cycle costs of the energy components of the building. This can be best accomplished by using the TLCC mode of analysis to sum (a) the present value of investment costs minus salvage value, (b) the present value of future nonfuel operation and maintenance costs, (c) the present value of replacement costs, and (d) the present value of energy costs for each alternative design. The design whose energy-related components result in the lowest TLCC for the building will be preferred, other things being equal.[1]

A set of worksheets, entitled "NEW BUILDING DESIGN WORKSHEETS," (appendix D-2), has been prepared to assist in calculating the TLCC of alternative building designs. The items and the calculation procedures given in these worksheets are essentially the same as those given in parts A through D of the Retrofit Worksheets. Instructions for completing the worksheets are found on the pages facing the worksheets.

The computer program in appendix E, introduced in part 4 for evaluating retrofit projects, also can be used to evaluate new building designs. The user must specify that the analysis is for a new building design and enter the necessary data.

As in the case of evaluating retrofit projects, it is unnecessary that agencies use either the NEW BUILDING DESIGN WORKSHEETS or the counterpart computer program; but it <u>is</u> necessary that the LCC method and assumptions set forth in the LCC Rule and <u>in</u> this manual be followed. The worksheets and computer program are provided as computational aids, and, in the interest of consistency among

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[1] As in the case of evaluating retrofit projects, it is important that any significant differences in the benefits associated with alternative designs of a new building be taken into account. If quantifiable, these differences in benefits can be incorporated into the TLCC measure as negative costs; if unquantifiable, a verbal description can be provided to amend the numerical TLCC evaluation.

agencies, their use is encouraged. Alternatively, agencies may develop or adopt their own forms and/or computer programs consistent with those provided here.

To help explain the LCC evaluation procedures for new building designs, a sample problem and step-by-step solution are given below, using the NEW BUILDING DESIGN WORKSHEETS from appendix D-2.[1] The problem compares two alternative designs for a given building, both of which are assumed to meet the functional requirements in approximately an equal way, but one of which is more energy conserving than the other.

5.2 PROBLEM STATEMENT

An energy-conserving building design is being considered as an alternative to a conventional building design for a Federal office building in Madison, Wisconsin (DoE region 5).[2] The two designs are approximately equivalent in total assignable and auxiliary spaces and in functional performance with respect to the purpose of the building. Each has two underground levels for parking and seven office floors, plus a mechanical house. Each has a floor area of approximately 176,000 ft^2 (gross).

The two designs differ primarily in the envelope, building configuration, orientation, and lighting systems. The energy-conserving design is slightly elongated on the east-west axis for greater exposure of the south side to solar radiation. The window area of the energy-conserving design is 25 percent of the wall area and most of that is located on the south side; in the conventional building, it is 40 percent. More massive exterior surfaces are used and insulation is increased, reducing the wall U value from 0.16 to 0.06, and the roof U value from 0.15 to 0.06. Horizontal window fins reduce the summer cooling load of the energy-conserving design. The north wall of the first floor of the energy-conserving design is earthbermed. It is assumed that both designs will last at least 25 years, and, for lack of a good basis for projecting differences in their salvage values, they are both assumed to have no salvage value remaining at the end of the 25-year study period. The question to be answered is which design is estimated to have the lowest life-cycle cost.

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[1] A set of blank worksheets is provided in appendix D-2.

[2] The designs are purely hypothetical and are solely for the purpose of illustrating the evaluation process.

Following are a listing of the major relevant costs for each design:

	Energy-Conserving Design	Conventional Design
(a) Site acquisition costs: (To ensure adequate exposure of south-facing windows, an additional acquisition cost of \$100,000 is necessary for the energy-conserving design. Other site costs are assumed to be identical for both designs and, hence are not shown).		
(b) Architectural and Engineering Design Fees and Construction Costs:	\$ 9,780,000	\$ 9,130,000
(c) Annual Energy Consumption:		
Natural Gas	$2,290 \times 10^6$ Btu	$4,980 \times 10^6$ Btu
Electricity	$3,886 \times 10^6$ Btu	$7,277 \times 10^6$ Btu
(d) Energy Prices:		
Actual Agency Price/Unit		
Natural Gas	\$ $3.57/10^6$ Btu	\$ $3.57/10^6$ Btu
Electricity	\$$15.73/10^6$ Btu	\$$15.73/10^6$ Btu
DoE Price/Unit		
Natural Gas	\$ $3.18/10^6$ Btu	\$ $3.18/10^6$ Btu
Electricity	\$$16.83/10^6$ Btu	\$$16.83/10^6$ Btu
(e) Nonfuel O&M Costs:		
Recurring Annual Cost:	\$70,000	\$ 90,000
Repairs to External Surfaces Every 10 Years:	\$60,000	\$100,000

5.3 PROBLEM SOLUTION

This problem can be solved by calculating the TLCC for each of the two designs being considered to determine which is estimated to have the lowest total cost over the life cycle.[1] The NEW BUILDING DESIGN WORKSHEETS shown in exhibit 5.1 are used to carry out the evaluations. For ease of comparison, both design alternatives are shown evaluated on the same worksheets, the figures for the conventional design being given in parentheses.

In reviewing the results, it might be pointed out that the differences in the TLCC measures obtained are small relative to the magnitude of the total building cost. However, the reduction in the building's TLCC attributable to the energy-conserving design is significant relative to the incremental investment costs required for the energy-conserving features. Estimated energy savings plus reduction in other costs total $1,085,702, compared with an estimated increase in actual investment costs of $750,000. After adjusting for the additional benefits to the nation of reducing the use of nonrenewable energy (via the 10 percent reduction in project investment costs), a net savings of $410,702 is estimated, further supporting the selection of the energy-conserving building design.

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[1] Any number of possible designs for a given building can be evaluated in this same way.

Exhibit 5.1 NEW BUILDING DESIGN LCC WORKSHEETS -- Completed for Problem 5.2

I. PROJECT DESCRIPTION (Hypothetical Example)

AGENCY: National Defense

ADDRESS: STREET
CITY/COUNTY Madison
STATE Wisconsin
DoE REGION 5

PROJECT CONTACT PERSON: NAME L.C.C. Designer
POSITION Facilities Architect
TELEPHONE

BUILDING OR FACILITY DESCRIPTION: FUNCTIONAL USE Offices

CLASSIFICATION FOR ENERGY CHARGES
___ Residential
X Commercial
___ Industrial

PROJECT DESCRIPTION: Energy Conserving Design--Earth-bermed; increased southern exposure; reduced window area; window location on the south; increased mass in building envelope; increased wall and roof insulation; horizontal window fins

EXPECTED BUILDING OR SYSTEM LIFE: 30 years or greater

ESTIMATED BUILDING OR SYSTEM INVESTMENT COST: *$9,880,000* *($9,130,000)*[1]
(Included site, planning, design, engineering and construction or purchase and installation)

ENERGY INFORMATION: (Complete for Each Type of Energy Affected by the Choice of Alternative Design or System)

Energy Type Natural Gas

Annual Quantity	Actual Agency Price/ Unit	DoE Price/ Unit (Table C-1 or C-2)
($4{,}980 \times 10^6$ Btu)	*($\$3.57/10^6$ Btu)*	*($\$3.18/10^6$ Btu)*
$2{,}290 \times 10^6$ Btu	*$3.57/10^6$ Btu*	*$3.18/10^6$ Btu*

Energy Type Electricity

Annual Quantity	Actual Agency Price/ Unit	DoE Price/ Unit (Table C-1 or C-2)
($7{,}277 \times 10^6$ Btu)	*($\$15.73/10^6$ Btu)*	*($\$16.83/10^6$ Btu)*
$3{,}886 \times 10^6$ Btu	*$15.73/10^6$ Btu*	*$16.83/10^6$ Btu*

Period of Study: From 1980 (Base Year) To 2005 (End Year)

Number of Years Covered: 25 (Not to exceed 25)

[1] Data for the Conventional Design is given in parentheses for illustrative comparison.

A. This part calculates the present value of energy cost. It is appropriate for use when (1) the annual physical quantity of energy required by the building design is expected to remain about constant, and (2) the type(s) of energy are not expected to change over the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sales units, e.g., gallons, kWh, etc.

(2) Price per unit purchased. Use the estimated base year[1] energy prices indicated in table C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge in Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the UPW* factor see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs.

B. This part calculates the investment costs.

(1) Costs of initial planning, site acquisition, design, engineering, purchase and installation.

(2) Special interim adjustment factor for reducing energy conservation and renewable energy investment costs in the LCC evaluation to reflect estimated societal benefits not adequately reflected by market energy prices. (The adjustment factor, set at .9 in the LCC Rule, is subject to future modification or deletion.

(3) Line (3) = Line (1) x Line (2).

---

1 The base year is the year the life-cycle cost evaluation is made.

2 Table C-2 is in terms of typical sales units and it can be used in lieu of table C-1, provided the quantity of energy in item (1) is also given in the same sales unit.

3 Revised energy price data and UPW* factors for use in the LCC evaluations will be published as available in the Federal Register as an amendment to the LCC Rule. The most current data should be used.

4 For projects using electricity as the energy source and which have separate charge components that may be affected by the design choice, the price to the agency should be used, since the prices in tables C-1 and C-2 do not take into account the separate charge components.

5 See footnote 3.

A. Calculating the Present Value of Energy Costs

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	*(7,277 x 10^6 Btu)* *3,866 x 10^6 Btu*	*\$16.83/10^6 Btu*	\$ *(122,471.91)* \$ *65,064.78* BASE CHARGE	*11.95*	*(1,463,539)* \$ *777,524*
			\$ ______ DEMAND CHARGE		\$ ______
			\$ ______ TIME OF DAY CHARGE		\$ ______
			\$ ______ CONTRACT CAPACITY CHARGE		\$ ______
			\$ ______ OTHER CHARGE COMPONENT		\$ ______
OIL					
GAS	*(4,980 x 10^6 Btu)* *2,290 x 10^6 Btu*	*\$ 3.57/10^6 Btu*[1]	*\$(17,778.60)* *\$ 8,175.30*	*14.15*	\$ *(251,567)* \$ *115,680*
OTHER _____					
TOTAL					\$ *(1,715,106)* \$ *893,204*

B. Calculating Investment Costs for the New Building Design

(1) Estimated Actual Investment Costs for the New Building Design		*(9,130,000)* \$ *9,880,000* [2]
(2) Investment Cost Adjustment Factor	x	*.9*
(3) Adjusted Investment Costs for the Retrofit Project	=	*(8,217,000)*[3] *8,892,000*

[1] Agency price is higher than DoE price and is therefore used in the LCC evaluation.

[2] Includes \$100,000 site acquisition cost, plus \$9,780,000 architectural and engineering design fees and construction costs.

[3] Investment Costs of the conventional design are not eligible for the investment cost adjustment; the adjustment applies only to energy conservation or renewable energy investment costs. However, applying the .9 adjustment factor to the total investment costs of both the energy-conserving and the conventional designs is equivalent in results to applying the .9 adjustment factor to the difference between the two costs.

C. This part gives the annually recurring (nonfuel) operating and maintenance costs.

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs, such as for routine maintenance, that are expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

D. This part gives the present value of nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factors for year(s) in which the amount(s) is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value.

E. This part calculates the total life-cycle cost (TLCC).

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (3).

(3) Transcribe from Part C, item (3).

(4) Transcribe from Part D, Column (6) Total.

(5) Transcribe from Part D, Column (7) Total.

(6) Transcribe from Part D, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

C. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
($90,000) $ 70,000	11.65	($1,048,500) $ 815,500

D. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
10	(100,000) 60,000			0.51	$(51,000) 30,600		
20	(100,000) 60,000			0.26	(26,000) 15,600		
TOTAL					(77,000) 46,200	0	0

E. Calculating the TLCC

(1) Present Value Energy Costs		(1,715,106) $ 893,204
(2) Present Value Adjusted Investment Costs	+	(8,217,000) $ 8,892,000
(3) Present Value of Annually Recurring (Nonfuel) O&M Costs	+	(1,048,500) 815,500
(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	(77,000) $ 46,200
(5) Present Value of Replacement Costs	+	$ 0
(6) Present Value of Salvage	-	$ 0
(7) TLCC of the New Building or System Design	=	(11,057,606) $ 10,646,904

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs or salvage value occur in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1980 costs in 1980 dollars, i.e., without future inflation.

Natural lighting control and solar window film reduce the energy requirements of this GSA leased building in Washington, D.C.

6. EVALUATING ENERGY CONSERVATION DECISIONS FOR LEASED BUILDINGS

The National Energy Act directs Federal agencies to give preference in leasing buildings to those "which use solar heating and cooling equipment or other renewable energy sources or which otherwise minimize life-cycle costs."

This section describes those specific life-cycle costing assumptions and procedures which pertain to the evaluation of energy conservation and renewable energy decisions for leased Federal buildings. The focus is on the special requirements for evaluating leased buildings that differ from those for owned buildings.

6.1 COST ASSUMPTIONS

Only those costs actually incurred or those savings actually realized by the Federal government are to be included in the life-cycle cost evaluation of a project for a leased building. At the one extreme--usually when an entire building is leased--the Federal government may directly pay all energy and nonfuel operating and maintenance costs. In this circumstance, the kinds of costs to be included in the evaluation are identical to the costs which would be included if the building were owned by the Federal government with the probable exception of salvage value at the end of the life of the investment.

At the other extreme, usually when a small part of a privately owned building is leased, the Federal government may directly pay no energy or nonfuel operation and maintenance costs. These costs may be paid entirely by the building owner and incorporated in the rent. In this circumstance, no energy savings are realized by the Federal government unless lease renegotiations are held to reduce the rent following energy-conserving retrofits. If there are no savings to be realized by the government occupant either by reduced utility bills or by lower rent, energy conservation investments are deemed under the program rules not to be cost effective and specific life-cycle cost evaluation is unnecessary.

Between the two extremes, the Federal government may directly pay some, but not all, of the energy and nonenergy operation and maintenance costs. The life-cycle cost evaluation should include the part of the costs that are directly paid by the Federal government. In this case, the cost effectiveness to the Government of a project for a leased building may vary markedly, depending upon the particular way in which energy and other costs are shared between the building owner and the Federal lessee.

6.2 STUDY PERIOD ASSUMPTIONS

The study period for leased buildings is the lesser of 25 years or the effective remaining term of the lease. If appropriate, the study period may include renewal options that are likely to be exercised. The cost effectiveness and ranking of a project for a leased building is therefore likely to be quite sensitive to the remaining effective term of the lease.

The LCC Rule allows a Federal agency to presume that a retrofit is <u>not</u> cost effective when a Federal building is occupied under a short-term (2 years or less) lease without a renewal option or with a renewal option which is not likely to be exercised. No evaluation is required under this condition.

6.3 LCC EVALUATIONS OF PROJECTS FOR LEASED BUILDINGS

The modes of analysis, the evaluation procedures as reflected in the worksheets, the computer program, and those assumptions not specifically changed for leased buildings, apply to evaluations for leased buildings. However, in using the worksheets and computer program, it is important to observe the special cost and study period assumptions for leased buildings that are described above in sections 6.1 and 6.2, as well as any other regulations governing Federal expenditures in leased buildings. Additionally, special attention is directed to the treatment of salvage values when evaluating projects for leased buildings. The lease, or the nature of the retrofit project, may require that ownership of certain kinds of capital assets retrofitted into a leased building be transferred from the Federal government to the building owner upon termination of the lease. If ownership transfers to the building owner, care should be taken to include only those salvage values that are actually likely to be recovered by the Federal government.

Polyurethane foam insulation was sprayed on this storage area for super conducting cyclotron magnets at the Brookhaven National Laboratory to reduce heat transfer and maintain proper temperature.

Solar Collector Panels meet part of the domestic hot water and space heating requirements of the Animal Quarantine Building, at the Plum Island Animal Disease Center in New York.

7. EVALUATING SOLAR ENERGY PROJECTS [1]

7.1 OBJECTIVE AND APPROACH

This part gives the prescribed methods for evaluating the life-cycle costs[2] of solar energy projects proposed under the Department of Energy's Solar Federal Buildings Program (SFBP). Under this program, DoE will fund "those incremental costs associated with a solar energy system that are over and above the normal cost of the conventional HVAC system equipment."[3]

The LCC evaluation requirements of the SFBP are intended to (1) encourage economic efficiency in the design and sizing of proposed projects and (2) give weight in SFBP project selection to those projects which are estimated to have relatively higher economic performance.

A special form, A-2, is used to submit SFBP project proposals to the Department of Energy.[4] This form, used here to demonstrate the evaluation of a solar energy system in a sample problem, provides for the calculation of the system's net savings or excess cost (NS), simple payback (SPB), and savings-to-investment ratio (SIR). The NS and a measure of the time to payback are specifically required by the National Energy Act. The NS measure is particularly useful in the project design phase for comparing systems of alternative design and size in order to identify the most promising system to propose for SFBP support. The SIR is used by the SFBP as a ranking measure for proposed projects within given categories of solar energy systems.

In the Solar Federal Buildings Program, a solar project need not be cost effective to be approved for funding support, although its comparative degree of cost effectiveness is one of the key criteria considered in its approval.

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1 Although this part is written specifically for solar energy, the methods and procedures presented here can be adapted to the economic evaluation of most other kinds of renewable energy systems.

2 For comprehensive information on many other aspects of solar design and evaluation, see Ref. [21].

3 See appendix D-3, Item G; and Ref. [22].

4 Form A-2 Worksheets are referenced in the Solar Federal Buildings Program Rules, Ref. [22], and are available from the NASA/George C. Marshall Space Flight Center. Contact Al Krupnick, FA 34 NASA/George C. Marshall Space Flight Center, Huntsville, Alabama, 35812; Telephone: 205-453-1870 (FTS 872-1870). Form A-2 is provided in appendix D-3, and section III of Form A-2--the Solar LCC evaluation section--is used here to illustrate the method.

A project's comparative economic performance rating accounts for 20 out of a total of 100 points in the SFBP proposal scoring process. Whether or not a project is cost effective, a life-cycle cost evaluation is an SFBP requirement.

7.2 SFBP DATA AND ASSUMPTIONS

This section focuses on those SFBP requirements that are either different from or not included in the list of common requirements of the LCC Rule given in part 3. (Unless specifically overridden here, the rules given in part 3 apply to SFBP solar energy projects.)

(1) The LCC evaluation must be formatted using Section III of Form A-2, provided by the Solar Federal Buildings Program.[1]

(2) A study period of 20 years should be used unless a more accurate life (not to exceed 25 years) for the candidate system can be established.

(3) As a general guideline for estimating nonfuel operating and maintenance (O&M) costs for the solar energy system, "typical" O&M costs are designated at between 1 and 4 percent of the system investment cost.

(4) Solar investment costs used in the LCC evaluation must include those cost elements set forth in Section II of the SFBP Form A-2 (see appendix D-3). Reported investment costs should be the incremental costs attributable to the solar project, over and above the "normal cost" of the HVAC system equipment. These incremental investment costs should be reduced by the investment adjustment factor to reflect societal benefits of reducing nonrenewable energy not adequately reflected by market energy prices. (The adjustment factor, set at .9 in the LCC Rule, is subject to future modification or deletion.) This adjustment to solar investment costs is made in Section III, Part G(2) of SFBP Form A-2.

(5) Salvage value should be assumed to be zero unless more definitive information is available.

(6) A measure of the estimated total life-cycle costs (TLCC) associated with a proposed solar energy system and its auxiliary system must be calculated and compared with a measure of the estimated TLCC of the alternative nonsolar energy system; and the estimated difference--the net savings (NS) or, if negative, excess cost (-NS)--must be determined.

(7) A ratio of savings-to-investment costs (SIR) must be calculated on the solar energy project to facilitate project ranking by the SFBP.

(8) The number of years to simple payback (SPB) on the solar energy investment must be calculated as a supplementary measure to meet legislated requirements.

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1 See footnote 4 on page 97.

7.3 SAMPLE SOLAR PROJECT EVALUATION

Federal agencies are encouraged to use LCC analysis throughout the solar design process in the selection and sizing of those projects that are ultimately submitted as proposed SFBP projects. The following example illustrates with a sample problem the use of LCC analysis both in the project design phase and in the project proposal and review stages.

7.3.1 Problem Statement

A Federal agency is considering the submittal of a proposal to the Solar Federal Buildings Program Office for a solar energy system for retrofit to an existing Federal office building located in Phoenix, Arizona (DoE Region 9). The facility engineer has under consideration two alternative solar energy system designs (A and B) to supplement the existing space heating boiler. System Design A costs less than Design B, but has a lower performance for a given system size than Design B. Table 7.1 gives the principal economic data and assumptions for the existing boiler and for the two solar designs.

The facility engineer wishes to determine the most cost effective of the available systems. This requires evaluating and comparing the estimated life-cycle costs for a range of possible sizes of each of the designs identified.

7.3.2 Problem Solution

Section III of SFBP Form A-2 guides the calculation of life-cycle costs for the nonsolar energy system that would be used in lieu of solar, and for the solar energy system of a given design and size. To compare alternative solar energy system designs and sizes using Form A-2, it is necessary to complete parts E through K for each alternative. As another option, the computer program given in appendix E could be used to perform the evaluations.[1]

For this example, Section III of Form A-2 is shown completed <u>only</u> for the existing energy system and for the <u>most</u> cost effective of the solar project alternative examined; i.e., parts E through K are not shown repeated for each alternative. Rather the TLCC's and NS's of all of the systems are shown summarized in table 7.2.

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[1] The computer program in appendix E evaluates a solar energy system of a specified design, size, and performance. It does not determine the optimal solar design and size, although it can be used to compare different systems if the user reruns the program for the different sets of values. The National Bureau of Standards is currently developing a more comprehensive computer program for Federal solar energy projects that provides an optimization analysis. See Ref. [23].

Table 7.1 Economic Data and Assumptions for the Sample Problem[a]

EXISTING SPACE HEATING SYSTEM

Type of System:	Distillate Oil-Fired Boiler
Annual Space Heating Load:	500×10^6 Btu
Plant Efficiency:	0.6
Remaining Life:	20 years
Actual Agency Price of Distillate:	$5.85/10^6$ Btu
DoE Price (Table C-1):	$6.55/10^6$ Btu

SOLAR ENERGY SYSTEMS

	Design A	Design B
Type of System:	Flat Plate	Advanced Design
Fixed Cost:	$33,620	$42,025
Variable Cost:[b]	$26.00/ft^2	$32.50/ft^2
Non-fuel O&M Cost:	1 percent of Investment Cost	1 percent of Investment Cost
Auxiliary System:	Existing Boiler	Existing Boiler
Salvage Value:[c]	20 percent of Investment Cost	25 percent of Investment Cost
Expected Life:	20 years	20 years
	Annual Solar Fractions of Load:	
Size Alternatives:[d] (ft^2 of collector)		
450	.27	.31
600	.37	.42
785	.40	.46
1070	.48	.55
1450	.56	.64

---

[a] These values are hypothetical and are intended only to illustrate the LCC evaluation procedure, not to recommend actual values for system designs nor components of costs.

[b] It is assumed that all variable costs change linearly with collector area.

[c] It is assumed that definitive estimates of scrap value of copper tubing and other materials justify an exception to the SFBP guideline to assume a 0 salvage value.

[d] It is assumed that collector area is a good indicator of overall system size.

Table 7.2 Using LCC Analysis in Project Design

(1) Size Alternatives (Collector Area, ft^2) Designs A & B	(2) Annual Solar Fraction[a] Design A	Design B	(3) Auxiliary System Energy Costs,[b] $ Design A	Design B	(4) Solar Energy System Costs,[c] $ Design A	Design B	(5) TLCC, Each Size Alternative,[d] $ Design A	Design B	(6) NS,[e] $ Design A	Design B
0	0	0	$78,436	$78,436	0	0	$78,436	$78,436	0	0
450	.27	.31	57,258	54,121	43,230	54,038	100,488	108,159	-22,052	-29,723
600	.37	.42	49,415	45,493	46,951	58,689	96,366	104,182	-17,930	-25,746
785	.40	.46	47,062	42,355	51,539	64,424	98,601	106,779	-20,165	-28,343
1,070	.48	.55	40,787	35,296	58,607	73,259	99,394	108,555	-20,958	-30,119
1,450	.56	.64	34,512	28,237	68,032	85,040	102,544	113,277	-24,108	-34,841

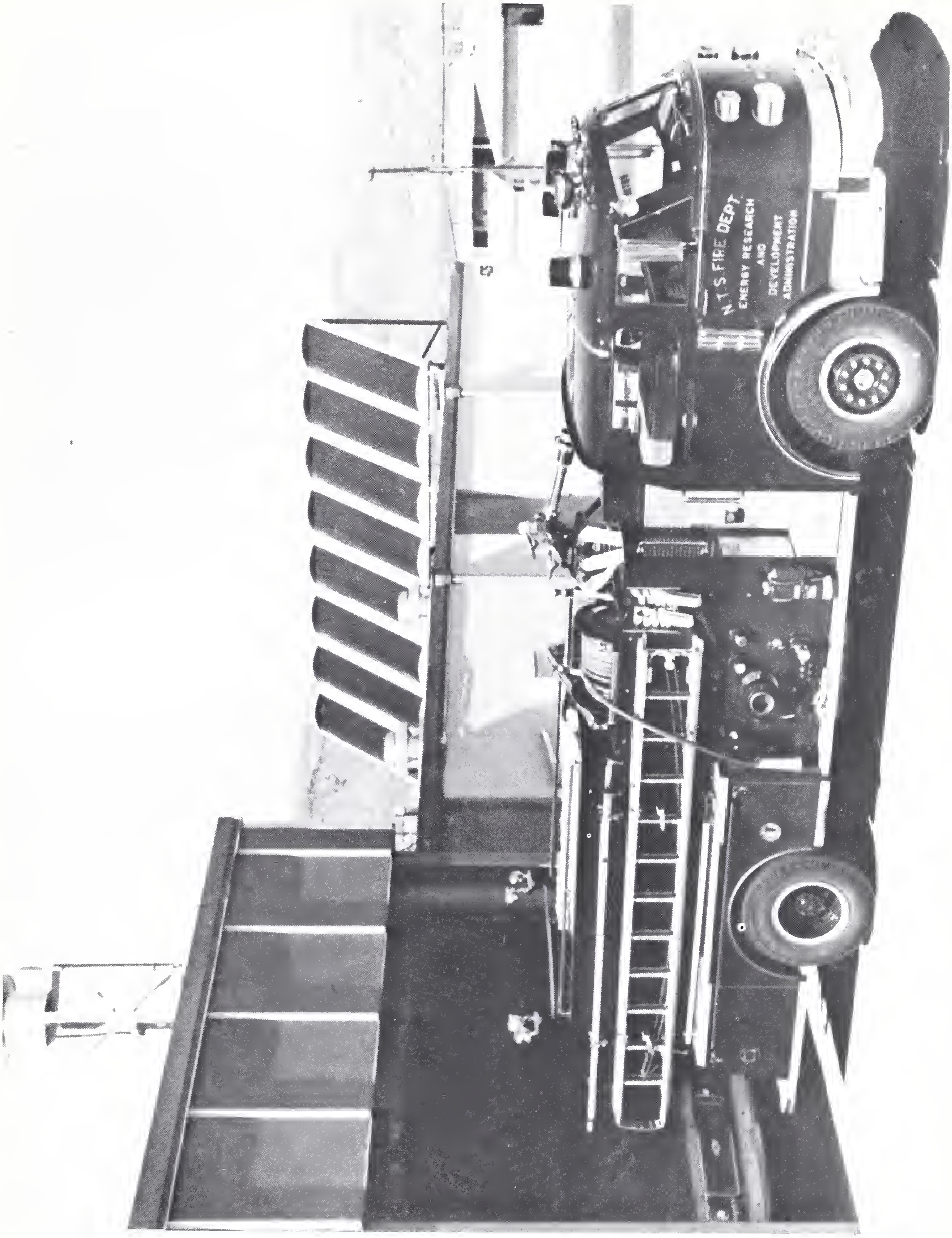
[a] Given in table 7.1.

