NISTIR 89-4129

LIFE-CYCLE COSTING FOR ENERGY CONSERVATION IN BUILDINGS: INSTRUCTOR'S GUIDE

Rosalie T. Ruegg

United States Department of Commerce
National Institute of Standards and Technology
(Formerly National Bureau of Standards)

Prepared for
United States Department of Energy
Federal Energy Management Program

August 1989

NISTIR 89-4129

AUGUST 1989

LIFE-CYCLE COSTING FOR ENERGY CONSERVATION IN BUILDINGS: INSTRUCTOR'S GUIDE

Rosalie T. Ruegg

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(Formerly National Bureau of Standards)

Applied Economics Group
Center for Computing and Applied Mathematics
Gaithersburg, MD 20899

Prepared for:

U. S. Department of Energy
Office of the Assistant Secretary for
Conservation and Renewable Energy

Federal Programs Office
Washington, D.C. 20585

LIFE-CYCLE COSTING

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIFE-CYCLE COSTING

COURSE OVERVIEW

DAY ONE

The course begins with practical illustrations to demonstrate how life-cycle costing and related methods can improve energy-related decisions. Brief overviews are given of five methods of economic evaluation. Each method is described, examples of its use are given, and its limitations are discussed. Then, the major elements in performing a life-cycle cost evaluation are explained. Emphasis is placed on clarifying those issues which often confuse practitioners. Issues include why it is necessary to adjust cash flows for time and how to do it, how to estimate costs and benefits, and what to do about inflation. Sample exercises are provided. Students are shown, step-by-step, how to compute life-cycle costs, net savings, savings-to-investment ratio, adjusted internal rate of return, and time to payback. Federal criteria for performing economic evaluations of energy-related choices are presented. Students are asked to solve a sample problem. Then two computer programs, FBLCC for Federal applications and NBSLCC for non-Federal applications, are introduced. Students get acquainted with the software by performing a simple life-cycle cost evaluation using microcomputers.

DAY TWO

The second day broadens coverage to solution of more complex problems: designing and sizing independent and interdependent building systems, and allocating limited budgets among competing projects. The issue of uncertainty is discussed and guidance is provided on what to do about it. A computer laboratory in which students are given sample problems to solve concludes the two-day course on life-cycle costing.

LIFE-CYCLE COSTING

COURSE AGENDA

DAY 1

TOPIC		TIME ALLOTTED
A.	ECONOMICS CAN IMPROVE DECISIONS	50 minutes
B.	WHAT YOU NEED TO GET STARTED	50 minutes
C.	ADJUSTING CASH AMOUNTS FOR TIME OF OCCURRENCE	100 minutes
D.	CALCULATING LIFE-CYCLE COSTS, NET SAVINGS, SAVINGS-TO-INVESTMENT RATIO, OVERALL RATE OF RETURN, AND TIME TO PAYBACK	75 minutes
E.	LCC COMPUTER PROGRAMS	90 minutes

DAY 2

F.	DESIGNING AND SIZING INDEPENDENT AND INTERDEPENDENT PROJECTS	75 minutes
G.	DETERMINING PROJECT PRIORITY	60 minutes
H.	UNCERTAINTY	60 minutes
I.	REVIEW	60 minutes
J.	COMPUTER LAB: USING FBLCC & NBSLCC	150 minutes

LIFE-CYCLE COSTING

COURSE OBJECTIVES

AT THE CONCLUSION OF THE TWO-DAY COURSE, THE STUDENT WILL BE ABLE TO:

Perform life-cycle cost analyses of energy-related building systems in order to make economic decisions.

AT THE CONCLUSION OF THE TOPIC, THE STUDENT WILL BE ABLE TO:

TOPIC A -- ECONOMICS CAN IMPROVE DECISIONS (50 minutes)

> Give examples of decisions affecting energy consumption which can be improved by economic evaluation, and explain the concepts of economic efficiency, cost-effectiveness, economic optimization, and marginal analysis.

TOPIC B -- WHAT YOU NEED TO GET STARTED (50 minutes)

> Define alternatives to be evaluated, specify data requirements, and identify sources of data.

TOPIC C -- ADJUSTING CASH AMOUNTS FOR TIME OF OCCURRENCE (100 minutes)

> Calculate the present value of (1) a single future amount (such as a replacement cost or residual value), (2) a uniform series of future amounts (such as routine maintenance and repair costs), and (3) a series of future amounts changing over time at specified rates (such as energy costs).

TOPIC D -- CALCULATING LIFE-CYCLE COSTS, NET SAVINGS, SAVINGS-TO-INVESTMENT RATIO, ADJUSTED INTERNAL RATE OF RETURN, AND TIME TO PAYBACK (75 minutes)

> Calculate life-cycle costs, net savings, savings-to-investment ratio, adjusted internal rate of return, and time to payback for a Federal energy conservation project and, on the basis of those measures, decide whether to accept or reject the project.

COURSE OBJECTIVES (Continued)

TOPIC E -- LCC COMPUTER PROGRAMS (90 minutes)

Run the FBLCC or NBSLCC computer program; enter data inputs for a sample problem; and read the results from a screen printout.

TOPIC F -- DESIGNING AND SIZING INDEPENDENT & INTERDEPENDENT SYSTEMS (75 minutes)

Find the cost-effective size of an energy-related building component, such as the level of attic insulation. Find the cost-effective combination of interdependent projects, such as the level of attic insulation and heating system efficiency.

TOPIC G -- DESIGNING PROJECT PRIORITY (60 minutes)

Use the SIR method to allocate a budget among independent projects.

TOPIC H -- UNCERTAINTY (60 minutes)

Perform sensitivity analysis, and make decisions under uncertainty.

TOPIC I -- REVIEW (60 minutes)

Summarize principal steps in performing economic evaluations, describe five methods of economic evaluation, and explain how each method is used to guide energy-related decisions.

TOPIC J -- COMPUTER LAB: USING FBLCC & NBSLCC (150 minutes)

Use FBLCC or NBSLCC to size a building system and establish funding priority among competing projects.

LIFE-CYCLE COSTING

LESSON PLAN NO. 1

Schedule Topic Set Up & Orientation Day 1

Time Scheduled 8:30-9:00

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
8:00	SET-UP: Arrive at designated classroom. Position slide projector and flipchart. Make sure there is a remote control on a long cord for the projector, a spare bulb for the projector, a full pad of paper on the easel, two markers of different color, and a long-stick pointer. If the classroom is large or noisy, request a portable microphone. Load slides into carousel. Open boxes and distribute student manuals. Arrange instructor's materials at front table. Place course name and your name on flip chart or project onto the screen.	Flipchart or Slide 1-1
8:30	INTRODUCTION OF INSTRUCTORS & STUDENTS: Call class to order. Introduce instructors. Ask students to complete registration cards and "tent" cards on both sides. Collect registration cards. Ask students to display tent cards. If class size permits, ask each student to introduce themselves. (Alternatively, for an "ice breaker," tell them that you will ask them to introduce each other right after the first break. Suggest that they pair up with someone they have not met prior to the course. (Suggest things to include in the introductions.) But control the time. Limit each introduction to about 1 minute. If you elect	

LESSON PLAN NO. 1, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	<u>INTRODUCTION OF INSTRUCTORS AND STUDENTS, CONTINUED</u> the latter style of introduction, you will need to compensate by beginning TOPIC A right away. If the class size is too large to allow time for individual introductions, ask questions to reveal class profile, e.g., "how many are engineers?, how many have performed an LCC evaluation?"	
8:50	<u>BRIEF OVERVIEW OF THE COURSE & INTRODUCTION TO COURSE MATERIAL:</u> First, state the broad course objective (see "Objectives"). Orient students to the Student Manual, pointing out that there are 10 modules to be covered. Explain that the manual provides background material on each topic; exercises and problems they will do in class; supporting tables; and copies of slides. It will serve as a workbook in class and can be used for a quick refresher or reference later on. (Hold administrative details until first break or just before lunch.)	
8:58	Introduce Topic A.	

LESSON PLAN NO. 2

Schedule Topic A. ECONOMICS CAN IMPROVE DECISIONS Day 1
Time Scheduled 9:00-9:50

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
9:00	EXAMPLES OF DECISIONS: Breathe life into the course in this first technical session by giving examples of problems that economics can help solve. This can be done by asking the following kinds of questions: o Is it a good idea to add a waste-heat recovery system to capture excess heat from a computer room to heat an adjoining space of an office building? o Suppose you must select an HVAC system for a new building and there are five different systems which will work, each having different first costs, fuel efficiencies, and using different fuel. Which system design should you choose? o Suppose you move into a house with an uninsulated attic. How much insulation should you add? o Suppose you wish to retrofit a building to make it more energy efficient. The furnace is old and inefficient and the envelope is uninsulated and drafty. If you improve the furnace efficiency, the payoff of increasing the resistance level of the building diminishes, and if you increase the resistance of the envelope, the payoff of improving the furnace efficiency diminishes. What combination of improvement to the envelope and to the furnace are cost effective? o You, as the energy manager of a facility, have identified 15 ways you could reduce energy consumption. The total cost of the 15 candidate projects is $100,000, but you have	

LESSON PLAN NO. 2, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	<u>EXAMPLES OF DECISIONS, CONTINUED</u>	
	received a budget of only $50,000. How do you assign priority to the projects competing for limited funding?	
	Summarize by showing that the examples are representative of generic classes of decisions to which methods of economic evaluation can be applied.	Slide A-1
9:10	<u>ECONOMIC EFFICIENCY CONCEPTS</u>:	Slide A-2 Slide A-3 Slide A-4
	Explain conceptually how economic evaluation can improve decisions. Start with concept of "cost effective" as implied in accept/reject decisions. Describe minimizing LCC, maximizing NS, and equating incremental costs and marginal savings. Point out relationship among three approaches.	
	Define terms "economic efficiency," "cost effectiveness," "optimization," "incremental (or "marginal") analysis."	Reference definitions in Student's Manual
9:25	<u>LCC PROFILES OF ENERGY-RELATED SYSTEMS</u>:	
	Demonstrate that it is important to take a long view when evaluating the economic performance of energy-related systems. Motor Example HVAC Example	 Slide A-5 Slide A-6

LESSON PLAN NO. 2, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
9:30	<u>OVERVIEW OF ECONOMIC EVALUATION METHODS</u>:	
	Give a brief overview of economic evaluation methods, describing each and telling how it is used.	Slide A-7 Reference equations 1-7 in Student's Manual
	Explain that we will focus on the LCC method because it emphasizes costs, takes a long-view, correctly adjusts cash flows for time of occurrence, and is particularly useful for making decisions about cost-reducing expenditures, such as energy conservation and renewable energy projects.	Slide A-8
	Briefly outline how to perform LCC analysis, and state that we will spend the next several modules on the details of how to calculate LCC.	Slide A-9
9:50	<u>BREAK</u> -- Announce that the class will resume promptly at 10:05 a.m. to discuss what is needed to get started in measuring economic performance.	

LIFE-CYCLE COSTING

LESSON PLAN NO. 3

Schedule Topic B. WHAT YOU NEED TO GET STARTED Day 1
Time Scheduled 10:05-10:55

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
10:05	DESIGN/RETROFIT ALTERNATIVES:	
	Discuss what is to be evaluated. Emphasize that no matter how good the economic evaluation, the outcome can be no better than the design or retrofit alternatives considered.	Slide B-1
	Explain that only alternatives which satisfy performance requirements should be considered. Discuss what to do if an alternative exceeds requirements. The additional benefits could be subtracted from LCC. But often no additional credit is given because it is assumed that performance requirements, if well specified, ensure a sufficient level of the attribute in question. Sometimes differences in benefits are described qualitatively rather than expressed in dollars.	
10:10	RELEVANT EFFECTS:	
	Explain that "relevant effects" are significant changes which are expected to result from a decision. Since the objective is to make a decision, not conform to an accounting system, it is unnecessary to include in an evaluation items of costs and benefits not affected. List the items which are often affected by energy conservation projects.	Slide B-2 Slide B-3
10:15	ESTIMATING CASH FLOWS:	
	Point out that the economic evaluation methods include only effects expressed in dollars. Discuss how they can obtain dollar estimates.	Slide B-4

LESSON PLAN NO. 3, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
10:25	<u>SETTING THE STUDY PERIOD</u>:	
	Explain factors to consider in setting the study period and give examples.	Slide B-5
10:35	<u>CLASS EXERCISES</u>:	
	Ask the class to divide into groups and identify relevant effects from a list of items, and to select a study period based on information given.	Exercise B-1 Exercise B-2
	Ask a group member to present the group's answers and ask the rest of the class to challenge if they disagree.	Solutions to Exercises B-1 & B-2
10:55	<u>BREAK</u> -- Discretionary. Omit if running behind or make it a short stand-and-stretch break.	

LIFE-CYCLE COSTING

LESSON PLAN NO. 4

Schedule Topic C. Adjusting Cash Amounts for Time of Occurrence Day 1
Time Scheduled 11:00 - 12:00 & 12:50 - 1:30

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
11:00	CASH-FLOW MODELING:	
	Remind students that dollar amounts for energy-related investments will typically be spread over an extended study period. Remind them that an essential attribute of the LCC and other technically correct methods of economic evaluation is that they adjust dollar amounts for time of occurrence. Therefore, it is necessary to estimate not only the dollar amount of each effect, but also its timing. Explain conventions for modeling cash flows. Recommend that they draw cash-flow diagrams as part of the data collection effort. Explain the "common-time conventions" for expressing all dollar amounts (i.e., present value and annual value).	Slide C-1 Slide C-2
11:15	TIME VALUE OF MONEY CONCEPT:	
	Explain why it is necessary to adjust cash flows to a common time basis, and, at the same time, lay the basis for how it is done by demonstrating compound interest computations. The following approach might be used:	
	(1) Ask a student whether he or she would prefer receiving \$100 today or \$100 in one year (guaranteed). Ask what they could do with the money if they received it now (in order to bring out the concept that they incur opportunity cost by deferring receipt).	Flip Chart
	(2) Raise the future amount in increments until the student switches preference to the future amount. Identify	

LESSON PLAN NO. 4, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	TIME VALUE OF MONEY CONCEPT, CONTINUED	
	the amount at which the student is indifferent between the present amount and the future amount.	Flip Chart
	(3) Show how the minimum acceptable rate of return (MARR) can be calculated: $P \times (1+MARR)^n = F$. Therefore, $MARR = (F/P)^{1/n} - 1$.	
	(4) Ask if he or she would be willing to forego \$100 today in order to receive the \$100 plus earnings on the \$100 at the MARR over two years.	
	(5) Explain that we can use the student's revealed preference for present dollars over future dollars to make capital investment decisions. Describe the approach and give an example using the student's MARR. Explain that the MARR used to find the present value equivalent of a future amount is called the "discount rate" and the process, "discounting": $P = F/(1+D)^n$.	Reference equations 8-10 in Student's Manual
	(6) Discuss the implications of the time-equivalent amount for the decision.	
	Emphasize that an individual or organization, including the government, by specifying its discount rate, gives us the information we need to make decisions (which entail trading present dollars for future dollars) on behalf of that entity.	

LESSON NO. 4, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	TIME VALUE OF MONEY, CONTINUED:	
11:30	Explain that there is a family of related formulas for finding time-equivalent values, and describe several.	Reference Table C-1 in Student Manual
	Explain that tables of multiplicative factors (derived by applying the discount formulas for specified rates, and lengths of time) are available to reduce computational requirements. Give several examples of how the factors are used and what they mean. Reference "DISCOUNT" computer program.	Reference Tables C-2, C-3, C-4; Tables A-1, A-2, and B in Appendix B, Student Manual and Computer Program
	Give discounting formulas using factors.	Slide C-3
	Discuss and illustrate the effect of the size of the discount rate on the capital investment decision.	Slide C-4
11:50	Work through examples finding P given F, P given A, and P given A and e. Explain what the results mean in terms of discounting operations associated with energy conservation projects. Encourage class participation in performing the calculations.	Slides C-5 - C-12 (including solution slides)
		Reference Sample Problems in Student Manual
	Announce that the first topic after lunch will be "What to do About Inflation/Deflation," an issue which is a source of confusion and error for many practitioners.	
12:00	Lunch	

LESSON PLAN NO. 4, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
12:50	<u>WHAT TO DO ABOUT INFLATION</u>:	
	Explain how inflation is handled in economic evaluations. Distinguish the requirements for accounting and preparing budget estimates from those of economic analysis. Point out that the former requires current dollars, and the latter, constant dollars. Explain why. You may wish to make an analogy of changing value and asking an architect or engineer to measure the physical dimensions of a room with a ruler of changing length.	Prop: "Fake Measuring Sticks"
	You may wish to show the magnitude of changes in the value of the dollar in the past to acknowledge the problem.	Slide C-13
	The following approach might be used to explain how to deal with inflation:	
	(1) Return to the MARR derived previously for a particular student and ask what rate he or she would have required if there were a guarantee of no change in the value of a dollar over time. Call this the "real MARR" (and "real discount rate") and point out that the rate excludes general price inflation. Call the former, the "nominal MARR" (and "nominal discount rate"). Derive the implied inflation rate, showing the mathematical relationship between the inflation rate and the two discount rates.	Flip Chart Used Throughout Exposition
	(2) Use the real discount rate (or "real MARR") to compute the number of constantly valued (or "constant") dollars the student would require in 1 year to be indifferent between receiving that amount and $100 today; also the amount in two years.	

