AN EMPIRICAL ASSESSMENT OF LIFE CYCLE COST AND ALTERNATIVE ENERGY LABEL FORMATS

Prepared for:

Consumer Research & Evaluation Branch

Consumer and Corporate Affairs Canada

Prepared by:

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March, 1980

STATUS REPORT

This study has been subcontracted to R. Bruce Hutton, Ph.D., University of Denver. The status of the experiment is as follows. The research design has been finalized. The questionnaire has been finalized and will go to printing by March 17, 1980. All of the labels are printed and ready to go. Enclosed are examples for the four treatment conditions for refrigerator-freezers. The labels are exactly the same format for room air-conditioners. An agreement has been reached with a local research firm for data gathering using a shopping mall intercept technique. The firm has a lab facility where shoppers will go through an actual simulated shopping trip. The mechanisms for data analysis are in place and available as soon as the data is gathered. An arrangement has been worked out to use appliances from a major retailer in the study. Data will be collected in April, 1980 and the final report will be prepared by June 1, 1980.

Refrigerator-Freezer
Capacity 17 Cubic Feet

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour.

Only models with 16.5 to 18.4 cubic feet are compared in the scale.

Model With Lowest Total Lifetime Cost **$1367**

$1394

Model With Highest Total Lifetime Cost **$2403**

▼ ▼THIS MODEL ▼

Total Lifetime Cost

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost
		Estimated yearly $ cost shown below
Cost per kilowatt hour	**2¢**	$21
	4¢	$41
	6¢	$62
	8¢	$82
	10¢	$103
	12¢	$124

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

(Part No. 371026)

Refrigerator-Freezer
Capacity 17 Cubic Feet

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour.

Only models with 16.5 to 18.4 cubic feet are compared in the scale.

Price + Energy + Service = Total Lifetime Cost

$545 + $765 ($750 $1320) + $84 = **$1394**

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost
		Estimated yearly $ cost shown below
Cost per kilowatt hour	**2¢**	$21
	4¢	$41
	6¢	$62
	8¢	$82
	10¢	$103
	12¢	$124

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

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(Part No. 371026)

Refrigerator-Freezer
Capacity 17 Cubic Feet

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour.

Only models with 16.5 to 18.4 cubic feet are compared in the scale.

Model With Lowest Energy Cost
$50

$82

Model With Highest Energy Cost
$88

THIS MODEL▼

Estimated Yearly Energy Cost

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost
		Estimated yearly $ cost shown below
Cost per kilowatt hour	2¢	$33
	4¢	$66
	6¢	$99
	8¢	$132
	10¢	$165
	12¢	$198

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

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(Part No. 371026)

Refrigerator-Freezer
Capacity 17 Cubic Feet

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour.

Only models with 16.5 to 18.4 cubic feet are compared in the scale.

Least Efficient Model 5.2

10.5

Most Efficient Model 10.7

THIS MODEL

Energy Efficiency Rating (EER)

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost
		Estimated yearly $ cost shown below
Cost per kilowatt hour	2¢	$21
	4¢	$41
	6¢	$62
	8¢	$82
	10¢	$103
	12¢	$124

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

(Part No. 371026)

Refrigerator-Freezer
Capacity 17 Cubic Feet

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour.

Only models with 16.5 to 18.4 cubic feet are compared in the scale.

Most Efficient Model 833

1367

Least Efficient Model 1467

THIS MODEL

Estimated Yearly Kilowatt-Hours Required

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost
		Estimated yearly $ cost shown below
Cost per kilowatt hour	2¢	$33
	4¢	$66
	6¢	$99
	8¢	$132
	10¢	$165
	12¢	$198

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

(Part No. 371026)

LIFE CYCLE COSTING:

A REVIEW AND EVALUATION

Prepared for:

Consumer Research and Evaluation Branch

Consumer and Corporate Affairs Canada

Prepared by:

C. Dennis Anderson

Faculty of Administrative Studies

University of Manitoba

R. Bruce Hutton

School of Business

University of Denver

March 1980

The Boeing Company
1973

Life Cycle Cost/System Effectiveness Evaluation and Criteria.

Objectives/scope: To provide a cost analysis technique that is simple, flexible, low cost and easily applied to various degrees of detail by engineers throughout the early phases of a program.

Abstract: This document contains results of an independent research and developoment task on life cycle cost performed by Boeing Aerospace Company. This seven month study is Phase I of a planned continued effort and includes discussion on life cycle cost current state-of-the-art, a planned approach and recommendations on where emphasis should be placed to effectively perform cost analysis studies on new systems. Included is a bibliography of 160 documents relevant to life cycle cost, and an evaluation of 14 computer programs which provided the data base from which cost consideration elements and new criteria were developed.

Briggs, Warren G., DeWolf, J. Barton, and Robert T. Lund

1975 — Life-Cycle Costs: Concepts, Considerations, and Cases.
Presented at the Joint National Meeting of the Operations Research Society of American and the Institute of Management Science.

Objectives/scope: (1) To enumerate the major considerations of LCC as applicable to consumer appliances; (2) to relate constraints which inhibit more extensive implementation of LCC.

Abstract: The major elements of LCC are acquisition costs, use (energy) costs, and service and maintenance costs. For television sets, these 3 elements are 53%, 12%, and 35% of total LCC respectively. For refrigerators, the corresponding figures are 36%, 58%, and 6%. A single minded effort to reduce energy consumption is not necessarily an optimal objective from the viewpoint of total LCC. A critical consideration in computing LCC is estimation of the useful lifetime. Another important concept, the appropriate discount rate to be used for computing present values of future costs, has been the subject of extensive analysis and is still quite controversial. The impact of disposal costs on the decision maker is generally negligible, partly because disposal is provided as a public service. Five procurements and contracts negotiated by the U.S. Navy Aviation Supply Office in which LCC concepts and criteria were a specific part of the procurement solicitation and of the actual contract are described. The cases involved the purchase of aircraft tachometers, gyroscope platforms, batteries, tires, and hydraulic pumps. There were difficulties encountered in using LCC: (1) government contracts are restricted to one year; (2) traditionally there has been a budgetary separation of funds for procurement and support; (3) measuring and controlling the support cost part of LCC precisely enough to legally bill to or otherwise penalize the manufacturers. The cases do reveal, however, that significant savings in LCC are possible through departures from rigid traditional military technical specs.

Butlin, John
1976

The Economics of Product Life - A Critical Bibliography.
Prepared for the OECD Environment Directorate.

Objectives/scope: To evaluate the contributions and to compare and contrast the conclusions reached by the papers reviewed regarding product life.

