

# LEAST - COST ENERGY DECISIONS FOR BUILDINGS



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## Introduction to Life - Cycle Costing

## Video Training Workbook

Prepared by  
ROSALIE T. RUEGG

Applied Economics Group  
Center for Computing and Applied Mathematics  
For

The Federal Energy Management Program  
U.S. Department of Energy

April 1990

U.S. DEPARTMENT OF COMMERCE  
NATIONAL INSTITUTE OF STANDARDS  
AND TECHNOLOGY



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## TO THE USER

This workbook accompanies the video training film "Least-Cost Energy Decisions for Buildings." It is the first in a series of video training films designed to assist you to use economic analysis to improve the long-run economy of your buildings. In this introductory module you will learn the fundamentals for applying the life-cycle cost (LCC) method to decisions affecting the energy consumption of your buildings.

This workbook is not intended to be used as a stand-alone tutorial. The video is the principal training tool, and, in fact, can be used without the workbook. But the workbook is helpful in the following ways:

- o *It provides a glossary of key terms used by the instructors.*
- o *It lists all formulas used in the video.*
- o *It gives the exercises, data, and discount factor tables that are presented in the video in a convenient form for solution at your preferred pace.*
- o *It is handy for taking notes while watching the film.*
- o *With the glossary, formulas, completed exercises, tables, and your notes, it will be useful for later reference.*

The approximate running time for the video (without pauses) is 60 minutes. To the running time, please add time for performing four exercises that you will be asked to do. These will take approximately 30 to 45 minutes more. Each problem statement will appear for a short time on the screen. For more time to solve the problem, press the "pause" button of your VCR control to freeze the frame, find the problem statement and data tables in your workbook, and perform the calculations. The problems are given in the workbook in the order presented in the video. An answer key is provided in Appendix C. You can, of course, pause the video at any time to consult the glossary or list of formulas.

Four instructors appear in the video. Their professional profiles are given in Appendix B.

An expanded treatment of the subject matter of the video is available in a three-day workshop offered through the U.S. General Services Administration. It is conducted several times each year at locations around the country. In Appendix A you will find a number to call for a schedule of up-coming workshops and order information for publications referenced in the video.



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## 1. GLOSSARY OF KEY TERMS

**Breakeven Analysis**--A technique for dealing with uncertainty in cost and benefit estimates which entails determining the minimum or maximum value that a variable can have and still result in a project whose present value benefits (savings) cover its costs. Note: The time to payback is a measure of breakeven life.

**Decision Theory**--A technique for dealing with uncertainty in economic evaluations which is based on probabilistic data inputs and which typically uses decision trees to represent decision alternatives.

**Discount Rate (D)**--The name given to an investor's minimum acceptable rate of return when it is used to adjust future benefits and costs to time-equivalent values. A "market" discount rate reflects expectations about future inflation or deflation and is based on a rate observed in the marketplace.

**First-Cost Approach**--Selecting among alternatives on the basis of which has the lowest up-front costs.

**General Price Inflation**--A rise in the general price level and a drop in the purchasing power of the dollar.

**Investor**--The person or organization whose money is at stake.

**Life-Cycle Cost (LCC)**--The sum of time-equivalent costs of acquiring, owning, operating and maintaining a building, system, or equipment over a designated study period. Comparing LCCs of alternative building designs, systems, or equipment which equally satisfy functional requirements is one way of choosing among them on economic grounds.

**Minimum Acceptable Rate of Return (MARR)**--The minimum percentage return required for an investment to be economically acceptable.

**Modified Uniform Present Worth (UPW\*) Factor**--A discount factor for computing the time-equivalent present value of a series of changing annual amounts. Each factor is unique for a given discount rate, rate(s) of change in future prices, and period of time. The factor is multiplied by the value of the annual amount as of the beginning of the study period to compute the present value of the entire series.

**Opportunity Cost of Capital**--The rate of return on the next best available use of investment funds. An investor typically uses this rate to establish the MARR.

**Residual Value**--The monetary value recaptured through resale, reuse, salvage or scrap, or remaining for continued use at the end of the study period.

**Risk Exposure**--The probability of investing in a project whose economic outcome is different from what is acceptable.

## GLOSSARY OF KEY TERMS (continued)

**Savings-to-Investment Ratio**--A ratio of savings to costs for one building design, system, equipment, or strategy versus an alternative.

**Sensitivity Analysis**--A technique for measuring the impact on project outcomes of changing one or more key input values about which there is uncertainty.

**Simulation Analysis**--A technique useful for determining risk exposure associated with an investment decision, performed by repeatedly drawing a value randomly from the probability distribution of each input and combining the input values to generate a probability distribution of LCC or other measure of economic performance.

**Single Present Worth (SPW) Factor**--A discount factor for computing the time-equivalent present value of a single future amount. The discount factor is multiplied by the future amount to compute its present value.