LESSON PLAN NO. 4, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	WHAT TO DO ABOUT INFLATION, CONTINUED:	
	(3) Compare the constant dollar amounts with the currently valued or "current" dollar amount determined previously. Note that the excess of current dollars over constant dollars does not add to buying power. Point out that the present value of both amounts is $100. The constant dollar amount does not require adjustment for inflation, only the real opportunity cost; but the current dollar amount must be adjusted both for the "real" opportunity cost and price inflation in order to find its present value equivalent.	Flip Chart
	Point out that the investor's expectation about inflation will be reflected both in the future amount and in the discount rate.	
	The main point is that to find the present value equivalent of a future amount which includes inflation, the inflation must be taken out. When we discount using a nominal discount rate, we take out the inflation.	
	(4) An alternative, which will give equal results, is to estimate future costs and benefits in constant dollars initially. Since there is no inflation to remove, a real discount rate can be used to find the present value equivalent.	
	(5) Explain that estimating future costs and benefits in constant dollars entails projecting how prices of a	

LESSON PLAN NO. 4, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	WHAT TO DO ABOUT INFLATION, CONTINUED:	
	particular good or service will change relative to prices in general, that is, computing differential rates of change only. Give examples of items increasing in price faster or slower than prices in general.	Slide C-14 (Series a to d)
	(6) Summarize (a) current dollar/nominal discount rate approach and (b) constant dollar/real discount rate approach. Demonstrate that they give identical results. Discuss the pros and cons of each. Explain the Federal approach.	Slide C-15 Reference Equations 11-14
1:10	Pose set of conditions and ask the class what the discount rate should be and whether it is real or nominal. For example, you might pose the following:	Flip Chart
	Suppose you have on hand $1000 of "discretionary" funds. You can put it in your savings account to earn 9% or you can use it to pay off a mortgage loan at 10%. Alternatively, you could repair your roof now for $1,000, and avoid replacing it in 5 years. What discount rate do you think you should use to evaluate the cost effectiveness of the roof repair? Is this a real rate or a nominal rate? Before tax or after tax? Suppose you expect inflation to average 5% per year over the next 5 years. What is your real after-tax discount rate? Assume the roof replacement would cost $4,000 if done today. Assume that roofing materials and labor are expected to increase at close to	

LESSON PLAN NO. 4, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	WHAT TO DO ABOUT INFLATION, CONTINUED:	
	the rate of general price inflation. What is the estimated future replacement cost in current dollars? What is the estimated future replacement cost in constant dollars? What is the present value of the replacement cost? Should you repair the roof now or replace it in 5 years?	Flip Chart
1:15	CLASS EXERCISE:	
	Ask students to calculate the present value of a set of sample cash flows.	Exercise C-1
1:30	Review Solutions.	Solution Slides C-S16 - C-S21
	Point out that they now have all of the elements for performing an economic analysis. By combining the appropriate discounting operations in the prescribed formats, they will calculate LCC, NS, SIR, AIRR, and PB.	

LESSON PLAN NO. 5

Schedule Topic D. Calculating Life-Cycle Costs, Net Savings, Savings-to-Investment Ratio, Adjusted Internal Rate of Return, and Time to Payback Day 1

Time Scheduled 1:35 - 2:50

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
1:35	FEDERAL CRITERIA:	
	Explain that because of emphasis on teaching how to perform economic analyses of Federal energy conservation projects, you will illustrate the economic evaluation methods for a Federal application. List the Federal criteria and discuss what they might do differently if (a) the Federal project is not for energy conservation, and (b) it is not a Federal project.	Slide D-1 Reference "FEDERAL CRITERIA" in Student's Manual
1:40	WORKSHEETS:	
	Briefly introduce the worksheets and explain that these are aids for performing evaluations manually.	Reference set of worksheets in Handbook 135
1:45	CALCULATIONS:	
	Present an illustrative retrofit problem and use slides or flip chart to compute LCC, NS, SIR, AIRR, and PB according to Federal criteria. If you use flip chart, tear off and tape to the wall the LCC calculations prior to starting the other calculations, because you will need those data. Ask the students to supply the data and to direct the computations as you work through the problem, without looking at the solution slides.	Refer to MODULE A, "Overview of Economic Methods" Slides D-2 - D-15, or alternatively, Flip Chart
2:15	Break -- Announce that the class will resume promptly at 2:25 to perform Problem D-1.	

LESSON PLAN NO. 5, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
2:25	CLASS PROBLEM:	Problem D-1
	Ask the class to work in pairs to perform Problem D-1.	
2:45	Review Results.	Slides D-S16-D-S18
2:50	Move to Computer Lab.	

LIFE-CYCLE COSTING

LESSON PLAN NO. 6

Schedule Topic E. LCC Computer Program Day 1
Time Scheduled 3:00 - 4:30

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
3:00	OVERVIEW OF FBLCC & NBSLCC: Describe principal features of the software. Distinguish between the two programs. Reference LCCID. Explain how to load and run the software.	Slides E-1 - E-13
3:15	GETTING ACQUAINTED WITH THE SOFTWARE: Direct the students to turn on their computers and load the program. Show them what they should see on their screens initially.	Reference FBLCC and NBSLCC Data Entry Screens in Student's Manual
	SUPPLEMENT TO FBLCC USER'S GUIDE: Point out that they have the supplement for reference. SUPPLEMENT TO NBSLCC USER'S GUIDE: Point out that they have the supplement for reference.	Reference Supplements to User's Guides in Student's Manual
3:20	PROBLEM-SOLVING USING FBLCC & NBSLCC: Ask students to solve problem E-1 (a problem performed manually in the preceding session).	Problem E-1
	Tell students to raise their hands if they need assistance at any time and an instructor will come to their aid. If computers are to be shared, form teams at the beginning of the session.	
	Ask students to raise their hands to be checked off when they have successfully completed the exercise. When they have finished, suggest they try Problem D-1. Suggest the addition of tax assumptions if they wish to use NBSLCC.	Problem D-1

LESSON FORM NO. 6, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	PROBLEM-SOLVING USING FBLCC & NBSLCC CONTINUED:	
4:25	Announce that tomorrow they will learn how to determine the cost-effective design and size of a building system; how to assign priority among projects so as to obtain the greatest savings from the available budget; and what to do about uncertainty. In the afternoon, an extended computer laboratory will provide them opportunity to put the new concepts into practice.	Flip Chart
	Announce tomorrow's starting time. Emphasize that they need the fundamentals covered today in order to accomplish tomorrow's objectives. Suggest that they review the Student's Manual, Modules A-E to prepare for the next modules.	Flip Chart Reference Student's Manual, Modules A-E
4:30	Adjournment.	

LIFE-CYCLE COSTING

LESSON PLAN NO. 7

Schedule Topic F. Designing & Sizing Independent and Interdependent Systems — Day 2

Time Scheduled 8:30 - 9:45

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
8:30	Explain that today we will cover (1) Designing/sizing individual building systems, (2) Designing/sizing in combination building systems which are interdependent, and (3) Deciding which projects to fund when the budget is limited.	Slide F-1
8:35	INDEPENDENT SYSTEMS:	
	Show how to find the cost-effective level of insulation using NS. Point out the agreement between basing NS on incremental costs and savings and on totals.	Slides F-2 - F-8
	First determine the cost-effective level assuming no budget limitation. Then set a budget constraint and show the constrained level.	
	If time allows, demonstrate that for designing/sizing, the SIR must be used incrementally.	Slide F-9
	Evaluate the heating system independent of the insulation. Encourage students to participate in working through each problem.	Slides F-10 - F-11
9:00	INTERDEPENDENT SYSTEMS:	Slides F-12 - F-22
	Now show how the cost-effectiveness of the heating system replacement is changed by the insulation, and how the cost-effectiveness of the insulation is changed by the heating system replacement. Show how to find the cost-effective combination of insulation and heating system replacement. (Note that Slides F-4 through F-7, F-12 through F-15, and F-17 through F-20 repeat the calculation procedure. It should	

LESSON PLAN NO. 7, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
	INTERDEPENDENT SYSTEMS, CONTINUED:	
	not be necessary to go through each in detail. Rather, focus on Slides F-4, F-12, and F-17; the others complete the series of calculations.)	
9:15	CLASS PROBLEM:	Problem F-1
	Ask the class to work in pairs to perform Problem F-1.	
9:40	Review Results.	Solution Slides F-S23 - F-S24
9:45	BREAK -- Announce that the class will resume promptly at 10:00 to learn how to assign priority to competing projects when the budget is limited.	

LIFE-CYCLE COSTING

LESSON PLAN NO. 8

Schedule Topic G. Determining Project Priority — Day 2
Time Scheduled 10:00 - 11:00

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
10:00	SIR USEFUL FOR ASSIGNING PRIORITY:	
	Explain and demonstrate why the SIR (and the AIRR) are useful for assigning project priority, but LCC, NS, and Btu/I are not.	Slides G-1 - G-6
10:15	LIMITATIONS OF SIR FOR ASSIGNING PRIORITY:	
	Demonstrate the circumstances under which ranking by the SIR can fail to identify the group of projects which will maximize the overall return on the budget. Explain how to use aggregate LCC or NS as a backup method.	Slides G-7 - G-8
10:30	ALLOCATING A BUDGET AMONG PROJECTS OF VARIABLE DESIGN/SIZE:	
	Remind students that in the session on designing/sizing projects, we first looked at designing/sizing individual projects assuming no budget limitation. When we assumed a smaller budget than required for the optimal design or size, we had to eliminate cost-effective increments. Point out that design/size decisions and budget allocation decisions are, in theory, simultaneous decisions. They must be in practice to achieve maximum aggregate NS for a given budget.	
	Demonstrate how to allocate a budget among projects of variable design and size. Compare with allocating a budget among pre-designed/presized projects. Point out conditions under which the first approach is practical (a single budget) and impractical (a series of related budgets.)	Slides G-9 - G-11 Slide G-12

LESSON PLAN 8, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
10:45	CLASS PROBLEM: Ask the class to work in pairs to perform Problem G-1.	Problem G-1
10:55	Review Results.	Solution Slide G-S1
11:00	BREAK -- Announce that the class will resume promptly at 11:15 to discuss what to do about uncertainty in performing economic evaluations.	

LESSON PLAN NO. 9

Schedule Topic H. Uncertainty — Day 2
Time Scheduled 11:15 - 12:15

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
11:15	SOURCES AND EFFECTS OF UNCERTAINTY:	
	Discuss major sources of uncertainty, such as not knowing exactly how much an energy conserving system will save, or exactly what it will cost to purchase, install, and maintain. Point out that economic evaluations which take a life-cycle perspective will by nature be based on projections, and projections mean uncertainty. Because this may cause some to think that a first-cost approach might be better, point out that using a first-cost approach has in it the implicit assumption that future costs are zero. Explain that uncertainty in input values means that the actual outcome may differ from what is estimated. Based on uncertain estimates, we may reject a cost-effective project. We may obtain lower net savings than expected or incur net losses. Uncertainty in input values creates risk that a decision will have a less favorable outcome than what is expected.	Flip Chart
	Point out that using our "best-guess estimates" as projected input values (as though they were certain), and calculating the results deterministically as a single-value outcome, provides no indication of the degree of uncertainty and no way to measure the associated risk.	

LESSON PLAN NO. 9, CONTINUED

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
11:30	WHAT TO DO ABOUT UNCERTAINTY & RISK:	
	Explain that there are techniques for treating uncertainty and risk, some of which entail the use of single- or multiple-value data, and some of which entail the use of probability distributions of data. Describe them briefly if time permits.	Slide H-1
	State that our time schedule permits only a very limited treatment of uncertainty and that we will focus on Sensitivity Analysis because it is easy to perform and to use, is practical, and can aid in making decisions in the face of uncertainty. Reference Marshall (1988), have several copies available for examination; and recommend that they read about the other techniques, some of which provide more definitive guidance on decisions under uncertainty and risk than does Sensitivity Analysis.	Reference Marshall (1988) Report
	Explain and illustrate how to do Sensitivity Analysis. Explain how to use the results of Sensitivity Analysis. Describe Federal criteria regarding uncertainty.	Slides H-2 - H-6
11:45	CLASS PROBLEM:	
	Ask the class to work in pairs to perform Problem H-1.	Exercise H-1
12:05	Review results and discuss in light of Federal criteria.	Slides H-S7 - H-S8
12:15	Lunch	

LIFE-CYCLE COSTING

LESSON PLAN NO. 10

Schedule Topic I. REVIEW
Time Scheduled 1:00 - 2:00

Day 2

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
1:00	[NOTE: If you plan to keep all students until the announced time of adjournment (as opposed to letting them leave when they have completed assigned exercises in the computer lab), you may wish to defer Session I to the last period of the day, and use it as a closing; alternatively, it can be moved to the beginning of the second day.] Begin with a short review of topics covered. Ask questions to ascertain the level of understanding and to identify problem areas. Or, ask students to divide into small groups and formulate a question (one or two per group) concerning discounting, inflation, evaluation methods, or using the computer. Each group puts its question to the others and evaluates their answer.	
2:00	Announce start of computer lab.	

LESSON PLAN NO. 11

Schedule Topic J. COMPUTER LABORATORY Day 2
Time Scheduled 2:00 - 4:30

TIME	DETAILED COVERAGE	TRAINING AIDS OR CUES
2:00	Explain how to use FBLCC and NBSLCC to design and size projects and to set priority among projects.	
	Form the class into teams of four (or six if there are three sharing a computer).	
	[Discretionary: Inform students that the first exercise of the afternoon will be a competition.]	
	Present Problems J-1 and J-2 to be carried out by each team. Request the teams to indicate when they have finished, so they can be checked off. [Reward the winning team if the exercise is performed as a competition.]	Problems J-1 & J-2 Recognition/ Prize/ Certificate
	If time permits and students wish additional practice, suggest they solve a problem from Appendix A.	Reference Appendix A of Student's Manual

EXERCISES AND PROBLEMS

(WITH SOLUTIONS)

EXERCISE B-1

Relevant Effects

Suppose you want to evaluate whether it is cost effective to replace an existing HVAC system with a new system. Assume that the existing system can continue to meet heating and cooling requirements over the remaining 10 years that the owner plans to occupy the building. From the following list, check the data you need:

	1.	Original land costs	\$100,000
	2.	Original site improvements	\$50,000
	3.	Initial construction costs	\$5,000
	4.	Purchase and installation costs of the existing HVAC system	\$10,000
	5.	Duct work for the existing HVAC system	\$10,000
√	6.	Modification of the existing duct work to meet requirements of the new HVAC system	\$2,000
√	7.	Purchase and installation costs of the new HVAC system	\$50,000
	8.	Maintenance cost of the existing HVAC	\$2,000/year
	9.	Maintenance cost of the new HVAC	\$2,000/year
√	10.	Heating efficiency/cooling COP of existing system	0.65/2.0
√	11.	Heating efficiency/cooling COP of new system	0.80/3.0
√	12.	Current price of energy used by the existing system	\$25.00/MBtu
√	13.	Current price of energy used by the new system	\$22.00/MBtu
√	14.	Projected rate of change in price of energy used by existing system	7%/year
√	15.	Projected rate of change in price of energy used by new system	5%/year
√	16.	Building heating load (annual)	3,000 MBtu
√	17.	Building cooling load (annual)	4,000 MBtu

EXERCISE B-1

Relevant Effects, continued

√	18.	Existing HVAC system's current resale, less removal costs	$5,000
	19.	New HVAC system's resale, less removal costs, at the end of its 30 year service life	$10,000
	20.	Replacement costs of existing system at end of its 15 year remaining service life	$35,000
	21.	Replacement of new system at the end of end of its 30 year service life	$45,000
√	22.	The amount the new system will add to resale value of the building in 10 years	$10,000
?	23.	The new system operates more quietly than the existing system	

EXERCISE B-2

Setting the Study Period

Choose a study period for each of the following situations:

1. A building owner wants to evaluate the cost effectiveness of an automatic thermostat control which will last 15 years. The building will be used indefinitely. (15-year study period)

2. A designer wishes to perform an LCC comparison of two solar window films. Film A lasts five years; film B lasts 10 years. The building will be used indefinitely. (10-year study period)

3. A state government sets a limit of 25 years on its LCC studies. An analyst is evaluating alternative roofing systems, one of which lasts 15 years and one of which lasts 30 years. (25-year study period)

EXERCISE C-1

Computing Time-Equivalent Values Using Discount Factor Tables

1. Find the value at the end of seven years of a present amount of $100 which grows at a rate of 9% compounded annually. (Sketch a cash-flow diagram.)