Abstract: The bibliography consists of selections that contribute to the understanding of a number of areas: (1) market structure and durability: discussion is quite abstract, concerned with theoretical market models; (2) measurement of durability: definitions of optimal durability and intensity of use are reviewed, as are methods for estimating product life; (3) measures of product life: measures are presented for different categories of goods, including automobiles, domestic appliances, and "others"; (4) servicing of durable goods: findings in this section are drawn from an M.I.T./Charles Stark Draper Laboratory Study, which was concerned with evaluating alternatives for increasing the productivity of servicing consumer durable products and/or reducing the need for service, in the context of total product acquisition and use cost; (5) disposal of durable products: describes technical and economic conditions of disposal, the means of disposal, and refurbishing vs. recycling alternatives; (6) conclusions and criteria for a case study: measurement of product life is not satisfactorily understood; data bases seem poor; patents registered information may yield useful information on the apparent underutilization of innovations that could extend product life; investigating only the extension of product life for consumer durables may be too narrow a perspective; the criteria for an ideal case study are outlined - the automobile seems to best fit these criteria. In general, the whole area of product life extension appears to be underinvestigated.

Booz-Allen and Hamilton Inc.

Life-Cycle Costing in the Public Buildings Service. Prepared for General Services Administration, Public Buildings Service.

Objectives/scope: The study was undertaken to provide GSA with a plan for establishing life cycle analyses of Federal Office Buildings. The study defines a life cycle cost system and presents a framework of analysis appropriate to the PBS building process.

Abstract: A number of forces have led to increased concern with government spending, requiring an intensified effort to make each dollar count. The development and design of buildings has a large impact on the life cycle costs of those buildings, so thus there is a need to apply life cycle cost techniques during the design and development stage. A lack of useful data has led to a gap between the ability to apply analysis techniques during design and development and the subsequent costs incurred during the building's life cycle. This lack of data may be overcome through the development of UNIFORMAT, an uniform cost element system developed by GSA in conjunction with the American Institute of Architects. The Life-Cycle Cost system developed for GSA involved four subsystems: (1) cost estimating; (2) cost monitoring and control; (3) project scheduling; (4) data bank. The system would lead to cost efficiencies because of the attention paid to life cycle costs during design and development. The energy situation simply makes the necessity of having a life cycle cost system even more crucial. It was felt that the current state of the art in life cycle costing could provide the expertise needed for the development of the system.

Chow, Wing S., and George C. Newton

Energy Utilization of Refrigerators and Television Receivers.

Cambridge, Mass.: M.I.T. Centre for Policy Alternatives.

Objectives/scope: (1) To discuss the energy utilization of consumer durables with an emphasis on television receivers and refrigerators; (2) to examine the technical aspects of refrigerators, in particular; (3) to evaluate design alternatives.

Abstract: The appliance industry can and should take actions to improve the efficiency of energy utilization in its products. The large consumers of residential electrical energy are: (1) refrigeration; (2) water heating; (3) lighting. The refrigerator has evolved since the simple icebox, and has had a strong upward trend in energy consumption throughout the evolution (partly because of increased freezer space). It is technically feasible to build more energy efficient refrigerators and economically feasible to reduce energy. Two changes that could be made to frost free refrigerators are: (1) changing the insulation material (to polyurethane) to reduce heat leakage; (2) improving the operating efficiency of the compressor motor. Initial purchase price would be increased, but reduced eleectrical usage makes the changes economically justifiable. Proper energy ratings at the point of sale would enable consumers to make intelligent purchase decisions. The potential energy savings in clothes drying, cooking and water heating appliances is somewhat limited. Better efficiency of utilization could be obtained in space heating, lighting and air conditioning. The potential for energy saving in televisions is unknown. Incorporating changes in design (the two mentioned plus four others) could result in a saving of 3.8% of total U.S. electrical usage, once all refrigerators have been changed over.

Claxton, John, et al.
1979 Consumer Energy Consumption and Conservation Research.
Presented at the Third Triennial Canadian Marketing Workshop, Toronto, June.

Objectives/scope: Focus of the paper is on research in the area of consumer energy consumption and conservation (CECC).

Abstract: A framework which provides a structure for cataloguing conservation policy initiatives and CECC research studies is presented. Policy initiatives are classified on two dimensions: (1) stage of intervention (whether they affect the availability, purchase decision or use behavior of energy forms or energy consuming products); (2) policy type (whether they are financial or non-financial in nature and whether they are mandatory or persuasive). Research must determine (1) the extent of energy savings (technical/potential) from alternative policy initiatives and (2) consumer reaction (attitudinal and behavioral) to the policy. CECC research focused on the latter area will help determine the extent to which actual energy savings will match the technical/potential energy savings of conservation policy initiatives. The purposes and conceptual and methodological issues facing CECC researchers are discussed and illustrated. This is followed by an overview of CECC research activity, much of which has been initiated by the Canadian Department of Consumer and Corporate Affairs and the U.S. Department of Energy. This research activity is classified according to the conservation policy framework. The paper closes with an indication of future CECC research directions.

Department of Defense
1970 — Life Cycle Costing Procurement Guide (Interim)

Objectives/scope: This is the first attempt by the Dept. of Defense to establish procedures for employing the LCC concept in acquisitions of material below the level of complete weapon systems. The report was intended to be modified as experience in the application of LCC techniques was gained. The experienced gained would eventually help DoD to develop LCC guidelines for complete weapon systems acquisition.

Chapter 1: Introduction

Chapter 2: Item Selection Criteria

This chapter provides the criteria to be employed in the selection of items for LCC procurement. The expense of employing LCC procedures should not outweigh the expected cost savings. The guidelines to be used are not to be considered inflexible. A decision chart to be used in considering items for LCC analysis is presented.

Chapter 3: Item Management Costs

This chapter provides guidelines for the procedures required for proper consideration of item management costs, costs which can be classified into three general groups:

(a) general administrative costs,
(b) management costs which vary by service, mission, etc., and
(c) special costs unique to a specific item.

An example of item management costs is outlined. An illustration of the degree of detail to be used in contract provisions concerning item management costs is provided.

Chapter 4: Training Costs

An outline for considering the LCC of training associated with a procurement is provided. Training costs should be considered in LCC anlaysis under certain conditions. The elements of training costs - acquisition training costs, initial trainign costs, and recurring training costs - are explained. An example of a contract provision covering LCC training costs is provided.

Chapter 5: Operating Cost

The chapter sets out guidelines for the identification of operating costs and the analysis of those costs as a part of LCC evaluation. Operating costs are those normally incurred in the operation of the item - ex. labor, fuel, etc.