**Study Period**--The period of time over which benefits and costs are taken into account in an economic evaluation in order to get a correct measure of economic worth.

**Time-Equivalent Future Values (F)**--A future amount which is time-equivalent to a specified present amount; that is, it is an amount that the investor would just as soon receive or pay as the present amount.

**Time-Equivalent Present Value (P)**--A lump-sum amount at the beginning of the study period which the investor would just as soon receive or pay as a specified future amount or a series of future amounts.

**Time-Value of Money**--The time-dependent value of money arising from price inflation/deflation and from its earning potential over time.

**Uncertainty**--A state of incomplete knowledge about the inputs to an economic analysis.

**Uniform Present Worth (UPW) Factor**--A discount factor, based on a given discount rate and a given period of time, which when multiplied by a recurring constant annual amount converts a series of the annual amounts to a time-equivalent present value.

**Uniform Capital Recovery (UCR) Factor**--A discount factor, based on a given discount rate and a given period of time, which when multiplied by a present value amount converts it to a time-equivalent uniform annual value.

## 2. FORMULAS

Single Compound Amount (SCA) Formula:

$$F = P (1 + \text{MARR})^N$$

or

$$F = P \times \text{SCA Factor}$$

Single Present Worth (SPW) Formula:

$$P = F / (1 + D)^N$$
$$= F \left[ \frac{1}{(1 + D)^N} \right]$$

or

$$P = F \times \text{SPW Factor}$$

Uniform Present Worth (UPW) Formula:

$$P = A \left[ \frac{(1 + D)^N - 1}{D(1 + D)^N} \right]$$

or

$$P = A \times \text{UPW Factor}$$

Modified Uniform Present Worth (UPW\*) Formula:

$$P = A_0 \sum_{j=1}^N \left( \frac{1 + E}{1 + D} \right)^j$$

or

$$P = A_0 \times \text{UPW* Factor}$$

Uniform Capital Recovery (UCR) Formula:

$$A = P \left[ \frac{D(1 + D)^N}{(1 + D)^N - 1} \right]$$

or

$$A = P \times \text{UCR Factor}$$

### 3. EXERCISES

#### 3.1 USING AN SPW DISCOUNT FACTOR TO COMPARE A FUTURE AMOUNT WITH ITS PRESENT VALUE EQUIVALENT

Use the SPW Discount Factor Table in part 4 to find how much it would be worth to you today to avoid a cost of \$5,000 in 8 years, if your discount rate is 6%.

Future Cost (F) - \$5,000

Study Period (N) - 8 years

Discount Rate (D) - 6%

SPW Discount Factor = \_\_\_\_\_

$$P = \$ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} = \$ \underline{\hspace{2cm}}$$

Therefore, it would be worth \$ \_\_\_\_\_ today to avoid the future cost.

3.2 USING A UPW DISCOUNT FACTOR TO COMPARE FUTURE SAVINGS WITH AN INITIAL COST

Suppose you work for an organization whose discount rate is 12%. Would you recommend acceptance of a project which costs \$200,000 up front and will save \$20,000 a year for the next 20 years? Use the UPW Discount Factor Table in part 4 to compute the present value equivalent of savings. Then compare present value savings against the initial investment cost to see which is larger.

Discount Rate (D) - 12%

Annual Savings (A) - \$20,000

Study Period (N) - 20 years

Initial Investment Cost (C<sub>0</sub>) - \$200,000

UPW Discount Factor - \_\_\_\_\_

$$P = \$ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} = \$ \underline{\hspace{2cm}}$$
$$\underline{\hspace{2cm}} < \underline{\hspace{2cm}}$$

Therefore, \_\_\_\_\_ (do or do not) recommend the project.

3.3 USING A UPW\* DISCOUNT FACTOR TO COMPARE A SERIES OF ESCALATING FUTURE COSTS WITH AN INITIAL COST

Again suppose you work for a company whose discount rate is 12%. You need to purchase equipment which requires maintenance. You expect to need the equipment for 10 years. You have two choices:

(1) You can buy the equipment from Supplier A who charges \$8,000 more in initial cost for the equipment than Supplier B, but includes maintenance at no additional charge over the life of the equipment.

(2) You can buy the equipment from Supplier B and purchase a separate annual maintenance contract from Supplier B. The annual charge is \$1,000 as of now, but the contract includes an escalation clause that increases the amount by 2% each year. Payment is due at the end of each year, with the first being due one year from now.

Which supplier do you choose? Use the UPW\* discount factor table given in part 4 (Table 4-4) to compute the present value of Supplier B's contract maintenance. Compare it against the \$8,000 charged by Supplier A in higher initial cost to see which is lower.

Supplier A's charge for maintenance: \$8,000 payment at the beginning of the study period

Supplier B's charge for maintenance: Annual end-of-year payment, based on a cost today of \$1,000 and an annual escalation rate of 2%.