[b] Calculated as follows: $E = \frac{500 \times 10^6 \text{Btu}}{.6} (1 - F)(\$6.55/10^6 \text{ Btu})(14.37)$, where E = the present value of auxiliary system energy costs, 500×10^6 Btu = the annual space heating load given in table 7.1, .6 = the efficiency of the existing plant, F = the fraction of the load met by solar, $\$6.55/10^6$ Btu = the price of fuel in DOE region 9, and 14.37 = the 20-year UPW* factor for distillate oil for commercial-type buildings in DOE region 9.

[c] Calculated as SSC = C(.9) + C(.01)(10.59) + C(.2)(.26), where SSC = the present value of owning and operating the solar energy system, C = the cost of purchase and installation, .9 = the investment adjustment factor, .01 = O + M costs expressed as a fraction of purchase and installation costs as given in table 7.1, 10.59 = the 20 year UPW factor, .2 = salvage value expressed as a fraction of purchase and installation cost, and .26 = the SPW factor for the 20th year.

[d] TLCC = Column (3) + Column (4).

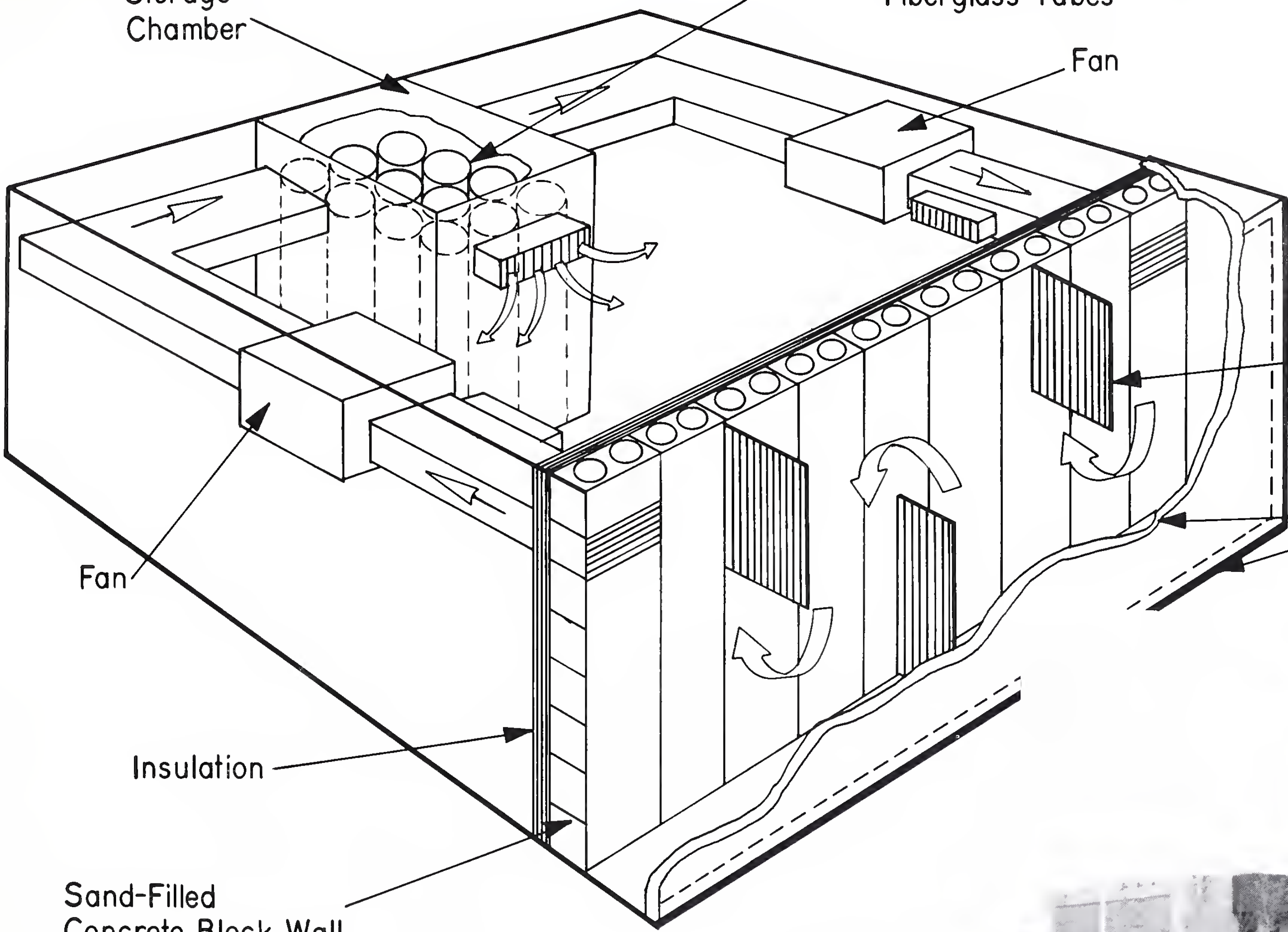
[e] NS = TLCC for the designated size of the solar energy system, less the TLCC for the auxiliary system used alone (i.e., TLCC for collector area = 0).



This fire station at the Nevada Test Site uses solar panels to help meet its energy needs.

The table summarizes the TLCC calculations for the existing system and for the alternative sizes of Solar Designs A and B. Column 1 of table 7.2 shows for both designs, A and B, the system sizes examined, as indicated by their collector areas. Column 2 shows the annual solar fraction for each size alternative of each design. Column 3 shows the life-cycle costs of distillate fuel for the auxiliary energy system, for each solar energy system alternative. Column 4 shows the cost of purchasing, installing, operating, and maintaining the solar energy system of each design/size. Column 5, the total life-cycle cost (TLCC) of the combined solar and auxiliary system, is obtained by adding columns 3 and 4. The last column of the table shows total life-cycle excess cost (-NS) resulting from the different sizes of each design. As column 6 of table 7.2 shows, excess costs are estimated for all sizes examined of both designs; that is, neither Solar Design A nor B is cost effective. However, excess costs are estimated to be lower for Design A than for Design B. Furthermore, excess costs for Design A are estimated to decrease from \$22,052 for the 450 ft^2 size to \$17,930 for the 600 ft^2 size, and then to increase to \$24,108 for the 1,450 ft^2 size. Hence, of those sizes examined, the solar energy system which minimizes excess costs is 600 ft^2 of Design A, providing 37 percent of the space heating requirement. If a solar energy system were to be installed--and the choice were between Designs A and B and the sizes indicated--it would be more economical, under the assumed conditions, to install a system of Design A of a size supplying 37 percent of the load than any of the other alternative systems.

The agency could then proceed to calculate the additional required LCC measures--SIR and SPB--for this design/size alternative and submit the proposal to the Solar Federal Buildings Program. Exhibit 7.1 shows the Solar Federal Buildings Worksheets completed for the solar energy system of Design A/Size 600 ft^2. The project's relative economic performance rating would serve as one of the SFBP project selection criteria, accounting for 20 out of a total of 100 points in DoE's proposal scoring process.



This passive solar-heating wall was installed in the Federal Aviation Administration's airport traffic control tower and radar facility in Springfield, Illinois.

Exhibit 7.1 SOLAR FEDERAL BUILDINGS LCC WORKSHEETS-Complete for Problem 7.3 (System Design A/Size 600 ft^2)[1]

I. PROJECT DESCRIPTION

AGENCY: Federal Agency

PROJECT TITLE: Solar Energy Retrofit for Executive Building

PROJECT CONTACT PERSON: J. Doe, facility engineer

BUILDING CATEGORY: NEW ___ EXISTING X

ADDRESS: STREET Federal Park

CITY/COUNTY Phoenix

STATE Arizona (DOE Region 9)

SOLAR APLICATION (CHECK ALL APPROPRIATE: DOMESTIC HOT WATER ___, SPACE HEATING X, SPACE COOLING ___, INDUSTRIAL PROCESS HEAT ___. If PROCESS HEAT, BRIEFLY EXPLAIN:

TYPE SOLAR ENERGY SYSTEM: ACTIVE ___ PASSIVE X

BRIEFLY DESCRIBE: A solar energy system consisting of 600 ft^2 of high quality, double-glazed flat-plate collectors with selective absorber coatings on the roof of the building, with liquid heat transfer and storage medium, will be used in combination with the existing oil-fired boiler to meet an estimated 37 percent of the annual space heating load.

FORM COMPLETION TIME (CHECK APPROPRIATE BLOCK)

PROPOSAL:
- CONCEPTUAL DESIGN X
- 60% DESIGN OR MORE ___
- FINAL DESIGN ___
- OTHER ___

1 This exhibit comprises sections I and III of Form A-2, the official forms for the Solar Federal Buildings Program. A blank set of Form A-2 in its entirety is provided in appendix D-3.

A. In order to evaluate the cost effectiveness of a solar energy system, it is necessary to estimate what costs would exist without solar. The purpose of this part is to estimate those costs based on the nonsolar energy system that would be used if the solar project were not undertaken. This system may be identical to or different from the system that would be used as a backup to the solar energy system. All applicants must complete this part for the type(s) of fuel(s) that solar will be displacing. Indicate in the appropriate columns:

(1) Total quantity of energy to be purchased expressed in MBtu's (10^6 Btu's).

(2) Price/MBtu. Use the estimated base-year[1] energy prices indicated in table C-1[2] of the MANUAL, or the "Life-Cycle Costing Rules," for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy prices exceed estimates in the table.

(3) Column (3) = Column (1) x Column (2). Sum up Column (3) and place in Column (3) Total line. This gives the Total Base-Year Energy Costs without solar. For electricity, only the base charge is Column (1) x Column (2).

(4) For the modified uniform present worth (UPW*) factor, see appendix B of the LCC MANUAL or the "Life-Cycle Costing Rules," for the appropriate region, sector, fuel type, and study period. Use a study period of 20 years unless a more accurate number for the particular system is available. Do not exceed a study period of 25 years.[3]

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs without solar.

B. All applicants must complete this part. This part gives the annually recurring nonfuel operating and maintenance costs of the nonsolar energy system. These are the O&M costs associated with the system which would have been used in lieu of the proposed solar energy system. Put in "0" if appropriate.

(1) Self-explanatory.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or "Life-Cycle Costing Rules," table A-2.

(3) Column (3) = Column (1) x Column (2)

---

1 The base year is the year the life-cycle cost evaluation is made.

2 For projects using electricity as the energy source and which have separate charge components that may be affected by the solar project, only the price to the agency should be used, since the prices in table C-1 do not take into account the separate charge components. The same UPW* (Column 4) should be applied to all charge components. Table C-2 is in terms of kWh and it can be used as a cross reference to table C-1.

3 This instruction in the Form A-2 is shown changed from a maximum study period of 30 years to a maximum of 25 years for consistency with the new legislated requirements (see Ref. [13]).

A. Calculating the Present Value of Fuel Costs Without Solar

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED (10^6 Btu)	(2) BASE-YEAR ENERGY PRICE $/$10^6$ Btu	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL	*833.33*[1]	*$6.55*	*$ 5,458.31*	*14.37*	*$78,436*
GAS					
OTHER ____					
TOTAL					*$ 78,436*

B. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without Solar

(1) Amount of Annually Recurring Costs in Base Year[2]	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ *0*	-	$ *0*

[1] 833.33 x 10^6 Btu/.6, from table 7.1.

[2] If the nonfuel O&M costs of the nonsolar energy system are assumed to remain constant whether the system is used alone or in varying combinations with solar energy, these costs can be considered of zero value for the LCC evaluation, since they would cancel out of the TLCC calculation. However, if they are not constant, they should be included here.

C. All applicants must complete this part. This part gives the nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values of the nonsolar system. These are the costs and values associated with the system which would have been used in lieu of the proposed solar energy system. Put "0" if appropriate.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Self-explanatory.

(5) Obtain single present worth (SPW) factors for year(s) in which each amount is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value.

D. All applicants must complete this part. This part calculates the total life-cycle cost of the system without solar.

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (3).

(3) Transcribe from Part C, Column (6) Total.

(4) Transcribe from Part C, Column (7) Total.

(5) Transcribe from Part C, Column (8) Total.

(6) Line (6) = Line (1) + Line (2) + Line (3) + Line (4) - Line (5).

C. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value Without Solar

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL					0	0	0

D. Calculating TLCC Without Solar

(1)	Present Value of Energy Costs	+	$ 78,436
(2)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ 0
(3)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ 0
(4)	Present Value of Replacement Costs	+	$ 0
(5)	Present Value of Salvage Value	-	$ 0
(6)	TLCC Without Solar	=	$ 78,436

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occurs in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1990 costs in 1980 dollars, that is, without future inflation.

E. All applicants must complete this part for each fuel used by each type of system that will be using solar.

(1) Self-explanatory.

(2) Transcribe from FORM A-1 Section VII, page 33, Total Line (16) for Active Systems, or transcribe from FORM A-1 Section VIII, page 39, Total Line (7) for Passive System.[1] Estimate the fuel split for each system. For example, in a solar heating and hot water project where the auxiliary heating system uses oil and the auxiliary hot water system uses electricity, estimate the amount of auxiliary energy required for each system by fuel type.

F. All applicants must complete this part for each type of fuel used. This part estimates the present value of fuel costs with solar.

(1) Transcribe from Part E, item (2).

(2) Price/MBtu. Use the estimated base-year[2] energy prices indicated in table C-1[3] of the LCC MANUAL, or the "Life-Cycle Costing Rules," for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in the table.

(3) Column (3) = Column (1) x Column (2). Sum up Column (3) and place in Column (3) Total line. This gives the total base-year energy costs with solar. For electricity, only the base charge is Column (1) x Column (2).

(4) For the UPW* factor see appendix B of the LCC MANUAL, or the "Life-Cycle Costing Rules," for the appropriate region, sector, fuel type, and study period. Use a study period of 20 years unless a more accurate number for the particular system is available. Do not exceed a study period of 25 years.[4]

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs with solar.

G. All applicants must complete this part. This part is used to calculate the investment costs with the solar system.

(1) Transcribe from FORM A-2, Section II, page 6, Line (R).[5]

(2) Self-explanatory.

(3) Line (3) = Line (1) x Line (2).

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[1] Form A-1, as well as Form A-2, is available from the NASA/George C. Marshall Space Flight Center. (See footnote 4, page 97.

[2] See footnote 1 on page 106 for explanation.

[3] See footnote 2 on page 106 for explanation.

[4] See footnote 3 on page 106 for explanation.

[5] See appendix D-3 for section II.

E. Calculating the Present Value of Fuel Costs With the Solar Energy System

(1) Type of Fuel *Distillate*

(2) Annual Units of Energy to be Purchased (10^6 Btu/Yr) *525.00*[1]

F. Calculating the Present Value of Fuel Costs With the Solar Energy System

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED (10^6 Btu)	(2) BASE-YEAR ENERGY PRICE PER UNIT $\$/10^6$ Btu	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	______	______	\$ ______ BASE CHARGE	______	\$ ______
			\$ ______ DEMAND CHARGE		\$ ______
			\$ ______ TIME OF DAY CHARGE		\$ ______
			\$ ______ CONTRACT CAPACITY CHARGE		\$ ______
			\$ ______ OTHER CHARGE COMPONENT		\$ ______
OIL	*525.00*	*6.55*	*3,438.75*	*14.37*	*\$ 49,415*
GAS					
OTHER ____					
TOTAL			*3,438.75*		*\$ 49,415*

G. Calculating Investment Costs with the Solar Energy System

(1) Total Investment Costs Attributable to the Solar Project[2] \$ *49,220*

(2) Adjustment in Investment Costs to Reflect Estimated Societal Benefits from Solar Energy in Excess of Dollar Energy Saving x *0.9*

(3) Adjusted Present Value Investment Costs for the Solar Energy System = \$ *44,298*

[1] 525.00×10^6 Btu = (833.33×10^6 Btu)(1 - .37)

[2] \$49,220 = \$33,620 + (\$26.00 x 600)

H. All applicants must complete this part. This part gives the annually recurring nonfuel operating and maintenance costs (O&M) with the solar energy system. These are the total O&M costs associated with the solar energy system including the O&M costs of the auxiliary system.[1] For the solar system, typical O&M costs are between 1 and 4 percent of the system costs.

(1) Self explanatory.

(2) Obtain UPW factor from the LCC MANUAL or "Life-Cycle Costing Rules," table A-2.

(3) Column (3) = Column (1) x Column (2).

I. All applicants must complete this part. This part gives nonannually recurring nonfuel operating, maintenance, and replacement costs and salvage values with the solar energy system. Put in "0" if appropriate.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage value = 0 unless more definitive information is available.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from the LCC MANUAL or the LCC Rule, table A-1.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring nonfuel O&M costs for the building or building system after the retrofit.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the building or building system after the retrofit.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the building or building system after the retrofit.

J. All applicants must complete this part. This part is used to calculate the TLCC with the solar energy system.

(1) Transcribe from Part F, Column (5) Total.

(2) Transcribe from Part G, item (3).

(3) Transcribe from Part H, item (3).

(4) Transcribe from Part I, Column (6) Total.

(5) Transcribe from Part I, Column (7) Total.

(6) Transcribe from Part I, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

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[1] If the nonfuel O&M costs of the auxiliary system are assumed constant regardless of the solar fraction, and if they were, on this basis, valued at zero in section B, they should also be valued at zero in this section.

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With Solar

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ 492.20	10.59	$ 5,212

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value with Solar

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
20			$ 9,844.00[2]	.26			$ 2,559
TOTAL					0	0	$ 2,559

J. Calculating the TLCC With the Solar Energy System

(1) Present Value of Energy Costs with Solar		$ 49,415
(2) Present Value Adjusted Investment Costs with Solar	+	$ 44,298
(3) Present Value of Annually Recurring Nonfuel O&M Costs with Solar	+	$ 5,212
(4) Present Value of Nonannually Recurring Nonfuel O&M Costs with Solar	+	$ 0
(5) Present Value of Replacement Costs with Solar	+	$ 0
(6) Present Value of Salvage Value	-	$ 2,559
(7) TLCC With the Retrofit Project	=	$ 96,366

[1] See footnote on page 109 for explanation.

[2] Given in table 7.1.

K. This part calculates the Net Savings or Excess Cost of the solar energy system.

(1) Transcribe from Part D, item (6).

(2) Transcribe from Part J, item (7).

(3) Line (3) = Line (1) - Line (2).

L. All applicants must complete this part. This part describes the Savings-to-Investment Ratio (SIR) calculation.

(1) (a) Line (a) = (Part D, item (1)) - (Part J, item (1)).

(b) Line (b) = (Part J, lines (3) plus (4)) - (Part D, lines (2) plus (3)).

(c) Line (c) = Line (a) - Line (b).

(2) (a) Transcribe from Part J, item (2).

(b) Line (b) = (Part J, line (5)) - (Part D, line (4)).

(c) Line (c) = (Part J, line (6)) - (Part D, line (5)).

(d) Line (d) = Line (a) + Line (b) - Line (c).

(3) Line (3) = Line (1)(c) ÷ Line (2)(d).

K. Net Savings or Excess Cost of the Solar Project

(1)	TLCC without Solar		$ 78,436
(2)	TLCC with Solar	-	$ 96,366
(3)	Net Savings (+) or net losses (-)	=	$ -17,930

L. SIR Calculation

(1)	SIR Numerator		
	(a) Energy Cost Savings from Solar		$ 29,021
	(b) Change in Nonfuel O&M Costs with Solar	-	$ 5,212
	(c) SIR Numerator	=	$ 23,809
(2)	SIR Denominator		
	(a) Adjusted Investment Cost with Solar		$ 44,298
	(b) Change in Replacement Costs with Solar	+	$ 0
	(c) Change in Salvage Value with Solar	-	$ 2,559
	(d) SIR Denominator	=	$ 41,739
(3)	SIR for Ranking the Solar Project		.57

M. This part describes two methods of calculating simple payback for the solar project, based on the type of cash flow anticipated. All applicants must complete either: (1) for uniform cash flow, or (2) for nonuniform cash flows.

(1) (a) Transcribe from Part L, item (2)(a).

(b) Line (b) = (Part A, Column (3) Total) - (Part F, Column (3) Total).

(c) Line (c) = (Part H, item (1)) - (Part B, item (1)).

(d) Line (d) = Line (b) - Line (c).

(e) Line (e) = Line (a) ÷ Line (d).

(2) (a) Self-explanatory.

(b) Column (b) = (Part A, Column (3) Total) - (Part F, Column (3) Total) x (number of years accumulated).

(c) Column (c) = (Part H, item (1)) + (Part I, item (2) + (3 - 4))[1] - (Part B, item (1) + Part C, items (2) + (3 - 4))[1]. This should be accumulated by year.

(d) Column (d) = Column (b) - Column (c).

(e) Column (e) = Part L, item (2)(a).

(f) Column (f) = Column (e) - Column (d).

(g) SPB = year in which Column (f) changes from positive to negative.

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[1] Items 2 and 3 of Parts C and I refer to nonannually recurring costs which only have to be included in those years that they occur.

M. Simple Payback (SPB)

(1) Calculating SPB when annual cash flows are uniform.

(a) Adjusted Investment Cost With Solar	(b) Base-Year Fuel Cost Savings With Solar	(c) Change in Base Year (Nonfuel O&M Costs With Solar	(d) Net Yearly Savings	(e) SPB (Years)
$ 44,298	$ 2,020	$ 492	$ 1,528	29

(2) Calculating SPB when annual cash flows are not uniform.

(a) CUMULATIVE YEAR	(b) CUMULATIVE ENERGY SAVINGS	(c) CUMULATIVE CHANGE IN NONFUEL O&M, REPLACEMENT, AND SALVAGE VALUE WITH SOLAR	(d) CUMULATIVE SAVINGS	(e) INVESTMENT COST WITH SOLAR	(f) INVESTMENT COST MINUS CUMULATIVE SAVINGS	(g) SPB (YEAR)

This active solar energy system atop the White House roof expresses Federal support for solar energy.

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[14] Marshall, Harold E. and Ruegg, Rosalie T. Simplified Energy Design Economics, National Bureau of Standards Special Publication 544 (Washington, D.C.: U.S. Government Printing Office; Stock No. 003-003-02156-3, January 1980).

[15] Grant, Eugene L., Ireson, W. Grant, and Leavenworth, Richard S. Principles of Engineering Economy, 6th Edition (New York: The Ronald Press Co., 1976).

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[19] Federal Register. "Issuance of Notice of Proposed Rulemaking Regarding Life Cycle Costing Regulation CS-163," October 7, 1980.

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APPENDIX A

DISCOUNTING FACTORS FOR FINDING PRESENT VALUES OF NONFUEL FUTURE AMOUNTS

CONTENTS

[Note: These SPW and UPW discount factors are based on a 7 percent discount rate as required by the Energy Security Act of 1980 (P.L. 96-294). They are intended for use beginning October 1, 1980.]

TABLE A-1. SPW FACTORS, BASED ON A 7 PERCENT DISCOUNT RATE, FOR FINDING THE PRESENT VALUE OF FUTURE NONANNUALLY RECURRING (NONFUEL) AMOUNTS, SUCH AS REPLACEMENT COSTS AND SALVAGE VALUES[1]

Study Period (Years)	Factor
1	0.93
2	0.87
3	0.82
4	0.76
5	0.71
6	0.67
7	0.62
8	0.58
9	0.54
10	0.51
11	0.48
12	0.44
13	0.42
14	0.39
15	0.36
16	0.34
17	0.32
18	0.30
19	0.28
20	0.26
21	0.24
22	0.23
23	0.21
24	0.20
25	0.18

[1] The formula for finding the present value (P) of a future amount (F) is the following:

$$P = \frac{F}{(1 + d)^n},$$

where d = the discount rate, and

n = the year in which F occurs.

TABLE A-2. UPW FACTORS, BASED ON A 7 PERCENT DISCOUNT RATE, FOR FINDING THE PRESENT VALUE OF FUTURE ANNUALLY RECURRING (NONFUEL) COSTS, SUCH AS ROUTINE MAINTENANCE COSTS[1]

Study Period (Years)	Factor
1	0.94
2	1.81
3	2.62
4	3.39
5	4.10
6	4.77
7	5.39
8	5.97
9	6.52
10	7.02
11	7.50
12	7.94
13	8.36
14	8.75
15	9.11
16	9.45
17	9.76
18	10.06
19	10.34
20	10.59
21	10.84
22	11.06
23	11.27
24	11.47
25	11.65

[1] The formula for finding the present value (P) of an annually recurring uniform amount (A) is the following:

$$P = \frac{A(1 + d)^n - 1}{d(1 + d)^n},$$

where d = the discount rate, and

n = the number of corresponding periods over which A occurs.

APPENDIX B

UPW* DISCOUNTING FACTORS FOR FINDING PRESENT VALUES OF FUTURE ENERGY COSTS OR SAVINGS

CONTENTS:

[Note: These "Modified Uniform Present Worth" (UPW)* discount factors are based on a 7% discount rate as required by the Energy Security Act of 1980 (P.L. 96-294). They incorporate the DoE Energy Information Administration's (EIA's) revised projected energy price escalation rates proposed to become effective October 1, 1980. (See "Notice of Proposed Rule Making," Ref. [19].) Life-cycle cost evaluations made prior to that date should use the UPW* factors based on the average energy price projections contained in appendix B to the LCC Rule as published in the Federal Register, January 23, 1980. It should be noted that the data contained in this appendix are subject to further revisions in the Federal Register.]