2. Find the present value of $1,000 to be received at the end of 20 years when the discount rate is 10%. (Sketch a cash-flow diagram.)

EXERCISE C-1

Computing Time-Equivalent Values Using Discount Factor Tables, continued

3. You are notified that you have won the million-dollar lottery, and that you will receive the $1,000,000 in $50,000 installments paid at the end of each of the next 20 years. Assuming you can invest funds on hand to earn 10% per annum, what is the present value of your prize? (Sketch a cash-flow diagram.)

4. What is the estimated present value of a $10,000 cost (in constant dollars) to be incurred five years from now, based on a 7% (real) discount rate?

EXERCISE C-1

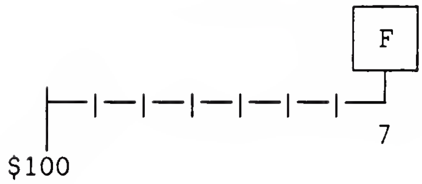
Computing Time-Equivalent Values Using Discount Factor Tables, continued

5. What is the estimated present value of a uniform annual cost of $1,000 (in constant dollars) that is expected to recur over the next 20 years, if the discount rate is 7% (real)?

6. What is the present value of the energy savings from a retrofit project in Seattle which reduces annual electricity bills in a Federal office building by $5,000, at today's prices, assuming that savings accrue over the next 25 years.

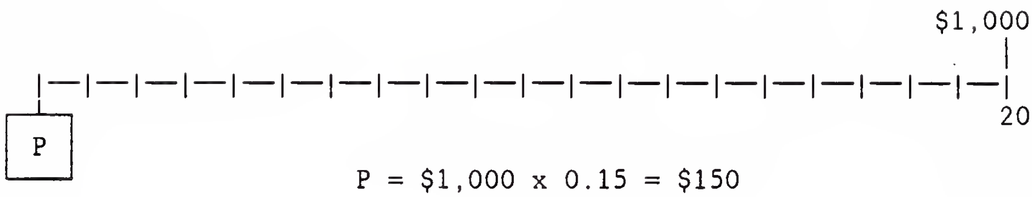
SOLUTIONS TO EXERCISE C-1

1.



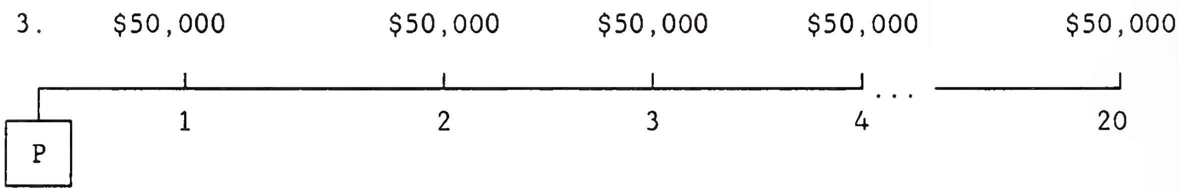
F = \$100 x 1.828 = \$182.80

2.



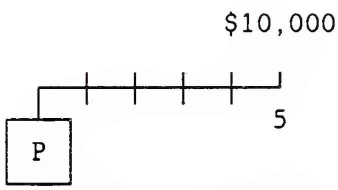
P = \$1,000 x 0.15 = \$150

3.



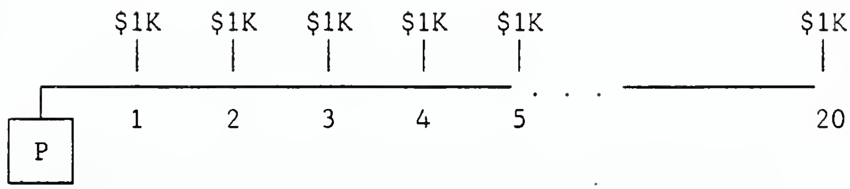
P = \$50,000 x 8.51 = \$425,500

4.



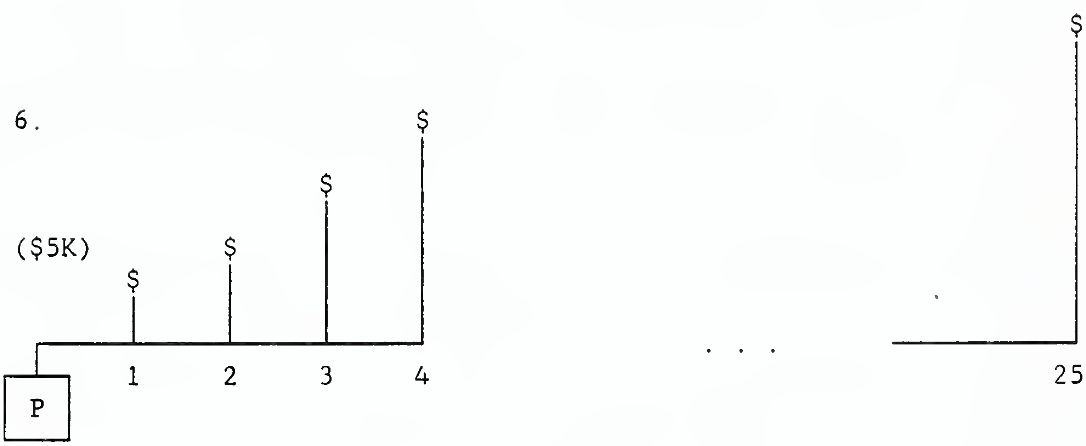
P = \$10,000 x 0.71 = \$7,100

5.



P = 1,000 x 10.59 = $10,590

6.



P = $5,000 x 12.10 = $60,500

PROBLEM D-1

Calculating LCC, NS, and SIR

Use LCC, NS, and SIR to determine if adding a solar hot water system to a military launderette is estimated to be cost-effective, and, if so, what funding priority it should receive relative to other energy conservation projects. The alternatives are to

(1) continue using the existing hot water system as it is, or

(2) add the solar hot water system and use the existing system as a backup.

Data and Assumptions:

Location: Arizona

Hot Water Load: 1,750 MBtu/year

Fraction of Load to be Supplied by Solar: 60%

Existing Hot Water Heater: Electric Resistance

Today's Price of Electricity: $20/MBtu

DOE Price Projections: Industrial pricing

Cost of Purchasing and Installing Solar Energy System: $140,000

Annual Electricity to Operate the Solar Energy System: 2% of annual load supplied by solar energy

Annual Maintenance & Repair Costs for the Solar Energy System: 3% of purchase and installation costs

System Lives: Both the existing system and the solar energy system are expected to last the remaining 15 years the launderette is expected to remain in use.

Salvage Value: 0

SOLUTION TO PROBLEM D-1

Calculate LCC without the Solar Energy System (alternative 1):

$$LCC_{WOS} = (1{,}750 \text{ MBtu/year}) \times \$20/\text{MBtu} \times 9.40$$

$$= \$329{,}000$$

Calculate LCC with the Solar Energy System (alternative 2):

$$LCC_{WS} = \$140{,}000 + (\$140{,}000 \times 0.03 \times 9.11)$$

$$+ 1{,}750 \text{ MBtu/year} \times \$20/\text{MBtu} \times 0.4 \times 9.40$$

$$+ 1{,}750 \text{ MBtu/year} \times (0.60 \times 0.02) \times \$20/\text{MBtu} \times 9.40$$

$$= \$140{,}000 + \$38{,}262 + \$131{,}600 + \$3{,}948$$

$$= \$313{,}810$$

Calculate NS for the Solar Energy System:

$$NS = \$329{,}000 - \$313{,}810$$

$$= \$15{,}190$$

Calculate SIR for the Solar Energy System:

$$SIR = [(\$329{,}000 - \$131{,}600) - \$38{,}262 - \$3{,}948]/\$140{,}000$$

$$= \$155{,}190/\$140{,}000$$

$$= 1.11$$

PROBLEM E-1

Selecting a Heating and Cooling System

Compare the LCCs of the following two systems for heating and cooling a house on a military base in Washington, D.C., based on their comparative cost effectiveness:

Baseboard Heating System with Window Air Conditioners (Lowest First-Cost System)

- Initial purchase and installation costs:

  Baseboard heaters = $500
  Window air conditioners = $1,000

- Annual maintenance cost = $50
- Air conditioner repairs in year 8 = $400
- Salvage values:

  Baseboard = $50 (10% of initial cost)
  Window air conditioners = $100 (10% of initial cost)

- Useful life = 15 years
- Annual electricity consumption = 60 MBtu (17,580 kWh)
- Price of electricity = $20/MBtu ($0.068/kWh) (Commercial Pricing)

Heat Pump

- Initial purchase and installation cost = $3,000
- Annual maintenance cost = $100
- Compressor repair at end of year 8 = $600
- Salvage value (net of disposal costs) at end of life = $250
- Useful life = 15 years
- Annual electricity consumption = 40 MBtu (11,720 kWh)
- Price of electricity = $20/MBtu (0.068/kWh) (Commercial Pricing)

PROBLEM E-1, continued

Selecting a Heating and Cooling System

Additional Assumptions Common to Both Systems

- All costs are stated in constant dollars
- Discount rate = 7% (real)
- All variables not specified, such as comfort level, are the same for both systems.

[Note: A copy of the solution to this problem is not provided because the problem will be solved using the latest version of "FBLCC" and, hence, the solution will change over time due to changing energy price projections. It is suggested that the instructor solve the problem in advance and either provide a hand-out of the solution or show slides or vugraphs of the solution.]

PROBLEM F-1

Use LCC or NS to Choose Among Single-, Double-, and Triple-Glazed Windows

Assumptions:

	Purchase & Installation Cost ($)	Δ Cost ($)	Annual Heating Load (MBtu)	Δ Annual Heating Load (MBtu)
Single-Glazed Windows	2,000	2,000	60	
Double-Glazed Windows	2,800	800	50	-10
Triple-Glazed Windows	3,400	600	48	-2

Furnace efficiency: 0.75

Fuel: Distillate Oil

Initial Price of Oil: $8.00/MBtu

Location: Vermont

Type of Building: Park Service Ranger's House (commercial pricing)

All costs other than purchase, installation, and energy are identical.

Estimated Life: Indefinite

SOLUTION TO PROBLEM F-1

Use LCC or NS to Choose Among Single-, Double-, and

Triple-Glazed Windows

LCC SOLUTION:

Calculate LCC of Single-Glazed Windows:

LCC_1 = \$2,000 + [(60 MBtu/0.75) x \$8.00 MBtu x 16.76]

= \$12,726

Calculate LCC of Double-Glazed Windows:

LCC_2 = \$2,800 + [(50 MBtu/0.75) x \$8.00/MBtu x 16.76]

= \$11,739

Calculate LCC of Triple-Glazed Windows:

LCC_3 = \$3,400 + [(48 MBtu/0.75) x \$8.00/MBtu x 16.76]

= \$11,981

Conclusion: Choose double-glazed windows.

SOLUTION TO PROBLEM F-1, continued

Use LCC or NS to Choose Among Single, Double, and

Triple Glazed Windows

NS SOLUTION:

Calculate NS of Double-Glazed Windows:

NS = [(10 MBtu/0.75) x $8.00/MBtu x 16.76] - $800

= $988

Calculate NS of Triple-Glazed Windows:

NS = [(2 MBtu/0.75) x $8.00/MBtu x 16.76] - $600

= -$242

Conclusion: Choose double-glazed windows.

PROBLEM G-1

Allocating a Budget among Projects of Variable Size Using SIR

Allocate a budget of \$6,500 among the following projects, assuming that no future funds will be available for retrofitting Buildings A, B, C and D.

Energy Conservation Projects	First Cost (\$)	PV Savings (\$)
Add Solar Water Heater in Building A	2,000	3,800
Replace Chillers in Building A	12,000	16,800
Add R-8 Insulation in Building B	1,000	5,000
Increase Insulation in Building B from R-8 to R-19	500	1,000
Increase Insulation in Building B from R-19 to R-30	500	600
Replace Lighting System in Building C	3,000	9,000
Replace Windows in Building D	6,000	9,600

What if the budget is \$7,000?

SOLUTION TO PROBLEM G-1

Allocating a Budget among Projects of Variable Size Using SIR

Energy Conservation Projects	First Cost ($)	PV Savings ($)	Net Savings ($)	SIR	Rank
Add Solar Water Heater in Building A	2,000	3,800	1,800	1.9	4
Replace Chillers in Building A	12,000	16,800	4,800	1.4	6
Add R-8 Insulation in Building B	1,000	5,000	4,000	5.0	1
Increase Insulation in Building B from R-8 to R-19	500	1,000	500	2.0	3
Increase Insulation in Building B from R-19 to R-30	500	600	100	1.2	7
Replace Lighting System in Building C	3,000	9,000	6,000	3.0	2
Replace Windows in Building D	6,000	9,600	3,600	1.6	5

For a budget of $6,500, choose R-19, lighting system, and solar.
For a budget of $7,000, choose R-30, lighting system, and solar.

PROBLEM H-1

Taking Into Account Uncertainties

Use LCC with sensitivity analysis to evaluate the cost-effectiveness of retrofitting a computer room with a waste heat recovery system to supply part of the heating load of the building.

Data

Location:	Wyoming
Building:	Federal Building
Installed Cost of Waste Heat Recovery System:	$6,000
Yearly Maintenance and Repair Cost of Waste Heat Recovery System:	$500
Heating Load:	900 MBtu
Existing Fuel:	Natural Gas
Today's Price:	$5.15/MBtu (Commercial Pricing)
Efficiency of Existing System:	0.65
Contribution of Waste Heat Recovery System to Building's Heating Load:	25% (Best Guess) 10% (Worst Case)
Expected Period of Use:	Indefinite

SOLUTION TO PROBLEM H-1

Taking Into Account Uncertainties

Calculate LCC for the Existing System (LCC_E):

$$LCC_E = (900 \text{ MBtu}/0.65) \times \$5.15/\text{MBtu} \times 13.75$$

$$= \$98{,}048$$

Calculate LCC with the Waste Heat Recovery System (LCC_W):

$$LCC_W = [(900 \text{ MBtu}/0.65) \times 0.75 \times \$5.15/\text{MBtu} \times 13.75] + \$6{,}000 + (\$500 \times 11.65)$$

$$= \$73{,}536 + \$6{,}000 + 5{,}825$$

$$= \$85{,}361$$

$$\boxed{NS_W = \$12{,}687}$$

Calculate LCC with the Waste Heat Recovery System Based on the Lower Contribution to Load (LCC_W):

$$LCC_W = [(900 \text{ MBtu}/0.65) \times 0.90 \times \$5.15/\text{MBtu} \times 13.75] + \$6{,}000 + (\$500 \times 11.65)$$

$$= \$88{,}243 + \$6{,}000 + \$5{,}825$$

$$= \$100{,}068$$

$$\boxed{NS_W = -\$2{,}020}$$

COMPUTER LAB PROBLEM J-1

Sizing Attic Insulation

Use either FBLCC or NBSLCC to determine the level of attic insulation with the lowest life-cycle cost for a single-family house with electric resistance heating, located in the suburbs of Washington, D.C. (Census Region 3).