Discount Rate (D) = 12%

Study Period (N) = 10 years

UPW\* Discount Factor = \_\_\_\_\_

$$P = \$ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} = \$ \underline{\hspace{2cm}}$$

$$\underline{\hspace{2cm}} \$ < \underline{\hspace{2cm}} \$$$

Therefore, choose Supplier \_\_\_\_\_ (A or B).



### 3.4 LCC ANALYSIS OF STORM WINDOWS

[For reference, please note that table 1 summarizes the video demonstration of LCC analysis for keeping the existing windows versus replacing them with double glazing.]

*Would you recommend adding storm windows over the existing windows in the office building in Boston instead of replacing them with new double-glazed windows on grounds of cost effectiveness?*

*Calculate and compare LCC of storm windows with LCC of replacement double-glazed windows to see which is lower. Then think of other factors which might be important to the decision.*

Storm Window Purchase & Installation Cost	\$3,150
Quantity of Fuel Oil	1,163
Quantity of Electricity	80,339
Price of Fuel Oil	\$0.99/gallon
Price of Electricity	\$0.10/kWh
Painting Costs	50% less than with existing windows alone (i.e., 0.5 x \$1,517)
Additional Cleaning Costs	\$90/year
Additional Resale Value	40% of storm window cost (i.e., 0.4 x \$3,150)
Study Period	12 years
Discount Rate	9%
Inflation Rate	5%
SCA Factor (Find in Table 4-1)	_____
SPW Factor (Find in Table 4-2):	_____
UPW* for Fuel Oil (Computed with "DISCOUNT") <sup>1</sup> :	11.89
UPW* for Electricity (Computed with "DISCOUNT"):	9.25

<sup>1</sup>"DISCOUNT" is a computer program which is referenced in the video. (Order information is given in Appendix A). DISCOUNT was used to compute these UPW\* factors because UPW\* factors for computing present value energy costs are published only for 7% and 10% discount rates and for DOE-projected rates of change in energy prices exclusive of general price inflation.



Calculate LCC for Storm Windows (LCC 3):

LCC 3 = window cost + painting costs + cleaning costs + energy costs  
+ fuel oil costs + electricity costs - residual value  
(where all amounts are in present value dollars)

LCC 3 = \_\_\_\_\_

Adding storm windows over the existing windows is estimated to be  
\_\_\_\_\_ (more, less) cost effective than replacing the existing windows  
with double-glazed windows.

Other factors which may influence the choice are \_\_\_\_\_

\_\_\_\_\_

Table 1. LCC analysis of replacing existing windows versus keeping them

[The following data and calculations are provided for reference in solving Exercise 3.4]

Data	(1) Keep Existing Windows	(2) Replace with Double Glazing
Window Costs	--	\$10,500
Quantity of Fuel Oil	1,778 gallons	1,163 gallons
Quantity of Electricity	88,371 kWh	80,339 kWh
Price of Fuel Oil <sup>a</sup>	\$0.99/gallon	\$0.99/gallon
Price of Electricity <sup>a</sup>	\$0.10/kWh	\$0.10/kWh
Painting Costs <sup>a</sup>	\$1,000/5 years	--
Additional Resale Value <sup>a</sup>	--	\$10,500 x 0.6
Study Period	12 years	
Discount Rate	9%	
Inflation Rate	5%	
Location	Boston	
Building Type	Commercial	
SCA Factor for 5% inflation & 5 years (Table 4-1)		1.28
SCA Factor for 5% inflation & 10 years (Table 4-1)		1.63
SPW Factor for 9% discount & 5 years (Table 4-2)		0.65
SPW Factor for 9% discount & 10 years (Table 4-2)		0.42
UPW* Factor for fuel oil (Computed with "DISCOUNT")		11.89
UPW* Factor for electricity (Computed with "DISCOUNT")		9.25

LCC Calculations:

$$\begin{aligned}
 & \text{Maintenance (Painting) Costs} \\
 \text{LCC 1} = & + (\$1,000 \times 1.28 \times 0.65) + (\$1,000 \times 1.63 \times 0.42) \\
 & \text{Fuel Oil Costs} \qquad \qquad \qquad \text{Electricity Costs} \\
 & + (\$0.99/\text{gal} \times 1778 \text{ gal} \times 11.89) + (\$0.10/\text{kWh} \times 88371 \text{ kWh} \times 9.25) \\
 = & \$1,517 + \$20,929 + \$81,743 = \$104,189
 \end{aligned}$$

$$\begin{aligned}
 & \text{Window Cost} \qquad \qquad \qquad \text{Fuel Oil Costs} \qquad \qquad \qquad \text{Electricity Costs} \\
 \text{LCC 2} = & \$10,500 + (\$0.99/\text{gal} \times 1,163 \text{ gal} \times 11.89) + (\$0.10/\text{kWh} \times 80,339 \text{ kWh} \times 9.25) \\
 & \text{Resale Value} \\
 & + (0.6 \times \$10,500) \times 1.80 \times 0.36 \\
 = & \$10,500 + \$13,690 + \$74,314 - \$4,082 = \$94,422
 \end{aligned}$$

<sup>a</sup> Prices and costs are given as of the beginning of the study period. The first instance of painting occurs 5 years from now and the second 10 years from now.