TABLE B-1--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 1
(MAINE, NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, CONNECTICUT, RHODE ISLAND)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.01	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.01	1.81	1.86	1.90	2.02	2.07
3	2.62	2.72	2.80	2.62	2.72	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.54	3.67	3.39	3.53	3.67	4.05	3.39	3.54	3.67	4.05	4.25
5	4.10	4.31	4.52	4.10	4.31	4.51	5.07	4.10	4.32	4.52	5.08	5.38
6	4.76	5.07	5.32	4.76	5.07	5.32	6.06	4.76	5.07	5.33	6.07	6.45
7	5.38	5.79	6.10	5.38	5.80	6.10	7.00	5.38	5.81	6.12	7.03	7.46
8	5.96	6.49	6.85	5.96	6.51	6.85	7.91	5.96	6.52	6.88	7.96	8.43
9	6.50	7.17	7.57	6.50	7.21	7.57	8.78	6.50	7.21	7.62	8.86	9.34
10	7.00	7.83	8.26	7.00	7.88	8.26	9.61	7.00	7.88	8.33	9.73	10.20
11	7.46	8.45	8.93	7.46	8.52	8.94	10.42	7.45	8.53	9.02	10.57	10.98
12	7.86	9.04	9.58	7.87	9.13	9.59	11.22	7.85	9.18	9.70	11.40	11.69
13	8.23	9.61	10.21	8.23	9.71	10.23	11.99	8.21	9.80	10.35	12.21	12.32
14	8.56	10.15	10.82	8.57	10.27	10.85	12.75	8.53	10.42	10.99	13.00	12.90
15	8.86	10.66	11.42	8.86	10.81	11.46	13.49	8.81	11.02	11.61	13.77	13.41
16	9.13	11.15	12.00	9.13	11.31	12.04	14.21	9.07	11.61	12.21	14.52	13.88
17	9.38	11.61	12.56	9.38	11.80	12.61	14.91	9.29	12.19	12.80	15.26	14.30
18	9.60	12.06	13.11	9.59	12.26	13.17	15.60	9.50	12.75	13.37	15.97	14.68
19	9.79	12.48	13.65	9.79	12.71	13.71	16.27	9.68	13.30	13.93	16.67	15.02
20	9.97	12.88	14.16	9.97	13.13	14.23	16.93	9.84	13.84	14.47	17.35	15.33
21	10.13	13.26	14.67	10.13	13.53	14.74	17.57	9.98	14.37	14.99	18.02	15.61
22	10.28	13.63	15.15	10.27	13.92	15.24	18.19	10.11	14.89	15.50	18.67	15.86
23	10.41	13.98	15.63	10.40	14.29	15.73	18.80	10.23	15.39	16.00	19.30	16.09
24	10.52	14.31	16.09	10.52	14.64	16.20	19.40	10.33	15.89	16.48	19.92	16.29
25	10.63	14.62	16.54	10.62	14.97	16.65	19.98	10.42	16.37	16.95	20.53	16.48

1 These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1 - \left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

2 Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-2--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 2
(NEW YORK, NEW JERSEY, PUERTO RICO, VIRGIN ISLANDS)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.00	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.72	2.80	3.03	2.62	2.72	2.80	3.03	3.14
4	3.39	3.54	3.67	3.39	3.53	3.67	4.05	3.39	3.53	3.67	4.05	4.24
5	4.10	4.31	4.52	4.10	4.31	4.52	5.07	4.10	4.31	4.52	5.07	5.36
6	4.76	5.06	5.33	4.76	5.06	5.33	6.06	4.76	5.07	5.33	6.06	6.43
7	5.37	5.78	6.10	5.37	5.79	6.11	7.00	5.37	5.81	6.11	7.00	7.44
8	5.94	6.47	6.85	5.94	6.48	6.85	7.91	5.93	6.54	6.86	7.90	8.41
9	6.47	7.13	7.57	6.47	7.16	7.57	8.78	6.45	7.24	7.58	8.77	9.32
10	6.97	7.77	8.26	6.97	7.81	8.27	9.61	6.94	7.93	8.27	9.60	10.19
11	7.43	8.37	8.93	7.42	8.43	8.94	10.42	7.39	8.61	8.94	10.41	11.01
12	7.85	8.94	9.58	7.85	9.01	9.59	11.22	7.80	9.27	9.60	11.20	11.78
13	8.25	9.49	10.21	8.24	9.58	10.23	11.99	8.19	9.91	10.23	11.97	12.51
14	8.62	10.01	10.82	8.61	10.11	10.85	12.75	8.55	10.54	10.85	12.73	13.20
15	8.96	10.50	11.42	8.96	10.62	11.45	13.48	8.88	11.16	11.46	13.46	13.86
16	9.28	10.97	12.00	9.28	11.11	12.04	14.20	9.19	11.76	12.05	14.17	14.47
17	9.58	11.41	12.56	9.57	11.57	12.61	14.91	9.48	12.35	12.62	14.87	15.05
18	9.86	11.84	13.11	9.85	12.01	13.17	15.59	9.74	12.93	13.17	15.55	15.60
19	10.12	12.24	13.64	10.11	12.43	13.71	16.26	9.99	13.49	13.71	16.21	16.12
20	10.36	12.62	14.16	10.35	12.83	14.23	16.91	10.22	14.04	14.24	16.86	16.60
21	10.58	12.98	14.66	10.57	13.21	14.74	17.55	10.43	14.58	14.75	17.49	17.07
22	10.79	13.33	15.15	10.77	13.57	15.24	18.17	10.63	15.10	15.25	18.11	17.50
23	10.98	13.65	15.62	10.97	13.92	15.72	18.78	10.81	15.61	15.73	18.71	17.91
24	11.16	13.97	16.08	11.15	14.24	16.19	19.37	10.98	16.12	16.20	19.29	18.30
25	11.33	14.26	16.53	11.31	14.56	16.65	19.94	11.14	16.61	16.66	19.86	18.66

1 These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW* = \sum_{j=1}^{n_1} \left(\frac{1 + e_1}{1 + d}\right)^j + \left(\frac{1 + e_1}{1 + d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1 + e_2}{1 + d}\right)^j + \left(\frac{1 + e_1}{1 + d}\right)^{n_1} \left(\frac{1 + e_2}{1 + d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1 + e_3}{1 + d}\right)^j + .. + \left(\frac{1 + e_1}{1 + d}\right)^{n_1} \left(\frac{1 + e_2}{1 + d}\right)^{n_2} .. \left(\frac{1 + e_{k-1}}{1 + d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1 + e_k}{1 + d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1 + e}{1 + d}\right)^j = \left(\frac{1 + e}{d - e}\right)\left(1 - \left(\frac{1 + e}{1 + d}\right)^{n_k}\right)$.

2 Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-3--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 3
(PENNSYLVANIA, MARYLAND, WEST VIRGINIA, VIRGINIA, DISTRICT OF COLUMBIA, DELAWARE)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.00	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.72	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.54	3.67	4.05	4.25
5	4.10	4.31	4.51	4.10	4.31	4.52	5.07	4.10	4.31	4.52	5.07	5.38
6	4.77	5.06	5.32	4.77	5.06	5.32	6.06	4.77	5.11	5.33	6.06	6.46
7	5.40	5.79	6.10	5.40	5.79	6.10	7.00	5.41	5.91	6.10	7.00	7.48
8	6.00	6.48	6.84	6.00	6.50	6.85	7.90	6.01	6.73	6.85	7.90	8.46
9	6.56	7.16	7.56	6.56	7.18	7.57	8.76	6.58	7.57	7.57	8.77	9.39
10	7.09	7.80	8.25	7.10	7.84	8.26	9.59	7.12	8.42	8.26	9.60	10.28
11	7.59	8.42	8.91	7.59	8.47	8.94	10.39	7.62	9.21	8.93	10.41	11.12
12	8.05	9.00	9.56	8.05	9.07	9.59	11.18	8.09	9.93	9.59	11.20	11.91
13	8.48	9.56	10.19	8.48	9.64	10.23	11.95	8.52	10.61	10.22	11.96	12.66
14	8.87	10.08	10.80	8.88	10.18	10.85	12.69	8.93	11.23	10.84	12.71	13.37
15	9.25	10.58	11.39	9.25	10.70	11.45	13.42	9.30	11.81	11.44	13.44	14.04
16	9.59	11.06	11.97	9.60	11.19	12.04	14.13	9.65	12.35	12.02	14.15	14.67
17	9.91	11.51	12.53	9.92	11.66	12.61	14.82	9.97	12.84	12.59	14.85	15.27
18	10.21	11.93	13.07	10.22	12.10	13.16	15.49	10.27	13.30	13.14	15.52	15.83
19	10.49	12.34	13.60	10.50	12.52	13.70	16.14	10.55	13.72	13.68	16.18	16.37
20	10.75	12.72	14.11	10.76	12.93	14.22	16.78	10.81	14.12	14.20	16.82	16.87
21	11.00	13.09	14.60	11.00	13.31	14.73	17.40	11.06	14.48	14.70	17.45	17.35
22	11.22	13.43	15.09	11.23	13.67	15.23	18.01	11.28	14.81	15.20	18.06	17.80
23	11.43	13.76	15.55	11.44	14.02	15.71	18.60	11.49	15.13	15.67	18.65	18.22
24	11.63	14.08	16.01	11.63	14.35	16.18	19.18	11.69	15.41	16.14	19.23	18.63
25	11.81	14.37	16.45	11.81	14.66	16.64	19.74	11.87	15.68	16.59	19.79	19.01

[1] These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1+e_3}{1+d}\right)^j + .. + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} .. \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1 - \left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

[2] Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-4--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 4
(KENTUCKY, TENNESSEE, NORTH CAROLINA, SOUTH CAROLINA, MISSISSIPPI, ALABAMA, GEORGIA, FLORIDA, CANAL ZONE)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.00	1.02
2	1.81	1.86	1.90	1.81	1.85	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.71	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.53	3.67	4.05	4.25
5	4.10	4.31	4.52	4.10	4.31	4.52	5.07	4.10	4.31	4.52	5.07	5.37
6	4.78	5.05	5.32	4.78	5.05	5.32	6.06	4.78	5.10	5.33	6.06	6.44
7	5.42	5.77	6.10	5.42	5.77	6.10	7.00	5.43	5.91	6.10	7.00	7.46
8	6.03	6.45	6.85	6.03	6.46	6.85	7.91	6.05	6.73	6.85	7.91	8.43
9	6.61	7.10	7.56	6.61	7.12	7.57	8.78	6.64	7.56	7.57	8.78	9.35
10	7.17	7.72	8.25	7.16	7.76	8.26	9.62	7.21	8.41	8.26	9.62	10.22
11	7.68	8.31	8.91	7.68	8.36	8.94	10.43	7.74	9.22	8.93	10.43	11.04
12	8.17	8.87	9.56	8.17	8.93	9.59	11.23	8.24	10.01	9.59	11.23	11.82
13	8.63	9.39	10.19	8.63	9.47	10.23	12.01	8.71	10.78	10.22	12.01	12.55
14	9.06	9.89	10.80	9.05	9.98	10.85	12.77	9.16	11.52	10.84	12.77	13.24
15	9.46	10.36	11.39	9.46	10.46	11.45	13.51	9.57	12.23	11.44	13.51	13.88
16	9.84	10.80	11.96	9.84	10.91	12.03	14.23	9.96	12.92	12.02	14.24	14.49
17	10.20	11.21	12.52	10.19	11.34	12.60	14.94	10.33	13.59	12.59	14.95	15.07
18	10.53	11.61	13.06	10.53	11.75	13.16	15.63	10.68	14.23	13.14	15.64	15.61
19	10.85	11.98	13.59	10.84	12.14	13.70	16.31	11.01	14.85	13.68	16.32	16.12
20	11.14	12.33	14.10	11.13	12.50	14.22	16.97	11.31	15.46	14.20	16.98	16.60
21	11.42	12.66	14.59	11.41	12.84	14.73	17.61	11.60	16.04	14.71	17.63	17.05
22	11.68	12.97	15.07	11.67	13.17	15.22	18.24	11.87	16.60	15.20	18.26	17.48
23	11.92	13.27	15.54	11.91	13.48	15.71	18.86	12.13	17.14	15.68	18.88	17.88
24	12.15	13.55	15.99	12.14	13.77	16.17	19.46	12.37	17.67	16.15	19.48	18.26
25	12.37	13.81	16.43	12.36	14.04	16.63	20.04	12.59	18.17	16.60	20.07	18.61

1 These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1 - \left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

2 Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-5--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 5
(MINNESOTA, WISCONSIN, MICHIGAN, ILLINOIS, INDIANA, OHIO)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.01	0.93	0.95	0.97	1.01	1.02
2	1.81	1.86	1.90	1.81	1.85	1.90	2.02	1.81	1.86	1.90	2.02	2.07
3	2.62	2.72	2.80	2.62	2.71	2.80	3.03	2.62	2.72	2.80	3.03	3.14
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.53	3.67	4.05	4.24
5	4.10	4.31	4.51	4.10	4.31	4.52	5.08	4.10	4.31	4.52	5.08	5.36
6	4.77	5.06	5.32	4.77	5.06	5.33	6.06	4.78	5.09	5.33	6.06	6.43
7	5.41	5.78	6.10	5.41	5.78	6.11	7.01	5.42	5.87	6.11	7.01	7.44
8	6.01	6.47	6.85	6.01	6.48	6.86	7.92	6.02	6.65	6.86	7.91	8.40
9	6.57	7.13	7.57	6.57	7.15	7.58	8.79	6.60	7.42	7.58	8.78	9.31
10	7.11	7.77	8.26	7.11	7.80	8.28	9.62	7.15	8.20	8.28	9.62	10.18
11	7.61	8.37	8.94	7.61	8.41	8.95	10.44	7.66	8.96	8.95	10.44	11.00
12	8.07	8.94	9.59	8.08	8.98	9.61	11.24	8.13	9.69	9.61	11.23	11.78
13	8.51	9.47	10.23	8.51	9.53	10.26	12.02	8.58	10.40	10.26	12.02	12.51
14	8.92	9.98	10.85	8.92	10.05	10.88	12.78	8.99	11.09	10.88	12.78	13.20
15	9.29	10.46	11.46	9.30	10.53	11.49	13.52	9.38	11.77	11.49	13.52	13.85
16	9.65	10.91	12.04	9.65	11.00	12.08	14.25	9.74	12.42	12.08	14.25	14.46
17	9.98	11.33	12.61	9.98	11.43	12.66	14.96	10.07	13.05	12.66	14.96	15.04
18	10.29	11.73	13.17	10.29	11.84	13.22	15.66	10.39	13.67	13.22	15.66	15.59
19	10.57	12.11	13.71	10.58	12.23	13.77	16.34	10.68	14.27	13.77	16.34	16.10
20	10.84	12.47	14.24	10.85	12.60	14.31	17.00	10.95	14.85	14.31	17.00	16.59
21	11.09	12.80	14.75	11.10	12.95	14.83	17.65	11.21	15.41	14.83	17.65	17.05
22	11.33	13.12	15.25	11.33	13.27	15.33	18.28	11.44	15.96	15.33	18.29	17.48
23	11.54	13.42	15.73	11.55	13.58	15.82	18.90	11.66	16.49	15.82	18.91	17.89
24	11.75	13.71	16.20	11.76	13.88	16.30	19.51	11.87	17.01	16.30	19.52	18.28
25	11.94	13.97	16.66	11.95	14.15	16.77	20.10	12.06	17.51	16.77	20.11	18.64

[1] These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1}\left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\sum_{j=1}^{n_2}\left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\sum_{j=1}^{n_3}\left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\cdots\left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}}\sum_{j=1}^{n_k}\left(\frac{1+e_k}{1+d}\right)^j,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k}\left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1-\left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

[2] Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-6--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 6
(TEXAS, NEW MEXICO, OKLAHOMA, ARKANSAS, LOUISIANA)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.01	1.02
2	1.81	1.86	1.90	1.81	1.85	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.71	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.54	3.67	4.05	4.25
5	4.10	4.31	4.51	4.10	4.31	4.51	5.07	4.10	4.32	4.52	5.07	5.38
6	4.77	5.07	5.32	4.78	5.07	5.32	6.06	4.78	5.09	5.33	6.06	6.45
7	5.42	5.81	6.10	5.42	5.83	6.10	7.00	5.43	5.85	6.10	7.00	7.46
8	6.02	6.54	6.85	6.03	6.57	6.85	7.91	6.04	6.61	6.85	7.91	8.43
9	6.60	7.25	7.57	6.61	7.29	7.57	8.78	6.63	7.35	7.58	8.78	9.34
10	7.15	7.94	8.26	7.16	8.01	8.27	9.61	7.19	8.09	8.27	9.62	10.20
11	7.66	8.60	8.93	7.67	8.70	8.94	10.43	7.72	8.80	8.94	10.43	11.02
12	8.14	9.23	9.58	8.15	9.36	9.60	11.22	8.20	9.49	9.60	11.23	11.78
13	8.58	9.84	10.21	8.60	9.99	10.24	12.00	8.66	10.14	10.24	12.01	12.50
14	8.99	10.42	10.83	9.01	10.59	10.86	12.76	9.08	10.78	10.86	12.77	13.17
15	9.38	10.97	11.43	9.40	11.18	11.46	13.51	9.47	11.38	11.47	13.52	13.81
16	9.74	11.50	12.01	9.76	11.74	12.05	14.24	9.84	11.97	12.06	14.24	14.41
17	10.07	12.01	12.58	10.10	12.27	12.63	14.95	10.18	12.53	12.63	14.96	14.97
18	10.39	12.49	13.12	10.41	12.79	13.18	15.64	10.50	13.07	13.19	15.65	15.49
19	10.68	12.96	13.66	10.70	13.28	13.73	16.32	10.80	13.59	13.73	16.33	15.99
20	10.95	13.40	14.18	10.98	13.75	14.25	16.98	11.07	14.09	14.26	16.99	16.46
21	11.20	13.82	14.68	11.23	14.21	14.77	17.63	11.33	14.57	14.78	17.64	16.90
22	11.44	14.23	15.17	11.47	14.64	15.27	18.26	11.57	15.03	15.28	18.28	17.31
23	11.66	14.62	15.65	11.69	15.06	15.75	18.88	11.79	15.48	15.76	18.90	17.70
24	11.86	14.99	16.11	11.89	15.46	16.23	19.49	12.00	15.91	16.24	19.50	18.06
25	12.05	15.34	16.56	12.08	15.85	16.69	20.08	12.19	16.32	16.70	20.09	18.40

1 These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1}\left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\sum_{j=1}^{n_2}\left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\sum_{j=1}^{n_3}\left(\frac{1+e_3}{1+d}\right)^j + .. + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2} .. \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}}\sum_{j=1}^{n_k}\left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k}\left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1-\left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

2 Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-7--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 7
(KANSAS, MISSOURI, IOWA, NEBRASKA)

Study Period[2]	Residential Sector			Commercial Sector				Industrial Sector				
	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.01	0.93	0.95	0.97	1.01	1.02
2	1.81	1.86	1.90	1.81	1.85	1.90	2.02	1.81	1.86	1.90	2.02	2.07
3	2.62	2.72	2.80	2.62	2.71	2.80	3.03	2.62	2.71	2.80	3.03	3.14
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.53	3.67	4.05	4.24
5	4.10	4.31	4.52	4.10	4.31	4.52	5.08	4.10	4.31	4.52	5.08	5.36
6	4.76	5.06	5.33	4.76	5.06	5.33	6.06	4.76	5.12	5.33	6.06	6.43
7	5.37	5.79	6.10	5.38	5.79	6.11	7.01	5.37	5.97	6.11	7.01	7.44
8	5.95	6.49	6.85	5.95	6.51	6.86	7.92	5.94	6.85	6.86	7.91	8.41
9	6.48	7.17	7.58	6.48	7.19	7.58	8.79	6.47	7.78	7.59	8.78	9.33
10	6.97	7.83	8.27	6.97	7.86	8.28	9.62	6.95	8.74	8.28	9.62	10.20
11	7.43	8.45	8.94	7.43	8.50	8.96	10.44	7.41	9.73	8.96	10.43	11.02
12	7.86	9.04	9.60	7.86	9.10	9.62	11.23	7.84	10.75	9.62	11.23	11.80
13	8.26	9.59	10.24	8.26	9.67	10.27	12.01	8.23	11.78	10.27	12.01	12.52
14	8.64	10.12	10.86	8.64	10.21	10.89	12.77	8.61	12.85	10.89	12.77	13.21
15	8.99	10.62	11.47	8.99	10.72	11.50	13.52	8.95	13.94	11.51	13.51	13.86
16	9.32	11.09	12.06	9.31	11.20	12.10	14.24	9.28	15.05	12.10	14.24	14.47
17	9.62	11.53	12.63	9.62	11.66	12.68	14.95	9.58	16.19	12.68	14.95	15.04
18	9.91	11.95	13.19	9.91	12.10	13.24	15.65	9.87	17.36	13.25	15.64	15.58
19	10.18	12.35	13.73	10.17	12.51	13.79	16.32	10.13	18.56	13.80	16.32	16.09
20	10.43	12.73	14.26	10.42	12.90	14.33	16.99	10.38	19.79	14.33	16.98	16.57
21	10.66	13.09	14.78	10.66	13.27	14.85	17.63	10.61	21.04	14.85	17.63	17.02
22	10.88	13.42	15.28	10.87	13.62	15.36	18.26	10.83	22.33	15.36	18.26	17.44
23	11.08	13.74	15.76	11.08	13.95	15.85	18.88	11.03	23.65	15.86	18.88	17.84
24	11.27	14.04	16.24	11.27	14.26	16.33	19.48	11.22	25.00	16.34	19.48	18.22
25	11.45	14.33	16.70	11.45	14.56	16.80	20.07	11.39	26.38	16.81	20.07	18.57

[1] These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1}\left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\sum_{j=1}^{n_2}\left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\sum_{j=1}^{n_3}\left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\cdots\left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}}\sum_{j=1}^{n_k}\left(\frac{1+e_k}{1+d}\right)^j,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k}\left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1-\left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

[2] Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-8--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 8
(MONTANA, NORTH DAKOTA, SOUTH DAKOTA, WYOMING, UTAH, COLORADO)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.00	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.71	2.80	3.03	2.62	2.72	2.80	3.03	3.13
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.54	3.67	4.05	4.22
5	4.10	4.31	4.52	4.10	4.31	4.52	5.07	4.10	4.32	4.51	5.07	5.33
6	4.75	5.07	5.32	4.74	5.07	5.32	6.05	4.74	5.08	5.32	6.06	6.37
7	5.33	5.80	6.10	5.33	5.81	6.10	7.00	5.31	5.83	6.10	7.00	7.34
8	5.87	6.51	6.85	5.86	6.52	6.85	7.90	5.82	6.57	6.85	7.91	8.25
9	6.36	7.21	7.57	6.34	7.22	7.57	8.77	6.29	7.29	7.57	8.78	9.10
10	6.80	7.88	8.26	6.78	7.91	8.27	9.60	6.70	7.99	8.26	9.61	9.89
11	7.20	8.52	8.93	7.18	8.56	8.94	10.42	7.07	8.67	8.94	10.43	10.64
12	7.57	9.14	9.58	7.54	9.18	9.60	11.21	7.40	9.33	9.59	11.23	11.34
13	7.90	9.73	10.22	7.87	9.78	10.24	11.99	7.70	9.96	10.23	12.01	12.00
14	8.21	10.29	10.83	8.17	10.36	10.86	12.75	7.97	10.56	10.85	12.77	12.62
15	8.49	10.83	11.43	8.44	10.91	11.47	13.50	8.21	11.14	11.46	13.52	13.20
16	8.74	11.35	12.02	8.68	11.43	12.06	14.22	8.43	11.70	12.05	14.25	13.75
17	8.97	11.84	12.59	8.91	11.94	12.63	14.94	8.62	12.23	12.62	14.96	14.27
18	9.18	12.31	13.14	9.11	12.42	13.19	15.63	8.80	12.75	13.18	15.66	14.75
19	9.38	12.77	13.67	9.30	12.88	13.74	16.31	8.96	13.24	13.72	16.34	15.21
20	9.55	13.20	14.20	9.47	13.33	14.27	16.97	9.10	13.72	14.25	17.01	15.64
21	9.71	13.61	14.71	9.62	13.75	14.78	17.62	9.22	14.18	14.77	17.67	16.04
22	9.86	14.01	15.20	9.76	14.16	15.29	18.26	9.34	14.62	15.27	18.30	16.42
23	9.99	14.38	15.68	9.89	14.55	15.78	18.88	9.44	15.04	15.75	18.93	16.78
24	10.11	14.75	16.15	10.00	14.92	16.25	19.49	9.53	15.45	16.23	19.54	17.11
25	10.22	15.09	16.60	10.11	15.28	16.72	20.08	9.61	15.84	16.69	20.14	17.43

[1] These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1 - \left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

[2] Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-9--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 9
(CALIFORNIA, NEVADA, ARIZONA, HAWAII, TRUST TERRITORY OF THE PACIFIC ISLANDS, AMERICAN SAMOA, GUAM)

	Residential Sector			Commercial Sector				Industrial Sector				
Study Period[2]	Electricity	Natural Gas	Distillate	Electricity	Natural Gas	Distillate	Residual	Electricity	Natural Gas	Distillate	Residual	Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.00	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.72	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.54	3.67	4.05	4.25
5	4.10	4.31	4.51	4.10	4.31	4.51	5.07	4.10	4.32	4.51	5.07	5.37
6	4.77	5.05	5.32	4.77	5.05	5.33	6.05	4.77	5.07	5.33	6.06	6.44
7	5.40	5.75	6.10	5.40	5.75	6.11	7.00	5.40	5.79	6.11	7.00	7.45
8	5.99	6.41	6.85	5.98	6.42	6.86	7.91	5.99	6.49	6.86	7.91	8.40
9	6.54	7.04	7.58	6.54	7.05	7.59	8.78	6.54	7.17	7.59	8.79	9.31
10	7.06	7.64	8.27	7.06	7.66	8.28	9.62	7.07	7.82	8.28	9.63	10.17
11	7.53	8.20	8.95	7.53	8.22	8.97	10.44	7.54	8.44	8.97	10.45	10.98
12	7.97	8.72	9.60	7.96	8.75	9.63	11.25	7.97	9.02	9.63	11.26	11.74
13	8.36	9.21	10.24	8.36	9.25	10.28	12.03	8.36	9.56	10.28	12.05	12.46
14	8.72	9.67	10.87	8.72	9.71	10.91	12.80	8.72	10.08	10.91	12.82	13.14
15	9.05	10.10	11.47	9.05	10.15	11.52	13.55	9.04	10.57	11.52	13.57	13.79
16	9.35	10.51	12.06	9.36	10.55	12.12	14.29	9.34	11.03	12.12	14.31	14.39
17	9.63	10.88	12.64	9.63	10.94	12.70	15.01	9.60	11.46	12.70	15.03	14.96
18	9.88	11.24	13.20	9.89	11.30	13.27	15.71	9.84	11.87	13.27	15.74	15.50
19	10.10	11.57	13.74	10.12	11.63	13.83	16.40	10.07	12.25	13.83	16.43	16.01
20	10.31	11.88	14.27	10.33	11.95	14.37	17.08	10.27	12.62	14.37	17.10	16.49
21	10.50	12.17	14.78	10.52	12.24	14.89	17.74	10.45	12.96	14.89	17.76	16.94
22	10.68	12.45	15.29	10.70	12.52	15.40	18.38	10.61	13.28	15.40	18.41	17.37
23	10.83	12.70	15.77	10.86	12.78	15.90	19.01	10.76	13.59	15.90	19.04	17.77
24	10.98	12.94	16.25	11.01	13.02	16.39	19.63	10.90	13.88	16.39	19.66	18.15
25	11.11	13.17	16.71	11.14	13.25	16.87	20.24	11.02	14.15	16.87	20.27	18.51