The criteria for identification of operating costs are first outlined, and a typical contractual provision covering operating costs is illustrated.

Chapter 6: Maintenance Cost

Equations are discussed which provide a method for converting numerial reliability and maintainability data in the common measure of dollars: (1) maintenance cost/item; (2) expected usage (in hrs.) of each item; (3) expected no. of failures in projected inventory; (4) usage period/item being procured; (5) repair labor cost/failure; (6) repair material cost/failure; (7) transportation cost/failure; (8) preventive maintenance costs/item; (9) preventive maintenance man-hours per month. The equations must be thoroughly understood or serious errors could occur in their use. A quantitative source evaluation checklist for the equations is provided, showing whether the government or the contractor should be responsible for providing data for the various items.

Chapter 7: Reliability Production and Verification

This chapter outlines guidelines to be followed in predicting the reliability of items, and also the procedures to be used in verifying the reliability estimates.

The reliability predictions are noted as mean time between failure and mean life.

"Failure" is defined, and a sample contract provision covering failures is included.

Chapter 8: Maintainability

Maintainability is concerned with 2 elements: the amount of system downtime required for maintenance and the amount of resources required for maintenance.

Techniques used by contractors to improve maintainability are listed. Maintenance costs are discussed extensively in Chapter 6.

Chapter 9: Other Costs

This chapter deals with other less visible LCC elements, such as: delivery, storage, insulation, terminal value, and technical data reproduction.

Examples of these and other costs are outlined.

Chapter 10: Verification and Price Adjustment

The government must have some mechanism whereby it can recoup any losses suffered as a result of broken promises, or estimates of costs/performance that were not realized. This chapter presents guidelines on appropriate mechanisms designed to ensure receipt of contracted value.

The DoD is intent on obtaining full value on all hardware and materials procured. Full recovery can be obtained by: 1) supply of additional units,
2) adjustment of unit price;
3) lump sum rebate or reduction levied vs. contractor.

Because contractors may be reluctant to bid on contracts where LCC must be virtually guaranteed, provision may have to be made for partial rather than full recovery.

Chapter 11: Discounting Costs

This chapter explains the rationale behind the use of present value, and how it should be used in the analysis of LCC.

Chapter 12: Preparation of the Solicitation

This chapter sets out the documentation required to include LCC in a contract agreement.

Chapter 13: This chapter presents a simple example and checklist to demonstrate the evaluation of proposals under LCC analysis.

Chapter 14: Non-Recoverable Items

This chapter deals with the guidelines to be followed in applying LCC to non-recoverable items - items which will not be repaired and returned to service upon failure.

Department of Defense
1973 — Life Cycle Costing Guide for Systems Acquisitions.

<u>Objectives/scope:</u> The report presents guidelines for the application of the LCC concept for the acquisition of complete defense systems.

<u>Chapter 1</u>: Introduction

Life cycle cost is defined, and its place in decision making is outlined.

<u>Chapter 2</u>: LCC in Decision Making

Life cycle cost should be used so that cost considerations properly influence virtually all decisions. LCC is one influence on decisions, the other being System Effectiveness. The detailed tools for measurement and evaluation of System Effectiveness are not examined in the Guide. The use of LCC may lead to reference for a different alternative than if only initial costs were considered in decision making.

<u>Chapter 3</u>: Cost Models

Cost models are made up of 1 or more mathematical relationships, arranged so that outputs (cost estimates) are derived from inputs. Two categories of models and their advantages and disadvantages are outlined: (1) cost estimating relationship (CER) method; (2) engineered cost estimate method.

<u>Chapter 4</u>: Acquisition Strategies

"Strategies" denotes the procedures for handling successive acquisition phases and are differentiated by a number of factors. LCC warrants application for all decisions. A number of strategies are outlined: (1) single source; (2) single source selected for entire program; (4) single source selected at end of validation phase; (5) parallel prototypes developed during validation - one contractor then selected; (6) single source selected only at production phase; (7) 1 contractor develops, competition for production; (8) similar, except subsystem broken up in production.

Chapter 5: Contract Principles

Contracts where the precedent RFPS' require LCC analyses and the contracts are awarded on the basis of those analyses are discussed.

"Life cycle cost procurement" is defined and discussed. Contractors should be advised if LCC estimates are required. The estimation of LCC can be done only after substantial experience related to a system has been acquired. The government should furnish the equations needed to estimate LCC. Care must be taken to avoid biased inputs by contractors.

Demonstrations are a necessary part of LCC contracting, since they help to avoid biased estimates by bidders.

Appendix 1: Operating and Support (O&S) Cost Model

Appendix contains information needed to interpret and apply typical O&S cost model equations. Specific equations are included for a number of costs - for example training costs, maintenance costs, etc.

Appendix II: Operating and Support (O&S) Cost Data Sources

Existing data are generally the result of studies for specific systems, since there is no general data gathering unit. Sources within the 3 branches of the armed forces are noted.

Dewees, D.N.
1977

Energy Conservation in Home Refrigeration. Toronto, Ontario: University of Toronto Institute for Policy Analysis-Institute for Environmental Studies.

Objectives/scope: To identify the variations in energy consumption among models of new (1976) refrigerators sold in Canada and to attempt to determine the reason for these variations.

Method: Complete data sets were gathered for 19 Canadian makes and models of refrigerators. The energy consumption of these refrigerators was compared to those of United States models listed in the Association of Home Appliance Manufacturers (AHAM) booklet. A multi-variate regression analysis was done using the Canadian data.

Findings: Energy consumption ranged from 102 kwh/month to 189 kwh/month for Canadian models. This compares to a range of 50 kwh/month to 245 kwh/month in the United States. If the sample is limited to 15-17 cubic foot models the Canadian data ranged from 114-163 kwh/month compared to 50-175 kwh/month for United States models. From the regression analysis the two most important variables were the log of refrigerator capacity and whether the refrigerators use up to twice as much electricity, other things being equal, as other models. An "energy saver" switch on some frost free models achieved significant energy savings. Other factors influencing energy consumption are the thickness of the refrigerator walls, the type of insulation in them, the presence of accessories such as an ice water dispenser or ice maker, and whether the freezer is on top of or beside the refrigerator compartment. Refrigerator efficiency in general and appliance efficiency in general should be of particularly great importance in areas where air conditioning is widely used because of the waste heat given off. In the Canadian situation, the benefits of appliance energy conservation should include adjustments for the space heating makeup required after appliance efficiency has been improved. It would probably be appropriate to reduce direct savings by one-third to two-thirds in most areas of the country. There is not a significant relationship between the price of refrigerators and their energy consumption when all other variables are accounted for. It would be economical to modify designs to reduce energy consumption if the increased production cost associated with this change was less than the present value of the discounted stream of savings in energy costs over the life of the refrigerator, adjusted for space heating implications.