#### 4. DISCOUNT FACTOR TABLES

(Directory)

Table 4-1. Single Compound Amount (SCA) Factors

Table 4-2. Single Present Worth (SPW) Factors

Table 4-3. Uniform Present Worth (UPW) Factors

Table 4-4. Modified Uniform Present Worth (UPW\*) Factors  
for a 12% Discount Rate and Constant Rate  
of Change

Table 4-5. Modified Uniform Present Worth (UPW\*) Factors  
for 7% Discount Rate and DOE-Projected  
Energy Price Changes

Table 4-1. Single Compound Amount (SCA) Discount Factors--for finding the future value of a present amount

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%
1	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.12	1.14
2	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.25	1.30
3	1.03	1.06	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.40	1.48
4	1.04	1.08	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.57	1.69
5	1.05	1.10	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.76	1.93
6	1.06	1.13	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77	1.97	2.19
7	1.07	1.15	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.21	2.50
8	1.08	1.17	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.48	2.85
9	1.09	1.20	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36	2.77	3.25
10	1.10	1.22	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	3.11	3.71
11	1.12	1.24	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.48	4.23
12	1.13	1.27	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.90	4.82
13	1.14	1.29	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	4.36	5.49
14	1.15	1.32	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.89	6.26
15	1.16	1.35	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	5.47	7.14
16	1.17	1.37	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	6.13	8.14
17	1.18	1.40	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	6.87	9.28
18	1.20	1.43	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	7.69	10.58
19	1.21	1.46	1.75	2.11	2.53	3.03	3.62	4.32	5.14	6.12	8.61	12.06
20	1.22	1.49	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	9.65	13.74
21	1.23	1.52	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	10.80	15.67
22	1.24	1.55	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	12.10	17.86
23	1.26	1.58	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	13.55	20.36
24	1.27	1.61	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	15.18	23.21
25	1.28	1.64	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.83	17.00	26.46

Table 4-2. Single Present Worth (SPW) Discount Factors--for finding the present value of a future amount

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%
1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.89	0.88
2	0.98	0.96	0.94	0.92	0.91	0.89	0.87	0.86	0.84	0.83	0.80	0.77
3	0.97	0.94	0.92	0.89	0.86	0.84	0.82	0.79	0.77	0.75	0.71	0.67
4	0.96	0.92	0.89	0.85	0.82	0.79	0.76	0.74	0.71	0.68	0.64	0.59
5	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.57	0.52
6	0.94	0.89	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.51	0.46
7	0.93	0.87	0.81	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.45	0.40
8	0.92	0.85	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.40	0.35
9	0.91	0.84	0.77	0.70	0.64	0.59	0.54	0.50	0.46	0.42	0.36	0.31
10	0.91	0.82	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39	0.32	0.27
11	0.90	0.80	0.72	0.65	0.58	0.53	0.48	0.43	0.39	0.35	0.29	0.24
12	0.89	0.79	0.70	0.62	0.56	0.50	0.44	0.40	0.36	0.32	0.26	0.21
13	0.88	0.77	0.68	0.60	0.53	0.47	0.41	0.37	0.33	0.29	0.23	0.18
14	0.87	0.76	0.66	0.58	0.51	0.44	0.39	0.34	0.30	0.26	0.20	0.16
15	0.86	0.74	0.64	0.56	0.48	0.42	0.36	0.32	0.27	0.24	0.18	0.14
16	0.85	0.73	0.62	0.53	0.46	0.39	0.34	0.29	0.25	0.22	0.16	0.12
17	0.84	0.71	0.61	0.51	0.44	0.37	0.32	0.27	0.23	0.20	0.15	0.11
18	0.84	0.70	0.59	0.49	0.42	0.35	0.30	0.25	0.21	0.18	0.13	0.09
19	0.83	0.69	0.57	0.47	0.40	0.33	0.28	0.23	0.19	0.16	0.12	0.08
20	0.82	0.67	0.55	0.46	0.38	0.31	0.26	0.21	0.18	0.15	0.10	0.07
21	0.81	0.66	0.54	0.44	0.36	0.29	0.24	0.20	0.16	0.14	0.09	0.06
22	0.80	0.65	0.52	0.42	0.34	0.28	0.23	0.18	0.15	0.12	0.08	0.06
23	0.80	0.63	0.51	0.41	0.33	0.26	0.21	0.17	0.14	0.11	0.07	0.05
24	0.79	0.62	0.49	0.39	0.31	0.25	0.20	0.16	0.13	0.10	0.07	0.04
25	0.78	0.61	0.48	0.38	0.30	0.23	0.18	0.15	0.12	0.09	0.06	0.04