1 These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1 - \left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

2 Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-10--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
DOE REGION 10
(WASHINGTON, OREGON, IDAHO, ALASKA)

Study Period[2]	Residential Sector: Electricity	Residential Sector: Natural Gas	Residential Sector: Distillate	Commercial Sector: Electricity	Commercial Sector: Natural Gas	Commercial Sector: Distillate	Commercial Sector: Residual	Industrial Sector: Electricity	Industrial Sector: Natural Gas	Industrial Sector: Distillate	Industrial Sector: Residual	Industrial Sector: Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.01	0.93	0.95	0.97	1.01	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.02	1.81	1.86	1.90	2.02	2.07
3	2.62	2.72	2.80	2.62	2.72	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.54	3.67	3.39	3.53	3.67	4.05	3.38	3.54	3.67	4.05	4.24
5	4.10	4.31	4.51	4.10	4.31	4.51	5.08	4.09	4.31	4.51	5.08	5.37
6	4.79	5.07	5.32	4.79	5.07	5.33	6.07	4.81	5.09	5.33	6.06	6.45
7	5.46	5.80	6.10	5.46	5.81	6.11	7.02	5.53	5.86	6.11	7.01	7.48
8	6.11	6.52	6.85	6.12	6.54	6.86	7.93	6.26	6.62	6.86	7.92	8.46
9	6.74	7.21	7.58	6.75	7.25	7.59	8.81	7.00	7.37	7.59	8.80	9.41
10	7.36	7.88	8.27	7.37	7.94	8.28	9.66	7.74	8.12	8.28	9.64	10.31
11	7.94	8.49	8.95	7.95	8.56	8.97	10.49	8.45	8.85	8.97	10.47	11.13
12	8.49	9.04	9.60	8.50	9.12	9.63	11.30	9.12	9.56	9.63	11.27	11.87
13	9.00	9.53	10.24	9.02	9.63	10.28	12.09	9.76	10.25	10.28	12.06	12.55
14	9.49	9.99	10.87	9.52	10.08	10.91	12.87	10.37	10.92	10.91	12.84	13.16
15	9.95	10.39	11.47	9.98	10.50	11.52	13.63	10.96	11.57	11.52	13.59	13.72
16	10.39	10.76	12.06	10.42	10.87	12.12	14.38	11.51	12.20	12.12	14.33	14.22
17	10.80	11.10	12.64	10.84	11.20	12.70	15.11	12.04	12.82	12.70	15.06	14.68
18	11.19	11.40	13.20	11.23	11.50	13.27	15.83	12.54	13.41	13.27	15.77	15.10
19	11.56	11.68	13.74	11.60	11.77	13.83	16.53	13.02	13.99	13.83	16.46	15.48
20	11.91	11.93	14.27	11.95	12.01	14.37	17.22	13.48	14.56	14.37	17.14	15.82
21	12.24	12.15	14.78	12.28	12.23	14.89	17.90	13.92	15.11	14.89	17.80	16.13
22	12.55	12.36	15.29	12.59	12.43	15.40	18.56	14.33	15.64	15.40	18.45	16.42
23	12.84	12.54	15.77	12.89	12.61	15.90	19.20	14.73	16.16	15.90	19.09	16.67
24	13.12	12.71	16.25	13.17	12.77	16.39	19.84	15.11	16.66	16.39	19.71	16.90
25	13.38	12.86	16.71	13.44	12.92	16.87	20.46	15.47	17.15	16.87	20.32	17.12

[1] These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1}\left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\sum_{j=1}^{n_2}\left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\sum_{j=1}^{n_3}\left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\cdots\left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}}\sum_{j=1}^{n_k}\left(\frac{1+e_k}{1+d}\right)^j,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k}\left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1-\left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

[2] Study Period 1 is Mid-1980 to Mid-1981.

TABLE B-11--UPW* DISCOUNT FACTORS ADJUSTED FOR ENERGY PRICE ESCALATION[1]
UNITED STATES AVERAGE

Study Period[2]	Residential Sector Electricity	Residential Sector Natural Gas	Residential Sector Distillate	Commercial Sector Electricity	Commercial Sector Natural Gas	Commercial Sector Distillate	Commercial Sector Residual	Industrial Sector Electricity	Industrial Sector Natural Gas	Industrial Sector Distillate	Industrial Sector Residual	Industrial Sector Coal
1	0.93	0.95	0.97	0.93	0.95	0.97	1.00	0.93	0.95	0.97	1.00	1.02
2	1.81	1.86	1.90	1.81	1.86	1.90	2.01	1.81	1.86	1.90	2.01	2.07
3	2.62	2.72	2.80	2.62	2.71	2.80	3.03	2.62	2.72	2.80	3.03	3.15
4	3.39	3.53	3.67	3.39	3.53	3.67	4.05	3.39	3.53	3.67	4.05	4.24
5	4.10	4.31	4.51	4.10	4.31	4.52	5.08	4.10	4.31	4.52	5.07	5.37
6	4.77	5.06	5.32	4.77	5.06	5.33	6.06	4.77	5.09	5.32	6.06	6.44
7	5.40	5.78	6.10	5.40	5.79	6.11	7.00	5.41	5.86	6.10	7.00	7.45
8	6.00	6.47	6.85	5.99	6.49	6.86	7.90	6.01	6.63	6.85	7.91	8.42
9	6.56	7.14	7.57	6.55	7.17	7.58	8.77	6.59	7.40	7.57	8.78	9.33
10	7.09	7.78	8.26	7.08	7.83	8.27	9.60	7.13	8.16	8.27	9.61	10.21
11	7.58	8.39	8.93	7.57	8.45	8.95	10.41	7.63	8.90	8.94	10.43	11.02
12	8.04	8.96	9.58	8.03	9.05	9.60	11.21	8.10	9.61	9.60	11.22	11.79
13	8.46	9.50	10.22	8.45	9.61	10.24	11.98	8.54	10.30	10.24	12.00	12.52
14	8.86	10.02	10.83	8.84	10.14	10.86	12.73	8.95	10.97	10.86	12.76	13.20
15	9.23	10.50	11.43	9.20	10.64	11.47	13.47	9.33	11.61	11.47	13.51	13.84
16	9.57	10.96	12.02	9.54	11.12	12.06	14.19	9.68	12.23	12.06	14.23	14.44
17	9.89	11.40	12.58	9.86	11.57	12.63	14.89	10.01	12.83	12.63	14.94	15.01
18	10.18	11.81	13.13	10.15	11.99	13.19	15.57	10.31	13.41	13.19	15.63	15.54
19	10.45	12.20	13.67	10.42	12.40	13.73	16.24	10.59	13.97	13.73	16.31	16.04
20	10.71	12.57	14.19	10.67	12.78	14.25	16.89	10.86	14.51	14.26	16.97	16.51
21	10.94	12.91	14.69	10.91	13.15	14.77	17.53	11.10	15.03	14.77	17.62	16.95
22	11.16	13.24	15.19	11.13	13.49	15.27	18.15	11.33	15.54	15.27	18.25	17.37
23	11.37	13.56	15.66	11.33	13.82	15.75	18.76	11.54	16.03	15.76	18.87	17.76
24	11.56	13.85	16.13	11.52	14.13	16.22	19.35	11.74	16.50	16.23	19.47	18.13
25	11.73	14.13	16.58	11.69	14.42	16.68	19.93	11.93	16.95	16.69	20.06	18.47

1 These "modified" uniform present worth discount (UPW*) factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System (MEFS), for the periods mid-1980 to mid-1985, mid-1985 to mid-1990, and mid-1990 to mid-1995 and beyond. The formula for calculating these UPW* factors is the following: For 1 to k escalation periods,

$$UPW^* = \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \sum_{j=1}^{n_3} \left(\frac{1+e_3}{1+d}\right)^j + \ldots + \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1+e_k}{1+d}\right)^j ,$$

where n_k = the length of the period for a given escalation rate in a given period, and the subscript k indicates the escalation period;

d = the discount rate; and $\sum_{j=1}^{n_k} \left(\frac{1+e}{1+d}\right)^j = \left(\frac{1+e}{d-e}\right)\left(1 - \left(\frac{1+e}{1+d}\right)^{n_k}\right)$.

2 Study Period 1 is Mid-1980 to Mid-1981.

APPENDIX C

ENERGY PRICES AND ESCALATION RATES

CONTENTS:

[Note: These projected average energy prices are proposed for updating the average price projections published in the January 23 issue of the *Federal Register*. They are proposed for use beginning October 1, 1980. It should be noted that these data are subject to further revision through publication in the *Federal Register*.]

TABLE C-1--BASE-YEAR ENERGY PRICES
(MID-1980 PRICES PER MILLION BTU IN MID-1980 DOLLARS)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	25.56	25.15	18.85	14.22	17.30	18.84	18.79	18.85	20.09	7.29	17.58
Natural Gas	4.86[a]	4.44[a]	3.95[a]	3.46[a]	3.55[a]	3.69[a]	3.50	3.62	4.34	4.58[a]	3.83[a]
Distillate	7.19	7.27	7.46	7.53	6.98	7.20	6.92	7.04	6.84	6.84	7.21
COMMERCIAL SECTOR											
Electricity	26.20	23.96	18.41	14.60	16.83	17.68	17.77	17.46	21.25	7.06	18.06
Natural Gas	4.12[a]	3.77[a]	3.43[a]	2.90[a]	3.18[a]	3.10	3.05	3.37	3.76	3.92[a]	3.33[a]
Distillate	6.94	7.01	7.05	7.06	6.78	6.94	6.73	6.80	6.55	6.55	6.91
Residual	4.96	5.03	5.29	4.96	4.97	4.97	5.00	4.88	4.73	4.57	4.99
INDUSTRIAL SECTOR											
Electricity	21.66	15.85	13.72	10.87	12.16	14.02	14.23	13.05	17.06	3.31	12.61
Natural Gas	5.81	5.77	4.77	3.90	4.16	2.76	3.24	2.83	5.43	4.89	3.58
Distillate	6.75	6.99	7.15	7.14	6.78	6.92	6.72	6.84	6.55	6.55	6.93
Residual	4.79	5.12	5.22	4.93	4.95	4.96	4.98	4.83	4.72	4.68	4.96
Coal	1.83[b]	1.63[b]	1.42[b]	1.59[b]	1.29[b]	1.49[b]	1.15[b]	0.90[b]	1.89	1.55[b]	1.46[b]

Prices are developed from average U.S. prices projected for the year 1980 as reported in "Short-Term Energy Outlook," DOE/EIA-0202/2, February 1980. Regional breakdown of 1980 prices is based on the proportional relationship of regional prices to U.S. average prices estimated by the DoE Mid-Term Energy Forecasting System (MEFS) for the year 1985. Simple arithmetic averaging of the regional prices shown will not yield the exact U.S. average prices shown due to energy consumption weighting reflected in the U.S. average prices.

[a] The reduction in the 1980 U.S. average price of natural gas relative to that published in the January 23, 1980, Federal Register reflects a downward revision in the EIA short-term natural gas price forecast.

[b] The reduction in the 1980 U.S. average price of coal relative to that published in the January 23, 1980, Federal Register reflects the current softness in the spot market for coal.

TABLE C-2--BASE-YEAR ENERGY PRICES[a]
(MID-1980 PRICES PER UNIT OF ENERGY PURCHASED IN MID-1980 DOLLARS)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity (kWh)	0.091	0.086	0.064	0.049	0.059	0.064	0.064	0.064	0.069	0.025	0.060
Natural Gas (cu ft)	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004
Distillate (gal)	0.997	1.008	1.035	1.044	0.968	0.999	0.960	0.976	0.949	0.949	1.000
COMMERCIAL SECTOR											
Electricity (kWh)	0.089	0.082	0.063	0.050	0.057	0.060	0.061	0.060	0.073	0.024	0.062
Natural Gas (cu ft)	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.003
Distillate (gal)	0.963	0.972	0.978	0.979	0.940	0.963	0.933	0.943	0.908	0.908	0.958
Residual (gal)	0.742	0.753	0.792	0.742	0.744	0.744	0.748	0.730	0.708	0.684	0.747
INDUSTRIAL SECTOR											
Electricity (kWh)	0.074	0.054	0.047	0.037	0.041	0.048	0.049	0.045	0.058	0.011	0.043
Natural Gas (cu ft)	0.006	0.006	0.005	0.004	0.004	0.003	0.003	0.003	0.006	0.005	0.004
Distillate (gal)	0.936	0.969	0.992	0.990	0.940	0.960	0.932	0.949	0.908	0.908	0.961
Residual (gal)	0.717	0.766	0.781	0.738	0.741	0.742	0.745	0.723	0.707	0.701	0.742
Coal (ton)	41.175	36.675	31.950	35.775	29.025	33.525	25.875	20.250	42.525	34.875	32.850

[a] Note that prices in tables C-1 and C-2 are equivalent prices stated in different units of energy. table C-1 prices are per million Btu (MBtu); table C-2 are per unit of energy typically sold, e.g., kWh of electricity, cubic feet of natural gas, and gallons of oil.

Prices in table C-2 were derived from the prices in table C-1 by multiplying the price per MBtu times the ratio of the Btu content per sales unit of energy to 1 MBtu. The conversions from price per MBtu to price per sales unit are based on the following assumed equivalencies: 3,412 Btu per kWh of electricity, 1,030 Btu per cu ft of natural gas, 138,690 Btu per gallon of distillate, 149,690 Btu per gallon of residual, and 22,500,000 Btu per short ton of coal. For example, price per kWh of electricity = price per MBtu x $\frac{3,412}{1,000,000}$; hence in DoE Region 1, the price per kWh of residential electricity = \$26.56 x $\frac{3,412}{1,000,000}$ = \$0.091.

TABLE C-3--PROJECTED MID-1985 ENERGY PRICES
(MID-1985 PRICES PER MILLION BTU IN MID-1980 DOLLARS)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	26.54	25.12	18.84	14.21	17.29	18.82	18.77	18.84	20.08	7.28	17.56
Natural Gas	5.31	4.85	4.31	3.77	3.87	4.03	3.82	3.95	4.74	5.00	4.18
Distillate	8.49	8.59	8.81	8.90	8.24	8.50	8.17	8.32	8.07	8.07	8.51
COMMERCIAL SECTOR											
Electricity	26.19	23.94	18.40	14.59	16.82	17.67	17.76	17.44	21.24	7.05	18.05
Natural Gas	4.50	4.11	3.74	3.16	3.47	3.38	3.32	3.67	4.10	4.28	3.63
Distillate	8.19	8.28	8.33	8.34	8.01	8.19	7.95	8.03	7.73	7.73	8.16
Residual	7.13	7.23	7.60	7.13	7.15	7.14	7.20	7.01	6.79	6.58	7.17
INDUSTRIAL SECTOR											
Electricity	21.64	15.83	13.71	10.86	12.15	14.01	14.22	13.04	17.05	3.30	12.59
Natural Gas	6.35	6.30	5.21	4.26	4.54	3.02	3.53	3.09	5.93	5.34	3.91
Distillate	7.98	8.26	8.45	8.44	8.01	8.17	7.94	8.07	7.73	7.73	8.18
Residual	6.89	7.36	7.50	7.09	7.12	7.13	7.16	6.94	6.78	6.74	7.13
Coal	2.90	2.57	2.25	2.51	2.03	2.36	1.81	1.40	2.98	2.45	2.30

Prices based on DOE Mid-Term Energy Forecasting System (MEFS) Projection Series "A" (High Case).

TABLE C-4--PROJECTED MID-1990 ENERGY PRICES
(MID-1990 PRICES PER MILLION BTU IN MID-1980 DOLLARS)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	26.27	24.36	19.67	15.47	18.21	20.31	18.22	16.40	20.55	8.80	18.32
Natural Gas	6.25	5.55	5.04	4.25	4.45	5.02	4.52	4.79	5.09	6.04	4.83
Distillate	9.75	9.86	10.08	10.17	9.51	9.77	9.45	9.55	9.35	9.35	9.80
				12.49	12.02						
COMMERCIAL SECTOR											
Electricity	25.93	23.18	19.23	15.85	17.74	19.15	17.21	15.01	21.70	8.57	18.71
Natural Gas	5.44	4.82	4.46	3.63	4.05	4.37	4.02	4.52	4.45	5.33	4.31
Distillate	9.46	9.54	9.60	9.61	9.28	9.47	9.23	9.27	9.01	9.01	9.43
Residual	8.13	8.25	8.61	8.15	8.17	8.16	8.22	8.00	7.81	7.60	8.16
INDUSTRIAL SECTOR											
Electricity	21.39	15.07	14.55	12.11	13.08	15.49	13.67	10.61	17.52	4.83	13.45
Natural Gas	7.66	7.83	7.98	6.49	6.36	4.02	6.15	3.94	6.97	7.22	5.39
Distillate	9.46	9.52	9.72	9.71	9.28	9.45	9.21	9.31	9.01	9.01	9.46
Residual	8.19	8.37	8.52	8.11	8.14	8.15	8.18	7.93	7.81	7.76	8.14
Coal	3.12	2.79	2.48	2.73	2.20	2.53	1.97	1.40	3.19	2.75	2.50

Prices based on DOE Mid-Term Energy Forecasting System (MEFS) Projection Series "A" (High Case).

TABLE C-5--PROJECTED MID-1995 ENERCY PRICES
(MID-1995 PRICES PER MILLION BTU IN MID-1980 PRICES)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	21.93	23.86	19.32	15.84	18.09	20.04	18.20	14.47	18.24	9.29	17.80
Natural Cas	6.88	6.03	5.44	4.46	4.67	5.64	4.80	5.39	5.16	5.17	5.13
Distillate	11.85	11.97	12.20	12.29	11.63	11.89	11.56	11.66	11.44	11.44	11.92
COMMERCIAL SECTOR											
Electricity	21.59	22.67	18.88	16.24	17.62	18.89	17.19	13.09	19.41	9.06	18.17
Natural Cas	6.06	5.30	4.88	3.85	4.28	4.98	4.30	5.11	4.52	4.44	4.62
Distillate	11.55	11.66	11.72	11.73	11.40	11.58	11.34	11.38	11.10	11.10	11.53
Residual	10.11	10.24	10.61	10.16	10.21	10.20	10.26	10.02	9.82	9.62	10.14
INDUSTRIAL SECTOR											
Electricity	17.04	14.57	14.18	12.49	12.96	15.23	13.65	8.69	15.22	5.32	13.16
Natural Gas	9.64	9.81	7.60	7.69	7.71	4.63	9.73	4.53	7.30	8.78	6.35
Distillate	11.55	11.64	11.84	11.83	11.40	11.56	11.33	11.42	11.10	11.10	11.57
Residual	10.18	10.36	10.51	10.11	10.18	10.19	10.21	9.95	9.82	9.76	10.17
Coal	2.61	2.93	2.62	2.84	2.31	2.61	2.05	1.45	3.35	2.38	2.58

Prices based on DOE Mid-Term Energy Forecasting System (MEFS) Projection Series "A" (High Case).

TABLE C-6--ENERGY PRICE ESCALATION RATES MID-1980 TO MID-1985[a]
(PERCENTAGE CHANGE COMPOUNDED ANNUALLY)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02
Natural Gas	1.78	1.78	1.77	1.75	1.75	1.76	1.75	1.76	1.77	1.78	1.76
Distillate	3.38	3.39	3.38	3.39	3.37	3.38	3.38	3.39	3.37	3.37	3.38
COMMERCIAL SECTOR											
Electricity	-0.01	-0.02	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02
Natural Gas	1.77	1.76	1.75	1.73	1.74	1.74	1.73	1.75	1.76	1.76	1.75
Distillate	3.38	3.39	3.38	3.38	3.39	3.38	3.40	3.38	3.38	3.38	3.39
Residual	7.53	7.52	7.52	7.53	7.55	7.52	7.55	7.51	7.50	7.57	7.53
INDUSTRIAL SECTOR											
Electricity	-0.01	-0.03	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.05	-0.03
Natural Gas	1.80	1.76	1.78	1.76	1.77	1.79	1.74	1.80	1.79	1.79	1.75
Distillate	3.39	3.40	3.39	3.39	3.39	3.38	3.40	3.37	3.38	3.38	3.38
Residual	7.54	7.53	7.53	7.53	7.54	7.53	7.54	7.53	7.51	7.55	7.53
Coal	9.62	9.51	9.63	9.58	9.49	9.62	9.50	9.30	9.56	9.56	9.55

a Derived from DOE 1980 and 1985 Price Forecasts shown in Tables C-1 and C-3.

TABLE C-7--ENERGY PRICE ESCALATION RATES MID-1985 TO MID-1990[a]
(PERCENTAGE CHANGE COMPOUNDED ANNUALLY)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	-0.02	-0.61	0.87	1.72	1.04	1.53	-0.59	-2.73	0.47	3.85	0.85
Natural Gas	3.33	2.74	3.15	2.38	2.84	4.53	3.43	3.95	1.44	3.86	2.92
Distillate	2.81	2.80	2.74	2.71	2.91	2.83	2.94	2.82	2.97	2.97	2.85
COMMERCIAL SECTOR											
Electricity	-0.19	-0.64	0.89	1.67	1.07	1.62	-0.63	-2.96	0.43	3.97	0.73
Natural Gas	3.88	3.20	3.60	2.82	3.15	5.26	3.85	4.22	1.66	4.50	3.49
Distillate	2.91	2.88	2.89	2.88	2.99	2.93	3.01	2.91	3.09	3.09	2.94
Residual	2.66	2.68	2.52	2.71	2.70	2.71	2.69	2.67	2.84	2.92	2.61
INDUSTRIAL SECTOR											
Electricity	-0.23	-0.98	1.19	2.20	1.47	2.03	-0.78	-4.05	0.55	7.89	1.32
Natural Gas	3.81	4.46	8.89	8.82	6.98	5.88	11.74	4.95	3.26	6.20	6.64
Distillate	3.47	2.88	2.85	2.85	2.99	2.94	3.02	2.90	3.09	3.09	2.93
Residual	3.53	2.60	2.58	2.73	2.71	2.71	2.70	2.69	2.87	2.86	2.68
Coal	1.47	1.65	1.97	1.69	1.67	1.45	1.76	0.00	1.36	2.39	1.66

[a] Derived from DOE Mid-Term Energy Price Forecasts shown in Tables C-3 and C-4.

TABLE C-8--ENERGY PRICE ESCALATION RATES MID-1990 TO MID-1995 AND BEYOND[a]
(PERCENTAGE CHANGE COMPOUNDED ANNUALLY)

DOE Region and Fuel Type	DOE 1	DOE 2	DOE 3	DOE 4	DOE 5	DOE 6	DOE 7	DOE 8	DOE 9	DOE 10	U.S. Average
RESIDENTIAL SECTOR											
Electricity	-3.55	-0.42	-0.36	0.48	-0.13	-0.26	-0.02	-2.47	-2.35	1.10	-0.57
Natural Gas	1.92	1.68	1.56	1.01	0.97	2.33	1.23	2.36	0.26	-3.09	1.24
Distillate	3.97	3.95	3.89	3.86	4.10	4.00	4.13	4.06	4.13	4.13	4.01
COMMERCIAL SECTOR											
Electricity	-3.60	-0.44	-0.37	0.48	-0.14	-0.28	-0.03	-2.70	-2.21	1.13	-0.59
Natural Gas	2.16	1.93	1.80	1.18	1.11	2.67	1.38	2.49	0.29	-3.58	1.39
Distillate	4.08	4.09	4.07	4.06	4.20	4.12	4.22	4.18	4.27	4.27	4.09
Residual	4.47	4.41	4.26	4.50	4.56	4.56	4.54	4.60	4.68	4.82	4.43
INDUSTRIAL SECTOR											
Electricity	-4.45	-0.68	-0.50	0.63	-0.19	-0.34	-0.03	-3.91	-2.78	1.97	-0.43
Natural Gas	4.72	4.60	-0.95	3.41	3.92	2.89	9.60	2.84	0.93	3.99	3.35
Distillate	4.08	4.10	4.02	4.02	4.20	4.13	4.22	4.16	4.27	4.27	4.12
Residual	4.43	4.35	4.28	4.52	4.58	4.57	4.53	4.64	4.68	4.71	4.55
Coal	-3.47	1.00	1.12	0.79	0.98	0.60	0.77	0.62	0.94	-2.87	0.61

[a] Derived from DOE Mid-Term Energy Price Forecasts shown in tables C-4 and C-5, and assumed to extend up to 10 years beyond mid-1995 to encompass a study period of 25 years beginning in 1980.

APPENDIX D

WORKSHEETS FOR MAKING LCC EVALUATIONS

CONTENTS:

Appendix D-I. RETROFIT LCC WORKSHEETS

(General Instructions)

These worksheets have been designed to cover a wide variety of retrofit projects. Not all parts of the worksheets will generally be required for any one project. Read the instructions for each part carefully to make sure it applies to your project.

Following the project description, parts A through F are used to determine the Total Life-Cycle Costs (TLCC) without the Retrofit Project.

Parts F through J are used to determine the Total Life-Cycle Costs (TLCC) with the Retrofit Project.

Parts K is used to determine the Net Savings (NS) of the Retrofit Project.

Part L is used to determine the Savings-to-Investment Ratio (SIR) of the Retrofit Project.

The worksheets have been designed to supply information on the costs and cost savings benefits of typical retrofit projects. If a project has important costs and/or benefits not covered in these worksheets, they may be added on an attachment sheet provided by the analyst. If the additional values are quantifiable, they may be incorporated into the LCC evaluation; if they are not quantifiable, the LCC evaluation may be amended with a verbal description.

The principal data needed to complete these worksheets are: (1) investment costs, (2) nonfuel O&M costs, (3) replacement costs, (4) resale, salvage, or reuse value, (5) quantity of energy consumed, (6) 7% discount factor tables (with energy discount factors preadjusted for DoE-projected energy price escalation), (7) current energy price data, and (8) estimated project and/or building life. Estimates of these data are required for the situation without the retrofit (Parts A-E), as well as for the case with the retrofit (Parts F-J), to provide a basis of comparison (Parts K & L).