Assume a life of 25 years, and no salvage value. Use the following insulation cost and space heating load schedule:

ATTIC INSULATION LEVEL	TOTAL COST	SPACE HEATING LOAD (MBtu)
0	0	50.2
R-19	$440	35.2
R-30	$650	33.8
R-38	$800	33.3

Current electricity cost (residential rates) = $22.08/MBtu ($0.0754/kWh)

Energy conversion efficiency = 100%

Suggested Approach:

Using FBLCC or NBSLCC, create a building characteristics file (BCF) for the zero insulation case. This base case will have no investment cost (i.e., no capital component), no maintenance, and no resale value, but will have annual energy consumption based on the space heating load shown above. This base case BCF can then be modified to create BCFs for each insulation level, based on the insulation costs and corresponding space heating loads shown. Run LCCMAIN for each case and display the summary of LCCs to determine which insulation level has the lowest LCC.

[Note: A copy of the solution to this problem is not provided because the problem will be solved using the latest version of "FBLCC" and, hence, the solution will change over time due to revisions in DoE energy price projections. It is suggested that the instructor solve the problem in advance and either provide a hand-out of the solution or show slides or vugraphs of the solution.]

COMPUTER LAB PROBLEM J-2

Combining Heating System Replacement with Attic Insulation

Use either FBLCC or NBSLCC to evaluate the cost effectiveness of replacing the electric resistance heating system described in Problem J-1, based on the data below. Determine the optimal combination of attic insulation and heat pump.

Cost of Heat Pump Installed:	$3,000
Seasonal Coefficient of Performance of Heat Pump: (Heating)	2.0
Annual Maintenance Cost of Heat Pump:	$100
Annual Maintenance Cost of Electric Resistance System:	0
Expected System Lives:	25 years
Salvage:	0

[Note: A copy of the solution to this problem is not provided because the problem will be solved using the latest version of "FBLCC" and, hence, the solution will change over time due to revisions in energy price projections. It is suggested that the instructor solve the problem in advance and either provide a hand-out of the solution or show slides or vugraphs of the solution.]

ADDITIONAL PROBLEMS

(from Appendix A of Student's Manual)

Appendix Problem 1:	Design Problem
Appendix Problem 2:	Sizing and Ranking Problem
Appendix Problem 3:	Deciding Whether a Building Investment is Subject to FEMP Guidelines and Taking into Account a Delay in Construction

APPENDIX PROBLEM 1

Building Design Problem

An energy-conserving building design (A) is being considered as an alternative to a conventional building design (B) for a Federal office building in Madison, Wisconsin (Census Region 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 side is 25% of the wall area and most of that is located on the south side; in the conventional building, it is 40%. 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 earth-bermed. It is assumed that both designs will last at least 25 years, and they are both assumed to have no salvage value remaining at the end of the 25-year study period.

Based on the data given on the following page, determine which design has the lowest life-cycle cost.

	Energy-Conserving Design (A)	Conventional Design (B)
(a) Site acquisition costs: (To ensure adequate exposure of south-facing windows, an <u>additional</u> acquisition cost of $100,000 is necessary for the energy-conserving design. Other site costs are assumed to be identical for the two designs.)	$2,100,000	$2,000,000
(b) Architectural and engineering design fees and construction costs	$9,780,000	$9,130,000
(c) Annual energy consumption:		
Natural Gas	2,290 MBtu	4,980 MBtu
Electricity	3,886 MBtu	7,277 MBtu
(d) Energy prices:		
Natural Gas	$5.49/MBtu	$5.49/MBtu
Electricity	$21.21/MBtu	$21.21/MBtu
(e) Nonfuel O&M costs:		
Recurring Annual Cost	$70,000	$90,000
Repairs to External Surfaces every 10 years	$60,000	$100,000

APPENDIX PROBLEM 2

Sizing and Ranking Problems

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:

Footage 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: $7.00/MBtu
Plant Efficiency: 0.55
Remaining Building Life: Indefinite
Insulation Life: Indefinite
Study Period: 25 years
Available Insulation Choices: 1" or 2" of Fiberglass
Heat Loss Rates[1] -- 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 -- 1" Insulation: $3.60/ft installed cost
2" Insulation: $6.00/ft installed cost

The following questions are to be answered:

(1) Would it be cost-effective to insulate the pipes?

(2) How much insulation should be added, 1 or 2 inches?

---

[1] Estimated from U.S. Department of Energy, Architects and Engineers Guide to Energy Conservation in Existing Buildings, Heat Loss Rate Nomogram, Figure H-1.

APPENDIX PROBLEM 2

Sizing and Ranking Problems, continued

(3) What priority should this project receive relative to the following independent projects: Project A, SIR=5.0; Project B, SIR=15.1; Project C, SIR=1.7; Project D, SIR=2.8?

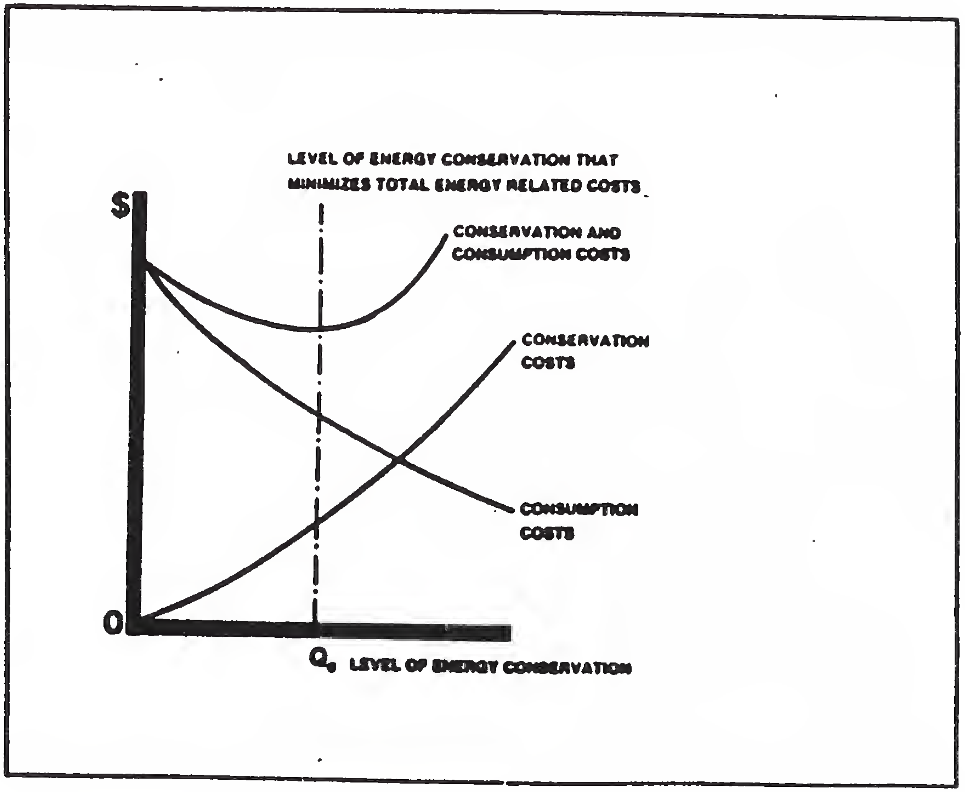
SLIDES

SLIDE A-1

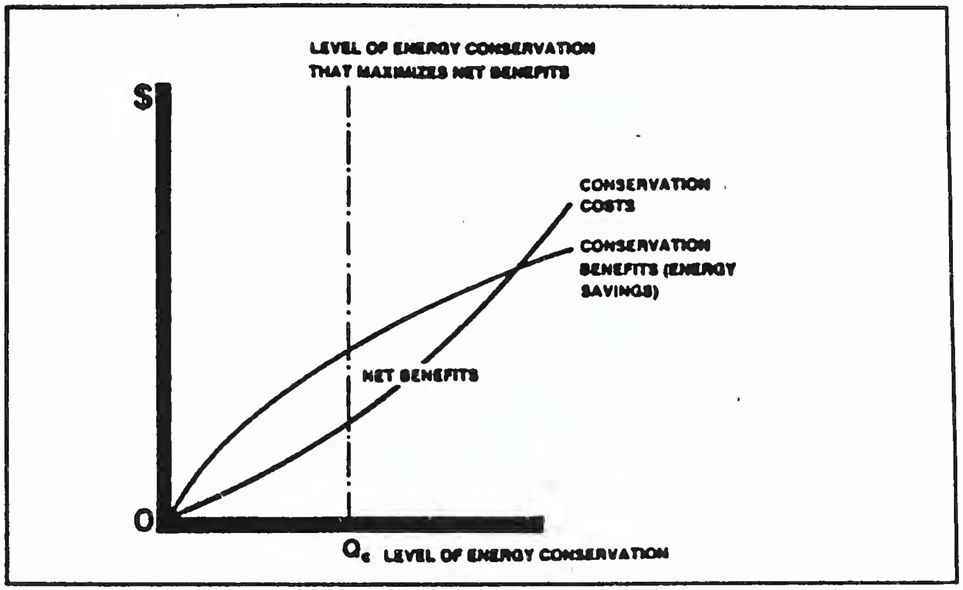
ECONOMICS CAN IMPROVE DECISIONS

- to accept or reject?
- which design?
- what size?
- what combination?
- what priority?

SLIDE A-2

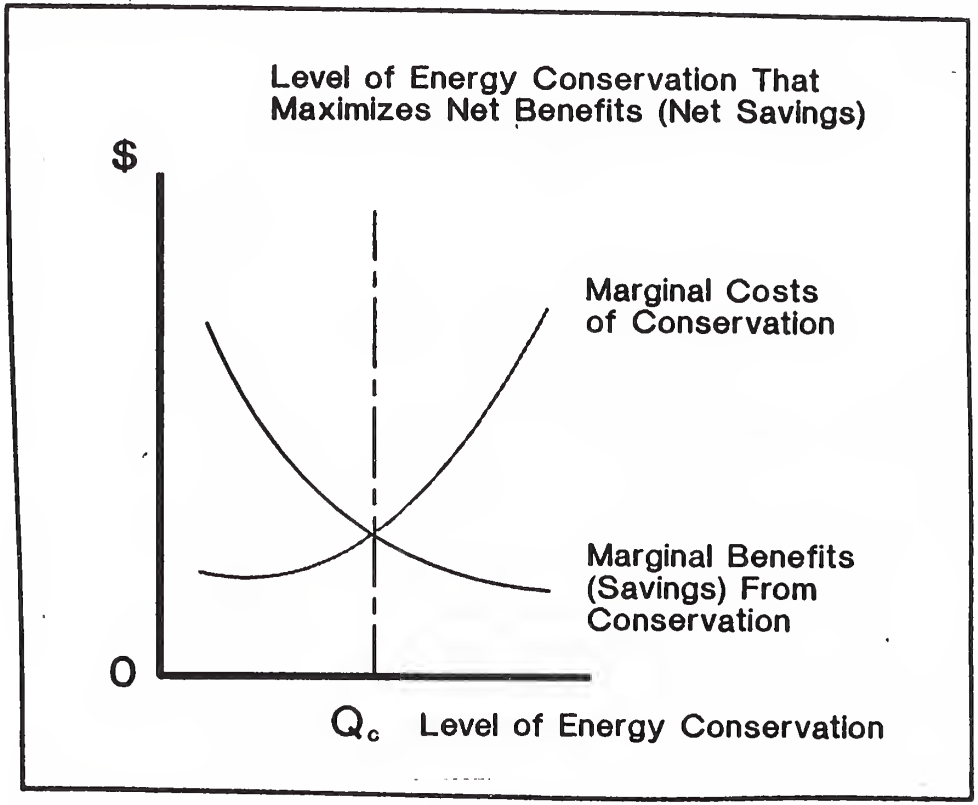

LEVEL OF ENERGY CONSERVATION THAT
MINIMIZES TOTAL ENERGY RELATED COSTS
$
CONSERVATION AND
CONSUMPTION COSTS
CONSERVATION
COSTS
CONSUMPTION
COSTS
0
Q_e LEVEL OF ENERGY CONSERVATION

SLIDE A-3

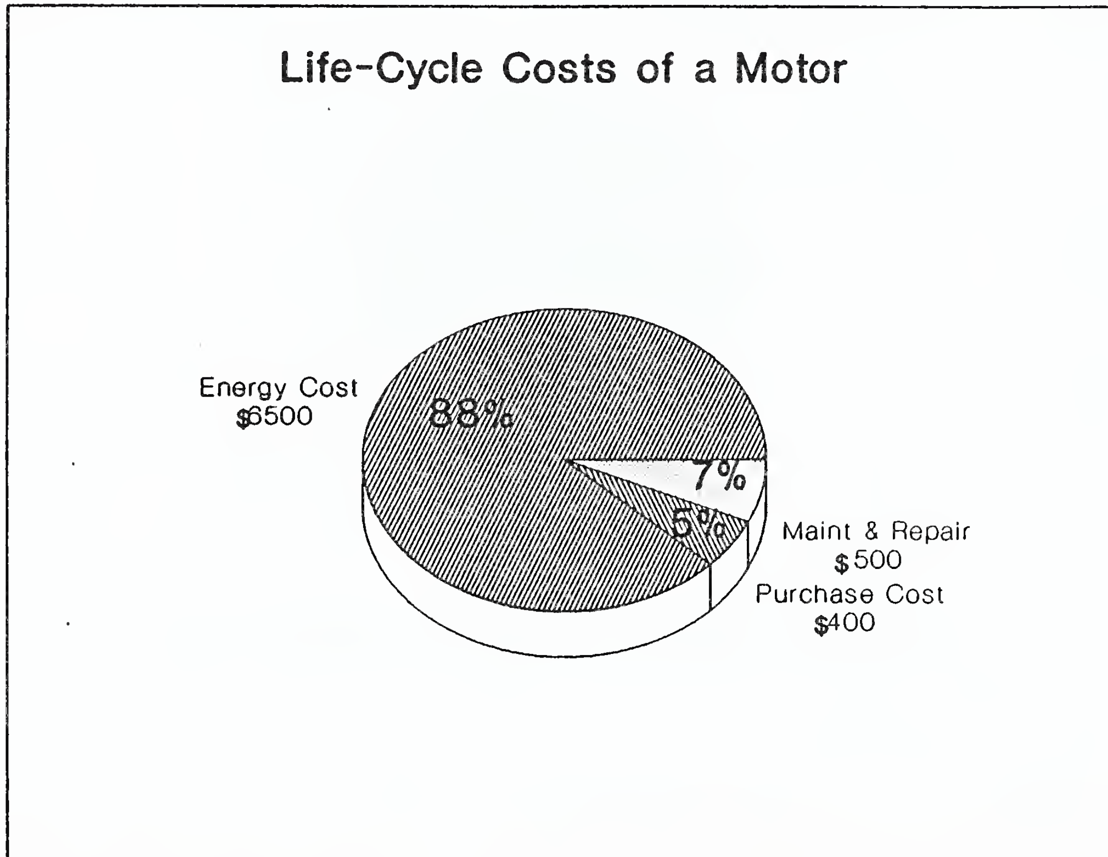


LEVEL OF ENERGY CONSERVATION
THAT MAXIMIZES NET BENEFITS
$
CONSERVATION
COSTS
CONSERVATION
BENEFITS (ENERGY
SAVINGS)
NET BENEFITS
O
Q_e
LEVEL OF ENERGY CONSERVATION

SLIDE A-4


Level of Energy Conservation That
Maximizes Net Benefits (Net Savings)
$
Marginal Costs
of Conservation
Marginal Benefits
(Savings) From
Conservation
0
Qc
Level of Energy Conservation

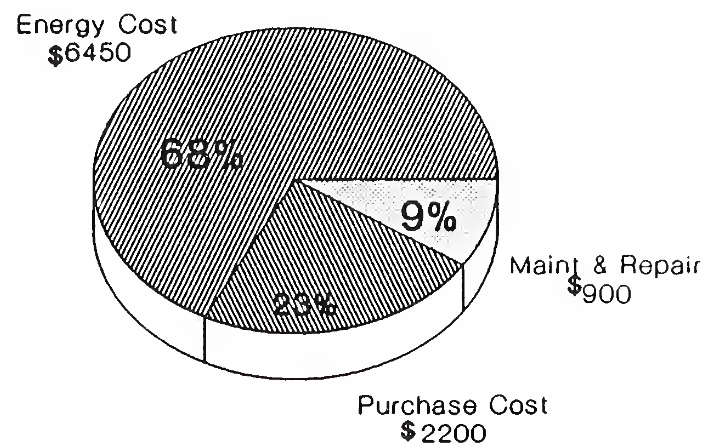
SLIDE A-5



Life-Cycle Costs of a Motor
Energy Cost
$6500
88%
7%
5%
Maint & Repair
$ 500
Purchase Cost
$400

SLIDE A-6

Life-Cycle Costs of a Heating System



SLIDE A-7

ECONOMIC EVALUATION METHODS

- Life-Cycle Cost (LCC)
- Savings-to-Investment Ratio (SIR)
- Net Savings (NS)
- Adjusted Internal Rate-of-Return (AIRR)
- Payback Period (PB) Discounted & Simple (DPB & SPB)

SLIDE A-8

KEY FEATURES OF LCC METHOD

- o takes into account
  - --first costs
  - --future costs (& benefits)
- o adjusts for time of occurrence
- o useful for making energy-related decisions

SLIDE A-9

HOW TO PERFORM LCC ANALYSIS

- compute LCC for each alternative
  - -- identify relevant effects
  - -- estimate in dollars
  - -- adjust $ amounts for time
  - -- sum time-equivalent amounts
- compare LCCs
- select alternative with lowest LCC

(alts must satisfy performance requirements)

SLIDE B-1

CHOOSE ALTERNATIVES

- good alternatives ESSENTIAL
- must meet performance requirements
- credit if benefits exceed requirements?