Table 4-3. Uniform Present Worth (UPW) Discount Factors--for finding the present value of a series of uniformly recurring future amounts

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%
1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.89	0.88
2	1.97	1.94	1.91	1.89	1.86	1.83	1.81	1.78	1.76	1.74	1.69	1.65
3	2.94	2.88	2.83	2.78	2.72	2.67	2.62	2.58	2.53	2.49	2.40	2.32
4	3.90	3.81	3.72	3.63	3.55	3.47	3.39	3.31	3.24	3.17	3.04	2.91
5	4.85	4.71	4.58	4.45	4.33	4.21	4.10	3.99	3.89	3.79	3.60	3.43
6	5.80	5.60	5.42	5.24	5.08	4.92	4.77	4.62	4.49	4.36	4.11	3.89
7	6.73	6.47	6.23	6.00	5.79	5.58	5.39	5.21	5.03	4.87	4.56	4.29
8	7.65	7.33	7.02	6.73	6.46	6.21	5.97	5.75	5.53	5.33	4.97	4.64
9	8.57	8.16	7.79	7.44	7.11	6.80	6.52	6.25	6.00	5.76	5.33	4.95
10	9.47	8.98	8.53	8.11	7.72	7.36	7.02	6.71	6.42	6.14	5.65	5.22
11	10.37	9.79	9.25	8.76	8.31	7.89	7.50	7.14	6.81	6.50	5.94	5.45
12	11.26	10.58	9.95	9.39	8.86	8.38	7.94	7.54	7.16	6.81	6.19	5.66
13	12.13	11.35	10.63	9.99	9.39	8.85	8.36	7.90	7.49	7.10	6.42	5.84
14	13.00	12.11	11.30	10.56	9.90	9.29	8.75	8.24	7.79	7.37	6.63	6.00
15	13.87	12.85	11.94	11.12	10.38	9.71	9.11	8.56	8.06	7.61	6.81	6.14
16	14.72	13.58	12.56	11.65	10.84	10.11	9.45	8.85	8.31	7.82	6.97	6.27
17	15.56	14.29	13.17	12.17	11.27	10.48	9.76	9.12	8.54	8.02	7.12	6.37
18	16.40	14.99	13.75	12.66	11.69	10.83	10.06	9.37	8.76	8.20	7.25	6.47
19	17.23	15.68	14.32	13.13	12.09	11.16	10.34	9.60	8.95	8.36	7.37	6.55
20	18.05	16.35	14.88	13.59	12.46	11.47	10.59	9.82	9.13	8.51	7.47	6.62
21	18.86	17.01	15.42	14.03	12.82	11.76	10.84	10.02	9.29	8.65	7.56	6.69
22	19.66	17.66	15.94	14.45	13.16	12.04	11.06	10.20	9.44	8.77	7.64	6.74
23	20.46	18.29	16.44	14.86	13.49	12.30	11.27	10.37	9.58	8.88	7.72	6.79
24	21.24	18.91	16.94	15.25	13.80	12.55	11.47	10.53	9.71	8.98	7.78	6.84
25	22.02	19.52	17.41	15.62	14.09	12.78	11.65	10.67	9.82	9.08	7.84	6.87

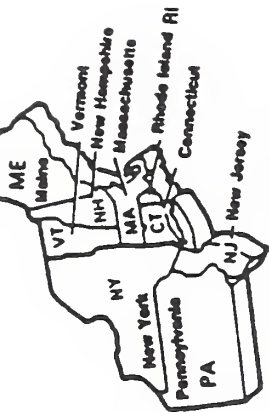


Table 4-4. Modified Uniform Present Worth (UPW\*) Discount Factors--for finding the present value of a series of future amounts escalating at a constant rate  
( D = 12% )