The energy price data and the discount factor tables are contained as of appendices A, B, and C Subpart A of Part 436 of Title 10 of the U.S. Code of Federal Regulations, and were published in "Methodology and Procedures for Life-Cycle Cost Analyses," Final Rule, Federal Register, Vol. 45, No. 16, Wednesday, January 23, 1980, with the energy-related data current through September 1980. The energy-related data are subject to periodic revisions published in the Federal Register as an amendment to the LCC Rule. Revised data, proposed for use beginning October 1, 1980, are provided in appendices A, B, and C of the Life-Cycle Costing Manual for the Federal Energy Management Programs, referred to hereafter as the "LCC Manual."

PROJECT DESCRIPTION (Hypothetical Example)

AGENCY: ______________________________

ADDRESS: STREET ______________________________
CITY/COUNTY ______________________________
STATE ______________________________
DoE REGION ______________________________

PROJECT CONTACT PERSON: NAME ______________________________
POSITION ______________________________
TELEPHONE ______________________________

BUILDING OR FACILITY DESCRIPTION: FUNCTIONAL USE ______________________________

CLASSIFICATION FOR ENERGY CHARGES

___ Residential

___ Commercial

___ Industrial

EXPECTED LIFE ______________________________

PROJECT DESCRIPTION: ______________________________

____

EXPECTED PROJECT LIFE: ______________________________

	1" Insulation	2" Insulation
Estimated Project Investment Cost[1]:	____________	____________

Energy Information: (Complete for Each Type of Energy Affected by the Retrofit Project)

	Energy Type ____________			Energy Type ____________		
	Annual Quantity	Actual Agency Price/Unit	DoE Price/Unit (Table C-1 or C-2)	Annual Quantity	Actual Agency Price/Unit	DoE Price/Unit (Table C-1 or C-2)
Without Retrofit						
With Retrofit						

Study Period: From ____________ (Base Year) To ____________ (End Year)

Number of Years Covered: ____________ (Not to exceed 25)

Parts A through E calculate TLCC of the existing building or building system without the retrofit project:

A. This part calculates the present value of energy costs without the retrofit. It is appropriate to use when (1) the annual physical quantity of energy used with or by the existing building or building system is expected to remain about constant over the study period, and (2) the type of energy used is not expected to change over the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

   (1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sales units, e.g. gallons, kWh, etc.

   (2) Price per unit purchased. Use the estimated base-year[1] energy prices indicated in tables C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

   (3) Column (3) = Column (1) x Column (2). For electricity, only the base charge is Column (1) x Column (2). Other charge components are entered directly in Column (3).

   (4) For the modified uniform present worth (UPW*) factor, see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

   (5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs without the retrofit.

B. This part calculates the equivalent of investment costs for the existing building or building system without the retrofit. It may be omitted if the existing system is to be left in place either "as is" or renovated at about the same cost whether or not the retrofit project is implemented.[6]

   (1) If the existing system will be sold, scrapped, or redirected to a new use if the retrofit project is implemented, enter in (1) the estimated resale, salvage, or reuse value of the existing system in the base year.

   (2) If the existing system is to be left in place, but will require an initial renovation or repair cost that will be different in amount without the retrofit project than with it, enter in (2) the amount of the initial repair or renovation cost in base-year dollars that will be required if the retrofit project is not implemented.

C. This part calculates the present value of annually recurring nonfuel operating and maintenance costs for the existing building or building system without the retrofit. If this category of cost is expected to be the same whether or not the retrofit project is implemented, this part may be omitted.[7]

   (1) State in base-year dollars the amount of annually recurring (nonfuel) costs for the existing building or building system, such as for routine maintenance, that is expected to remain about the same from one year to the next when inflation is not included.

   (2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

   (3) Column (3) = Column (1) x Column (2).

---

[1] The base year is the year the life-cycle cost evaluation is made.

[2] Table C-2 is in terms of typical sales units and it can be used in lieu of table C-1, provided the quantity of energy in item (1) is also given in the same sales unit.

[3] Revised energy price data and UPW* factors for use in the LCC evaluations will be published as available in the Federal Register as an amendment to the LCC Rule. The most current data should be used.

[4] For projects using electricity as the energy source and which have separate charge components that may be affected the retrofit project, the price to the agency should be used, since the prices in tables C-1 and C-2 do not take into account the separate charge components.

[5] See footnote 3.

[6] Only those costs that will be affected by an investment decision need be considered in making that decision.

[7] See footnote 6.

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ____					
TOTAL					

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

D. This part calculates the present value of nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values for the existing building or building system without the retrofit. If these costs are expected to be the same whether or not the retrofit project is implemented, this part may be omitted.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs for the existing building or system.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the existing building or system.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the existing building or system.

E. This Part calculates the total life-cycle cost (TLCC) without the retrofit.

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (1) or (2).

(3) Transcribe from Part C, Column (3).

(4) Transcribe from Part D, Column (6) Total.

(5) Transcribe from Part D, Column (7) Total.

(6) Transcribe from Part D, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

D. Calculating Non-Annually Recurring O&M (Non-fuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL							

E. Calculating TLCC Without the Retrofit

(1)	Present Value of Energy Costs		$ ______
(2)	Present Value of Investment Costs	+	$ ______
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ ______
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ ______
(5)	Present Value of Replacement Costs	+	$ ______
(6)	Present Value of Salvage	-	$ ______
(7)	TLCC Without the Retrofit	=	$ ______

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1990 costs in 1980 dollars, i.e., without future inflation.

Parts F through J calculate TLCC with the Retrofit

F. This part calculates the present value of energy costs with the retrofit. It is appropriate to use when (1) the annual physical quantity of energy required after the retrofit is expected to remain about constant over the study period, and (2) the type of energy required after the retrofit is not expected to change over the remainder of the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sales units, e.g., gallons, or kWh, etc.

(2) Price per unit purchased. Use the estimated base-year[1] energy prices indicated in table C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge is Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the UPW* factor see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs with the retrofit.

G. This part calculates the investment costs with the retrofit project.

(1) Costs of initial planning, design, engineering, purchase and installation, all in base-year prices.

(2) Special interim adjustment factor to reflect estimated societal benefits from reducing the use of nonrenewable energy resources, not adequately reflected by market energy prices. (The adjustment factor, set presently at .9 in the LCC Rule, is subject to future modification or deletion.)

(3) Line (3) = Line (1) x Line (2).

(4) If the existing system is to be left in place, but will require an initial renovation or repair cost that will be different in amount with the retrofit project than without it, enter in item (4) the amount of the initial renovation or repair cost in base-year dollars that will be required if the retrofit is performed. This part may be omitted if nothing was entered in Part B, item (2).

(5) Line (5) = Line (3) + Line (4).

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[1] See footnote 1 on page 150 for explanation.

[2] See footnote 2 on page 150 for explanation.

[3] See footnote 3 on page 150 for explanation.

[4] See footnote 4 on page 150 for explanation.

[5] See footnote 5 on page 150 for explanation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ____					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project = ______

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented + ______

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project = ______

H. This part gives the annually recurring (nonfuel) operating and maintenance costs with the retrofit.

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs, such as for routine maintenance, that is expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

I. This part gives the present value of these nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values for the building or building system after the retrofit. <u>If these costs are expected to be the same whether or not the retrofit project is implemented, and have not been included in part D, this part can be omitted</u>.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from the LCC MANUAL or the LCC Rule, table A-1.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs for the building or building system after the retrofit.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the building or building system after the retrofit.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the building or building system after the retrofit.

J. This part calculates the TLCC with the retrofit.

(1) Transcribe from Part F, Column (5) Total.

(2) Transcribe from Part G, item (5).

(3) Transcribe from Part H, item (3).

(4) Transcribe from Part I, Column (6) Total.

(5) Transcribe from Part I, Column (7) Total.

(6) Transcribe from Part I, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ ________	________	$ ________

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs		________
(2) Present Value of Adjusted Investment Costs	+	________
(3) Present Value of Annually Recurring (Nonfuel) O&M Costs	+	________
(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	________
(5) Present Value of Replacement Costs	+	________
(6) Present Value of Salvage	-	________
(7) TLCC With the Retrofit Project	=	________

[1] See footnote on page 153 for explanation.

K. This part calculates the Net Savings (NS) (or Excess Cost (-NS)) from the retrofit project.

(1) Transcribe from Part E, item (7).

(2) Transcribe from Part J, item (7).

(3) Line (3) = Line (1) - Line (2).

L. This part describes the Savings-to-Investment Ratio (SIR) calculation.

(1) (a) Line (a) = (Part E, item (1)) - (Part J, item (1)).

(b) Line (b) = (Part J, lines (3) plus (4)) - (Part E, lines (3) plus (4)). (Note that this will be a negative value if nonfuel O&M costs are lower with the retrofit project than without it.)

(c) Line (c) = Line (a) - Line (b).

(2) (a) Line (a) = (Part J, Line (2)) - (Part E, Line (2)).

(b) Line (b) = (Part J, Line (5)) - (Part E, Line (5)).

(c) Line (c) = (Part J, Line (6)) - (Part E, Line (6)).

(d) Line (d) = Line (a) + Line (b) - Line (c).

(3) Line (3) = Line (1)(c) ÷ Line (2)(d).

K. Net Savings or Excess Cost of the Retrofit Project

(1)	TLCC without the Retrofit		$ ______
(2)	TLCC with the Retrofit	-	$ ______
(3)	Net Savings (+) or net losses (-)	=	$ ______

L. SIR Calculation

(1)	SIR Numerator		
	(a) Energy Cost Savings from the Retrofit		$ ______
	(b) Change in Nonfuel O&M Costs	-	$ ______
	(c) SIR Numerator	=	$ ______
(2)	SIR Denominator		
	(a) Adjusted Differential Investment Cost		
	(b) Change in Replacement Costs	+	$ ______
	(c) Change in Salvage Value	-	$ ______
	(d) SIR Denominator	=	$ ______
(3)	SIR for Ranking the Retrofit Project		______

APPENDIX D-II. NEW BUILDING DESIGN LCC WORKSHEETS

(General Instructions)

All new Federal buildings are required by law to be life-cycle cost effective. This means that of alternative designs for a building, the one which meets requirements at lowest total life-cycle cost (TLCC) should be selected.

To compare the TLCC of alternative building designs or of alternative building systems for a new building design, complete this worksheet (or perform an equivalent analysis) for each alternative.

Following the building or project description, parts A through E, are used to calculate Total Life-Cycle Costs (TLCC) for the design or system being evaluated.

The principal data required to complete these are: (1) investment costs, (2) nonfuel O&M costs, (3) replacement costs, if applicable, (4) resale, salvage, or reuse value, if applicable, (5) the quantity of energy consumed (6) 7 percent discount factor tables, (7) current energy price data, and (8) estimated building or system life. The discount factor tables, preadjusted for projected energy price escalation, and the energy prices are contained as appendices A, B, and C of Subpart A of Part 436 of Title 10 of the U.S. Code of Federal Regulations, and were published in "Methodology and Procedures for Life Cycle Cost Analysis," Final Rule, Federal Register, Vol. 45, No. 16, Wednesday, January 23, 1980, with the energy-related data current through September 1980. The energy related data are subject to periodic revisions published in the Federal Register as an amendment to the LCC rule. Revised data proposed for use beginning October 1, 1980, are provided in appendices A, B, and C of the Life-Cycle Costing Manual for the Federal Energy Management Programs, referred to hereafter as the "LCC MANUAL."

I. PROJECT DESCRIPTION (Hypothetical Example)

AGENCY: ______________________________

ADDRESS: STREET ______________________________
CITY/COUNTY ______________________________
STATE ______________________________
DoE REGION ______________________________

PROJECT CONTACT PERSON: NAME ______________________________
POSITION ______________________________
TELEPHONE ______________________________

BUILDING OR FACILITY DESCRIPTION: FUNCTIONAL USE ______________________________

CLASSIFICATION FOR ENERGY CHARGES
___ Residential
___ Commercial
___ Industrial

PROJECT DESCRIPTION: ______________________________

EXPECTED BUILDING OR SYSTEM LIFE: ______________________________

ESTIMATED BUILDING OR SYSTEM INVESTMENT COST: $ ______________
(Included site, planning, design, engineering and construction or purchase and installation)

ENERGY INFORMATION: (Complete for Each Type of Energy Affected by the Choice of Alternative Design or System)

Energy Type ______________ Energy Type ______________

Annual Quantity	Actual Agency Price/ Unit	DoE Price/ Unit (Table C-1 or C-2)	Annual Quantity	Actual Agency Price/ Unit	DoE Price/ Unit (Table C-1 or C-2)

Period of Study: From ______ (Base Year) To ______ (End Year)

Number of Years Covered: ______ (Not to exceed 25)

A. This part calculates the present value of energy cost. It is appropriate for use when (1) the annual physical quantity of energy required by the building design is expected to remain about constant, and (2) the type(s) of energy are not expected to change over the study period. To calculate the present value of energy costs when these two conditions do not hold, see appendix G.

(1) Total annual quantity of energy to be purchased expressed in MBtu's (10^6 Btu's) or, alternatively, in sales units, e.g., gallons, kWh, etc.

(2) Price per unit purchased. Use the estimated base year[1] energy prices indicated in table C-1 or C-2[2] of the LCC MANUAL or of the LCC Rule (subject to periodic revision in the Federal Register)[3] for the appropriate region, sector and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in table C-1 or C-2.[4]

(3) Column (3) = Column (1) x Column (2). For electricity, only the base charge in Column (1) x Column (2). Other charge components are entered directly in Column (3).

(4) For the UPW* factor see appendix B of the LCC MANUAL or of the LCC Rule[5] for the appropriate region, sector, fuel type, and study period. (In no case shall the study period exceed 25 years.) For electricity, the same UPW* factor should be applied to all charge components.

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs.

B. This part calculates the investment costs.

(1) Costs of initial planning, site acquisition, design, engineering, purchase and installation.

(2) Special interim adjustment factor for reducing energy conservation and renewable energy investment costs in the LCC evaluation to reflect estimated societal benefits not adequately reflected by market energy prices. (The adjustment factor, set at .9 in the LCC Rule, is subject to future modification or deletion.

(3) Line (3) = Line (1) x Line (2).

---

[1] The base year is the year the life-cycle cost evaluation is made.

[2] Table C-2 is in terms of typical sales units and it can be used in lieu of table C-1, provided the quantity of energy in item (1) is also given in the same sales unit.

[3] Revised energy price data and UPW* factors for use in the LCC evaluations will be published as available in the Federal Register as an amendment to the LCC Rule. The most current data should be used.

[4] For projects using electricity as the energy source and which have separate charge components that may be affected by the retrofit project, the price to the agency should be used, since the prices in tables C-1 and C-2 do not take into account the separate charge components.

[5] See footnote 3.

A. Calculating the Present Value of Energy Costs

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	______	______	$ ______ BASE CHARGE $ ______ DEMAND CHARGE $ ______ TIME OF DAY CHARGE $ ______ CONTRACT CAPACITY CHARGE $ ______ OTHER CHARGE COMPONENT	______	$ ______ $ ______ $ ______ $ ______ $ ______
OIL					
GAS					
OTHER ____					
TOTAL					

B. Calculating Investment Costs for the New Building Design

(1) Estimated Actual Investment Costs for the New Building Design		$ ______
(2) Investment Cost Adjustment Factor	x	______
(3) Adjusted Investment Costs for the Retrofit Project	=	______

C. This part gives the annually recurring (nonfuel) operating and maintenance costs.

(1) State in base-year dollars the amount of annually recurring (nonfuel) costs, such as for routine maintenance, that are expected to remain about the same from one year to the next when inflation is not included.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or the LCC Rule, table A-2.

(3) Column (3) = Column (1) x Column (2).

D. This part gives the present value of nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage values may occur during the study period in conjunction with replacements, as well as at the end of the study period.

(5) Obtain single present worth (SPW) factors for year(s) in which the amount(s) is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value.

E. This part calculates the total life-cycle cost (TLCC).

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (3).

(3) Transcribe from Part C, item (3).

(4) Transcribe from Part D, Column (6) Total.

(5) Transcribe from Part D, Column (7) Total.

(6) Transcribe from Part D, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

C. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ ________	________	$ ________

D. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL							

E. Calculating the TLCC

(1)	Present Value Energy Costs		$ ________
(2)	Present Value Adjusted Investment Costs	+	$ ________
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ ________
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ ________
(5)	Present Value of Replacement Costs	+	$ ________
(6)	Present Value of Salvage	-	$ ________
(7)	TLCC of the New Building or System Design	=	$ ________

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs or salvage value occur in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1980 costs in 1980 dollars, i.e., without future inflation.

APPENDIX D-III. SOLAR LCC WORKSHEETS[1]

FORM A-2

COST DATA

FEDERAL BUILDINGS DEMONSTRATION PROGRAM

THESE FORMS ARE THE OFFICIAL FORMS FOR THE SOLAR FEDERAL BUILDINGS PROGRAM REFERENCED IN THE FINAL RULE (SUBPART D OF 10 CFR, PART 436), AND ARE TO BE SUBMITTED BY A PROPOSING AGENCY UPON PROGRAM INITIATION.

[1] In part 7 of this manual, only section III (the LCC evaluation section) was illustrated in exhibit 7.1. Here, for completeness, Form A-2 is given in its entirety. (Page numbers on Form A-2 have been changed to correspond with the page numbering system used in this manual.)

FORM A-2

TABLE OF CONTENTS

FORM A-2

RECORD OF CHANGES

All proposers who have completed a version of Form A-2 other than the final version dated October 5, 1979, please take note of the following changes:

A. Response Items: This is a group of changes to Form A-2 which consists of added items and requires a response from the proposer. To respond the proposer should complete page 172, items 1 through 4, as indicated. Write answers in the space provided or use additional sheets.

B. Information Items: This group of changes to Form A-2 which is intended to correct and clarify certain items in the earlier versions of the form. Proposers should review the information on pages 173, items 1 through 9 and examine their previous responses in light of these changes. If revised responses are found to be necessary, please note and write in the appropriate sections of this form. (Use additional sheets if required.)

FORM A-2

RECORD OF CHANGES

Response Items

1.	Pages 179 & 181	For those submitting combined active and passive projects, please submit the cost breakdown per the forms on pages 179 and 181.
2.	Pages 180 & 181	Read instructions on page 5 for new line item "J" added for Acceptance Testing.
3.	Pages 180 & 181	Read instructions on page 180 for new line item "T" added for cost sharing.
4.	Page 185 thru 195	Complete pages 185 through 195 for Life-Cycle Cost Evaluation.

Item 2 — Write costs below:

Material Active/Passive		Labor Active/Passive		Total
$_______	$_______	$_______	$_______	$_______

Item 3 — Write in cost share below:

$ to be cost shared by agency = $ ___________

FORM A-2

RECORD OF CHANGES

Information Items

1. Page 169: Blocked information in cover sheet rewritten.

2. Page 174: Introduction rewritten for clarity. Was page ii in earlier version.

   Fourth paragraph on Section III rewritten to drop original cost analysis requirement and added Life-Cycle Cost Evaluation. Was page iii in earlier version.

3. Page 176: Item D, added the words "commercial, industrial."

4. Page 177: Line item C, moved "New __ " and "Existing __ " to line D.

   Items F and G, removed the asterisks.

   Bottom of page, removed note, "Proposals covering the use of process heat and passive are allowable submissions but contract awards are restrained due to funding limitations."

5. Page 178: First paragraph added, "and designate active, passive, or both, as applicable." First sentence, changed letter "J" to "K".

6. Page 180: Line item M, changed letter "K" to "L" in second sentence.

   Line item O, changed letter "M" to "N" in last sentence.

   Line item Q, deleted last sentence.

7. Pages 180 & 181: Old item J changed to, "K. Other Solar."

   Item K changed to, "L. Subtotal (A through K)."

   Item L changed to, "M. Contingency (___% of L)."

   Item M changed to, "N. Subtotal Construction Funds (L + M)."

   Item N changed to, "O. Design Cost (___% of N)."

   Item O changed to, "P. On-Site (___% of N)."

   Item P changed to, "Q. Total Design Cost (O + P)."

   Item R changed to, "S. Total N ÷ Collector Area (Refer to A))."

   Line item G, replaced word "cooling" with acronym "HVAC." Added sentence "Identify equipment related to the incremental costs."

8. Page 181: Line item S, changed "Sq. Ft." to "Collector Area."

9. Pages 183 & 184: The original pages 7 & 8 titled "Solar Systems Cost Analysis" have been replaced with "Life-Cycle Cost Evaluation," pages 183 through 195.

FORM A-2

INTRODUCTION

Form A-2 is designed to collect data about the cost of proposed solar projects. It is appropriate for active, passive, or combined systems intended to supply space heating, space cooling, domestic hot water, or industrial process heat.

Section I describes the project location, application and lists the contact agent.

Section II, pages 167 & 181, gives the cost sheets to be completed for each proposed solar project.

> Note: If a combination passive and active system is proposed, then Section II must be completed for each of the two systems.

Section III is the Life-Cycle Cost Evaluation to be completed for each proposed solar project using information from Section II and some of the information in FORM A-1.

Since the form will be used as one of the methods for determining project selection, it is essential that it be completed as accurately as possible. The form is designed in a step-by-step manner, with each item explanation on the facing page. If there are any questions regarding completion of FORM A-2, contact Albert Krupnick, FA34, George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812, (205) 453-1870 (FTS 872-1870).

FORM A-2 (Instruction Sheet)

I. PROJECT DESCRIPTION

A. The appropriate Federal agency, such as DOD, DOE, etc.

B. The project title should be descriptive, such as "The Fort Mullins Commissary Solar Water Heating System."

C. Name, title, mailing address, and business phone.

D. The building should be identified as retail, office, health, education, public service, storage, residential, commercial, industrial, or other, and if referred to as other, briefly describe.

E. Address of the proposed site.

F. Self-explanatory.

G. Example: For an active system, glycol liquid system utilizing flat plate collectors.

FORM A-2

1. PROJECT DESCRIPTION

AGENCY: ____________________

____

PROJECT TITLE: ____________________

____

____

PROJECT CONTACT PERSON: ____________________

____

BUILDING CATEGORY: NEW ___ EXISTING ___

ADDRESS: STREET ____________________

CITY/COUNTY ____________________

STATE ____________________

SOLAR APLICATION (CHECK ALL APPROPRIATE): DOMESTIC HOT WATER ___, SPACE HEATING ___, SPACE COOLING ___, INDUSTRIAL PROCESS HEAT ___. If PROCESS HEAT, BRIEFLY EXPLAIN:

____

____

____

TYPE SOLAR ENERGY SYSTEM: ACTIVE ___ PASSIVE ___

BRIEFLY DESCRIBE: ____________________

____

____

____

FORM COMPLETION TIME
(CHECK APPROPRIATE BLOCK)

PROPOSAL:
- CONCEPTUAL DESIGN ___
- 60% DESIGN OR MORE ___
- FINAL DESIGN ___
- OTHER ___

II. SOLAR SYSTEM COSTS

In Sections A-K furnish the cost breakdown for material and labor when available and designate active, passive, or both, as applicable. As a minimum, dollar totals must be furnished. Materials include contractor's material costs with overhead and profit, and labor includes contractor's labor costs with overhead and profit. If design is at 60% design point or better, the dollar material, dollar labor, and totals must be furnished.

A. Includes cost associated with the purchase, delivery, and installation, on the structural frame (including tracking system). Square feet refers to the gross area of the collector array. Reflector costs should include reflector material required for backing (plywood, steel, etc.), along with lamination/bonding material and hinges and brackets for mounting. For a passive heating system, this includes any additional costs associated with glazed collection area over and above conventional costs. Examples are the costs of building a greenhouse-materials and labor as defined above, or additional costs associated with double or triple glazing, and increasing southern wall glazed area.

B. Consists of structural assemblies and members used to support the collector/reflector array. For passive systems this would apply to any additional costs incurred by the structural requirements of the collection system.

C. This is the combined cost of the thermal storage subsystems (heating, cooling, hot water, industrial process heat) including purchase, delivery, and installation, but not including tank insulation. For a passive system of a direct gain type, this would include the cost of any additional thermal mass designed into the building interior over and above the conventional interior cost. For indirect gain this would include the the cost of mass or water trombe walls, roof ponds, etc. For isolated gain this would include thermal storage cost associated with isolated gain structure.

D. Includes valves, pumps, heat exchangers, blowers, expansion tanks, fittings, heat exchanger fluids, piping and ductwork other than that for conventional HVAC systems.

E. Includes cost of interior and exterior piping and duct insulation as well as storage tank insulation. For passive system, this includes cost of movable insulation (insulating drapes, panels, etc.).

F. Solar control costs should include differential temperature devices, on/off damper controls (electrical/pneumatic), and thermostats. Instrument costs should include pressure gauges, thermometers, flowmeters, or Btu meters required for monitoring system operation/performance. Instrumentation costs shall be limited to the minimum required for system operation and record-keeping purposes. For passive systems this would also include cost of sensor controls associated with mechanically assisted movable insulation, vents, etc.

FORM A-2

II. SOLAR SYSTEM COSTS

FORM COMPLETION TIME
(CHECK APPROPRIATE BLOCK)

PROPOSALS:
- CONCEPTUAL DESIGN ___
- 60% DESIGN OR MORE ___

FINAL DESIGN ___

OTHER ___

MAJOR COMPONENTS	$ MATERIAL ACTIVE/PASSIVE		$ LABOR ACTIVE/PASSIVE		$ TOTAL
A. 1. SOLAR COLLECTORS					
_____ SQ. FT. x $/SQ. FT. =	________	+	________	=	$ ________
2. REFLECTORS					
_____ SQ. FT. x $/SQ. FT. =	________	+	________	=	$ ________
B. COLLECTOR/REFLECTOR SUPPORTS					
_____ SQ. FT. x $/SQ. FT. =	________	+	________	=	$ ________
C. THERMAL STORAGE					
_____ GAL x _____ $/GAL OR					
_____ CU. FT. x _____ $/CU. FT. OR					
_____ LBS. MASS x _____ $/LB =	________	+	________	=	$ ________
D. PIPING/DUCTWORK	________	+	________	=	$ ________
E. INSULATION	________	+	________	=	$ ________
F. 1. SOLAR CONTROLS	________	+	________	=	$ ________
2. INSTRUMENTATION	________	+	________	=	$ ________

G. DoE will fund those incremental costs associated with solar over and above the normal cost of the conventional HVAC system equipment. Identify equipment related to the incremental cost.

H. Includes all electrical materials, power wiring, starters, control wiring, and installation of motors and heaters.

I. General construction normally includes related equipment rental, painting, site preparation, solar related building modifications (safety rails, walkways, stairways to roof and roof penetration), and environmental aesthetics.