SLIDE B-2

RELEVANT EFFECTS

are --

- amounts that change
- significant amounts
- not "sunk costs"

SLIDE B-3

RELEVANT EFFECTS

may include --

- o acquisition costs
- o energy costs
- o maintenance costs
- o repair costs
- o replacement costs
- o residual value
- o revenue
- o other

SLIDE B-4

ESTIMATE IN DOLLARS

- information from suppliers
- energy analyses
- data bases
- previous experience
- engineering judgment
- today's costs and benefits

SLIDE B-5

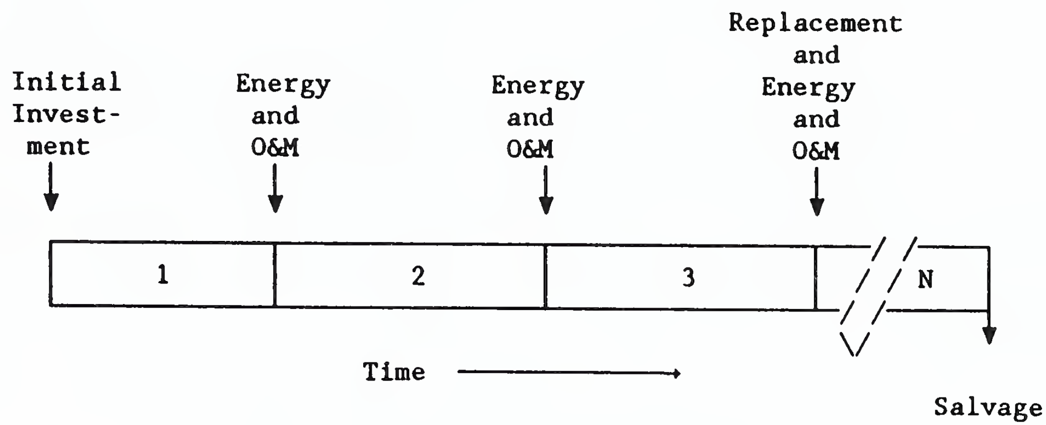
STUDY PERIOD

should--

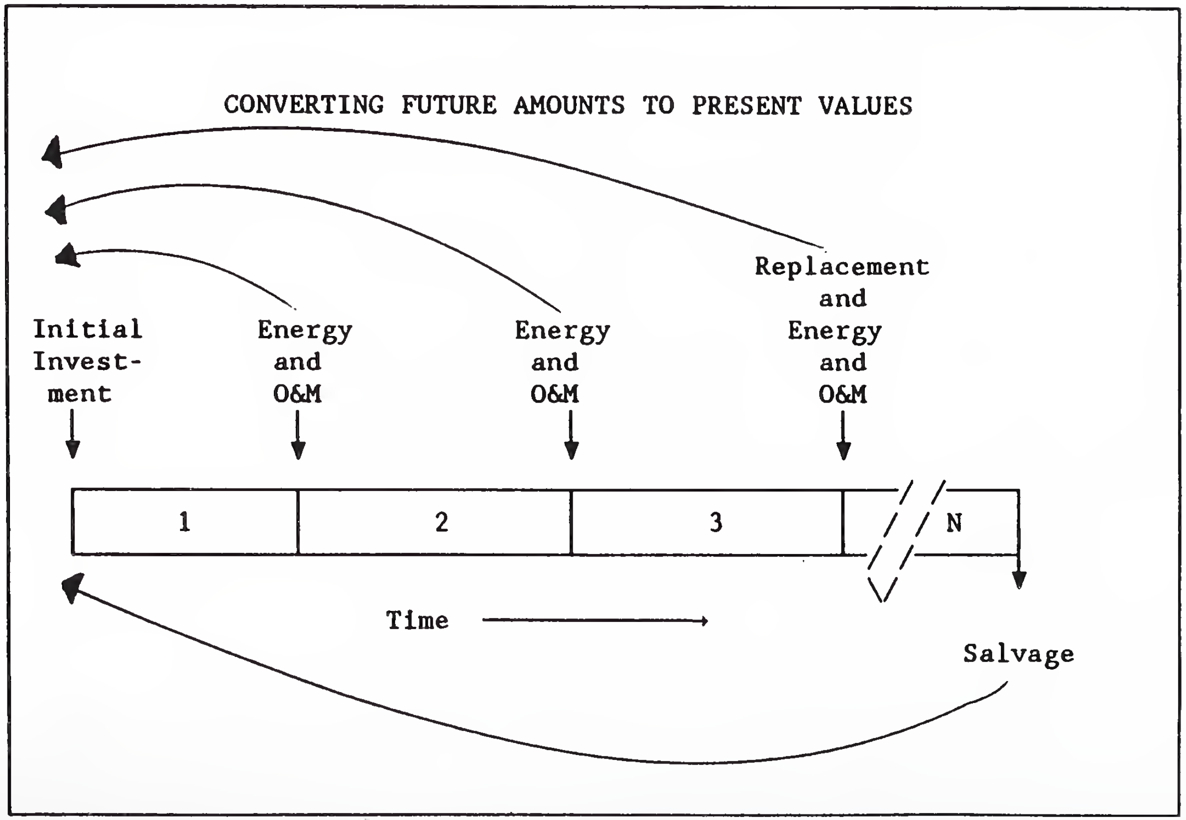
- o be same length for alternatives if compared using LCC or NS
- o correspond with time perspective of investor
- o not exceed imposed limit

SLIDE C-1

CASH-FLOW DIAGRAM



SLIDE C-2



CONVERTING FUTURE AMOUNTS TO PRESENT VALUES
Initial Invest-ment
Energy and O&M
Energy and O&M
Replacement and Energy and O&M
1
2
3
N
Time
Salvage

SLIDE C-3

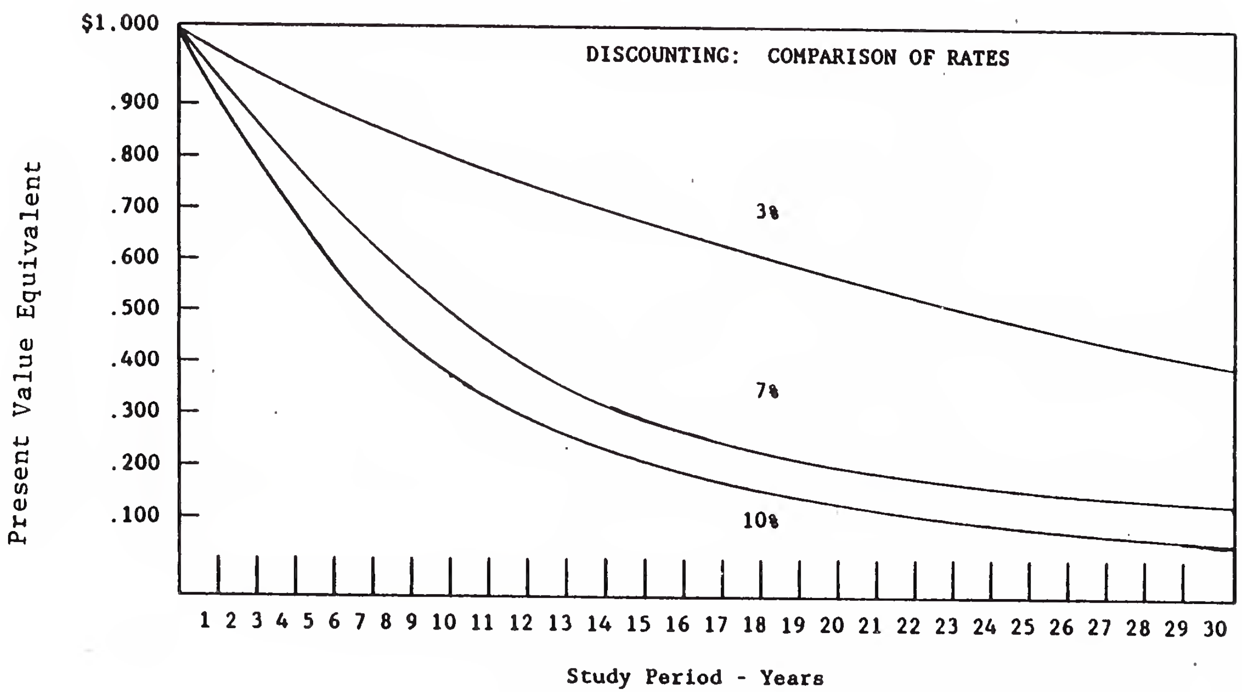
DISCOUNTING FORMULAS

Amount to be discounted	Formula
single future amount	P = F x SPW
recurring annual amount	P = A x UPW
changing annual amount	P = A_0 x UPW*

where:

SPW = Single Present Worth factor
UPW = Uniform Present Worth factor
UPW*= Modified Uniform Present Worth factor

SLIDE C-4



DISCOUNTING: COMPARISON OF RATES
$1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
Present Value Equivalent
3%
7%
10%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Study Period - Years

SLIDE C-5

DISCOUNTING EXAMPLE

Find present value (P) of a future replacement cost (F)

- o replacement cost: $10,000
- o time of replacement: end of year 6
- o discount rate: 3%

SLIDE C-6

Solution:

P = F x SPW

= ____ X ____

= $________

SLIDE C-S6

Solution:

$$P = \$10,000 \times 0.8375$$

$$= \$8,375$$

SLIDE C-7

DISCOUNTING EXAMPLE

Find present value (P) of an annually recurring maintenance cost (A)

- o annual maintenance cost: $200
- o occurrence: end of each of 12 years
- o discount rate: 9%

SLIDE C-8

Solution:

$$P = A \times UPW$$

$$= \$\_\_\_\_\_\_$$

SLIDE C-S8

Solution:

$$P = \$200 \times 7.161$$

$$= \$1,432$$

SLIDE C-9

DISCOUNTING EXAMPLE

Find present value (P) of energy costs which are changing at a constant rate

- annual energy cost at today's price (A_0): $25,000
- occurrence: end of years 1-7
- discount rate: 6%
- projected annual rate of change: 2%

SLIDE C-10

Solution:

$$P = A_0 \times UPW^*$$

$$= \_\_\_\_\_\_ \times \_\_\_\_\_\_$$

$$= \$\_\_\_\_\_\_\_\_\_\_$$

SLIDE C-S10

Solution:

$$P = \$25{,}000 \times 6.019$$

$$= \$150{,}475$$

DISCOUNTING EXAMPLE

Find present value (P) of energy costs which are changing at annual rates projected by DOE

- annual energy cost at today's price (A_0): $50,000
- occurrence: beginning 1988 and continuing over 25 years
- building location: Federal office building in Atlanta
- energy type: natural gas
- DOE 1988 energy price projections

SLIDE C-12

Solution:

$$P = A_0 \times UPW^*$$

$$= \underline{\qquad\quad} \times \underline{\qquad\quad}$$

$$= \$\underline{\qquad\qquad\qquad}$$

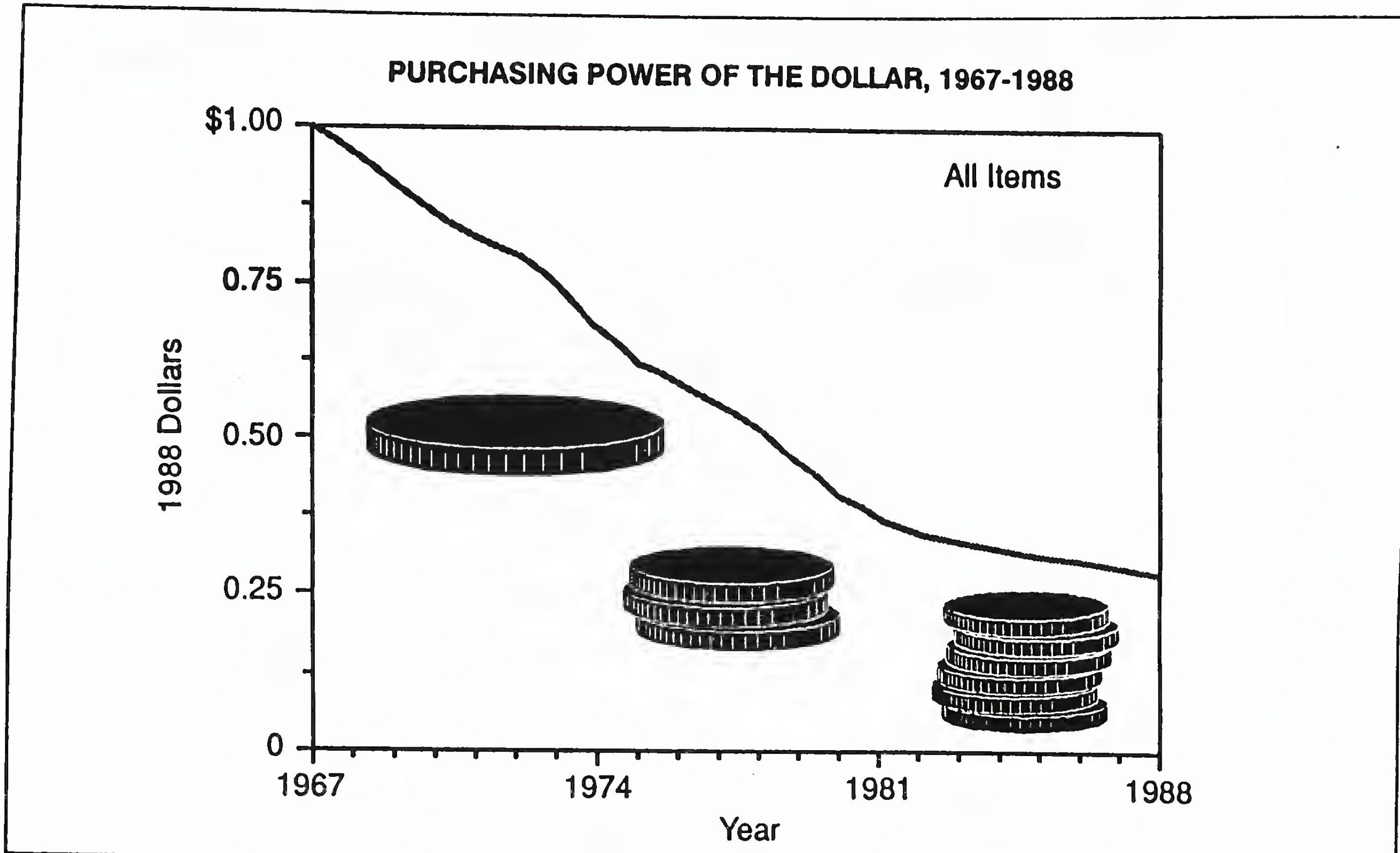
SLIDE C-S12

Solution:

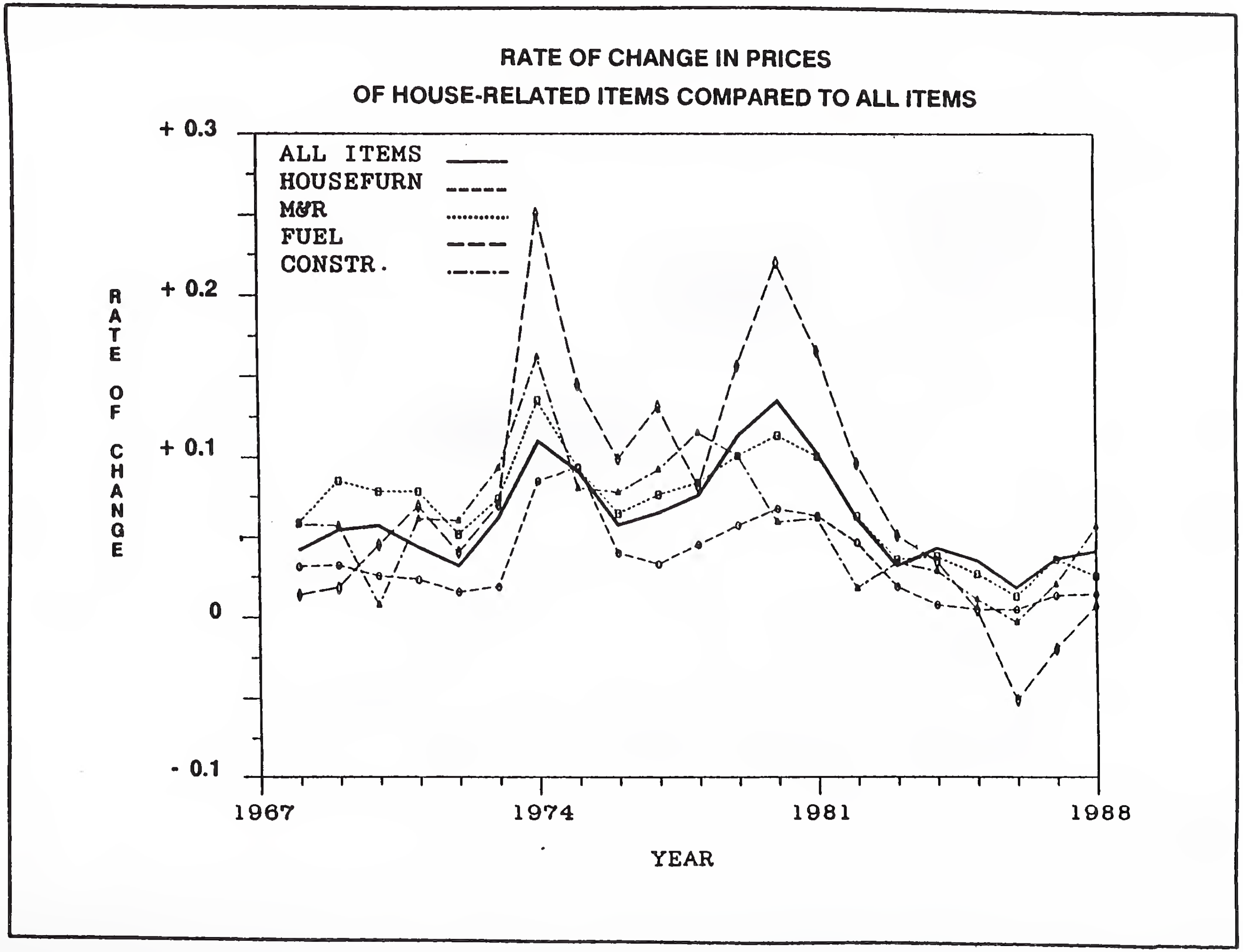
$$P = \$50{,}000 \times 14.01$$

$$= \$700{,}500$$

SLIDE C-13


PURCHASING POWER OF THE DOLLAR, 1967-1988
All Items
1988 Dollars
$1.00
0.75
0.50
0.25
0
1967
1974
1981
1988
Year

SLIDE C-14
(series a to d)



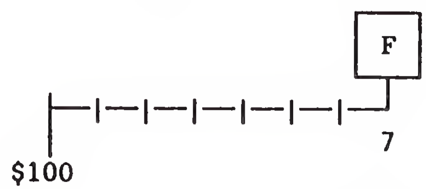
SLIDE C-15

Two approaches for dealing with inflation

1. work in absolute terms (current $ & nominal discount rate)

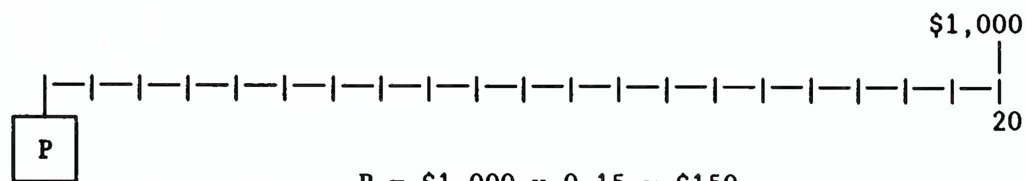
2. work in relative terms (constant $ & real discount rate)

SLIDE C-S16



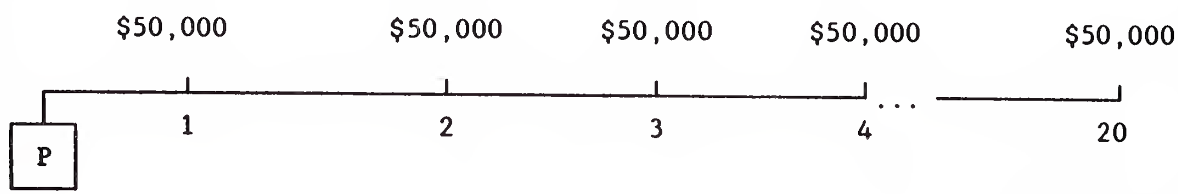
F = \$100 x 1.828 = \$182.80

SLIDE C-S17



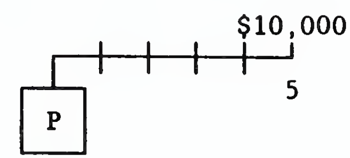
$$P = \$1{,}000 \times 0.15 = \$150$$

SLIDE C-S18



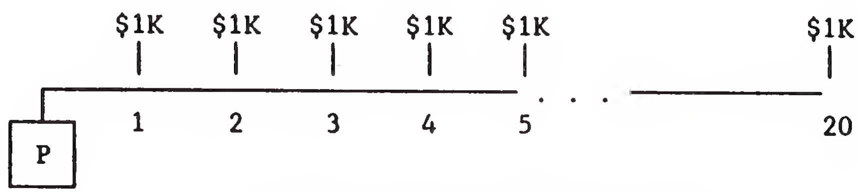
P = $50,000 x 8.51 = $425,500

SLIDE C-S19



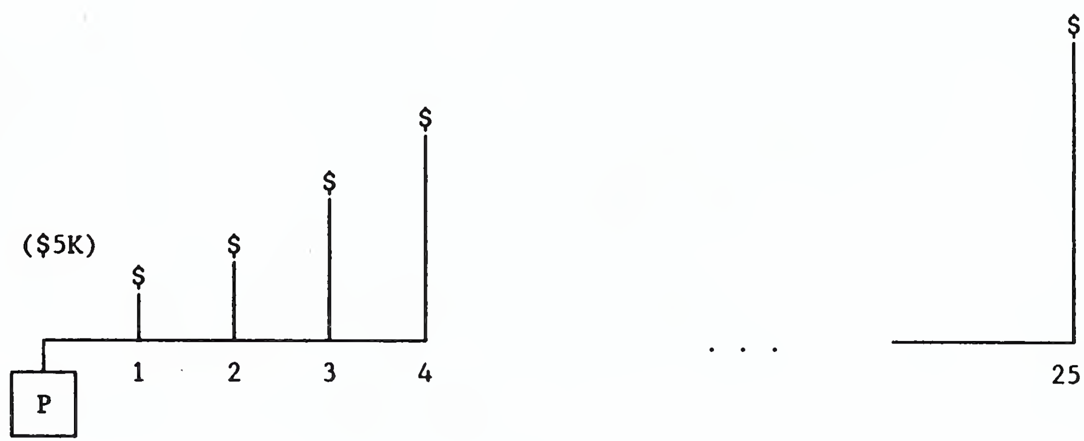
$$P = \$10,000 \times 0.71 = \$7,100$$

SLIDE C-S20



P = \$1,000 x 10.59 = \$10,590

SLIDE C-S21



P = \$5,000 x 12.10 = \$60,500

SLIDE D-1

FEDERAL CRITERIA

- DOE discount rate
- constant dollars
- present values
- quantity of energy at boundary
- actual agency energy prices
- DOE energy price projections
- instantaneous or delayed investment
- study period 25 years
- end-of-year or when-actually-incurred cash flows
- no evaluation required under certain conditions

SLIDE D-2

DATA

Location:	Washington, DC
Building:	House on a military base (commercial pricing)
Performance:	Both systems meet performance requirements
Discount Rate:	7%, real
Energy Prices:	Based on DOE 1988 projections

Costs stated in constant 1989 dollars.

Base Case: Baseboard Heating System with Window Air Conditioners

- o Purchase and installation costs: $1,500
  - Baseboard heaters = $500
  - Window air conditioners = $1,000
- o Annual maintenance cost = $50
- o Air conditioner repairs in year 8 = $400
- o Salvage value = $150
  - Baseboard = $50 (10% of initial cost)
  - Window air conditioners = $100 (10% of initial cost)
- o Annual electricity cost valued at the beginning of the study Period = $1,200
- o Useful life = 15 years
- o Study Period = 15 years

SLIDE D-4

Alternative System: Heat Pump

- o Purchase and installation cost = \$3,000
- o Annual maintenance cost = \$100
- o Compressor repair at end of year 8 = \$600
- o Salvage value (net of disposal costs) at end of life = \$250
- o Annual electricity costs, valued at the beginning of the study period = \$800
- o Useful life = 15 years
- o Study period: 15 years

SLIDE D-5

Calculate LCC of Base Case:

$$LCC = I - S + M + R + E$$

I = \$1,500

S = \$150 x SPW_{15}

M = [\$50 x UPW_{15}] + [\$400 x SPW_8]

R = 0

E = \$1,200 x $UPW^*_{Reg3,Com,Elec,15}$

$$LCC = \$1{,}500 - (\$150 \times 0.36) + (\$50 \times 9.11) + (\$400 \times 0.58) + (\$1{,}200 \times 8.88)$$

$$= \$1500 - \$54 + \$455.50 + \$232 + \$10{,}656$$

$$= \$12{,}790$$

SLIDE D-6

Calculate LCC of Alternative:

$$I = \$3{,}000$$
$$S = \$250 \times SPW_{15}$$
$$M = [\$100 \times UPW_{15}] + [\$600 \times SPW_{8}]$$
$$R = 0$$
$$E = \$800 \times UPW^{*}_{Reg3,Com,Elec,15}$$

$$LCC = \$3{,}000 - (\$250 \times 0.36) + (\$100 \times 9.11) + (\$600 \times 0.58) + (\$800 \times 8.88)$$
$$= \$3{,}000 - \$90 + \$911 + \$348 + \$7{,}104$$
$$= \$11{,}273$$

SLIDE D-7

Calculate NS of Heat Pump from LCCs:

$$
\begin{aligned}
NS &= LCC_{BC} - LCC_A \\
&= \$12,790 - \$11,273 \\
&= \$1,517
\end{aligned}
$$

SLIDE D-8

Calculate NS of Heat Pump by Subtracting Differences in Costs from Savings:

$$NS = [\Delta E] - [\Delta I - \Delta S + \Delta M + \Delta R]$$

$$\begin{aligned}
\Delta E &= (\$1{,}200 - \$800) \times UPW^{*}_{Reg3,Com,Elec,15} \\
\Delta I &= (\$3{,}000 - \$1{,}500) \\
\Delta S &= (\$250 - \$150) \times SPW_{15} \\
\Delta M &= [(\$100 - \$50) \times UPW_{15}] + [(\$600 - \$400) \times SPW_{8}] \\
\Delta R &= 0
\end{aligned}$$

$$\begin{aligned}
NS = {} & [(\$1{,}200 - \$800) \times 8.88] \\
& - \Big[(\$3{,}000 - \$1{,}500) \\
& - (\$250 - \$150) \times 0.36 \\
& + [(\$100 - \$50) \times 9.11] + [(\$600 - \$400) \times 0.58]\Big] \\
= {} & [\$3{,}552] - [\$1{,}500 - \$36 + \$571.50] \\
= {} & \$1{,}517
\end{aligned}$$

SLIDE D-9

Calculate SIR of Heat Pump:

$$\begin{aligned} SIR &= [\Delta E - \Delta M]/[\Delta I - \Delta S + \Delta R] \\ &= [\$3{,}552 - \$571.50]/[\$1{,}500 - \$36 + 0] \\ &= \$2{,}980.50/\$1{,}464 \\ &= 2.04 \end{aligned}$$

SLIDE D-10

Formula for Calculating AIRR:

$$AIRR = -1 + [TV/PVC]^{1/N}$$

TV = terminal value of savings
PVC = present value investment-related costs

Calculate TV Savings of Heat Pump:

$$TV = \sum_{j=1}^{N} (\Delta\bar{E}_j - \Delta\bar{M}_j)(1 + r)^{N-j}$$

$$
\begin{aligned}
&= [(\$400 \times 0.99) - \$50] \times (1.07)^{14} &&= \$892.17\\
&+ [(\$400 \times 0.98) - \$50] \times (1.07)^{13} &&= \$824.17\\
&+ [(\$400 \times 0.97) - \$50] \times (1.07)^{12} &&= \$761.24\\
&+ [(\$400 \times 0.96) - \$50] \times (1.07)^{11} &&= \$703.02\\
&+ [(\$400 \times 0.96) - \$50] \times (1.07)^{10} &&= \$657.03\\
&+ [(\$400 \times 0.95) - \$50] \times (1.07)^{9} &&= \$606.69\\
&+ [(\$400 \times 0.96) - \$50] \times (1.07)^{8} &&= \$573.87\\
&+ [(\$400 \times 0.96) - \$50 - \$200] \times (1.07)^{7} &&= \$215.17\\
&+ [(\$400 \times 0.97) - \$50] \times (1.07)^{6} &&= \$507.25\\
&+ [(\$400 \times 0.98) - \$50] \times (1.07)^{5} &&= \$479.67\\
&+ [(\$400 \times 0.98) - \$50] \times (1.07)^{4} &&= \$448.29\\
&+ [(\$400 \times 1.00) - \$50] \times (1.07)^{3} &&= \$428.77\\
&+ [(\$400 \times 1.00) - \$50] \times (1.07)^{2} &&= \$400.72\\
&+ [(\$400 \times 1.00) - \$50] \times (1.07)^{1} &&= \$374.50\\
&+ [(\$400 \times 1.00) - \$50] \times (1.07)^{0} &&= \$350.00\\
&= \$8,223
\end{aligned}
$$

[Note use of Energy Price Indices from appendix B, Table Ca-3, to estimate yearly cash flow.]

r = reinvestment rate = discount rate

SLIDE D-12

Calculate PVC of Heat Pump:

$$\begin{aligned} PVC &= \Delta I + \Delta R - \Delta S \\ &= (\$3,000 - \$1,500) + 0 - \$36 \\ &= \$1,464 \end{aligned}$$

SLIDE D-13

Calculate AIRR of Heat Pump:

$$\begin{aligned} AIRR &= -1 + [TV/PVC]^{1/N} \\ &= -1 + [\$8{,}223/\$1{,}464]^{1/15} \\ &= 0.12 \text{ or } 12\% \end{aligned}$$

SLIDE D-14

Estimate SPB of Heat Pump:

$$\text{SPB} = \Delta I/\Delta S$$

$$= (\$3{,}000 - \$1{,}500)/(\$400 - \$50)$$

$$= (\$3{,}000 - \$1{,}500)/\$350$$

$$= 4.3$$

APPROXIMATE DPB FROM SPB:

- find in UPW* table, ELEC column
- find factor closest to SPB of 4.3
- read off corresponding year in N column

(Appendix B) TABLE B-3a. UPW* DISCOUNT FACTORS
Census Region 3

N	ELEC	DIST	RESID	NATGAS	COAL
1	0.93	1.01	0.98	0.95	0.95
2	1.78	1.97	1.90	1.84	1.85
3	2.58	2.89	2.76	2.68	2.71
4	3.31	3.78	3.57	3.46	3.53
5	3.99	4.64	4.37	4.22	4.31
6	4.63	5.49	5.17	4.94	5.05
7	5.23	6.32	6.00	5.64	5.75
8	5.79	7.14	6.85	6.32	6.42
9	6.31	7.96	7.71	6.97	7.05

SLIDE D-S16

Calculate LCC without the Solar Energy System (alternative 1):

LCC_{WOS} = (1,750 MBtu/year) x $20/MBtu x 9.40

= $329,000

Calculate LCC with the Solar Energy System (alternative 2):