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%
1	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.96	0.97	0.98	1.00	1.02
2	1.72	1.74	1.77	1.79	1.82	1.84	1.87	1.89	1.92	1.95	2.00	2.05
3	2.45	2.50	2.54	2.59	2.64	2.69	2.74	2.79	2.84	2.89	3.00	3.11
4	3.11	3.18	3.26	3.33	3.41	3.49	3.57	3.66	3.74	3.82	4.00	4.18
5	3.71	3.81	3.92	4.03	4.14	4.25	4.37	4.49	4.61	4.74	5.00	5.27
6	4.24	4.38	4.52	4.67	4.82	4.97	5.13	5.29	5.46	5.64	6.00	6.39
7	4.73	4.90	5.08	5.26	5.45	5.65	5.86	6.07	6.29	6.52	7.00	7.52
8	5.17	5.37	5.59	5.81	6.05	6.29	6.55	6.82	7.09	7.38	8.00	8.67
9	5.56	5.80	6.06	6.33	6.61	6.90	7.21	7.54	7.88	8.23	9.00	9.84
10	5.92	6.20	6.49	6.80	7.13	7.48	7.85	8.23	8.64	9.07	10.00	11.04
11	6.24	6.55	6.89	7.25	7.62	8.03	8.45	8.90	9.38	9.89	11.00	12.25
12	6.53	6.88	7.26	7.66	8.09	8.54	9.03	9.55	10.10	10.69	12.00	13.49
13	6.79	7.18	7.59	8.04	8.52	9.03	9.58	10.17	10.81	11.49	13.00	14.75
14	7.02	7.45	7.90	8.39	8.92	9.49	10.11	10.77	11.49	12.26	14.00	16.03
15	7.23	7.69	8.19	8.72	9.30	9.93	10.61	11.35	12.15	13.03	15.00	17.33
16	7.43	7.92	8.45	9.03	9.66	10.35	11.09	11.91	12.80	13.78	16.00	18.66
17	7.60	8.12	8.69	9.31	9.99	10.74	11.55	12.45	13.43	14.51	17.00	20.01
18	7.75	8.31	8.91	9.58	10.31	11.11	11.99	12.97	14.05	15.23	18.00	21.39
19	7.89	8.47	9.11	9.82	10.60	11.46	12.41	13.47	14.64	15.94	19.00	22.79
20	8.02	8.63	9.30	10.05	10.87	11.79	12.82	13.95	15.22	16.64	20.00	24.21
21	8.13	8.77	9.47	10.26	11.13	12.11	13.20	14.42	15.79	17.33	21.00	25.66
22	8.24	8.90	9.63	10.45	11.37	12.41	13.56	14.87	16.34	18.00	22.00	27.14
23	8.33	9.01	9.78	10.64	11.60	12.69	13.91	15.30	16.88	18.66	23.00	28.64
24	8.41	9.12	9.91	10.80	11.81	12.95	14.25	15.72	17.40	19.31	24.00	30.17
25	8.49	9.22	10.03	10.96	12.01	13.21	14.57	16.12	17.90	19.95	25.00	31.72

Table 4-5. Modified Uniform Present Worth UPW\* Factors, For a 7% Discount Rate and DoE-Projected Rates of Change in Energy Prices<sup>a</sup>

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



N	RESIDENTIAL				COMMERCIAL				INDUSTRIAL				TRANSPORTATION			
	ELEC	DIST	LPG	NATGAS	ELEC	DIST	RESID	NATGAS	COAL	ELEC	DIST	RESID	NATGAS	COAL	GASLINE	N
1	0.95	0.98	0.98	0.94	0.95	1.01	0.98	0.94	0.95	0.95	1.01	0.98	0.95	0.95	0.95	1
2	1.81	1.92	1.91	1.83	1.81	1.96	1.89	1.83	1.85	1.81	1.97	1.89	1.85	1.85	1.86	2
3	2.62	2.80	2.79	2.67	2.62	2.88	2.75	2.66	2.70	2.61	2.90	2.75	2.71	2.71	2.71	3
4	3.36	3.65	3.62	3.47	3.36	3.76	3.55	3.45	3.52	3.34	3.78	3.55	3.54	3.52	3.51	4
5	4.05	4.46	4.40	4.23	4.05	4.62	4.34	4.19	4.30	4.02	4.65	4.34	4.34	4.29	4.29	5
6	4.70	5.25	5.16	4.96	4.70	5.45	5.13	4.90	5.03	4.65	5.50	5.12	5.12	5.02	5.04	6
7	5.30	6.01	5.89	5.66	5.30	6.28	5.94	5.59	5.73	5.24	6.33	5.92	5.89	5.71	5.79	7
8	5.87	6.75	6.61	6.32	5.87	7.09	6.76	6.24	6.40	5.80	7.16	6.73	6.63	6.36	6.53	8
9	6.41	7.48	7.30	6.97	6.41	7.89	7.59	6.88	7.03	6.34	7.97	7.56	7.37	6.98	7.26	9
10	6.92	8.18	7.97	7.60	6.91	8.67	8.42	7.49	7.62	6.84	8.78	8.38	8.10	7.56	7.98	10
11	7.40	8.86	8.61	8.19	7.40	9.44	9.23	8.07	8.19	7.33	9.56	9.17	8.80	8.11	8.66	11
12	7.85	9.51	9.22	8.76	7.85	10.17	10.00	8.63	8.73	7.79	10.32	9.94	9.48	8.64	9.31	12
13	8.27	10.13	9.80	9.30	8.27	10.87	10.73	9.15	9.24	8.21	11.04	10.66	10.12	9.13	9.93	13
14	8.67	10.71	10.35	9.81	8.67	11.53	11.42	9.65	9.72	8.61	11.72	11.34	10.73	9.60	10.52	14
15	9.04	11.26	10.86	10.29	9.04	12.16	12.07	10.12	10.18	8.99	12.36	11.99	11.30	10.05	11.07	15
16	9.39	11.79	11.35	10.75	9.39	12.75	12.70	10.57	10.61	9.34	12.97	12.60	11.85	10.47	11.59	16
17	9.71	12.28	11.82	11.19	9.71	13.31	13.28	10.99	11.02	9.67	13.55	13.18	12.36	10.87	12.09	17
18	10.02	12.75	12.25	11.59	10.02	13.84	13.84	11.39	11.41	9.98	14.09	13.73	12.85	11.25	12.56	18
19	10.31	13.19	12.66	11.98	10.30	14.34	14.36	11.77	11.78	10.27	14.60	14.24	13.31	11.61	13.00	19
20	10.57	13.60	13.05	12.34	10.57	14.80	14.84	12.12	12.13	10.54	15.08	14.73	13.74	11.95	13.41	20
21	10.82	13.99	13.41	12.68	10.82	15.24	15.31	12.45	12.46	10.79	15.53	15.18	14.14	12.27	13.80	21
22	11.06	14.36	13.76	13.00	11.06	15.66	15.74	12.76	12.77	11.03	15.96	15.61	14.52	12.58	14.17	22
23	11.28	14.70	14.08	13.30	11.28	16.05	16.15	13.06	13.07	11.25	16.36	16.01	14.88	12.87	14.51	23
24	11.49	15.02	14.38	13.58	11.49	16.41	16.53	13.33	13.35	11.46	16.74	16.39	15.22	13.14	14.83	24
25	11.68	15.33	14.66	13.85	11.68	16.76	16.89	13.59	13.62	11.66	17.09	16.75	15.53	13.40	15.14	25