J. Includes all cost involved in acceptance testing of solar system per acceptance test plan requirements.

K. Specify additional solar-related costs not identified in I.

L. Self-explanatory.

M. Contingency estimates include such things as increases in labor costs or increases in building material costs from authority to proceed until construction is completed. Indicate as a percentage of L and a dollar amount, up to 15 percent is allowable; anything over 15 percent requires an explanation at bottom of page.

N. Self-explanatory.

O. Includes architectural, engineering and consulting feees. Include design cost as a percent of N and a dollar amount.

P. Briefly describe the type of work. Include SIOH as a percent of M and a dollar amount.

Q. Self-explanatory.

R. Self-explanatory.

S. The construction costs of the project divided by the total square footage of collector gross area.

T. Self-explanatory.

FORM A-2

II. SOLAR SYSTEM COST (Continued)

MAJOR COMPONENTS	$ MATERIAL ACTIVE/PASSIVE		$ LABOR ACTIVE/PASSIVE		$ TOTAL
G. SOLAR-RELATED EQUIPMENT (IF APPLICABLE) (IDENTIFY) ______	______	+	______	=	$ ______
H. ELECTRICAL	______	+	______	=	$ ______
I. GENERAL CONSTRUCTION	______	+	______	=	$ ______
J. ACCEPTANCE TESTING	______	+	______	=	$ ______
K. OTHER SOLAR-RELATED COSTS (IDENTIFY) ______	______	+	______	=	$ ______
L. SUBTOTAL (A THROUGH K)					$ ______
M. CONTINGENCY (__% OF L)					$ ______
N. SUBTOTAL CONSTRUCTION FUNDS (L + M)					$ ______
O. DESIGN COST(__% OF N)					$ ______
P. ON-SITE SUPERVISION, INSPECTION AND OVERHEAD (SIOH) (__% OF N) (EXPLAIN) ______					$ ______
Q. TOTAL DESIGN COST (O + P)					$ ______
R. GRAND TOTAL (N + Q)					$ ______
S. TOTAL SYSTEM COST/SQ. FT. (N ÷ COLLECTOR AREA (REFER TO A))					$ ______ SQ. FT.
T. $ TO BE COST SHARED BY AGENCY					$ ______

III. LIFE-CYCLE COST EVALUATION

Section III has been designed to cover a wide variety of solar projects. Not all parts of it will generally be required for any one project. Read the instructions for each part carefully to make sure it applies to your project.

Parts A through D of Section III are used to determine the Total Life-Cycle Costs (TLCC) without the Solar System.

Parts E through J of Section III are used to determine the Total Life-Cycle Costs (TLCC) with the Solar System.

Parts K through M of Section III give the Life-Cycle Cost Modes of Analysis.

The forms have been designed to supply information for costs and benefits for typical projects. If the project has costs and benefits not covered in these forms, contact NASA for additional information.

The principal data required to complete this section are: (1) solar energy system cost data collected on Section II (pages D-29 through D-31) of this form, (2) estimated costs of the nonsolar system which would be used in lieu of the proposed solar energy system, (3) discount factor tables, and (4) current energy price data. The discount factor tables, preadjusted for projected energy price escalation, and the energy prices for end-of-year 1979 are contained as appendices A, B, and C of the "Life-Cycle Costing Rules" published as Subpart A of Part 436 of the U.S. Code of Federal Regulations, effective through September 1980. Revised process, effective October 1980, are provided in the Life-Cycle Costing Manual for the Federal Energy Management Program (FEMP). These prices are subject to periodic revision in the Federal Register. If assistance is needed to complete this worksheet, please consult the Life-Cycle Costing Manual, referred to here after as the LCC MANUAL.

A. In order to evaluate the cost effectiveness of a solar energy system, it is necessary to estimate what costs would exist without solar. The purpose of this part is to estimate those costs based on the nonsolar energy system that would be used if the solar project were not undertaken. This system may be identical to or different from the system that would be used as a backup to the solar energy system. All applicants must complete this part for the type(s) of fuel(s) that solar will be displacing. Indicate in the appropriate columns:

(1) Total quantity of energy to be purchased expressed in MBtu's (10^6 Btu's).

(2) Price/MBtu. Use the estimated base-year[1] energy prices indicated in table C-1[2] of the MANUAL, or the "Life-Cycle Costing Rules," for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy prices exceed estimates in the table.

(3) Column (3) = Column (1) x Column (2). Sum up Column (3) and place in Column (3) Total line. This gives the Total Base-Year Energy Costs without solar. For electricity, only the base charge is Column (1) x Column (2).

(4) For the modified uniform present worth (UPW*) factor, see appendix B of the LCC MANUAL or the "Life-Cycle Costing Rules," for the appropriate region, sector, fuel type, and study period. Use a study period of 20 years unless a more accurate number for the particular system is available. Do not exceed a study period of 25 years.[3]

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs without solar.

B. All applicants must complete this part. This part gives the annually recurring nonfuel operating and maintenance costs of the nonsolar energy system. These are the O&M costs associated with the system which would have been used in lieu of the proposed solar energy system. Put in "0" if appropriate.

(1) Self-explanatory.

(2) Obtain UPW factor for the length of the study period from the LCC MANUAL or "Life-Cycle Costing Rules," table A-2.

(3) Column (3) = Column (1) x Column (2)

---

[1] The base year is the year the life-cycle cost evaluation is made.

[2] For projects using electricity as the energy source and which have separate charge components that may be affected by the solar project, only the price to the agency should be used, since the prices in table C-1 do not take into account the separate charge components. The same UPW* (Column 4) should be applied to all charge components. Table C-2 is in terms of kWh and it can be used as a cross reference to table C-1.

[3] This instruction in the Form A-2 is shown changed from a maximum study period of 30 years to a maximum of 25 years for consistency with the new legislated requirements (see Ref. [13]).

A. Calculating the Present Value of Fuel Costs Without Solar

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED (10^6 Btu)	(2) BASE-YEAR ENERGY PRICE $\$/10^6$ Btu	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	________	________	\$ ________ BASE CHARGE \$ ________ DEMAND CHARGE \$ ________ TIME OF DAY CHARGE \$ ________ CONTRACT CAPACITY CHARGE \$ ________ OTHER CHARGE COMPONENT	____	\$ ________ \$ ________ \$ ________ \$ ________ \$ ________
OIL					
GAS					
OTHER ____					
TOTAL					

B. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without Solar

(1) Amount of Annually Recurring Costs in Base Year[1]	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
\$ ________________	________	\$ ________________

[1] If the nonfuel O&M costs of the nonsolar energy system are assumed to remain constant whether the system is used alone or in varying combinations with solar energy, these costs can be considered of zero value for the LCC evaluation, since they would cancel out of the TLCC calculation. However, if they are not constant, they should be included here.

C. All applicants must complete this part. This part gives the nonannually recurring (nonfuel) operating, maintenance, replacement costs, and salvage values of the nonsolar system. These are the costs and values associated with the system which would have been used in lieu of the proposed solar energy system. Put "0" if appropriate.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Self-explanatory.

(5) Obtain single present worth (SPW) factors for year(s) in which each amount is (are) expected to occur from table A-1 of the LCC MANUAL or the LCC Rule.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring (nonfuel) O&M costs.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value.

D. All applicants must complete this part. This part calculates the total life-cycle cost of the system without solar.

(1) Transcribe from Part A, Column (5) Total.

(2) Transcribe from Part B, item (3).

(3) Transcribe from Part C, Column (6) Total.

(4) Transcribe from Part C, Column (7) Total.

(5) Transcribe from Part C, Column (8) Total.

(6) Line (6) = Line (1) + Line (2) + Line (3) + Line (4) - Line (5).

C. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value Without Solar

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL							

D. Calculating TLCC Without Solar

(1)	Present Value of Energy Costs	+	$ _______
(2)	Present Value of Annually Recurring (Nonfuel) O&M Costs	+	$ _______
(3)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs	+	$ _______
(4)	Present Value of Replacement Costs	+	$ _______
(5)	Present Value of Salvage Value	-	$ _______
(6)	TLCC Without Solar	=	$ _______

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occurs in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1990 costs in 1980 dollars, that is, without future inflation.

E. All applicants must complete this part for each fuel used by each type of system that will be using solar.

(1) Self-explanatory.

(2) Transcribe from FORM A-1 Section VII, page 33, Total Line (16) for Active Systems, or transcribe from FORM A-1 Section VIII, page 39, Total Line (7) for Passive System.[1] Estimate the fuel split for each system. For example, in a solar heating and hot water project where the auxiliary heating system uses oil and the auxiliary hot water system uses electricity, estimate the amount of auxiliary energy required for each system by fuel type.

F. All applicants must complete this part for each type of fuel used. This part estimates the present value of fuel costs with solar.

(1) Transcribe from Part E, item (2).

(2) Price/MBtu. Use the estimated base-year[2] energy prices indicated in table C-1[3] of the LCC MANUAL, or the "Life-Cycle Costing Rules," for the appropriate region, sector, and fuel type, or use the actual price to the agency if the agency's base-year energy price exceeds the estimate in the table.

(3) Column (3) = Column (1) x Column (2). Sum up Column (3) and place in Column (3) Total line. This gives the total base-year energy costs with solar. For electricity, only the base charge is Column (1) x Column (2).

(4) For the UPW* factor see appendix B of the LCC MANUAL, or the "Life-Cycle Costing Rules," for the appropriate region, sector, fuel type, and study period. Use a study period of 20 years unless a more accurate number for the particular system is available. Do not exceed a study period of 25 years.[4]

(5) Column (5) = Column (3) x Column (4). Sum up Column (5) and place in Column (5) Total line. This gives the total present value energy costs with solar.

G. All applicants must complete this part. This part is used to calculate the investment costs with the solar system.

(1) Transcribe from FORM A-2, Section II, page 6, Line (R).[5]

(2) Self-explanatory.

(3) Line (3) = Line (1) x Line (2).

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1 Form A-1, as well as Form A-2, is available from the NASA/George C. Marshall Space Flight Center. (See footnote 4, page 97.

2 See footnote 1 on page 184 for explanation.

3 See footnote 2 on page 184 for explanation.

4 See footnote 3 on page 184 for explanation.

5 See appendix D-3 for section II.

E. Calculating the Present Value of Fuel Costs With the Solar Energy System

(1) Type of Fuel ________ ________ ________ ________

(2) Annual Units of Energy to be Purchased (10^6 Btu/Yr) ________ ________ ________ ________

F. Calculating the Present Value of Fuel Costs With the Solar Energy System

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED (10^6 Btu)	(2) BASE-YEAR ENERGY PRICE PER UNIT $\$/10^6$ Btu	(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	________	________	$ ________ BASE CHARGE	________	$ ________
			$ ________ DEMAND CHARGE		$ ________
			$ ________ TIME OF DAY CHARGE		$ ________
			$ ________ CONTRACT CAPACITY CHARGE		$ ________
			$ ________ OTHER CHARGE COMPONENT		$ ________
OIL					
GAS					
OTHER _____					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Solar Energy System

(1) Total Investment Costs Attributable to the Solar Project[1] $ ______

(2) Adjustment in Investment Costs to Reflect Estimated Societal Benefits from Solar Energy in Excess of Dollar Energy Saving x ______

(3) Adjusted Present Value Investment Costs for the Solar Energy System = $ ______

[1] \$49,220 = \$33,620 + (\$26.00 x 600)

H. All applicants must complete this part. This part gives the annually recurring nonfuel operating and maintenance costs (O&M) with the solar energy system. These are the total O&M costs associated with the solar energy system including the O&M costs of the auxiliary system.[1] For the solar system, typical O&M costs are between 1 and 4 percent of the system costs.

(1) Self explanatory.

(2) Obtain UPW factor from the LCC MANUAL or "Life-Cycle Costing Rules," table A-2.

(3) Column (3) = Column (1) x Column (2).

I. All applicants must complete this part. This part gives nonannually recurring nonfuel operating, maintenance, and replacement costs and salvage values with the solar energy system. Put in "0" if appropriate.

(1) State the year(s) in which the expenditure(s) for the nonannually recurring cost item(s) is (are) expected to occur.

(2) Self-explanatory.

(3) Self-explanatory.

(4) Note that salvage value = 0 unless more definitive information is available.

(5) Obtain single present worth (SPW) factor(s) for year(s) in which the amount(s) is (are) expected to occur from the LCC MANUAL or the LCC Rule, table A-1.

(6) Column (6) = Column (2) x Column (5). Sum up Column (6) and place in Column (6) Total line. This gives the total present value of nonannually recurring nonfuel O&M costs for the building or building system after the retrofit.

(7) Column (7) = Column (3) x Column (5). Sum up Column (7) and place in Column (7) Total line. This gives the total present value of replacement costs for the building or building system after the retrofit.

(8) Column (8) = Column (4) x Column (5). Sum up Column (8) and place in Column (8) Total line. This gives the total present value of salvage value for the building or building system after the retrofit.

J. All applicants must complete this part. This part is used to calculate the TLCC with the solar energy system.

(1) Transcribe from Part F, Column (5) Total.

(2) Transcribe from Part G, item (3).

(3) Transcribe from Part H, item (3).

(4) Transcribe from Part I, Column (6) Total.

(5) Transcribe from Part I, Column (7) Total.

(6) Transcribe from Part I, Column (8) Total.

(7) Line (7) = Line (1) + Line (2) + Line (3) + Line (4) + Line (5) - Line (6).

---

[1] If the nonfuel O&M costs of the auxiliary system are assumed constant regardless of the solar fraction, and if they were, on this basis, valued at zero in section B, they should also be valued at zero in this section.

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With Solar

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value with Solar

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(7) PRESENT VALUE OF REPLACEMENT	(8) PRESENT VALUE OF SALVAGE VALUE
TOTAL							

J. Calculating the TLCC With the Solar Energy System

(1)	Present Value of Energy Costs with Solar		$ ______
(2)	Present Value Adjusted Investment Costs with Solar	+	$ ______
(3)	Present Value of Annually Recurring Nonfuel O&M Costs with Solar	+	$ ______
(4)	Present Value of Nonannually Recurring Nonfuel O&M Costs with Solar	+	$ ______
(5)	Present Value of Replacement Costs with Solar	+	$ ______
(6)	Present Value of Salvage Value	-	$ ______
(7)	TLCC With the Retrofit Project	=	$ ______

[1] See footnote on page 187 for explanation.

K. This part calculates the Net Savings or Excess Cost of the solar energy system.

(1) Transcribe from Part D, item (6).

(2) Transcribe from Part J, item (7).

(3) Line (3) = Line (1) - Line (2).

L. All applicants must complete this part. This part describes the Savings-to-Investment Ratio (SIR) calculation.

(1) (a) Line (a) = (Part D, item (1)) - (Part J, item (1)).

(b) Line (b) = (Part J, lines (3) plus (4)) - (Part D, lines (2) plus (3)).

(c) Line (c) = Line (a) - Line (b).

(2) (a) Transcribe from Part J, item (2).

(b) Line (b) = (Part J, line (5)) - (Part D, line (4)).

(c) Line (c) = (Part J, line (6)) - (Part D, line (5)).

(d) Line (d) = Line (a) + Line (b) - Line (c).

(3) Line (3) = Line (1)(c) ÷ Line (2)(d).

K. Net Savings or Excess Cost of the Solar Project

(1)	TLCC without Solar		$ ______
(2)	TLCC with Solar	-	$ ______
(3)	Net Savings (+) or net losses (-)	=	$ ______

L. SIR Calculation

(1)	SIR Numerator		
	(a) Energy Cost Savings from Solar		$ ______
	(b) Change in Nonfuel O&M Costs with Solar	-	$ ______
	(c) SIR Numerator	=	$ ______
(2)	SIR Denominator		
	(a) Adjusted Investment Cost with Solar		$ ______
	(b) Change in Replacement Costs with Solar	+	$ ______
	(c) Change in Salvage Value with Solar	-	$ ______
	(d) SIR Denominator	=	$ ______
(3)	SIR for Ranking the Solar Project		______

M. This part describes two methods of calculating simple payback for the solar project, based on the type of cash flow anticipated. All applicants must complete either: (1) for uniform cash flow, or (2) for nonuniform cash flows.

(1) (a) Transcribe from Part L, item (2)(a).

(b) Line (b) = (Part A, Column (3) Total) - (Part F, Column (3) Total).

(c) Line (c) = (Part H, item (1)) - (Part B, item (1)).

(d) Line (d) = Line (b) - Line (c).

(e) Line (e) = Line (a) ÷ Line (d).

(2) (a) Self-explanatory.

(b) Column (b) = (Part A, Column (3) Total) - (Part F, Column (3) Total) x (number of years accumulated).

(c) Column (c) = (Part H, item (1)) + (Part I, item (2) + (3 - 4))[1] - (Part B, item (1) + Part C, items (2) + (3 - 4))[1]. This should be accumulated by year.

(d) Column (d) = Column (b) - Column (c).

(e) Column (e) = Part L, item (2)(a).

(f) Column (f) = Column (e) - Column (d).

(g) SPB = year in which Column (f) changes from positive to negative.

---

[1] Items 3 and 4 of Parts C and I refer to nonannually recurring costs which only have to be included in those years that they occur.

M. Simple Payback (SPB)

(1) Calculating SPB when annual cash flows are uniform.

(a) Adjusted Investment Cost With Solar	(b) Base-Year Fuel Cost Savings With Solar	(c) Change in Base Year (Nonfuel O&M Costs With Solar	(d) Net Yearly Savings	(e) SPB (Years)
$ ______	$ ______	$ ______	$ ______	______

(2) Calculating SPB when annual cash flows are not uniform.

(a) CUMULATIVE YEAR	(b) CUMULATIVE ENERGY SAVINGS	(c) CUMULATIVE CHANGE IN NONFUEL O&M, REPLACEMENT, AND SALVAGE VALUE WITH SOLAR	(d) CUMULATIVE SAVINGS	(e) INVESTMENT COST WITH SOLAR	(f) INVESTMENT COST MINUS CUMULATIVE SAVINGS	(g) SPB (YEAR)

APPENDIX E

COMPUTER PROGRAM FOR MAKING LCC EVALUATIONS OF ENERGY CONSERVATION AND SOLAR ENERGY INVESTMENTS IN NEW AND EXISTING FEDERAL BUILDINGS plus Sample Problems*

This program performs the following calculations:

SIR for Evaluating Retrofit Energy Conservation Projects
TLCC for Evaluating New Building Designs
NS for Designing and Sizing Projects
NS for Evaluating a Solar Demonstration Project
SIR for Ranking a Solar Demonstration Project
SPB for Evaluating a Solar Demonstration Project

* Program is written in BASIC Language. (See BASIC Language, Time-Sharing Program System (TSPS), Manual #BR03, Honeywell Series 400- Software, Honeywell Information Systems, Wellesley Hills, Massachusetts, 1971.)

LCCEO2

```
10 DIM A(2),C(3),D(30),E(30),G(30),H(30)
20 DIM F(3,6),I(2,3),T(3,6)
30 DIM S(2,30)
40 DIM B$(2)
50 DIM P(6),M(2),R(2)
60 DIM Z(2,10),U$(8), E$(8)
70 REM: SINGLE PRESENT WORTH DISCOUNT FORMULA
80 DEF FNP(X,Z)=1/(1+X)^Z
90 REM: MODIFIED UNIFORM PRESENT WORTH DISCOUNT FORMULA
100 DEF FNU(X,Y,Z)=(1+Y)/(X-Y)*(1-((1+Y)/(1+X))^Z)
110:'CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
120 X$="IDENTIFYING INFORMATION"
130 PRINT USING 110,X$
140 PRINT
150 PRINT "INPUT NAME OF AGENCY"
160 INPUT Q$(1)
170 PRINT "INPUT PROJECT NAME"
180 INPUT Q$(2)
190 PRINT "INPUT LOCATION OF AGENCY"
200 INPUT Q$(3)
210 PRINT "TYPE 1 IF THIS IS A SOLAR ENERGY INVESTMENT ANALYSIS, 0 IF NOT"
220 INPUT S1
230 IF S1=0 THEN 280
240 B$(1)="SOLAR ENERGY"
250 B$(2)="CONVENTIONAL"
260 Q=1
270 GOTO 350
280 PRINT "TYPE 1 IF PROJECT IS FOR AN EXISTING BUILDING, 0 IF IT IS FOR A"
290 PRINT "NEW BUILDING"
300 INPUT Q
310 B$(1)="RETROFIT"
320 B$(2)="EXISTING"
330 IF Q=1 THEN 350
340 B$(1)="NEW"
350 PRINT "INPUT GROSS FLOOR AREA AFFECTED"
360 INPUT Q$(4)
370 PRINT "INPUT EXPECTED LIFE OF SYSTEM"
380 INPUT N1
390 PRINT "INPUT EXPECTED LIFE OF BUILDING"
400 INPUT Q$(5)
410 PRINT "INPUT STUDY PERIOD"
420 INPUT N2
430 PRINT "TYPE 1 IF THIS ANALYSIS IS FOR A MORE COMPLEX CASE (I.E. A"
440 PRINT "CHANGING AMOUNT OF ANNUAL ENERGY USAGE AND/OR A CONVERSION TO AN"
450 PRINT "ALTERNATE FUEL TYPE DURING STUDY PERIOD), 0 IF FOR A SIMPLER CASE"
460 INPUT C
470 IF C=1 THEN 500
480 Q1=0
490 Q2=0
500 REM: DISCOUNT RATE ASSUMED TO BE 7 PERCENT
```

LCCEO2 CONTINUED

```
510 D=.07
520 PRINT
530 PRINT
540 W$="SYSTEM INFORMATION"
550 PRINT USING 110,B$(Q+1)
560 PRINT USING 110,W$
570 PRINT
580 PRINT
590 PRINT "- ENERGY COSTS FOR "B$(Q+1)" SYSTEM -"
600 IF Q=1 THEN 720
610 REM : Q=1 IMPLIES FIRST STAGE OF ANALYSIS
620 IF Q7=1 THEN 720
630 IF Q6=1 THEN 650
640 IF A(2)=0 THEN 720
650 PRINT
660 REM : DO NOT NEED TO RETYPE FUEL PRICE INFORMATION IF IT IS THE SAME
670 PRINT "TYPE 1 IF ENERGY TYPES, PRICES AND ESCALATION RATES ARE EXACTLY"
680 PRINT "THE SAME FOR THIS PART OF ANALYSIS, OTHERWISE TYPE 0"
690 INPUT Q4
700 IF Q4=0 THEN 720
710 GOTO 780
720 PRINT
730 Q4=0
740 PRINT "INPUT NUMBER OF ENERGY TYPES USED BY SYSTEM AT BEGINNING"
750 PRINT "OF STUDY PERIOD"
760 INPUT N4
770 PRINT
780 FOR J=1 TO N4
790 IF Q4=0 THEN 820
800 IF Q2=1 THEN 1320
810 GOTO 1550
820 PRINT "INPUT ENERGY TYPE #"J" AND UNIT (EXAMPLE: ELECTRICITY,MBTU)"
830 INPUT E$(J),U$(J)
840 PRINT "INPUT LOCAL PRICE PER "U$(J)
850 INPUT P(J)
860 REM: ASSUME 3 FUEL PRICE ESCALATION PERIODS
870 N8=3
880 T3=0
890 FOR K=1 TO N8
900 IF K>1 THEN 950
910 PRINT "FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),"
920 PRINT "INPUT THE "E$(J)" ESCALATION RATE FOR PERIOD "K" AND"
930 PRINT "NUMBER OF YEARS IT IS TO BE APPLIED"
940 GOTO 960
950 PRINT "FOR PERIOD "K;
960 INPUT F(K,J),T(K,J)
970 T3=T3+T(K,J)
980 NEXT K
990 REM: THE ESCALATION RATE OF THE THIRD PERIOD WILL BE APPLIED TO ANY
1000 REM: REMAINING YEARS OF THE STUDY PERIOD THAT EXTEND BEYOND THE LENGTH OF
```

```
1010 REM: THE THREE TIME PERIODS COMBINED
1020 IF T3>=N2 THEN 1050
1030 T(N8,J)=T(N8,J)+(N2-T3)
1040 REM : IF THIS IS SIMPLE CASE, GO TO INPUT OF AMOUNT OF ENERGY USED
1050 IF C=0 THEN 1550
1060 PRINT "TYPE 1 IF THERE WILL BE A CONVERSION TO A DIFFERENT FUEL TYPE"
1070 PRINT "SOMETIME DURING THE STUDY PERIOD, 0 IF NOT"
1080 INPUT Q1
1090 IF Q1=0 THEN 1320
1100 REM : Q7 IS FLAG TO INDICATE THAT AT LEAST ONE CONVERSION HAS
1110 REM :  TAKEN PLACE IN THE ANALYSIS
1120 Q7=1
1130 PRINT "INPUT YEAR IN WHICH THIS CONVERSION WILL TAKE PLACE"
1140 PRINT " (ASSUMES BEGINNING OF YEAR)"
1150 INPUT T1
1160 PRINT "INPUT NEW ENERGY TYPE AND UNIT"
1170 INPUT C$,D$
1180 PRINT "INPUT PRESENT LOCAL PRICE PER "D$
1190 INPUT C1
1200 FOR I=1 TO N8
1210 IF I>1 THEN 1260
1220 PRINT "FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),"
1230 PRINT "INPUT THE "C$" ESCALATION RATE FOR PERIOD "I" AND"
1240 PRINT "NUMBER OF YEARS IT IS TO BE APPLIED"
1250 GOTO 1270
1260 PRINT "FOR PERIOD "I;
1270 INPUT C(I),U(I)
1280 NEXT I
1290 U(N8)=N2
1300 Q2=0
1310 GOTO 1420
1320 PRINT "TYPE 1 IF ANALYSIS ASSUMES A CHANGING ANNUAL AMOUNT OF "E$(J)
1330 PRINT "USED, 0 IF AMOUNT REMAINS CONSTANT OVER LIFE OF THE SYSTEM"
1340 INPUT Q2
1350 IF Q2=0 THEN 1550
1360 PRINT "TYPE 1 IF THE CHANGE IS A PERIODIC ONE (I.E. CAN BE SPECIFIED"
1370 PRINT "AS A PERCENTAGE CHANGE EVERY N YEARS), 0 IF NOT"
1380 INPUT Q3
1390 REM : IF NOT A % CHANGE, MUST INPUT AMOUNT OF ENERGY USED EACH YEAR
1400 REM :  OF STUDY PERIOD
1410 IF Q3=1 THEN 1580
1420 PRINT "INPUT AMOUNT OF ENERGY USED IN EACH YEAR"
1430 FOR K=1 TO N2
1440 REM : WHEN A CONVERSION TAKES PLACE, PUT NEW VALUES INTO OLD VARIABLES
1450 IF Q1=0 THEN 1490
1460 IF K<>T1 THEN 1490
1470 E$(J)=C$
1480 U$(J)=D$
1490 PRINT "AMOUNT OF "E$(J)" ("U$(J)"S) YEAR "K;
1500 INPUT D(K)
```