Dover, Lawrence E., and Billie E. Oswald
1974 — A Summary and Analysis of Life Cycle Costing Techniques and Models.
Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology.

Objectives/scope: (1) To produce an annotated bibliography summarizing significant LCC thoughts and processes; (2) to develop a logical taxonomy of LCC models; (3) to provide some analysis of LCC literature by discussing advantages, disadvantages and inconsistencies in the application of LCC techniques.

Abstract: Weapon system costs have traditionally referred to initial research, development, test, and evaluation (RDT & E) costs and to investment costs required to introduce a new system into the operational inventory. However, these costs occur only once in the life cycle of a weapon system and may represent only a small portion of a system's total ownership cost. Another category (operational costs) continues to recur throughout the life of a system and normally represents the majority of life cycle costs. Presented are an 'Annotated Bibliography of Selected Life Cycle Costing Literature' and a 'Taxonomy of Selected Life Cycle Cost Models.' The Annotated Bibliography is sectionalized into six areas: Directives and Guides; General Philosophy and Methodology; Reliability and Maintainability; Cost-Effectiveness; Cost Models; and Case Studies and Technical Reports. The Taxonomy discusses six types of life cycle cost models including accounting, cost estimating relationship, simulation, failure-free warranty, reliability, and economic analysis models. One conclusion is that awareness of life cycle costing concepts results in better planning and decision making. On the other hand, the usefulness of life cycle costing is somewhat limited by the complexity of cost models and the difficult task of anticipating all potential costs of sophisticated weapon systems.

Fiorello, Marco R.
1975

Getting 'Real' Data for Life-Cycle Costing. Santa Monica, California: Rand Corporation. Prepared for the U.S. Department of Commerce.

Objectives/scope: To discuss the process of identifying, collecting and utilizing historical data for estimating the life-cycle costs of a weapon system.

Abstract: The focus is on data-related problems which currently constrain the accuracy and reliability of life-cycle cost estimates. Particular attention is given to the costs of ownership. A case example is provided to illustrate the estimation of life-cycle costs using macro cost data for an operational weapon system. Some of the uncertainties inherent in the data collection and analysis processes are also discussed. Currently approximation of aircraft weapons system life-cycle costs is possible, but the process is not straightforward. Major difficulties include using multiple data system products, different data nomenclatures, and insufficient data quality and quantity. Specific recommendations include implementing operationally consistent life-cycle cost estimation procedures, improving weapon-system cost visibility in cost data systems, establishing and maintaining a nomenclature directory, implementing better cost allocation rules, anticipation of life-cycle cost decision data requirements, and constructing and maintaining a special data base for life cycle cost analysis and methodology development.

Fitzer, Stephen R.
1974 — The State-of-the-Art: Life Cycle Costing. General Services Administration.

Objectives/scope: The report reviews and summarizes the state-of-the-art in life cycle costing, and also provides a bibliography to aid future research in the area.

Abstract: The lack of attention accorded life cycle costing may be a result of the fact that the concept is often too narrowly defined. Not all items can be subjected to life cycle costing, because of difficulties involved in estimating costs and service life, and in choosing a discount rate. The most accurate prediction of life cycle costs can be obtained from multiple linear regression techniques. The total life cycle cost is the initial cost plus the maintenance and operating costs (discounted) less the present value of the salvage value of the item.

Fricker, David V.
1979

Terotechnology and Life-Cycle Costing: An Introduction.
National Terotechnology Centre.

Objectives/scope: To introduce and describe terotechnology and its basic tool, life-cycle costing.

Abstract: Terotechnology is defined as a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life-cycle costs. It was developed by a governmental committee to help British industry lower the cost of ownership of physical assets. The history and techniques of terotechnology are provided in the paper along with a list of documents which are available from the National Terotechnology Centre. Terotechnology requires the pursuit of the economic life-cycle cost of an asset. This is not necessarily the lowest life-cycle cost if this means that the asset will not adequately fulfill its intended use. In the ideal situation the life-cycle cost will be traded off against some measure of effectiveness of the asset in meeting its intended use. The first step in the LCC process is to analyze the total life-cycle events for the physical asset. The second step is to define the cost factors and estimate relationships which are fundamental to the size of the costs which will be incurred during the life of the asset. The next step is to work up the cost of each of the life cycle elements by using the previously determined cost estimating factors and relationships. Depending on the level of accuracy required in the finally calculated life-cycle cost and the nature of the physical asset, there are time related factors which affect costs and can be accounted for duing the LCC process. Two of these are inflation and learning curves. The next step covers another time related factor which is that all the estimated prices be discounted to a base period. The final step in the LCC process is to calculate the final life cycle cost according to an appropriate cost model. Some applications of LCC in industrial decision making are also given.

Garribba, S., et al.
1979

Energy and Economic Cost of a Washing Machine: Statistical Life Cycle Analysis for Energy Savings. Presented at International Conference on Energy Use Management, Los Angeles, California, October.

Objectives/scope: To assess and weigh actions regarding washing machines directed towards energy conservation. Actions considered are system-specific, in the sense that they refer only to modifications of the appliance and its operation.

Abstract: Washing machines are assessed on their economic and net energy balance. Fixed costs include the purchase of the asset and account for salvage value after use. Variable costs are made by the cost of spare parts, maintenance actions, cleansing agents, water and power. Once cost components have been evaluated and summed up, given the cumulated life time and number of washing cycles (operation cycles), it is possible to obtain the so-called (total) unit cost, i.e. the cost of the generic cycle. A statistical correspondence can be established between the generic cycle and other operation characteristics such as type of the cycle, load factor, consumption of power and cleansing agents and so on. Therefore the generic cycle to be used in the cost analysis can be related with Service Unit (SU) which is supplied. In its turn, unit cost and SU cost are random variables. Indeed uncertainties come from scattered data, and variability in the conditions of operation of the machine. As a result, one is led to the consideration of probability density functions. Cost estimates are made assuming constant money and energy values. The knowledge of unit cost offers a possibility for evaluating the effect of any action intended to reduce energy consumption during the entire life cycle of the system. Possible actions are, for instance, life cycle extensions, better thermal insulation and lower washing temperature.