LCC_{WS} = $140,000 + ($140,000 x 0.03 x 9.11)

+ (1,750 MBtu/year) x $20/MBtu x 0.4 x 9.40

+ 1,750 MBtu/year x 0.60 x 0.02 x $20/MBtu x 9.40

= $140,000 + $38,262 + $131,600 + $3,948

= $313,810

SLIDE D-S17

Calculate NS of the Solar Energy System:

$$NS = \$329{,}000 - \$313{,}810$$

$$= \$15{,}190$$

SLIDE D-S18

Calculate SIR of the Solar Energy System:

$$\text{SIR} = [(\$329{,}000 - \$131{,}600 - \$3{,}948) - \$38{,}262]/\$140{,}000$$

$$= \$155{,}190/\$140{,}000$$

$$= 1.11$$

SLIDE E-1

INTRODUCTION TO FBLCC AND NBSLCC

FBLCC: THE FEDERAL BUILDINGS LIFE-CYCLE COST PROGRAM

NBSLCC: NATIONAL BUREAU OF STANDARDS LIFE-CYCLE COST PROGRAM

SLIDE E-2

FBLCC

- o life-cycle cost computations for analysis of Federal energy conservation projects
- o based on NBS Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program
- o also supports OMB Circular A-94 requirements for LCC analysis of non-energy-related Federal building projects

SLIDE E-3

FBLCC and NBSLCC

- evaluate life-cycle costs of buildings and building systems over a specified time horizon
- compare LCCs of projects with the same purpose but with different costs and savings
- determine most cost-effective building or system for a specific operating environment
- MS-DOS applications
- compiled BASIC

SLIDE E-4

FBLCC

- constant dollar analysis only
- maximum study period = 25 years from end of planning/ construction period (FEMP)

  50 years (OMB A-94)
- no tax-related or mortgage computations
- planning/construction period: optional
- current year is base year

SLIDE E-5

NBSLCC

- life-cycle cost computations conforming with ASTM E-917 (Measuring Life-Cycle Costs of Buildings and Building Systems)
- taxable and non-taxable projects (depreciation allowed)
- constant or current dollar analysis
- maximum study period = 50 years
- financing costs can be included
- up to 10-year planning/construction period allowed
- base year can be specified

SLIDE E-6

FBLCC and NBSLCC FILES

- building characteristics files: Extension = .BCF
- LCC output files: Extension = .LCC
- extensions are automatically assigned
- filenames have maximum of 8 characters (no spaces):

  examples: HOUSE1.BCF HOUSE1.LCC
  HEATPUMP.BCF HEATPUMP.LCC

- files are always stored on drive B

SLIDE E-7

START UP

program disk in drive B

at DOS prompt, type B: <Enter>

at DOS prompt, type **FBLCC** <Enter>
or
NBSLCC <Enter>

SLIDE E-8

INITIAL MENU

(1) LCCDATA -	create or modify building characteristics files for a project
(2) PRINTBCF -	print out building characteristics files for a project
(3) LCCMAIN -	compute project LCC, display summary, save LCC computations
(4) PRINTLCC -	print out detailed LCC report for a project
(5) COMPARE -	compute and print comparative LCC analysis for two alternative projects

select option by number (1-5)

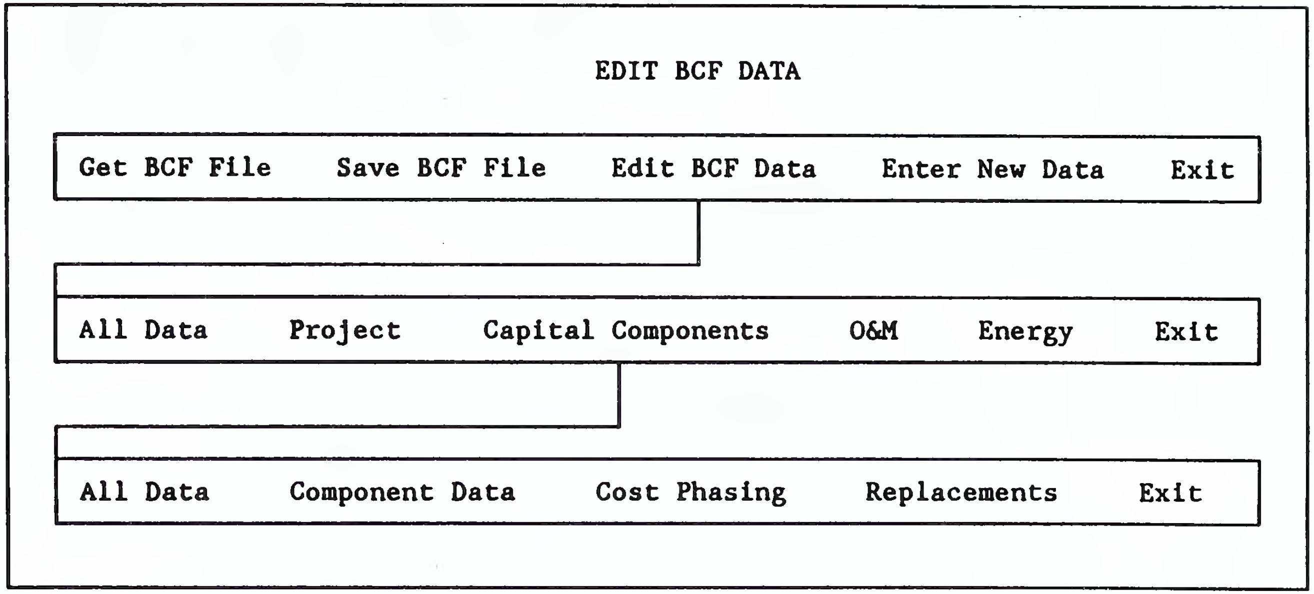
SLIDE E-9

INITIAL LCCDATA SCREEN

Get BCF File   Save BCF File   Edit BCF Data   Enter New Data   Exit

- use right and left arrows to highlight choice,
  then press <Enter>
- get BCF File: need old file before editing
  BCF files on disk are displayed on screen;
  Move highlight to desired file and press <Enter>
- save BCF file: enter new file name for saved file
- enter new data: start new BCF file
- ALWAYS SAVE YOUR FILE BEFORE EXITING OR GETTING NEW FILE!

SLIDE E-10


EDIT BCF DATA
Get BCF File
Save BCF File
Edit BCF Data
Enter New Data
Exit
All Data
Project
Capital Components
O&M
Energy
Exit
All Data
Component Data
Cost Phasing
Replacements
Exit

SLIDE E-11

PROJECT DATA INPUT SCREEN

FBLCC input -

PROJECT INFORMATION (See NBS Technical Note 1222 for description of variables)

Section 1. Project Title: ____________

Section 2. Basic LCC Analysis Assumptions:

LCC Analysis Type ____
1 = Energy Conservation or Renewable Energy Projects (NBS HB 135)
2 = Non-Energy Related Projects (OMB Circular A-94)
Base Year for LCC Analysis (default) 1990
Study Period (Years) ____
Occupancy Year (e.g., 1990) ____
Discount Rate (%) ____
2-Char. State Code (for DOE default energy prices) ____
Building Type (1=Residential 2=Commercial 3=Industrial) ____
Comment:

F3 - Delete Entry   F8 - Default   F9 - Help   F10 - Menu

SLIDE E-12

EXIT TO OTHER FBLCC PROGRAMS

Print Calculation Results (PRINTLCC)
Enter Building Characteristics Data (LCCDATA)
Print Building Characteristics Data (PRINTBCF)
Perform Comparative Analysis (COMPARE)
ASEAM2 MENU
DOS
Previous Menu (Shown Above)

SLIDE E-13

FBLCC BUILDING CHARACTERISTICS REPORT PROGRAM

Get BCF File	Print Report	Exit

FBLCC CALCULATIONS

Get BCF File - Calculate	Save LCC Calcs	Display Results	Exit

FBLCC COMPARE PROGRAM

Get Base Case File	Get Alternative File	Print Report	Exit

SLIDE F-1

DECISIONS

Focus of Day 2:

- o what design or size of a given system
- o how to combine interdependent systems
- o which projects -- in what design and size -- to fund with a limited budget

SLIDE F-2

Assumptions

- 1200 ft^2 Single-Family House
- Ohio (Region 2)
- Annual Space Heating Load (AHL) = 50 MBtu
- Electric Resistance System, Efficiency (EFF) = 100%
- ΔAHL (MBtu) as Attic Insulation is Added:

	0 - R11	R11 - R19	R19 - R30	R30 - R38
ΔAHL (MBtu)	-13.0	-2.1	-1.3	-0.5
ΔInsulation Cost:	$300	$150	$200	$150

- Price of Electricity = $21.75/MBtu
- Commercial Electricity Rates
- 1988 DOE Price Projections
- Heating Only
- Study Period: 25 years

SLIDE F-3

Annual Heating Energy Requirement
Depends on
Load & System Efficiency:

$$\mathrm{AER} = \frac{\mathrm{AHL}}{\mathrm{EFF}} = \frac{50\ \mathrm{MBtu}}{1} = 50\ \mathrm{MBtu}$$

AER = Annual Energy Requirement
AHL = Annual Heating Load
EFF = Heating System Efficiency
or Seasonal Coefficient of Performance

SLIDE F-4

NET SAVINGS FROM ADDING R11 INSULATION

$$NS = \left[\Delta\ AHL/EFF \times Price/MBtu \times UPW^{*} \right] - I$$

$$= [(13.0\ MBtu/1) \times \$21.75/MBtu \times 11.34] - \$300$$

$$= \$3,206 - \$300$$

$$= \$2,906$$

SLIDE F-5

NET SAVINGS FROM INCREASING INSULATION FROM R11 TO R19

$$
\begin{aligned}
NS &= [(2.1\ \text{MBtu}/1) \times \$21.75/\text{MBtu} \times 11.34] - \$150 \\
&= \$518 - \$150 \\
&= \$368
\end{aligned}
$$

SLIDE F-6

NET SAVINGS FROM INCREASING INSULATION FROM R19 TO R30

$$NS = [(1.3 \text{ MBtu}/1) \times \$21.75/\text{MBtu} \times 11.34] - \$200$$

$$= \$321 - \$200$$

$$= \$121$$

SLIDE F-7

NET SAVINGS FROM INCREASING INSULATION FROM R30 TO R38

$$NS = [(0.5 \text{ MBtu}/1) \times \$21.75/\text{MBtu} \times 11.34] - \$150$$

$$= \$123 - \$150$$

$$= -\$27$$

SLIDE F-8

SIZING ATTIC INSULATION

Level of Insulation	Δ Cost $	Total Cost $	Δ Savings $	Total Savings $	Δ Net Savings $	Total Net Savings $
0 - R11	300	300	3,206	3,206	2,906	2,906
R11 - R19	150	450	518	3,724	368	3,274
R19 - R30	200	650	321	4,045	121*	3,395*
R30 - R38	150	800	123	4,168	-27	3,368

SLIDE F-9

INCREMENTAL SIR -- NOT TOTAL SIR -- <u>MUST</u> BE USED TO SIZE!

Level of Insulation	Δ Cost $	Total Cost $	Δ Savings $	Total Savings $	Incremental SIR	Total SIR
0 - R11	300	300	3,206	3,206	10.7	10.7
R11 - R19	150	450	518	3,724	3.5	8.3
R19 - R30	200	650	321	4,045	1.6*	6.2
R30 - R38	150	800	123	4,168	0.8	5.2

No Indication
of
Optimal Size

SLIDE F-10

REPLACE ELECTRIC RESISTANCE SYSTEM WITH HEAT PUMP?

Assumptions

no attic insulation	
purchase and installation cost:	$3,000
seasonal coefficient of performance (EFF):	1.8
maintenance and repair cost:	same as existing system
service life:	25 years

SLIDE F-11

NET SAVINGS FROM REPLACING EXISTING HEATING SYSTEM

(No Attic Insulation)

$$NS = \left[(AHL/EFF_{E} - AHL/EFF_{HP}) \times Price/MBtu \times UPW^{*} \right] - I$$

$$= \left[(50\ MBtu/1.0 - 50\ MBtu/1.8) \times \$21.75/MBtu \times 11.34 \right] - \$3{,}000$$

$$= \$5{,}481 - \$3{,}000$$

$$= \$2{,}481$$

SLIDE F-12

NET SAVINGS FROM REPLACING EXISTING HEATING SYSTEM

(R11 Attic Insulation)

$$NS = \left[(37\ \text{MBtu}/1.0) - (37\ \text{MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34 \right] - \$3{,}000$$

$$= \$4{,}056 - \$3{,}000$$

$$= \$1{,}056$$

SLIDE F-13

NET SAVINGS FROM REPLACING EXISTING HEATING SYSTEM

(R19 Attic Insulation)

$$NS = \left[(34.9 \text{ MBtu}/1.0) - (34.9 \text{ MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34 \right] - \$3{,}000$$

$$= \$3{,}826 - \$3{,}000$$

$$= \$826$$

SLIDE F-14

NET SAVINGS FROM REPLACING EXISTING HEATING SYSTEM

(R30 Attic Insulation)

$$NS = \left[(33.6 \text{ MBtu}/1.0) - (33.6 \text{ MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34 \right] - \$3{,}000$$

$$= \$3{,}683 - \$3{,}000$$

$$= \$683$$

NET SAVINGS FROM REPLACING EXISTING HEATING SYSTEM

(R38 Attic Insulation)

$$NS = \left[(33.1 \text{ MBtu}/1.0) - (33.1 \text{ MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34\right] - \$3{,}000$$

$$= \$3{,}628 - \$3{,}000$$

$$= \$628$$

SLIDE F-16

NET SAVINGS FROM HEAT PUMP
WITH DIFFERENT LEVELS OF INSULATION

Level of Insulation	Heat Pump Net Savings
None	$2,481
R11	1,056
R19	826
R30	683
R38	628

Conclusion: Heat Pump is cost-effective with all levels of insulation considered

SLIDE F-17

NET SAVINGS FROM ADDING R11 INSULATION

(with heat pump)

$$NS = \left[\Delta \text{ AHL}/\text{EFF}_{HP} \times \text{Price/MBtu} \times \text{UPW*} \right] - I$$

$$= \left[(13.0 \text{ MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34 \right] - \$300$$

$$= \$1,781 - \$300$$

$$= \$1,481$$

SLIDE F-18

NET SAVINGS FROM INCREASING INSULATION FROM R11 TO R19

(with heat pump)

$$NS = \left[(2.1\ \text{MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34\right] - \$150$$

$$= \$288 - \$150$$

$$= \$138$$

SLIDE F-19

NET SAVINGS FROM INCREASING INSULATION FROM R19 TO R30

(with heat pump)

$$NS = \left[(1.3 \text{ MBtu}/1.8) \times \$21.75/\text{MBtu} \times 11.34 \right] - \$200$$

$$= \$178 - \$200$$

$$= -\$22$$

SLIDE F-20

NET SAVINGS FROM INCREASING INSULATION FROM R30 TO R38

(with heat pump)

$$NS = \left[(0.5 \times MBtu/1.8) \times \$21.75/MBtu \times 11.34 \right] - \$150$$

$$= \$69 - \$150$$

$$= -\$81$$

SLIDE F-21

NS FROM ATTIC INSULATION ALONE
(Does not include Heat Pump Savings)

Replacement of Heating System		Insulation Level			
		R11	R19	R30	R38
	No	2,906	3,274	3,395*	3,368
	Yes	1,481	1,619*	1,597	1,516

Conclusion: With the heat pump, R19 insulation--not R30--is cost effective.

SLIDE F-22

Cost-Effective Combination of Investments

* heat pump
* R19 attic insulation

<u>LCC SOLUTION</u>:

Calculate LCC of Single-Glazed Windows:

LCC_1 = \$2,000 + [(60 MBtu/0.75) x \$8.00/MBtu x 16.76]

= \$12,726

Calculate LCC of Double-Glazed Windows:

LCC_2 = \$2,800 + [(50 MBtu/0.75) x \$8.00/MBtu x 16.76]

= \$11,739

Calculate LCC of Triple-Glazed Windows:

LCC_3 = \$3,400 + [(48 MBtu/0.75) x \$8.00/MBtu x 16.76]

= \$11,981

Conclusion: Choose double-glazed windows.