<sup>a</sup> ELEC = Electricity; DIST = Distillate; LPG = Liquefied Petroleum Gas; NATGAS = Natural Gas; RESID = Residual; COAL = Steam Coal; and GASLINE = Gasoline.

Source: Barbara C. Lippiatt and Rosalie T. Ruegg, Energy Prices and Discount Factors for Life-Cycle Cost Analysis 1988; Annual Supplement to NBS Handbook 135 and NBS Special Publication 709, NISTIR 85-3273-3, Gaithersburg, MD: National Institute of Standards and Technology.



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## APPENDIX A. ORDER INFORMATION

To receive a current listing of LCC workshops and to find out how to order the publications and computer programs references in the video, call (301) 975-6132.

Or, request the information by writing:

The Applied Economics Group  
Room 415, Building 101  
National Institute of Standards and Technology  
Gaithersburg, Maryland 20899

## APPENDIX B. INSTRUCTOR PROFILES

(In order of appearance)

*ROSALIE T. RUEGG*

---

Ms. Ruegg, an economist in the Applied Economics Group of the National Institute of Standards and Technology, specializes in developing and applying methods of economic analysis to investment decisions of public and private organizations. She is coauthor of the new book, Building Economics: Theory and Practice, published by Van Nostrand Reinhold. Among the more than 40 book chapters, journal articles, and reports she has published is the Life-Cycle Costing Manual for the Federal Energy Management Program (HB 135). It guides life-cycle cost analysis of energy-related building design and retrofit decisions of the Federal government. In addition to research, she has developed prototype training curricula in building economics and taught short courses in the U.S. and abroad for university schools of engineering and architecture, government agencies, and professional societies. Ms. Ruegg was earlier a financial economist at the Board of Governors of the Federal Reserve System, and a college instructor in economics. She holds a BA in economics from the University of North Carolina, where she was elected to Phi Beta Kappa; an MA in economics from the University of Maryland, where she was a Woodrow Wilson Fellow; an MBA with a specialty in finance from the American University; and certification as a training specialist from Georgetown University. She received the Department of Commerce's Silver Medal Award for pioneering work in solar economics and, twice, the Center for Building Technology's Outstanding Communicator Award.

*K. DEAN DeVINE*

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Mr. DeVine is a program manager with the U.S. Department of Energy, Office of the Assistant Secretary for Conservation and Renewable Energy, Federal Programs Office. A graduate of San Diego State University, he began his career as a mechanical engineer on HVAC systems in Las Vegas, Nevada, under the Atomic Energy Commission engineering intern program. After serving as project engineer on several U.S. projects, Mr. DeVine accepted a position at AEC Headquarters where he became involved in program management. In 1975 with the creation of ERDA, Mr. DeVine was a part of the initial cadre that manned the conservation program office. He has served in numerous positions in the conservation and renewable programs including Chief of Field Operations and Director of Policy Coordination. In 1985 Mr. DeVine joined the Federal Programs Office as its first professional engineer. The Federal Programs Office is located in the Office of the Deputy Assistant Secretary for Conservation and is responsible for Federal conservation programs worldwide. Mr. DeVine is a member of the national honorary society in mechanical engineering, Pi Tau Sigma, and resides in Alexandria, Virginia, with his wife Anita, also a DOE program manager, and his son Chris.