General Services Administration

1975 — Life Cycle Costing in the Procurement of Water Heaters.
Washington, D.C.: Federal Supply Service.

Objectives/scope: To describe the nationwide competitive procurement of residential type water heaters, using LCC criteria in order to obtain those units which would result in the lowest total cost of ownership.

Method: Bids were sought on two sizes each of electric and gas water heaters. The Federal Supply Service (FSS) partitioned the U.S. into 10 zones to allow factors for the varying cost of electric power and gas to be included in the LCC criteria. Warranty provisions were required as conditions of the procurement to reduce the risk to the government and to substitute for maintenance costs in developing the LCC criteria. A 10 year service life and a 10% discount rate were used in the calculations.

Findings: Only 2 suppliers submitted final bids. One bidder offered lower bid prices for every model of water heater in every zone. In every case the other bidder's Life Cycle Cost was lower because of lower operating costs. The total savings afforded by LCC procurement was obtained by the differences in LCC cost for the two bidders for each zone, multiplied by the anticipated number of units to be purchased in each zone. The total savings were calculated to be $326,457 on the anticipated purchase of 7,650 water heaters.

General Services Administration

1975 — Life Cycle Costing in the Procurement of Room Air Conditioners.
Washington, D.C.: Federal Supply Service.

Objectives/scope: To describe the nationwide competitive procurement of room air conditioners, using LCC criteria in order to obtain those units which would result in the lowest total cost of ownership.

Method: Bids were sought on 5 sizes of room air conditioners. The Federal Supply Service (FSS) partitioned the U.S. into 10 zones to permit bidders to offer their best price in each zone. In addition the selected LCC criteria involved factors for operating hours and electricity costs in different areas. Warranty provisions were required as conditions of the procurement to reduce the risk to the government and to substitute for maintenance costs in developing the LCC criteria. A 7 year service life and a 10% discount rate were used in the calculations.

Findings: Successful LCC bidders achieved EER improvements over Interim Federal Specifications ranging from 9% to 42%. EER is the energy efficiency ratio which is equal to the ratio of cooling capacity (in BTUs per hour) to the power input (in watts). While even larger EERs are available the increase in acquisition cost more than offset the decrease in energy consumption costs. The basis for determining the total savings afforded by LCC procurement was the dollar difference in LCc prices between the winner and the low price bidder for each size, multiplied by the anticipated number of units of each size to be procured. Total savings were calculated to be $414,708 based on expected purchases of 27,000 air conditioners. $347,460 of these savings were realized on the anticipated purchase of 6,000 air conditioners of the largest size (more than 23,000 BTU/hour). Informal estimates of manpower costs involved in LCC criteria development was $20,000 or about 6% of the net savings.

General Services Administration

1976 — Life Cycle Costing in the Procurement of High-Speed Printer Ribbons. Washington, D.C.: Federal Supply Service.

Objectives/scope: To describe the nationwide competitive procurement of high-speed printer ribbons, using LCC criteria in order to obtain those units which would result in the lowest total cost of ownership.

Method: Bids were sought on accounting machine ribbons of 14 1/16 inches width and 20 yard length for use on the IBM 1403 high speed printer. Each bidder had the option of specifying the total number of minutes that a 4 yard sample ribbon was warranted to print before functional illegibility (45% reflectance). If that option was exercised, the lesser of that time or the measured time was used in determining CMPU. The Federal Supply Service (FSS) specified 10 destinations throughout the U.S. to permit bidders to offer their best price to each destination.

Findings: Seven acceptable bids were received. Two of the offerors chose to exercise the option of specifying the time the sample ribbon was warranted to print. No obvious cost savings can be attributed to the use of life cycle costing because the low price bids won for each of the ten destinations. However, the FSS does have the assurance that the ribbons selected more than satisfy the specified performance standards. One bidding firm would have been the winner for all ten destinations if it had not taken the option of specifying their ribbon's performance. However because it specified a substantially lower time (6 hours vs. 4.5 hours) than the FSS test results for their sample ribbon, they lost out for every destination. The performance reexamined in the next procurement, to avoid, if possible, rejecting clearly superior products.

Gery, Frank W.
1980

Life Cycle Costing of Solar Assisted Heating Systems: The Effect of Tax and Financial Incentives on the Homeowners Decision.
Northfield, Minnesota: St. Olar College.

Objectives/scope: (1) To review considerations which may enhance consumer acceptance of SAHS, via a simulation of results for Minneapolis/St. Paul using LCC; (2) to examine the effects of the various incentives.

Abstract: Assuming the technical feasibility of solar assisted heating (including domestic hot water) systems (SAHS) is demonstrated, there are still at least three deterrents to widespread adoption by consumers: (1) large front-end investment costs: (2) uncertain cash savings, which depend on future fossil fuel price extrapolations; (3) substantial early year cash deficits even if front-end costs are spread out through conventional mortgage financing. Other investigators have largely dealt with the first two issues. The recommended procedure has been to use life cycle costs to find the number of years to break even: (1) tax credits on solar installations, which reduce front-end costs; (2) an excise tax on fossil fuels and electricity, which increase cash savings. Under the best of circumstances--low collector installation costs and high fossil fuel price escalation--it is possible for a SAHS in a cold climate to break even in a reasonable number of years (± 15). However, even with the current Federal and State income tax credits for SAHS installation the homeowners may suffer substantial cash flow deficits while awaiting the savings payoff toward the end of the break even time horizon. It is the contention of this paper that additional tax and financial incentives are required to reduce or eliminate this cash deficit if homeowners are to be induced to install SAHS. The various incentives examined include: (1) tax rebates on fossil fuel saved; (2) subsidized interest cost, with and without variable payment mortgages; (3) third party funding of capital costs with variable rental of SAHS paid by the homeowner. The differential impacts of these incentives on LCC and cash flows are evaluated.

Herendeen, Robert A.
1975

Appliance Energy Use.
Urbana, Illinois: Centres for Advanced Computation, University of Illinois at Urbana-Champaign.

Objectives/scope: To evaluate the relative importance of operating energy for 30 household appliances. The gross energy requirement for 3 example kitchens and the economic aspects of more efficient air conditioners are also discussed.