NS SOLUTION:

Calculate NS of Double-Glazed Windows:

NS = [(10 MBtu/0.75) x $8.00/MBtu x 16.76] - $800

= $988

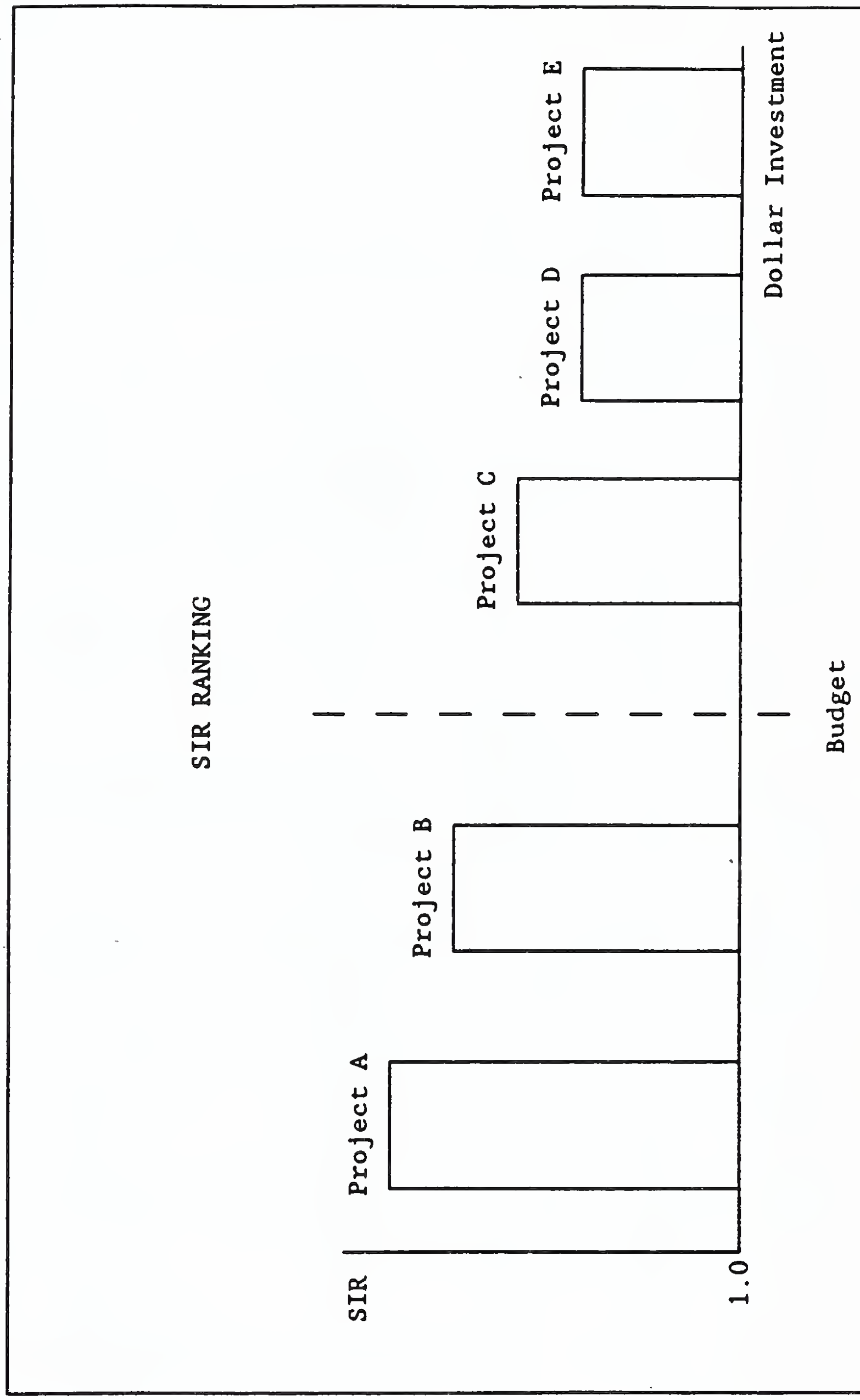
Calculate NS of Triple-Glazed Windows:

NS = [(2 MBtu)/0.75) x $8.00/MBtu x 16.76] - $600

= -$242

Conclusion: Choose double-glazed windows.

SLIDE G-1


SIR RANKING
SIR
1.0
Project A
Project B
Budget
Project C
Project D
Project E
Dollar Investment

SLIDE G-2

ASSUMPTIONS

Project	I ($1,000)	MBtu Saved	PV Energy Savings ($1,000)
A	10	100	20.0
B	10	1,000	17.0
C	5	200	11.0
D	5	220	11.5

Budget = $20,000

SLIDE G-3

RANKING BY BTU/I

Project	I ($1,000)	MBtu Saved	MBTU/ $1,000	Rank
A	10	100	10	4
B	10	1,000	100	1
C	5	200	40	3
D	5	220	44	2

SLIDE G-4

RANKING BY NET SAVINGS

Project	I ($1,000)	PV Energy Savings ($1,000)	NS ($1,000)	Rank
A	10	20.0	10.0	1
B	10	17.0	7.0	2
C	5	11.0	6.0	4
D	5	11.5	6.5	3

SLIDE G-5

RANKING BY SIR

Project	I ($1,000)	PV Energy Savings ($1,000)	SIR	Rank
A	10	20.0	2.0	3
B	10	17.0	1.7	4
C	5	11.0	2.2	2
D	5	11.5	2.3	1

SLIDE G-6

COMPARISON OF NET SAVINGS
FROM RANKING BY Btu/I, NS, and SIR

Projects Selected & Net Savings ($1,000)

	Btu/I	NS	SIR
		A (10.0)	A (10.0)
	B (7.0)	B (7.0)	
	C (6.0)		C (6.0)
	D (6.5)		D (6.5)
Total NS:	19.5	17.0	22.5

SLIDE G-7

SETTING PROJECT PRIORITIES -- LIMITED BUDGET ($10,000)

PROJECTS	FIRST COST ($1,000)	PV SAVINGS ($1,000)	NET SAVINGS ($1,000)	SIR	SIR RANKING
A	0.2	0.9	0.7	4.5	7
B	2.0	10.0	8.0	5.0	6
C	1.6	12.0	10.4	7.5	5
D	10.0	80.0	70.0	8.0	4
E	2.0	25.0	23.0	12.5	1
F	3.0	36.0	33.0	12.0	2
G	1.0	9.0	8.0	9.0	3
	$19.8	$172.9	$153.1		

SLIDE G-8

Projects	First-Cost ($1,000)	Net Savings ($1,000)
Option 1 -- accept all projects except D:		
E	2.0	23.0
F	3.0	33.0
G	1.0	8.0
C	1.6	10.4
B	2.0	8.0
A	0.2	0.7
Total	$9.8	$\boxed{\$83.1}$
Option 2 -- accept only project D:		
D	$10.0	$\boxed{\$70.00}$

SLIDE G-9

Allocating a Budget Among Projects of Variable Size: Data

Project Alternatives	First Cost ($)	PV Savings ($)	NS ($)
A	12,000	60,000	48,000
B(1)	5,000	15,000	10,000
B(2)	6,000	17,000	11,000
C	6,000	5,000	-1,000
D	3,000	12,000	9,000
E	8,000	12,000	4,000
F	5,000	14,500	9,500

SLIDE G-10

ALLOCATING A BUDGET AMONG PROJECTS OF <u>VARIABLE</u> SIZE: SIR RANKING

Projects	I ($)	Savings ($)	NS ($)	Δ SIR	Priority
A	12,000	60,000	48,000	5.00	1
B(1)	5,000	15,000	10,000	3.00	3
B(1) $\longrightarrow$ B(2)	1,000	2,000	1,000	2.00	5
D	3,000	12,000	9,000	4.00	2
E	8,000	12,000	4,000	1.50	6
F	5,000	14,500	9,500	2.90	4

SLIDE G-11

Selection for budget of $20K:

Select	I ($)	NS ($)
A	12,000	48,000
D	3,000	9,000
B(1)	5,000	10,000
	$20,000	$67,000

SLIDE G-12

ALLOCATING A BUDGET AMONG PRESIZED PROJECTS: SIR RANKING

Projects	I ($)	Savings ($)	NS ($)	SIR	Priority
A	12,000	60,000	48,000	5.00	1
B(2)	6,000	17,000	11,000	2.83	4
D	3,000	12,000	9,000	4.00	2
E	8,000	12,000	4,000	1.50	5
F	5,000	14,500	9,500	2.90	3

for budget of $20,000:

	I ($)	NS ($)
A	12,000	48,000
D	3,000	9,000
F	5,000	9,500
	$20,000	$66,500

SLIDE G-S13

Energy Conservation Projects	First Cost ($)	PV Savings ($)	Net Savings ($)	SIR	Rank
Add Solar Water Heater in Building A	2,000	3,800	1,800	1.9	4
Replace Chillers in Building A	12,000	16,800	4,800	1.4	6
Add R-8 Insulation in Building B	1,000	5,000	4,000	5.0	1
Increase Insulation in Building B from R-8 to R-19	500	1,000	500	2.0	3
Increase Insulation in Building B from R-19 to R-30	500	600	100	1.2	7
Replace Lighting System in Building C	3,000	9,000	6,000	3.0	2
Replace Windows in Building D	6,000	9,600	3,600	1.6	5

SLIDE H-1

TECHNIQUES THAT ACCOUNT FOR UNCERTAINTY, RISK, OR BOTH

1. conservative benefit and cost estimating
2. breakeven analysis
3. sensitivity analysis
4. risk-adjusted discount rate
5. certainty equivalent technique
6. input estimate using expected values
7. mean-variance criterion and coefficient of variation
8. decision analysis
9. simulation
10. mathematical/analytical technique

SLIDE H-2

SENSITIVITY ANALYSIS IS PERFORMED --

by repeating an economic evaluation

with one or more input values changed.

(It may be used with any of the five evaluation methods.)

SLIDE H-3

SENSITIVITY ANALYSIS IS USED TO --

(1) identify critical data inputs

(2) estimate range of results

(3) answer "what if" questions

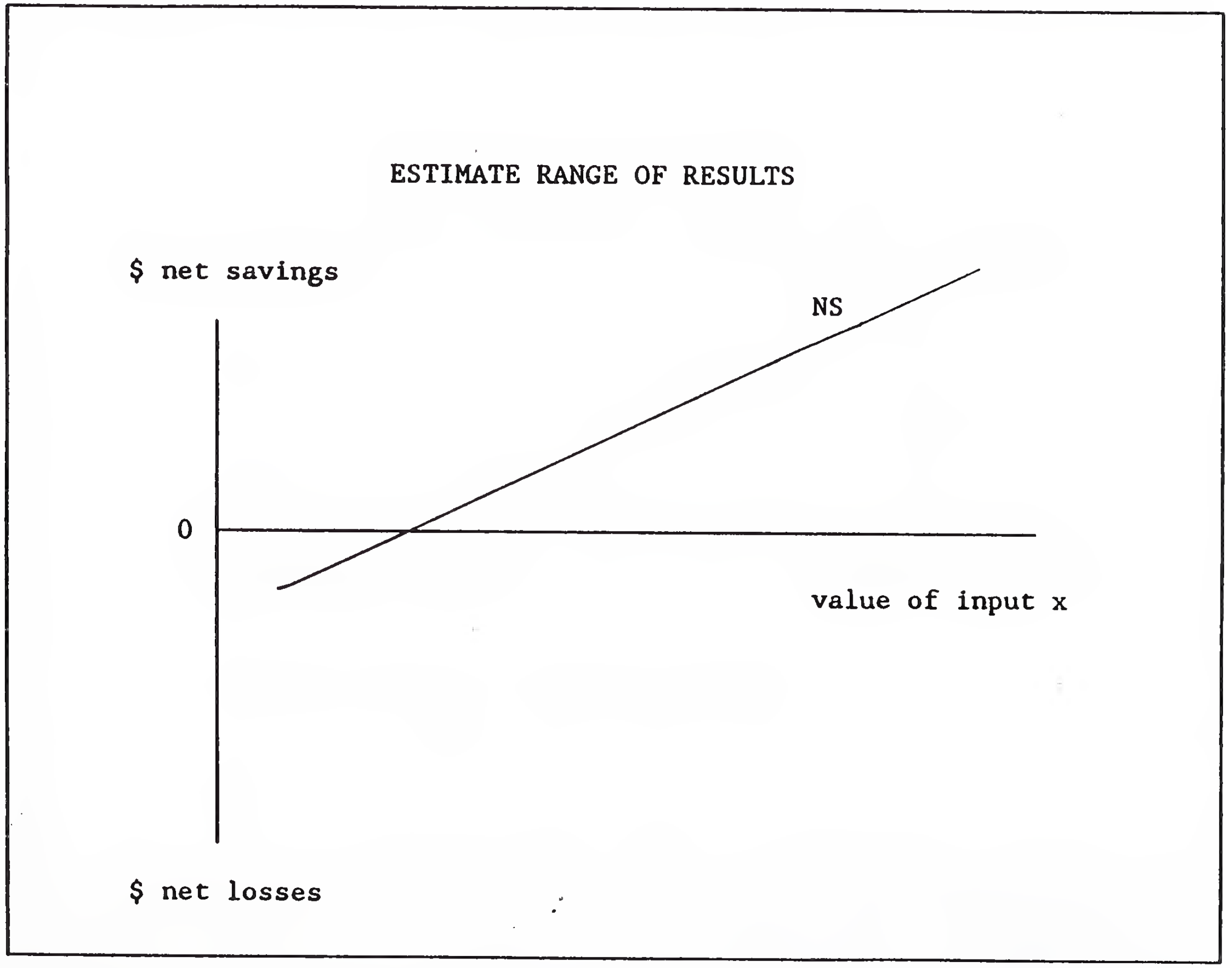
SLIDE H-4

IDENTIFY CRITICAL INPUTS

10% change in input	% change in output
input 1	2
input 2	10
* input 3	20

Conclusion: devote more resources to improving data estimates for input 3 than input 1.

SLIDE H-5


ESTIMATE RANGE OF RESULTS
$ net savings
NS
0
value of input x
$ net losses

SLIDE H-6

"WHAT IF?"

scenario	NS
1	$10,000
2	5,000
3	-1,000
4	3,000

SLIDE H-S7

Calculate LCC for the Existing System (LCC_E):

LCC_E = (900 MBtu/0.65) x \$5.15/MBtu x 13.75

= \$98,048

Calculate LCC with the Waste Heat Recovery System (LCC_W):

LCC_W = [(900 MBtu/0.65) x 0.75 x \$5.15/MBtu x 13.75]

+ \$6,000 + (\$500 x 11.65)

= \$73,536 + \$6,000 + 5,825

= \$85,361

$\boxed{NS_W = \$12,687}$

SLIDE H-S8

Calculate LCC with the Waste Heat Recovery System Based on the Lower Contribution to Load (LCC_W):

$$LCC_W = [(900 \text{ MBtu}/0.65) \times 0.90 \times \$5.15/\text{MBtu} \times 13.75]$$

$$+ \$6,000 + (\$500 \times 11.65)$$

$$= \$88,243 + \$6,000 + \$5,825$$

$$= \$100,068$$

$$\boxed{NS_W = -\$2,020}$$

FORM NBS-114A (REV. 11-84)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NISTIR 89-4129	2. Performing Organ. Report No.	3. Publication Date MARCH 1990

4. TITLE AND SUBTITLE

Life-Cycle Costing for Energy Conservation in Federal Buildings: Instructor's Guide

5. AUTHOR(S)

Rosalie T. Ruegg

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

Final

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

U.S. Department of Energy, Federal Energy Management Program
1000 Independence Avenue, S.W.
Washington, D.C. 20585

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 is the Instructor's Guide for an intensive two-day course on how to use life-cycle costing and related economic evaluation methods to make cost-effective decisions in designing and retrofitting Federal buildings for energy conservation. The Guide provides an overview of the course; an agenda; learning objectives; daily detailed lesson plans; exercises and problems with solutions, and paper copies of slides used in the course. The course combines theory with application to teach engineers, architects, and other building professionals how to design and size independent and interdependent building systems for cost effectiveness, allocate a budget among competing projects for maximum net savings, and make decisions under uncertain conditions. Two computer programs for evaluating economic performance are taught in the course.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

building economics; capital investment; energy conservation; energy economics; engineering economics; Federal buildings; life-cycle costing; training courses

13. AVAILABILITY

[XX] Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.
[X] Order From National Technical Information Service (NTIS), Springfield, VA 22161

14. NO. OF PRINTED PAGES

177

15. Price

A09

USCOMM-DC 85-6006