HAROLD E. MARSHALL

---

Dr. Marshall heads the Applied Economics Group at the National Institute of Standards and Technology. His specialty is developing standard economic methods and risk analysis techniques for evaluating investment projects. Dr. Marshall is coauthor of the new book Building Economics: Theory and Practice, published by Van Nostrand Reinhold, and has published over 40 articles, chapters in books, and technical reports. He chairs for the American Society of Testing and Materials The Building Economics Subcommittee which has produced seven standard economic methods used worldwide for evaluating investments in buildings and construction. Dr. Marshall also leads the task group on economic methods in the Building Economics Working Commission of the International Council for Building Research, Studies, and Documentation. His post as advisory editor to the international journal Construction Management and Economics also helps keep him abreast of developments abroad in building economics. A graduate of The George Washington University (Ph.D., 1969, M.A., 1965, and B.A., 1964), Dr. Marshall's early career included teaching economics for two years on World Campus Afloat's around-the-world shipboard college and performing economic research at the Department of Agriculture. In recognition of his contributions in building economics, Dr. Marshall received in 1986 the American Association of Cost Engineers' highest honor, the Award of Merit, and in 1988 the American Society of Testing and Materials Award of Merit and accompanying honorary title of Fellow of the Society.

STEPHEN R. PETERSEN

---

Steve Petersen is an economist in the Applied Economics Group at the National Institute of Standards and Technology. His area of research has been largely focused on engineering economics, energy conservation in the design of new residential buildings, and the design and selection of heating and cooling systems for buildings. He has published over 30 articles, reports, books, and computer programs related to these subjects. He is a member of the Building Economics Subcommittee in the American Society of Testing and Materials (ASTM), and has played a key role in the development of the building economics standards and related computer programs published by that group. In 1980 Mr. Petersen was accepted into the President's Executive Exchange Program, and worked in the Engineering and Research Division of the Carrier Corporation in Syracuse, NY for one year. A graduate of the University of California (B.A., 1969) and UCLA (M.A., 1972) in economics, Mr. Petersen also served four years in the USAF as a Russian Interpreter, and worked several years as an analyst for the Defense Department in Washington, D.C.

APPENDIX C. ANSWER KEY

Exercise 3-1.

$$P = \$5,000 \times 0.63 = \$3,150$$

Exercise 3-2.

$$P = \$20,000 \times 7.47 = \$149,400$$

$$\$149,400 < \$200,000$$

*Therefore, do not recommend the project.*

Exercise 3-3.

$$P = \$1,000 \times 6.20 = \$6,200$$

$$\$6,200 < \$8,000$$

*Therefore, choose Supplier B.*

Exercise 3-4.

SCA Factor (From Table 4-1):	1.80
SPW Factor (From Table 4-2):	0.36
UPW* for Fuel Oil (From Table 4-4):	11.89
UPW* for Electricity (From Table 4-5):	9.25

Calculate LCC for Storm Windows (LCC 3):

$$\begin{aligned} \text{LCC 3} &= \$3,150 + (0.5 \times \$1,517) + (\$90 \times 9.49) \\ &\quad + (\$0.99/\text{gal} \times 1,163 \text{ gal} \times 11.89) \\ &\quad + (\$0.10/\text{kWh} \times 80,339 \text{ kWh} \times 9.25) \\ &\quad - (0.4 \times \$3,150 \times 1.80 \times 0.36) \\ &= \$3,150 + \$759 + \$854 + \$13,690 + \$74,314 - \$816 \\ &= \$91,951 \end{aligned}$$

Examples of other factors which may influence the choice:

Aesthetic concerns

Restrictions on exterior modifications to historic buildings





# BIBLIOGRAPHIC DATA SHEET

4. TITLE AND SUBTITLE

Least-Cost Energy Decisions for Buildings: Workbook to Accompany the Video Training Film

5. AUTHOR(S)

Rosalie T. Ruegg

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U.S. DEPARTMENT OF COMMERCE  
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY  
GAITHERSBURG, MD 20899

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10. SUPPLEMENTARY NOTES

This workbook and the video training film it accompanies will be available from the National Audiovisual Center, an agency of the U.S. National Archives.

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 workbook accompanies the video training film "Least-Cost Energy Decisions for Buildings;" it is not a stand-alone tutorial. The workbook contains a glossary of key terms, formulas, exercises, and discount factor tables presented in the video. Running time (without pauses to do the exercises) is about one hour.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

building economics; economic analysis; energy economics; life-cycle costing; training

13. AVAILABILITY

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