Abstract: The energy cost of an appliance is the sum of the energies of manufacture, maintenance, operation, and disposal. The energy cost of disposal is relatively small and difficult to obtain so it is assumed to be zero. The energies of manufacture and maintenance were obtained by converting the dollar costs using input-output economics. Rough estimates were used for maintenance and appliance life. For ranges, refrigerators, freezers, air conditioners, dryers and water heaters, operational energy comprises over 90% of the total energy cost. For these appliances, the conservation potential appears to lie in efficiency rather than increased desirability. A fully equipped kitchen which includes frost-free options where available has a yearly energy impact of about 120 million Btu (gas) or 150 million Btu (electric). The moderate kitchen with frost less models where possible, no dishwasher and fewer small appliances had an energy impact of about 80% of that of the full kitchen. The spartan kitchen with only a frostless refrigerator, range, clothes washer and water heater had an energy cost of about 55% of that of the full kitchen with 20 appliances. The air conditioner which was cheapest to own and operate in a certain size class was not always the most energy efficient. However, if life cycle costing was used rather than initial cost as the purchase criterion, energy would be saved in all 6 size classes studied. For the larger sizes, energy savings would be about 30%. Rising energy prices will have the effect of pushing dollar and energy conservation in the same direction.

Hirst, Eric, et al.
1977

An Improved Engineering-Economic Model of Residential Energy Use.
Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Objectives/scope: This paper presents an improved version (III) of the ORNL residential energy model. The model is to be used to evaluate a variety of energy conservation policies, programs, and technologies for their effects on energy use, energy costs, and capital costs over time.

Abstract: The improved version of the energy use model was developed to simulate energy use in the residential sector from 1970 to 2000. The model provides considerable detail on annual energy uses by fuel, end use, and housing type; and also estimates annual equipment installations and ownership, equipment energy requirements, costs for improving thermal integrities on new and existing housing units. Thus, the model provides considerable detail on residential energy uses and associated costs. These details are useful for evaluating alternative energy conservation policies, programs, and technologies for their energy and economic effects during the next quarter century. The present version of the model deals with four fuels, eight end uses, and three housing types. Each of these 96 fuel use components is calculated each year as a function of stocks of occupied housing units and new construction, equipment ownership by fuel and end use, thermal integrity of housing units, average unit energy requirements for each equipment type, and usage factors that reflect household behavior. Simulations of energy use from 1960 to 1975 show that the model accurately predicts historical data on aggregate energy use, energy use by fuel, energy use by end use, and equipment ownership market-shares. A reference projection developed with the model shows residential energy use growing from 17.5 GGJ (10^{18} joules) in 1975 to 18.5 GGJ in 1980 and 26.6 GGJ in 2000, with an average annual growth rate of 1.7%. Electricity increases its share of the energy budget from 44% in 1975 to 67% in 2000. Shares provided by gas, oil, and other fuels all decline in this period.

Hoskins, Robert A., Hirst, Eric, and W.S. Johnson

1978 — Residential Refrigerators: Energy Conservation and Economics.
Energy, 3, 1 (January) 43-49.

Objectives/scope: To develop a computer model of energy flows and electricity uses in residential refrigerators, and to use this model to evaluate the energy and cost impacts of alternative energy conserving designs.

Method: An energy model was developed to perform three functions. First, it evaluates thermal gains to the refrigerator. Second, the model determines electricity consumption based on thermal load and operation of heaters and fans. Finally, the model is flexible enough so that energy conservation measures can be evaluated by changing values of various parameters in the model equations. A computer program was written to perform the calculations required by the energy model for any size or type of refrigerator and for any set of operating conditions.

Findings: Heat gains to refrigerated spaces are due to conduction through walls and door openings, infiltration through gaskets, food, operation of heaters and fans, and operation of an ice maker in some units. Most of the electricity is used to operate the compressor that drives the refrigerator cycle. Electricity is also used to power heaters and fans. Application of all the changes considered would reduce refrigerator electricity use 71% and increase initial cost 5% relative to units without any of these design changes. Implementing all these changes except for elimination of the frost-free feature would reduce electricity use 52% and increase initial cost 19%.

Implications: Large increases in energy efficiency with only small cost increases imply life cycle cost would be lower, because LCC might lead to energy conservation.

Hoskins, Robert A., and Eric Hirst
1977 Energy and Cost Analysis of Residential Refrigerators.
Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Objectives/scope: (1) To develop a model of energy flows and electricity uses in residential refrigerators; (2) to use the model to evaluate the energy and cost impacts of alternative energy conserving designs; (3) to use the outputs in ORNL's model of residential energy use to estimate long term energy conservation impacts.

Abstract: A detailed computer model is developed to calculate energy flows and electricity use for residential refrigerators. Model equations are derived from applications of the first law of thermodynamics, analysis of manufacturer's literature, and related studies. The model is used to evaluate the energy (and associated initial cost) impacts of alternative designs to reduce refrigerator energy use. Model results show that 56% of the total heat gain in a typical .45m^3 (16 $ft.^3$) top-freezer refrigerator is due to conduction through cabinet walls and doors. The remaining 44% is from door openings, heaters, fans, food, gasket area infiltration, and miscellaneous heat sources. Operation of the compressor to remove this heat and maintain the refrigerated spaces at constant temperatures accounts for 70% of the unit's electricity use. The remainder is for operation of heaters and fans. Several energy-saving design changes are examined: (1) increasing fiberglass insulation thickness (electricity consumption down 14%); (2) changing to urethane foam insulation (down 22%); (3) removing fan motor from cooled area (down 4%); (4) use of anti-sweat heater switch (down 9%); (5) improved compressor efficiency (down 13%); (6) increased condenser and evaporation surface areas (down 10%); (7) elimination of frost free feature (down 29%). If all changes were made, energy consumption would be reduced by 71% and initial cost increased 5%. The life cycle cost to consumers would be less. It is doubtful that many consumers would be willing to eliminate the frost free feature despite the savings involved because of the convenience offered. Without eliminating this feature, energy consumption would be reduced 52% and initial cost increased 19%.

Hutchins, Paul F., and Eric Hirst
1978 Engineering-Economic Analysis of Single-Family Dwelling Thermal Performance.
Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Objectives/scope: The purpose of the report is to define relationships between annual energy use for home space heating/cooling and initial investment in single family dwellings (1200 ft^2) in 9 U.S. cities. The "optimal" design for single family dwellings in each location is developed, the optimal defined as that design which minimizes LCC (purchase price plus heating & cooling operating costs).

Abstract: The annual loads calculation and cost surveys are based on a National Bureau of Standards report. The economic analyses were done utilizing an ORNL computer program. Among the Design options studied were additional insulation, multiple paned windows, sliding glass doors, storm doors, and styrofoam wall sheathing. Relationships were defined between annual energy savings in space heating and cooling vs. additional initial cost. The most cost effective order of implementation was generally constant for all locations (for heating only). Potential reductions in annual energy use range from 30 to 60% when compared to the 1974 Housing & Urban Development Minimum Property Standards (HUD-MPS). The optimal levels of investment in energy conserving design (heating only) were calculated for each of the 9 cities. When compared to 1974 HUDMPS, major differences were noted for all but the natural gas heated homes in areas less than 5200 heating degree days. The HUD-MPS would be more effective if they were sensitive to fuel prices as well as to climate. Payback periods for additional investment beyond current standards range from 15 to 20 years for natural gas users to 4-6 years for electrically heated homes.