LCCEO2 CONTINUED

```
1510 NEXT K
1520 DØ=D(1)
1530 GOTO 1730
1540 REM : INPUT % CHANGE IN ENERGY USE OR Ø FOR NO CHANGE
1550 C2=Ø.Ø
1560 C3=1
1570 GOTO 1620
1580 PRINT "INPUT PERCENT THAT ANNUAL AMOUNT OF "E$(J)" IS TO CHANGE AND "
1590 PRINT "HOW OFTEN IT WILL CHANGE (EXAMPLE: IF ENERGY USED WILL"
1600 PRINT "INCREASE AT A RATE OF 1% EVERY 2ND YEAR, TYPE: .Ø1,2)"
1610 INPUT C2,C3
1620 PRINT "INPUT ANNUAL AMOUNT OF "E$(J)" ("U$(J)"S) USED IN BASE YEAR BY"
1630 PRINT B$(Q+1)" SYSTEM"
1640 INPUT DØ
1650 REM : ADJUST ANNUAL AMOUNT IF NECESSARY - FILL D ARRAY
1660 D(1)=DØ
1670 FOR I=2 TO N2
1680 IF (I-1)/C3=INT((I-1)/C3) THEN 1710
1690 D(I)=D(I-1)
1700 GOTO 1720
1710 D(I)=D(I-1)*(1+C2)
1720 NEXT I
1730 REM : MUST CONVERT TO PRESENT VALUE ENERGY COSTS
1740 REM
1750 REM : ASSUME THAT THE TIME PERIODS FOR FPE RATES ARE THE SAME FOR
1760 REM :  EACH FUEL TYPE
1770 K2=1
1780 T2=T(1,J)
1790 FOR K=1 TO N2
1800 IF K<=T2 THEN 1840
1810 IF K2=N8 THEN 1970
1820 K2=K2+1
1830 T2=T2+T(K2,J)
1840 IF Q1=Ø THEN 1950
1850 IF K=T1 THEN 1900
1860 REM : C1 USED TO ESCALATE PRICE OF NEW ENERGY TYPE TO YEAR IT
1870 REM :  WILL FIRST BE USED
1880 C1=C1*(1+C(K2))
1890 GOTO 1950
1900 FOR I=1 TO N8
1910 T(I,J)=U(I)
1920 F(I,J)=C(I)
1930 NEXT I
1940 C5=C1
1950 G(K)=F(K2,J)+1
1960 NEXT K
1970 REM : NOW HAVE G ARRAY FILLED WITH FPE RATE FOR EACH YEAR
1980 HØ=P(J)
1990 FOR I=1 TO N2
2000 IF Q1=Ø THEN 2030
```

```
2010 IF I<>T1 THEN 2030
2020 H(I-1)=C5
2030 IF I=1 THEN 2060
2040 H(I)=H(I-1)*G(I)
2050 GOTO 2080
2060 H(I)=H0*G(I)
2070 REM : H ARRAY IS FOR YEARLY PRICE OF ENERGY (END OF YEAR)
2080 E(I)=D(I)*H(I)*FNP(D,I)
2090 Z(Q+1,J)=Z(Q+1,J)+E(I)
2100 S(Q+1,I)=S(Q+1,I)+(D(I)*P(J))
2110 NEXT I
2120 REM : E ARRAY IS FOR YEARLY PRESENT VALUE ENERGY COSTS
2130 A(Q+1)=A(Q+1)+Z(Q+1,J)
2140 REM NOW DO NEXT FUEL TYPE
2150 PRINT
2160 PRINT
2170 NEXT J
2180 PRINT
2190 PRINT
2200 PRINT "- INVESTMENT COST FOR "B$(Q+1)" SYSTEM -"
2210 PRINT
2220 PRINT "INPUT INITIAL INVESTMENT COST (BASE YEAR)"
2230 IF Q=0 THEN 2260
2240 PRINT "EQUAL TO THE SYSTEM´S CURRENT SALVAGE VALUE FOR THE EXISTING SYS."
2250 GOTO 2290
2260 PRINT "THE SOCIAL ADJUSTMENT FACTOR APPLIED TO INVESTMENT"
2270 PRINT "COST IS SET AT 10 PERCENT RESULTING IN A MULTIPLIER"
2280 PRINT "OF .9"
2290 INPUT I(Q+1,1)
2300 IF Q<>0 THEN 2330
2310 REM : 10% REDUCTION IN INITIAL INVESTMENT COST FOR NEW SYSTEM
2320 I(Q+1,1)=.9*I(Q+1,1)
2330 PRINT
2340 PRINT "TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE"
2350 PRINT "CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS"
2360 INPUT O1
2370 PRINT
2380 IF O1=0 THEN 2440
2390 R(Q+1)=0
2400 M(Q+1)=0
2410 I(Q+1,2)=0
2420 I(Q+1,3)=0
2430 GOTO 2870
2440 PRINT
2450 PRINT
2460 B$=B$(Q+1)
2470 PRINT "- NON-FUEL OPERATION AND MAINTENANCE (O+M) COSTS FOR "B$" SYSTEM -"
2480 PRINT
2490 PRINT "INPUT BASE-YEAR ANNUAL RECURRING O+M COST "
2500 INPUT R(Q+1)
```

```
2510 FOR I=1 TO N2
2520 S(Q+1,I)=S(Q+1,I)+R(Q+1)
2530 NEXT I
2540 R(Q+1)=R(Q+1)*FNU(D,Ø,N2)
2550 PRINT
2560 PRINT "INPUT TOTAL NUMBER OF NON-RECURRING O+M COSTS"
2570 INPUT N7
2580 IF N7=Ø THEN 268Ø
2590 FOR K=1 TO N7
2600 IF K>1 THEN 262Ø
2610 PRINT "INPUT AMOUNT OF COST (BASE YEAR $) AND YEAR OF OCCURRENCE FOR"
2620 PRINT "NON-RECURRING O+M COST "K;
2630 INPUT M1,M2
2640 S(Q+1,M2)=S(Q+1,M2)+M1
2650 M3=M1*FNP(D,M2)
2660 M(Q+1)=M(Q+1)+M3
2670 NEXT K
2680 PRINT
2690 PRINT
2700 PRINT "- REPLACEMENT COSTS AND SALVAGE VALUES FOR "B$(Q+1)" SYSTEM -"
2710 PRINT
2720 PRINT "INPUT NUMBER OF REPLACEMENT COSTS"
2730 INPUT N5
2740 FOR K=1 TO N5
2750 PRINT "INPUT BASE-YEAR COST OF REPLACEMENT "K" AND YEAR IT"
2760 PRINT "IS TO BE INCURRED"
2770 INPUT I1,I2
2780 PRINT "INPUT SALVAGE VALUE OF EQUIPMENT BEING REPLACED (BASE YEAR $)"
2790 INPUT I3
2800 S(Q+1,I2)=S(Q+1,I2)+I1-I3
2810 I4=I1*FNP(D,I2)
2820 I5=I3*FNP(D,I2)
2830 I(Q+1,2)=I(Q+1,2)+I4
2840 I(Q+1,3)=I(Q+1,3)+I5
2850 PRINT
2860 NEXT K
2870 PRINT "INPUT FINAL SALVAGE VALUE OF SYSTEM"
2880 INPUT I6
2890 S(Q+1,N2)=S(Q+1,N2)-I6
2900 I(Q+1,3)=I(Q+1,3)+I6*FNP(D,N2)
2910 REM
2920 REM : CALCULATE LIFE-CYCLE COSTS
2930 Z=Q+1
2940 L(Z)=A(Z)+I(Z,1)+R(Z)+M(Z)+I(Z,2)-I(Z,3)
2950 REM : NOW DO RETROFIT SYSTEM IF NECESSARY
2960 IF Q=Ø THEN 299Ø
2970 Q=Ø
2980 GOTO 52Ø
2990 REM : CALCULATE NEW COSTS IF NECESSARY
3000 IF A(2)=Ø THEN 32ØØ
```

```
3010 REM: D9 IS THE SIR DENOMINATOR
3020 N(1)=I(1,1)-I(2,1)
3030 N(2)=I(1,2)-I(2,2)
3040 N(3)=I(1,3)-I(2,3)
3050 D9=N(1)+N(2)-N(3)
3060 REM: N9 IS THE SIR NUMERATOR
3070 N(4)=A(2)-A(1)
3080 N(5)=R(2)-R(1)
3090 N(6)=M(2)-M(1)
3100 N9=N(4)+N(5)+N(6)
3110 REM : IF INVESTMENT COSTS ARE THE SAME, SET SIR = 0
3120 IF D9<>0 THEN 3150
3130 S9=0
3140 GOTO 3160
3150 S9=N9/D9
3160 GOTO 3180
3170 REM : OUTPUT RESULTS
3180 PRINT
3190:-------------------------------------------------------------------------------
3200 PRINT USING 3190
3210 PRINT
3220 PRINT "                          PROJECT SUMMARY REPORT"
3230 PRINT USING 3190
3240 PRINT USING 3190
3250 PRINT
3260 PRINT "       NAME OF AGENCY                              "Q$(1)
3270 PRINT
3280 PRINT "       PROJECT                                     "Q$(2)
3290 PRINT
3300 PRINT "       LOCATION OF AGENCY                          "Q$(3)
3310 PRINT
3320 PRINT "       GROSS FLOOR AREA AFFECTED                   "Q$(4)
3330 PRINT
3340 PRINT "       EXPECTED LIFE OF SYSTEM                    "N1" YEARS"
3350 PRINT
3360 PRINT "       EXPECTED LIFE OF BUILDING                   "Q$(5)"  YEARS"
3370 PRINT
3380 PRINT "       STUDY PERIOD                               "N2" YEARS"
3390 PRINT
3400 D8=D*100
3410 PRINT "       DISCOUNT RATE                              "D8" PERCENT"
3420 PRINT
3430 PRINT "       NUMBER OF ESCALATION PERIODS               "N8
3440 PRINT
3450 PRINT USING 3190
3460 PRINT
3470 PRINT "                                                 (IN THOUSANDS $)"
3480 PRINT
3490 IF A(2)=0 THEN 3530
3500 A(2)=A(2)/1000
```

```
3510 PRINT USING 3640
3520 PRINT USING 3650,B$(2),A(2)
3530 PRINT
3540 A(1)=A(1)/1000
3550 PRINT USING 3640
3560 PRINT USING 3650,B$(1),A(1)
3570 PRINT
3580 PRINT
3590 IF A(2)=0 THEN 3680
3600 L(2)=L(2)/1000
3610 PRINT USING 3660
3620 PRINT USING 3670,B$(2),L(2)
3630 PRINT
3640:          PRESENT VALUE ENERGY COSTS -
3650:           'RRRRRRRRRRRRRRRR SYSTEM          #########.##
3660:          TOTAL LIFE-CYCLE COSTS-
3670:           'RRRRRRRRRRRRRRRR SYSTEM          #########.##
3680 L(1)=L(1)/1000
3690 PRINT USING 3660
3700 PRINT USING 3670,B$(1),L(1)
3710 PRINT
3720 IF A(2)=0 THEN 3980
3730 V$="*     *     *     *     *"
3740 PRINT USING 110,V$
3750 PRINT
3760 V9=L(2)-L(1)
3770 PRINT USING 3910,V9
3780 PRINT
3790 PRINT USING 3920,S9
3800 PRINT
3810 IF S1=0 THEN 3980
3820 S3=0
3830 FOR I=1 TO N2
3840 S3=S3+(S(2,I)-S(1,I))
3850 IF S3<I(1,1)-I(2,1) THEN 3880
3860 P9=I
3870 GOTO 3900
3880 NEXT I
3890 GOTO 3950
3900 PRINT USING 3930,P9
3910:              NET PRESENT VALUE (TH. $)   ########.##
3920:              SAVINGS-TO-INVESTMENT RATIO      ###.#####
3930:              SIMPLE PAYBACK                    ##   YEARS
3940 GOTO 3980
3950 PRINT "              SIMPLE PAYBACK > STUDY PERIOD"
3960 PRINT
3970 PRINT
3980 PRINT USING 3190
3990 PRINT
4000 PRINT "TYPE 1 IF YOU WISH TO LOOK AT ANOTHER "B$(Q+1)" SYSTEM, 0 IF NOT"
```

LCCEO2 CONTINUED

```
4010 INPUT Q6
4020 IF Q6=0 THEN 4180
4030 I(1,2)=0
4040 I(1,3)=0
4050 M(1)=0
4060 A(1)=0
4070 A(2)=A(2)*1000
4080 L(2)=L(2)*1000
4090 FOR I=1 TO N2
4100 S(1,I)=0
4110 NEXT I
4120 FOR J=1 TO 10
4130 Z(1,J)=0
4140 NEXT J
4150 PRINT "INPUT NEW PROJECT NAME"
4160 INPUT Q$(2)
4170 GOTO 530
4180 END
```

SAMPLE RETROFIT PROBLEM #1*

IDENTIFYING INFORMATION

```
INPUT NAME OF AGENCY
 ? FEDERAL SCIENCE AGENCY
INPUT PROJECT NAME
 ? INSULATION OF WATER PIPES
INPUT LOCATION OF AGENCY
 ? MASSACHUSETTS
TYPE 1 IF THIS IS A SOLAR ENERGY INVESTMENT ANALYSIS, 0 IF NOT
 ? 0
TYPE 1 IF PROJECT IS FOR AN EXISTING BUILDING, 0 IF IT IS FOR A
NEW BUILDING
 ? 1
INPUT GROSS FLOOR AREA AFFECTED
 ? NOT APPLICABLE
INPUT EXPECTED LIFE OF SYSTEM
 ? 25
INPUT EXPECTED LIFE OF BUILDING
 ? INDEFINITE
INPUT STUDY PERIOD
 ? 25
TYPE 1 IF THIS ANALYSIS IS FOR A MORE COMPLEX CASE (I.E. A
CHANGING AMOUNT OF ANNUAL ENERGY USAGE AND/OR A CONVERSION TO AN
ALTERNATE FUEL TYPE DURING STUDY PERIOD), 0 IF FOR A SIMPLER CASE
 ? 0
```

EXISTING SYSTEM INFORMATION

```
- ENERGY COSTS FOR EXISTING SYSTEM -

INPUT NUMBER OF ENERGY TYPES USED BY SYSTEM AT BEGINNING
OF STUDY PERIOD
 ? 1

INPUT ENERGY TYPE # 1  AND UNIT (EXAMPLE: ELECTRICITY,MBTU)
 ? OIL,MBTU
INPUT LOCAL PRICE PER MBTU
 ? 6.94
FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),
INPUT THE OIL ESCALATION RATE FOR PERIOD  1  AND
NUMBER OF YEARS IT IS TO BE APPLIED
 ? .0339,5
FOR PERIOD  2  ? .0291,5
FOR PERIOD  3  ? .0408,15
INPUT ANNUAL AMOUNT OF OIL (MBTUS) USED IN BASE YEAR BY
EXISTING SYSTEM
 ? 283.6
```

* See Chapter 4 for a more detailed problem statement and a manual solution using the Retrofit Worksheets. (Note: Small discrepancies may exist between the problem solutions obtained by the computer program and those obtained by the Worksheet approach due to rounding errors.

```
- INVESTMENT COST FOR EXISTING SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
EQUAL TO THE SYSTEM'S CURRENT SALVAGE VALUE FOR THE EXISTING SYS.
 ? 0

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 1

INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0

                                RETROFIT
                           SYSTEM INFORMATION

- ENERGY COSTS FOR RETROFIT SYSTEM -

TYPE 1 IF ENERGY TYPES, PRICES AND ESCALATION RATES ARE EXACTLY
THE SAME FOR THIS PART OF ANALYSIS, OTHERWISE TYPE 0
 ? 1
INPUT ANNUAL AMOUNT OF OIL (MBTUS) USED IN BASE YEAR BY
RETROFIT SYSTEM
 ? 37.8

- INVESTMENT COST FOR RETROFIT SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
THE SOCIAL ADJUSTMENT FACTOR APPLIED TO INVESTMENT
COST IS SET AT 10 PERCENT RESULTING IN A MULTIPLIER
OF .9
 ? 2500

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 1

INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0
```

PROJECT SUMMARY REPORT

NAME OF AGENCY	FEDERAL SCIENCE AGENCY
PROJECT	INSULATION OF WATER PIPES
LOCATION OF AGENCY	MASSACHUSETTS
GROSS FLOOR AREA AFFECTED	NOT APPLICABLE
EXPECTED LIFE OF SYSTEM	25 YEARS
EXPECTED LIFE OF BUILDING	INDEFINITE YEARS
STUDY PERIOD	25 YEARS
DISCOUNT RATE	7. PERCENT
NUMBER OF ESCALATION PERIODS	3

	(IN THOUSANDS $)
PRESENT VALUE ENERGY COSTS - EXISTING SYSTEM	32.77
PRESENT VALUE ENERGY COSTS - RETROFIT SYSTEM	4.37
TOTAL LIFE-CYCLE COSTS- EXISTING SYSTEM	32.79
TOTAL LIFE-CYCLE COSTS- RETROFIT SYSTEM	6.62

* * * * *

NET PRESENT VALUE (TH. $)	26.17
SAVINGS-TO-INVESTMENT RATIO	12.63190

SAMPLE RETROFIT PROBLEM #2*

IDENTIFYING INFORMATION

```
INPUT NAME OF AGENCY
 ? NATIONAL ADMINISTRATION
INPUT PROJECT NAME
 ? AUTOMATIC CONTROL SYSTEM
INPUT LOCATION OF AGENCY
 ? DC
TYPE 1 IF THIS IS A SOLAR ENERGY INVESTMENT ANALYSIS, 0 IF NOT
 ? 0
TYPE 1 IF PROJECT IS FOR AN EXISTING BUILDING, 0 IF IT IS FOR A
NEW BUILDING
 ? 1
INPUT GROSS FLOOR AREA AFFECTED
 ? NOT APPLICABLE
INPUT EXPECTED LIFE OF SYSTEM
 ? 25
INPUT EXPECTED LIFE OF BUILDING
 ? INDEFINITE
INPUT STUDY PERIOD
 ? 25
TYPE 1 IF THIS ANALYSIS IS FOR A MORE COMPLEX CASE (I.E. A
CHANGING AMOUNT OF ANNUAL ENERGY USAGE AND/OR A CONVERSION TO AN
ALTERNATE FUEL TYPE DURING STUDY PERIOD), 0 IF FOR A SIMPLER CASE
 ? 0
```

EXISTING
SYSTEM INFORMATION

```
- ENERGY COSTS FOR EXISTING SYSTEM -

INPUT NUMBER OF ENERGY TYPES USED BY SYSTEM AT BEGINNING
OF STUDY PERIOD
 ? 2

INPUT ENERGY TYPE # 1  AND UNIT (EXAMPLE: ELECTRICITY,MBTU)
 ? ELECTRICITY, KWH
INPUT LOCAL PRICE PER  KWH
 ? .063
FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),
INPUT THE ELECTRICITY ESCALATION RATE FOR PERIOD  1  AND
NUMBER OF YEARS IT IS TO BE APPLIED
 ? -.0001,5
FOR PERIOD  2  ? .0089,5
FOR PERIOD  3  ? -.0037,15
INPUT ANNUAL AMOUNT OF ELECTRICITY ( KWHS) USED IN BASE YEAR BY
EXISTING SYSTEM
 ? 9982200


INPUT ENERGY TYPE # 2  AND UNIT (EXAMPLE: ELECTRICITY,MBTU)
 ? NATURAL GAS, MBTU
INPUT LOCAL PRICE PER  MBTU
 ? 3.43
FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),
INPUT THE NATURAL GAS ESCALATION RATE FOR PERIOD  1  AND
NUMBER OF YEARS IT IS TO BE APPLIED
 ? .0175,5
FOR PERIOD  2  ? .0360,5
FOR PERIOD  3  ? .0180,15
INPUT ANNUAL AMOUNT OF NATURAL GAS ( MBTUS) USED IN BASE YEAR BY
EXISTING SYSTEM
 ? 433600
```

* See chapter 4 for a more detailed problem statement and a manual solution using the New Building Design Worksheets.

```
- INVESTMENT COST FOR EXISTING SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
EQUAL TO THE SYSTEM´S CURRENT SALVAGE VALUE FOR THE EXISTING SYS.
 ? 260000

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 0


- NON-FUEL OPERATION AND MAINTENANCE (O+M) COSTS FOR EXISTING SYSTEM -

INPUT BASE-YEAR ANNUAL RECURRING O+M COST
 ? 120000

INPUT TOTAL NUMBER OF NON-RECURRING O+M COSTS
 ? 3
INPUT AMOUNT OF COST (BASE YEAR $) AND YEAR OF OCCURRENCE FOR
NON-RECURRING O+M COST  1  ? 25000, 5
NON-RECURRING O+M COST  2  ? 25000, 15
NON-RECURRING O+M COST  3  ? 25000, 20


- REPLACEMENT COSTS AND SALVAGE VALUES FOR EXISTING SYSTEM -

INPUT NUMBER OF REPLACEMENT COSTS
 ? 1
INPUT BASE-YEAR COST OF REPLACEMENT  1  AND YEAR IT
IS TO BE INCURRED
 ? 150000, 10
INPUT SALVAGE VALUE OF EQUIPMENT BEING REPLACED (BASE YEAR $)
 ? 0

INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0
```

```
                              RETROFIT
                         SYSTEM INFORMATION

- ENERGY COSTS FOR RETROFIT SYSTEM -

TYPE 1 IF ENERGY TYPES, PRICES AND ESCALATION RATES ARE EXACTLY
THE SAME FOR THIS PART OF ANALYSIS, OTHERWISE TYPE 0
 ? 1
INPUT ANNUAL AMOUNT OF ELECTRICITY ( KWHS) USED IN BASE YEAR BY
RETROFIT SYSTEM
 ? 9190000


INPUT ANNUAL AMOUNT OF NATURAL GAS ( MBTUS) USED IN BASE YEAR BY
RETROFIT SYSTEM
 ? 386800



- INVESTMENT COST FOR RETROFIT SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
THE SOCIAL ADJUSTMENT FACTOR APPLIED TO INVESTMENT
COST IS SET AT 10 PERCENT RESULTING IN A MULTIPLIER
OF .9
 ? 1500000

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 0



- NON-FUEL OPERATION AND MAINTENANCE (O+M) COSTS FOR RETROFIT SYSTEM -

INPUT BASE-YEAR ANNUAL RECURRING O+M COST
 ? 145000

INPUT TOTAL NUMBER OF NON-RECURRING O+M COSTS
 ? 2
INPUT AMOUNT OF COST (BASE YEAR $) AND YEAR OF OCCURRENCE FOR
NON-RECURRING O+M COST  1  ? 40000, 10
NON-RECURRING O+M COST  2  ? 40000, 20


- REPLACEMENT COSTS AND SALVAGE VALUES FOR RETROFIT SYSTEM -

INPUT NUMBER OF REPLACEMENT COSTS
 ? 0
INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0
```

PROJECT SUMMARY REPORT

NAME OF AGENCY	NATIONAL ADMINISTRATION
PROJECT	AUTOMATIC CONTROL SYSTEM
LOCATION OF AGENCY	DC
GROSS FLOOR AREA AFFECTED	NOT APPLICABLE
EXPECTED LIFE OF SYSTEM	25 YEARS
EXPECTED LIFE OF BUILDING	INDEFINITE YEARS
STUDY PERIOD	25 YEARS
DISCOUNT RATE	7. PERCENT
NUMBER OF ESCALATION PERIODS	3

	(IN THOUSANDS $)
PRESENT VALUE ENERGY COSTS - EXISTING SYSTEM	29234.43
PRESENT VALUE ENERGY COSTS - RETROFIT SYSTEM	26291.34
TOTAL LIFE-CYCLE COSTS- EXISTING SYSTEM	31002.46
TOTAL LIFE-CYCLE COSTS- RETROFIT SYSTEM	29361.78

*   *   *   *   *

NET PRESENT VALUE (TH. $)	1640.68
SAVINGS-TO-INVESTMENT RATIO	2.61843

SAMPLE NEW BUILDING DESIGN PROBLEM*

IDENTIFYING INFORMATION

```
INPUT NAME OF AGENCY
 ? NATIONAL DEFENSE
INPUT PROJECT NAME
 ? CONVENTIONAL DESIGN
INPUT LOCATION OF AGENCY
 ? WISCONSIN
TYPE 1 IF THIS IS A SOLAR ENERGY INVESTMENT ANALYSIS, 0 IF NOT
 ? 0
TYPE 1 IF PROJECT IS FOR AN EXISTING BUILDING, 0 IF IT IS FOR A
NEW BUILDING
 ? 0
INPUT GROSS FLOOR AREA AFFECTED
 ? 176000 SQUARE FEET
INPUT EXPECTED LIFE OF SYSTEM
 ? 25
INPUT EXPECTED LIFE OF BUILDING
 ? INDEFINITE
INPUT STUDY PERIOD
 ? 25
TYPE 1 IF THIS ANALYSIS IS FOR A MORE COMPLEX CASE (I.E. A
CHANGING AMOUNT OF ANNUAL ENERGY USAGE AND/OR A CONVERSION TO AN
ALTERNATE FUEL TYPE DURING STUDY PERIOD), 0 IF FOR A SIMPLER CASE
 ? 0
```

NEW
SYSTEM INFORMATION

```
- ENERGY COSTS FOR NEW SYSTEM -

INPUT NUMBER OF ENERGY TYPES USED BY SYSTEM AT BEGINNING
OF STUDY PERIOD
 ? 2

INPUT ENERGY TYPE # 1  AND UNIT (EXAMPLE: ELECTRICITY,MBTU)
 ? ELECTRICITY, MBTU
INPUT LOCAL PRICE PER  MBTU
 ? 16.83
FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),
INPUT THE ELECTRICITY ESCALATION RATE FOR PERIOD  1  AND
NUMBER OF YEARS IT IS TO BE APPLIED
 ? -.0002, 5
FOR PERIOD  2  ? .0107, 5
FOR PERIOD  3  ? -.0014, 15
INPUT ANNUAL AMOUNT OF ELECTRICITY ( MBTUS) USED IN BASE YEAR BY
NEW SYSTEM
 ? 7277


INPUT ENERGY TYPE # 2  AND UNIT (EXAMPLE: ELECTRICITY,MBTU)
 ? NATURAL GAS, MBTU
INPUT LOCAL PRICE PER  MBTU
 ? 3.18
FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),
INPUT THE NATURAL GAS ESCALATION RATE FOR PERIOD  1  AND
NUMBER OF YEARS IT IS TO BE APPLIED
 ? .0174, 5
FOR PERIOD  2  ? .0315, 5
FOR PERIOD  3  ? .0111, 15
INPUT ANNUAL AMOUNT OF NATURAL GAS ( MBTUS) USED IN BASE YEAR BY
NEW SYSTEM
 ? 4980
```

* See chapter 5 for a more detailed problem statement and a manual solution using the New Building Design Worksheets.

```
- INVESTMENT COST FOR NEW SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
THE SOCIAL ADJUSTMENT FACTOR APPLIED TO INVESTMENT
COST IS SET AT 10 PERCENT RESULTING IN A MULTIPLIER
OF .9
 ? 9130000

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 0


- NON-FUEL OPERATION AND MAINTENANCE (O+M) COSTS FOR NEW SYSTEM -

INPUT BASE-YEAR ANNUAL RECURRING O+M COST
 ? 90000

INPUT TOTAL NUMBER OF NON-RECURRING O+M COSTS
 ? 2
INPUT AMOUNT OF COST (BASE YEAR $) AND YEAR OF OCCURRENCE FOR
NON-RECURRING O+M COST  1  ? 100000, 10
NON-RECURRING O+M COST  2  ? 100000, 20


- REPLACEMENT COSTS AND SALVAGE VALUES FOR NEW SYSTEM -

INPUT NUMBER OF REPLACEMENT COSTS
 ? 0
INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0
--------------------------------------------------------------------------

                         PROJECT SUMMARY REPORT
--------------------------------------------------------------------------
--------------------------------------------------------------------------

       NAME OF AGENCY                          NATIONAL DEFENSE

       PROJECT                                 CONVENTIONAL DESIGN

       LOCATION OF AGENCY                      WISCONSIN

       GROSS FLOOR AREA AFFECTED               176000 SQUARE FEET

       EXPECTED LIFE OF SYSTEM                 25   YEARS

       EXPECTED LIFE OF BUILDING               INDEFINITE  YEARS

       STUDY PERIOD                            25   YEARS

       DISCOUNT RATE                           7.   PERCENT

       NUMBER OF ESCALATION PERIODS            3

--------------------------------------------------------------------------

                                           (IN THOUSANDS $)


         PRESENT VALUE ENERGY COSTS -
                        NEW SYSTEM               1686.61


         TOTAL LIFE-CYCLE COSTS-
                        NEW SYSTEM              11029.11

--------------------------------------------------------------------------
```

```
TYPE 1 IF YOU WISH TO LOOK AT ANOTHER NEW SYSTEM, 0 IF NOT
 ? 1
INPUT NEW PROJECT NAME
 ? ENERGY-CONSERVING DESIGN

                              NEW
                       SYSTEM INFORMATION


- ENERGY COSTS FOR NEW SYSTEM -

TYPE 1 IF ENERGY TYPES, PRICES AND ESCALATION RATES ARE EXACTLY
THE SAME FOR THIS PART OF ANALYSIS, OTHERWISE TYPE 0
 ? 1
INPUT ANNUAL AMOUNT OF ELECTRICITY ( MBTUS) USED IN BASE YEAR BY
NEW SYSTEM
 ? 3886


INPUT ANNUAL AMOUNT OF NATURAL GAS ( MBTUS) USED IN BASE YEAR BY
NEW SYSTEM
 ? 2290



- INVESTMENT COST FOR NEW SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
THE SOCIAL ADJUSTMENT FACTOR APPLIED TO INVESTMENT
COST IS SET AT 10 PERCENT RESULTING IN A MULTIPLIER
OF .9
 ? 9880000

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 0


- NON-FUEL OPERATION AND MAINTENANCE (O+M) COSTS FOR NEW SYSTEM -

INPUT BASE-YEAR ANNUAL RECURRING O+M COST
 ? 70000

INPUT TOTAL NUMBER OF NON-RECURRING O+M COSTS
 ? 2
INPUT AMOUNT OF COST (BASE YEAR $) AND YEAR OF OCCURRENCE FOR
NON-RECURRING O+M COST  1  ? 60000, 10
NON-RECURRING O+M COST  2  ? 60000, 20


- REPLACEMENT COSTS AND SALVAGE VALUES FOR NEW SYSTEM -

INPUT NUMBER OF REPLACEMENT COSTS
 ? 0
INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0
```

PROJECT SUMMARY REPORT

NAME OF AGENCY	NATIONAL DEFENSE
PROJECT	ENERGY-CONSERVING DESIGN
LOCATION OF AGENCY	WISCONSIN
GROSS FLOOR AREA AFFECTED	176000 SQUARE FEET
EXPECTED LIFE OF SYSTEM	25 YEARS
EXPECTED LIFE OF BUILDING	INDEFINITE YEARS
STUDY PERIOD	25 YEARS
DISCOUNT RATE	7. PERCENT
NUMBER OF ESCALATION PERIODS	3

	(IN THOUSANDS $)
PRESENT VALUE ENERGY COSTS - NEW SYSTEM	884.04
TOTAL LIFE-CYCLE COSTS- NEW SYSTEM	10637.80

SAMPLE SOLAR ENERGY PROBLEM*

IDENTIFYING INFORMATION

```
INPUT NAME OF AGENCY
 ? FEDERAL AGENCY X
INPUT PROJECT NAME
 ? SOLAR HEATING RETROFIT
INPUT LOCATION OF AGENCY
 ? ARIZONA
TYPE 1 IF THIS IS A SOLAR ENERGY INVESTMENT ANALYSIS, 0 IF NOT
 ? 1
INPUT GROSS FLOOR AREA AFFECTED
 ? NOT APPLICABLE
INPUT EXPECTED LIFE OF SYSTEM
 ? 20
INPUT EXPECTED LIFE OF BUILDING
 ? INDEFINITE
INPUT STUDY PERIOD
 ? 20
TYPE 1 IF THIS ANALYSIS IS FOR A MORE COMPLEX CASE (I.E. A
CHANGING AMOUNT OF ANNUAL ENERGY USAGE AND/OR A CONVERSION TO AN
ALTERNATE FUEL TYPE DURING STUDY PERIOD), 0 IF FOR A SIMPLER CASE
 ? 0
```

CONVENTIONAL
SYSTEM INFORMATION

```
- ENERGY COSTS FOR CONVENTIONAL SYSTEM -

INPUT NUMBER OF ENERGY TYPES USED BY SYSTEM AT BEGINNING
OF STUDY PERIOD
 ? 1

INPUT ENERGY TYPE # 1  AND UNIT (EXAMPLE: ELECTRICITY,MBTU)
 ? OIL,MBTU
INPUT LOCAL PRICE PER MBTU
 ? 6.55
FOR THREE ESCALATION PERIODS (1980-85, 1985-90, 1990+BEYOND),
INPUT THE OIL ESCALATION RATE FOR PERIOD  1  AND
NUMBER OF YEARS IT IS TO BE APPLIED
 ? .0338,5
FOR PERIOD  2  ? .0309,5
FOR PERIOD  3  ? .0427,10
INPUT ANNUAL AMOUNT OF OIL (MBTUS) USED IN BASE YEAR BY
CONVENTIONAL SYSTEM
 ? 833.33



- INVESTMENT COST FOR CONVENTIONAL SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
EQUAL TO THE SYSTEM'S CURRENT SALVAGE VALUE FOR THE EXISTING SYS.
 ? 0

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
 ? 1

INPUT FINAL SALVAGE VALUE OF SYSTEM
 ? 0
```

* See chapter 7 for a more detailed statement of the problem and a manual solution using the SFBP Form A-2.

SOLAR ENERGY
SYSTEM INFORMATION

- ENERGY COSTS FOR SOLAR ENERGY SYSTEM -

TYPE 1 IF ENERGY TYPES, PRICES AND ESCALATION RATES ARE EXACTLY
THE SAME FOR THIS PART OF ANALYSIS, OTHERWISE TYPE 0
? 1
INPUT ANNUAL AMOUNT OF OIL (MBTUS) USED IN BASE YEAR BY
SOLAR ENERGY SYSTEM
? 525

- INVESTMENT COST FOR SOLAR ENERGY SYSTEM -

INPUT INITIAL INVESTMENT COST (BASE YEAR)
THE SOCIAL ADJUSTMENT FACTOR APPLIED TO INVESTMENT
COST IS SET AT 10 PERCENT RESULTING IN A MULTIPLIER
OF .9
? 49220

TYPE 1 IF THE INITIAL INVESTMENT IS THE ONLY COST TO BE
CONSIDERED, 0 IF THERE ARE OTHER OPERATION AND MAINTENANCE COSTS
? 0

- NON-FUEL OPERATION AND MAINTENANCE (O+M) COSTS FOR SOLAR ENERGY
SYSTEM -

INPUT BASE-YEAR ANNUAL RECURRING O+M COST
? 492.2

INPUT TOTAL NUMBER OF NON-RECURRING O+M COSTS
? 0

- REPLACEMENT COSTS AND SALVAGE VALUES FOR SOLAR ENERGY SYSTEM -

INPUT NUMBER OF REPLACEMENT COSTS
? 0
INPUT FINAL SALVAGE VALUE OF SYSTEM
? 9844

PROJECT SUMMARY REPORT

NAME OF AGENCY	FEDERAL AGENCY X
PROJECT	ALTERNATIVE 2A
LOCATION OF AGENCY	ARIZONA
GROSS FLOOR AREA AFFECTED	NOT APPLICABLE
EXPECTED LIFE OF SYSTEM	20 YEARS
EXPECTED LIFE OF BUILDING	INDEFINITE YEARS
STUDY PERIOD	20 YEARS
DISCOUNT RATE	7. PERCENT
NUMBER OF ESCALATION PERIODS	3

	(IN THOUSANDS $)
PRESENT VALUE ENERGY COSTS - CONVENTIONAL SYSTEM	78.41
PRESENT VALUE ENERGY COSTS - SOLAR ENERGY SYSTEM	49.40
TOTAL LIFE-CYCLE COSTS- CONVENTIONAL SYSTEM	78.41
TOTAL LIFE-CYCLE COSTS- SOLAR ENERGY SYSTEM	96.36

* * * * *

NET PRESENT VALUE (TH. $) -17.96

SAVINGS-TO-INVESTMENT RATIO 0.56990

SIMPLE PAYBACK > STUDY PERIOD

APPENDIX F

CONVERTING A SIMPLE PAYBACK (SPB) TO A DISCOUNTED PAYBACK (DPB): NOMOGRAM METHOD

Years to Simple Payback (SPB) is used in the evaluation of solar demonstration projects as a supplementary measure to the life-cycle costing measure, Net Savings (NS). As noted in the text, SPB is a rough measure both of cost effectiveness and of the time to payback. It neglects the time value of money and may result in an incorrect determination of the payback period. Use of SPB, as a sole evaluation criterion, may lead to decisions which are not cost effective. Years to Discounted Payback (DPB), though not a comprehensive measure, is somewhat more accurate than SPB. DPB incorporates the time value of money, and also facilitates the incorporation of differential rates of price escalation for energy.

The semi-log nomogram shown in figure F-1 provides an easy method of converting a simple payback to a discounted payback. The discounted payback period for a simple investment project can be calculated from figure F-1 as follows: Assume for the purpose of illustration that the initial conservation investment is $35,000, and the annual energy savings is $5,000. To use the nomogram, connect a line from the annual savings to the investment costs (located on the two vertical scales to the right of the nomogram), and project this line to the vertical axis of the graph labeled "Simple Payback." For this example, the projected line indicates a simple payback of 7 years.

Next, project a line from the point on the vertical axis, horizontally to the appropriate discount rate/energy price escalation rate curve. The nomogram has four discount rate/energy price escalation rate curves: (1) the curve labeled "0%" is for a 7 percent discount rate and a 0 percent energy price escalation rate, (2) the curve labeled "5%" is for a 7 percent discount rate and a 5 percent energy price escalation rate, (3) the curve labeled "7%" is for a 7 percent discount rate and a 7 percent energy price escalation rate, and (4) the curve labeled "10%" is for a 7 percent discount rate and a 10 percent energy price escalation rate. (Although none of these energy price escalation rates for which curves are provided may match exactly the EIA-projected rate for the appropriate sector, region, and fuel type, they may serve to bracket that rate.)

Then project a third line 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 7 percent energy price escalation rate is used. It is between 7 and 8 years if a 5 percent escalation rate is used, and 10 years if a 0 percent escalation rate is used. The values for other energy price escalation rates must be interpolated from the four curves shown.

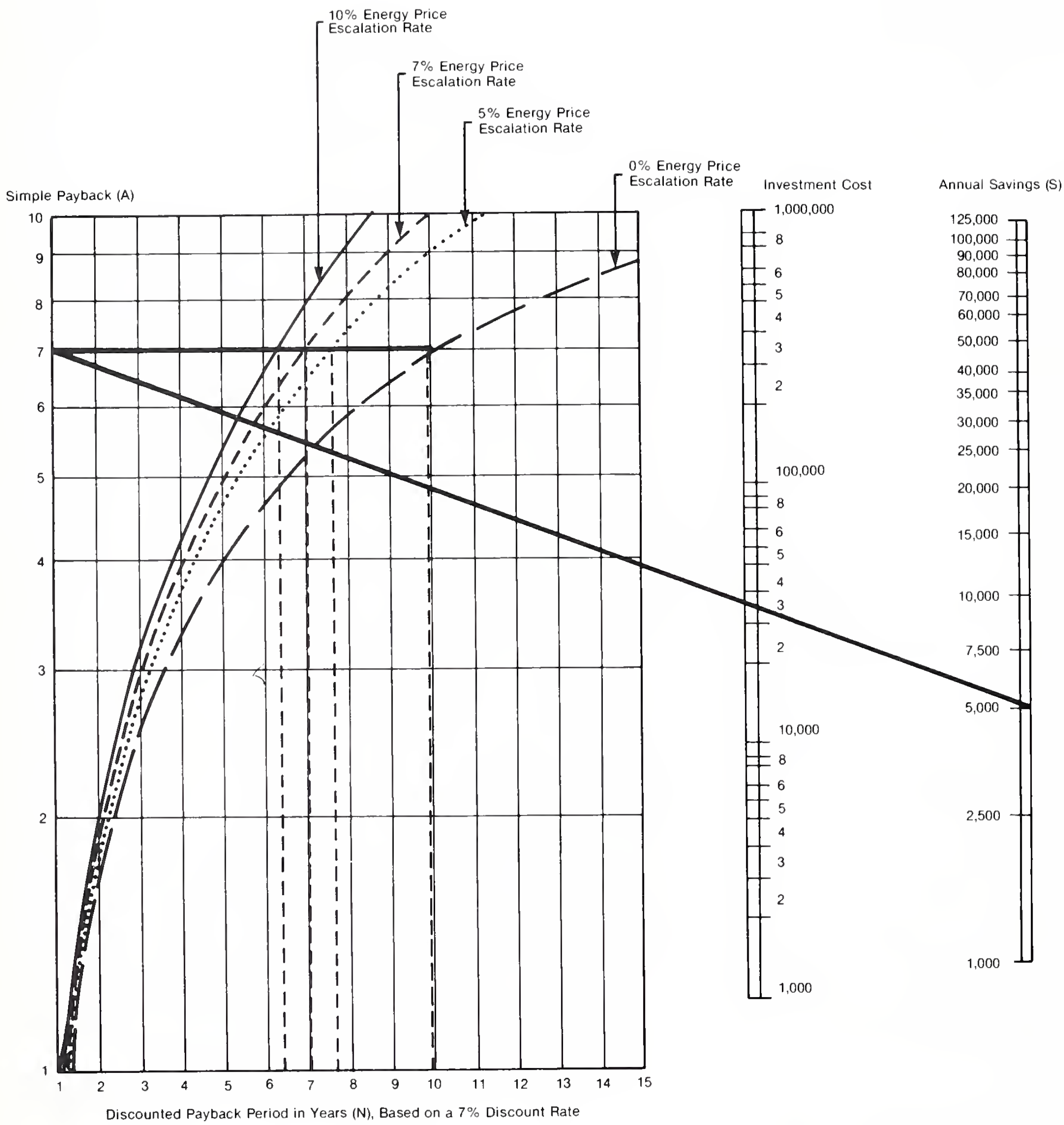

Figure F-1. Discounted Payback Nomogram

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.

APPENDIX G

YEAR-BY-YEAR METHOD OF CALCULATING PRESENT VALUE ENERGY COSTS

Note: This method is intended for Use When the Quantity or Type of Energy is Expected to Change Over the Project Study Period.

This appendix describes the life-cycle costing methodology for calculating the present value of energy costs to use when conditions exist that cause the worksheet calculation procedure (as given in the energy sections of each of the worksheets of appendix D) to be insufficient. These conditions are as follows: (1) the annual physical quantity of energy used is expected to change over the study period, e.g., due to declining technical efficiency of equipment over time, (2) the energy source affected by the energy conservation investment is expected to change during the course of the study period, e.g., a conversion from natural gas to coal may be planned in the future, prior to the end of the study period for the investment.[1]

If either of these conditions exists, the present value of energy costs cannot be calculated simply by multiplying the base-year quantity of energy by the base-year price, and the product by the UPW* factor (as is called for in the LCC worksheets in appendix D). Instead, it will be necessary to adjust for changes in quantity and/or source of energy. This can be done by using a year-by-year calculation procedure. Two tables, G-1 and G-2, are given in this appendix to handle the year-by-year calculations. Table G-1 is used to calculate the present value of energy costs. Table G-2 is a supplement to table G-1 for calculating the year-by-year price of energy needed to complete table G-1. (If more than one type of energy is involved, it will be necessary to complete tables G-1 and G-2 for each energy type.)

Once the total present value of energy cost is calculated using tables G-1 and G-2, the amount can be entered in the energy sections of the appropriate LCC worksheet in appendix D and the remainder of that worksheet can then be completed following the instructions.

The use of tables G-1 and G-2 is illustrated with a hypothetical example for a residence in DoE region 3. The example is for the evaluation of a heating retrofit with an estimated economic life of 15 years, which is to be installed in the residence. It is assumed that the heat pump is installed in mid-1980, the base year, and that energy savings begin to accrue at that time. For the purpose of installation, it is estimated that the heat pump's efficiency will

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1 Note that this second condition is a type of project interdependency. A separate life-cycle cost analysis would need to be carried out to evaluate the cost-effectiveness of the planned conversion from gas to coal.

Table G-1. Year-by-Year Calculation of Present Value Energy Costs

(1) Year	(2) Type of Energy	(3) Annual Units of Energy Measured at Bldg/Facility Boundary	(4) Price of Energy at End of Each Study-Period Year (Brought Forward from Col 4, table G-2) $/unit	(5) Yearly Value of Energy Costs (5) = (3) x (4) $	(6) SPW Factor (Appendix table A-1)[a]	(7) Present Value of Annual Energy Cost (7) = (5) x (6) $
mid 1980- mid 81	E	100 Btu x 10^6	18.85	1885.00	.91	1715.35
1981-82	E	100 Btu x 10^6	18.84	1884.00	.83	1563.72
1982-83	E	100 But x 10^6	18.84	1884.00	.75	1413.00
1983-84	E	100 Btu x 10^6	18.83	1883.00	.68	1280.44
1984-85	E	100 Btu x 10^6	18.83	1883.00	.62	1167.46
1985-86	E	105 Btu x 10^6	18.99	1993.95	.56	1116.61
1986-87	E	105 Btu x 10^6	19.16	2011.80	.51	1026.02
1987-88	E	105 Btu x 10^6	19.33	2029.65	.47	953.94
1988-89	E	110 Btu x 10^6	19.49	2143.90	.42	900.44
1989-90	E	110 Btu x 10^6	19.66	2162.60	.39	843.41
1990-91	E	110 Btu x 10^6	19.59	2154.90	.35	754.22
1991-92	E	110 Btu x 10^6	19.52	2147.20	.32	687.10
1992-93	E	115 Btu x 10^6	19.43	2234.45	.29	647.99
1993-94	E	115 Btu x 10^6	19.38	2228.70	.26	579.46
1994-95	E	115 Btu x 10^6	19.31	2220.65	.24	532.96

(8) Present Value of Energy Costs over the Study Period = $ 15,182.12

[a] Based on SPW factors for a 10% discount rate as given in appendix table A-1 of the LCC Rule, Federal Register, January 23, 1980. Exactly the same procedure would be employed in using the SPW factors based on the 7% discount rate required as of October 1, 1980.

Table G-2. Year-by-Year Calculation of Energy Prices
(For Use in table G-1)

(1) Year	(2) Price at Beginning of Each Study-Period Year (Start with Base-Year Price from table C-1 or C-2 and thereafter carry over the price at the end of that Study-Period year from Col. 4) \$/unit	(3) Price Growth Factor Constructed From tables C-6 through C-8)[a]	(4) End-of-Year (4) = (2) x (3) \$/unit
1980-mid 1981	18.8500	0.9998	18.8462
1981-1982	18.8462	0.9998	18.8424
1982-1983	18.8424	0.9998	18.8386
1983-1984	18.8386	0.9998	18.8348
1984-1985	18.8348	0.9998	18.8310 (18.84)[b]
1985-1986	18.8310	1.0087	18.9948
1986-1987	18.9948	1.0087	19.1601
1987-1988	19.1601	1.0087	19.3268
1988-1989	19.3268	1.0087	19.4949
1989-1990	19.4949	1.0087	19.6645 (19.67)[b]
1990-1991	19.6645	0.9964	19.5937
1991-1992	19.5937	0.9964	19.5232
1992-1993	19.5232	0.9964	19.4529
1993-1994	19.4529	0.9964	19.3828
1994-1995	19.3829	0.9964	19.3131 (19.32)[b]

a See footnote 1, p. G-5 for directions on constructing the price growth factor.

b Prices in parentheses are the DoE-projected reference prices for 1985, 1990, and 1995, taken from tables C-3, C-4, and C-5, respectively. They may be used in lieu of the generated prices. Discrepancies between calculated prices and reference prices reflect rounding errors.

decline after the fifth year of use. It is the assumed decline in system efficiency which causes the yearly quantity of energy to change and which thereby necessitates the use of tables G-1 and G-2.

Table G-1 is for making the year-by-year calculations of present value energy savings. Column 1 identifies the year, and column 2, the type of energy used each year. In this example, the type of energy, electricity (E), is not expected to change. If the type of energy were planned for change, that change would be reflected in this column for the year in which the change is expected. Column 3 lists the physical quantity of energy for each year. As may be seen, the example assumes an increase in the quantity of energy required over time as the technical efficiency of the heat pump declines. Column 4 gives the yearly price per 10^6 Btu of energy. These yearly prices are calculated in table G-2 (as explained below) and transferred to table G-1. The yearly value of energy costs (in constant dollars) is found in column 5 by multiplying the yearly quantity of energy in column 3 by the yearly price of energy in column 4. The yearly value of energy costs in column 5 is then multiplied by the SPW factor, obtained from appendix table A-1 and listed in column 6, to obtain the present value of energy costs for each year in column 7. The present value of energy costs over the study period (item 8) is obtained by summing the yearly values in column 7. Item 8 gives the amount to be transmitted to the appropriate section(s) of the LCC worksheets.

Table G-2 is used to calculate the end-of-year prices of energy which are needed in column 4 of table G-1 to calculate the present value of energy costs.

We can find mid-year prices for the years 1980, 1985, 1990, and 1995 from appendix C, tables C-1 through C-5; but we need corresponding prices for the intervening years.[1] These can be calculated from the prices that are given in appendix C.

We begin by listing in column 1 of table G-2 the years over which energy costs are expected to accrue--in this case, mid-1980 through mid-1995. We can use the mid-1980 price given in appendix table C-1 as a starting point and enter it in column 2. For the illustrative case, the mid-1980 price of residential electricity in DoE Region 3 is $18.85 per MBtu. Since we assume that energy costs begin to accrue at the beginning of the study period and are evaluated as lump-sum amounts at the end of each year during the study period, we need price of the end of each study-period year to evaluate each year's energy costs. Thus, to evaluate the first year's energy costs, mid-1980 to mid-1981, we need the mid-1981 price. The mid-1981 price is then found by applying to the mid-1980 price an appropriate price growth factor constructed from the price escalation rates given in appendix table C-6. The mid-1982 price is

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1 This year-by-year procedure for calculating the price of energy may not produce the exact projected energy prices for 1985, 1990, and 1995, given in tables C-3 through C-5. Variation between the year-by-year calculated energy prices and the projected prices is due to rounding errors.

found by applying to the calculated mid-1981 price, the price growth factor for that year. To facilitate this calculation for each year, we list in column 3 of the table the energy price growth factors constructed from appendix tables C-6 through C-8 for the appropriate fuel type, sector, and region. In the example, the energy price growth factor for each of the years through 1985 is .9998; it is 1.0087 for each of the following years through 1990, and .9964 for each year thereafter.[2]

The procedure is repeated for each year of the 15 year study period to calculate energy prices for the end of each study-period year. The resulting prices in column 4 of table G-1 are then carried forward to column 4 of table G-2 and are used to calculate the present value of energy costs in each year.

After tables G-1 and G-2 are completed, the resulting total present value of energy costs over the study period can be entered in the appropriate worksheet in appendix D, and the LCC evaluation continued. For the example, the present value amount of $15,182.12 from table G-1 would be carried over to the total line of section F of the Retrofit Worksheets. The Retrofit Worksheets could then be completed as instructed.

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1 The energy price growth factor (PGF) = 1 + (ER x 10^{-2}), where ER = the energy price escalation from tables C-6 through C-8. For example the PGF for 1980-85 used in the above illustration is constructed as follows: .9998 = 1 + (-0.02 x 10^{-2}).

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5. AUTHOR(S)

Rosalie T. Ruegg

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. 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 manual is a guide to understanding the life-cycle costing method and an aid to calculating the measures required for evaluating energy conservation and renewable energy investments in all Federal buildings. It expands upon life-cycle costing criteria contained in the Program Rules of the Federal Energy Management Program (Subpart A of Part 436, Title 10, U.S. Code of Federal Regulations) and is consistent with those criteria. Its purpose is to facilitate the implementation of the Program Rules by explaining the life-cycle costing method, defining the measures, describing the assumptions and procedures to follow in performing evaluations, and giving examples. It provides worksheets, a computer program, and instructions for calculating the required measurements.

The life-cycle costing method and evaluation procedures set forth in the Federal Energy Management Program Rules and described in greater detail in this guide are to be followed by all Federal agencies for all energy conservation and renewable energy projects undertaken in new and existing buildings and facilities owned or leased by the Federal government, unless specifically exempted. The establishment of the methods and procedures and their use by Federal agencies to evaluate energy conservation and solar energy investments are required by Section 381(a)(2) of the Energy Policy and Conservation Act, as amended, 42 U.S.C 6361 (a)(2); Section 10 of Presidential Executive Order 11912, amended; and by Title V of the National Energy Conservation Policy Act, 92 Stat. 3275.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Cost effectiveness; economic evaluations; energy conservation; Federal Energy Management Program; life-cycle costing; public buildings; renewable energy; solar energy; solar photovoltaic.

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