Hutchins, Paul F., and Eric Hirst
1978 Engineering-Economic Analysis of Mobile-Home Thermal Performance.
Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Objectives/scope: The report presents a detailed analysis of different levels of investment in energy-efficient designs for new mobile homes. The purpose is to define relationships between annual energy use for mobile home space heating and air conditioning as functions of initial investment in the structure for a range of climates (9) in the United States, then using the relationships to define the 'optimal' design of mobile homes for each area.

Abstract: Mobile homes are increasing in popularity, mainly because of their relatively low price. The optimal design for the mobile home as developed in this paper is defined as that design which minimizes the lifecycle cost. Annual heating and cooling requirements are determined using NASA's Energy-Cost Analysis Program (NECAP). An economic analysis was performed, an analysis designed to: (1) develop relationships between annual heating and cooling loads and additional investment in thermal improvements; (2) calculate payback period and net present worth (using life cycle cost analysis) for each design option; (3) perform sensitivity analysis to determine the effects of changes in the various input parameters. The optimal level of investment varies by location and heating fuel choice as well as other factors. Design changes considered included adding insulation, storm windows, underpinnings, and awnings. Optimal designs calculated involved additional investment and required less energy for heating than do HUD (Housing & Urban Development) standards except in the warmest climate areas. Energy use reduction for natural gas heating is 20-30% relative to 1976 HUD standards (except in warm areas), while for electric heat or liquid propane it is 30-50%. HUD standards should be made more sensitive to location, fuel choices and fuel prices. The findings of this study can be utilized to establish cost effective mobile home standards, and in analyzing mobile home thermal performance.

Hutton, R. Bruce
1977

Consumer Perceptions of Product Cost: A Changing Conceptual Structure.
University of Denver.

Objectives/scope: (1) To discuss the concept of LCC within current information environment perspectives; (2) to evaluate LCC in light of policy objectives for information provision.

Abstract: Programs designed to increase the provision of product information have generally met with a lack of success in terms of consumer response. The information provided must be relevant for the consumer's evaluation and decision making purposes. Certain evaluative dimensions may be more important or salient than others, but the availability of information may create the salience. The concept of LCC provides a comprehensive and consistent framework for three basic product cost dimensions - price, energy and service. The potential impacts of LCC on consumers include: (1) increased information; (2) improved conceptualization of product "cost;" (3) increased salience of energy and service as cost dimensions of a product; (4) improved bases for consumer evaluation of alternatives; (5) sharpened cost/benefit judgements on product features; (6) new tradeoffs between initial and deferred costs; (7) shifts in products purchased. These impacts seemingly coincide with the stated objectives of two U.S. government information programs (Voluntary Labelling Program for Household Appliances and Energy Policy & Conservation Act). The preliminary results of a recently completed research project regarding the impacts of LCC are reviewed.

Hutton, R. Bruce, and William L. Wilkie
1979 "Life Cycle Cost": A New Form of Consumer Information.
University of Denver, and University of Florida, respectively.

Objectives/scope: (1) To raise the LCC concept as one worthy of careful attention in the fields of consumer research, marketing, and public policy; (2) to present a number of hypotheses regarding LCC, and the findings of a consumer experiment investigating the effects of LCC information on consumers.

Abstract: Concern with energy and the growing acceptance of consumer information as a worthwhile policy alternative are interacting to spur interest in the development and implementation of the LCC concept. The concept has been implicitly used in industry for years. There are some relatively severe problems in obtaining precise and accurate LCC figures because of the estimating required. There are, however, a number of potential benefits that might be provided by LCC information. The presumed impacts of LCC that might be isolated as significant possibilities resulting from successful communication of the information and subsequent use by consumers are presented. The consumer experiment investigating LCC was conducted in Gainesville, Florida, and was concerned with refrigerator-freezers. Consumers exposed to LCC information were significantly more accurate in estimating feature costs in awareness fo correct cost relationships vis-a-vis energy, and appeared to be able to deal with the complexity of the information more readily than did the control group. The control group chose models which were significantly higher on lifetime energy costs than those chosen by the LCC group. The experiment results appear to support LCC as a superior information form. LCC data should be developed to be valid and relevant to a particular consumer.

Kirkwood, T.F., and A.D. Lee

1975 A Generalized Model for Comparing Automobile Design Approaches to Iproved Fuel Economy. Santa Monica, California: The Rand Corporation.

Abstract: Describes an automobile design model that assesses the effects of design changes on fuel economy, lifetime energy required, sticker price, and annual cost of ownership of automobiles having specified acceleration capabilities, passenger and trunk compartment dimensions, and unrefueled range. The results indicate that large savings (as much as one-half) in automobile energy consumption are possible through technical improvements such as the use of a continuously variable transmission, improvements to the internal combustion engine, and the use of lighter weight structural materials. Important savings can also be realized by reducing the spaciousness of the auto. The use of methanol or hydrogen as automotive fuels does not result in an overall conservation of energy, but could result in a conservation of petroleum if the energy required to produce these fuels is obtained from nonpetroleum sources.

Kutta, Richard M., and Robert T. Lund

1978 Remanufacturing: A Preliminary Assessment. Cambridge, Massachusetts: Centre for Policy Alternatives, M.I.T.

Objectives/scope: To provide the results of a preliminary exploration of the state of durable product remanufacturing in the United States.

Method: An interview questionnaire was developed to provide an insight into the everyday operations of remanufacturing. Companies were selected for interviewing based only on criteria of uniqueness and the willingness of the manufacturers to cooperate.

Findings: The survey yielded twenty usable responses. The primary remanufacturing targets to date have been in industrial capital goods. A major secondary target has been automotive replacement components. Other than automotive, there are relatively few consumer products remanufactured. Products that are good candidates for remanufacturing appear to have the following characteristics: long-term stability of design, limited numbers of different models, sources of good quality cares at low cost, high new product prices, and a market that accepts used goods. Remanufacturing is considered labour intensive, and the capital equipment requirements in remanufacturing are lower than those in comparable original equipment manufacturing firms. Problem areas identified by remanufacturers include market resistance to remanufactured products, sources of supply for cores and worn or broken items, changes in product design, and competition with original equipment manufacturers. Present-day economics of our labour, material and energy resources, and demands for greater efficiency of consumption indicate that now is an appropriate time for an assessment of the potential for remanufacturing.

Logistics Management Institute
1969 — Life Cycle Costing in System Acquisition. Springfield, Virginia: National Technical Information Service. Prepared for the U.S. Department of Commerce.

Objectives/scope: To discuss the objectives, characteristics and methods of life cycle costing in systems acquisition for the Department of Defense (DoD).

Abstract: Life Cycle Costing is defined as the process of estimating all those costs -- development, production, operation, and support -- which can influence the choice among competing design concepts or specifications, among possible procurement procedures, or among competing proposals for production in the acquisition of major defense hardware systems. After discussion of its objectives and characteristics, Life Cycle Costing is separated into three methods: the Implicit Method; the Cost Estimating Relationship Method; and the Element Estimate Method. The appropriateness of each method is discussed (a) for different stages of the system life cycle, (b) for 'incremental improvement' systems and 'new generation' systems, and (c) for overall system investment, overall operation and support cost, major subsystem investment, and selected operation and support cost elements. The roles of element structures, cost factors, and costing rules in Life Cycle Cost analysis are outlined. It is recommended that the DoD should require Life Cycle Costing in all system acquisition programs, recognizing that it assumes different forms in different stages. It also is recommended that current developmental efforts on cost estimating relationships should be redirected or expanded to give more attention to operation and support costs.

Logistics Management Institute

1976 — Life Cycle Costing in the Procurement of Refrigerator-Freezers. Prepared for Experimental Technology Incentives Program, General Services Administration.

Objectives/scope: To describe the nationwide procurement of no-frost refrigerator freezers, using LCC criteria in order to obtain those units which would result in the lowest total cost of ownership.

Method: Bids were sought on two different configurations, top mounted freezer and side-by-side freezer, and twelve sizes of refrigerator-freezers. The Federal Supply Service partitioned the U.S. into 4 zones to permit bidders to offer their best FOB destination bid price in each zone. Warranty provisions were required to reduce the risk to the government and to substitute for maintenance costs in developing the LCC criteria. A 15 year service life and an 8% discount rate were used in the calculations.

Findings: In this procurement, LCC determined the outcome in six of the twelve sizes and, based upon the anticipated purchase of 10,080 units, provided an estimated present value cost saving of $377,000. The basis for determining the total savings afforded by LCC procurement was the dollar difference in LCC prices between the winner and low price bidder for each size and zone, multiplied by the anticipated number of units to be procured. With an allocation of $15,000 to this procurement, the cost of LCC criteria development represents only 4% of the savings obtained.

Lund, Robert T.
1977

Making Products Live Longer.
Technology Review, 79, 3 (January) 1-7.

Objectives/scope: To describe the possibility for increasing product life and the implications of such action.

Abstract: For major appliances future costs represent a significant fraction of the total cost of ownership, even when these costs are discounted to present value. It remains to be seen whether life cycle costing can be shifted from being a research tool into everyday use by the average consumer. An appliance's lifespan is a critical measurement for life cycle costing and determining the rate of appliance discard. There has been little change in the service lives of new products in the past 20 years. Although, technically, appliances could be made more durable through improved product design, indications are that product durability does not govern the life of consumer durables. Products are being discarded that still function or that could be repaired because of: (1) rising service costs relative to new appliance prices; (2) the effects of consumer affluence; (3) weak used appliance market; (4) population mobility; (5) appearance; (6) unavailability of replacement parts. The benefits of longer appliance life would include: (1) savings to consumers; (2) reduction in solid wastes; (3) a lower demand on natural resources. Adverse effects might include: (1) reduced manufacturing profits; (2) higher unemployment, and 3) slower technological innovation. Some specific topics requiring investigation are: (1) the reasons for product discard and the relative number of discards for each appliance; (2) service incidence rates for appliances over their entire lives; (3) the nature of second hand equipment markets and of used parts markets; (4) appliance remanufacturing, (5) economic consequences of longer product life. The types of public policy might be effective in increasing product life are: (1) reducing the cost of appliance repair; (2) reducing service costs relative to purchase costs; (3) encouraging remanufacturing; (4) encouraging extended service contracts; (5) ensuring the continuation of parts supplies, (6) informing and educating consumers.

Lund, Robert T., and W. Michael Denney
1977 — Opportunities and Implications of Extending Product Life.
Cambridge, Massachusetts: Centre for Policy Alternatives, M.I.T.

Objectives/scope: The opportunities and implications of extending product life are examined.

Abstract: Longer product life involves important tradeoffs. Benefits include: (1) direct savings to consumers; (2) increased consumer satisfaction; (3) resource conservation; (4) reduction in solid wastes. Adverse effects include: (1) increased initial product costs; (2) use of scarce or precious materials to achieve durability; (3) slower technological innovation; (4) unemployment and profit losses in the associated manufacturing industry. Factors influencing product life are not only technological in nature, but also include consumer attitudes and usage behavior. Technological solutions can be ineffectual if consumers refuse to cooperate. A four fold classification scheme for policy alternatives for extending product life is developed. In the short term market quadrant, efforts to promote longer product life must focus on the way consumers use the products they currently own and/or on the service and disposal mechanisms that are currently available. On the supply side, short term policy options could include: (1) encouragement of used product markets; (2) ensuring the availability of replacement parts, (3) lowering service costs. In the long term consumer education is required to induce the purchase of models in the market with a longer technically useful life. Suppliers have a major role in increasing product life through product design in the long term. Remanufacturing is an especially promising strategy for achieving a fully extended product life. This strategy captures the residual functional value (or value added) in a used product as opposed to recycling for material content. The benefits of remanufacturing include: (1) employment; (2) low cost like-new products; (3) lower cost replacement assemblies to repair products still in use. To make remanufacturing more attractive, standardized product designs that allow for easy disassembly and reassembly should be promoted.

Lund, Robert T., and W. Michael Denney

1977 Providing Individualized Consumer Information in the Marketplace: A Life-Cycle Cost Approach for Durable Products.
Cambridge, Mass.: M.I.T Centre for Policy Alternatives.

Objectives/scope: (1) To build upon and contribute to the field of consumer information processing; (2) to examine alternative methods for information delivery, and, particularly, ways of linking the ordinary consumer to a computer based LCC information system; (3) to examine methods generally of making the LCC model more useful as an instrument for consumer decision making.

Abstract: This is a proposal to study consumer reactions to product cost information, using the concept of individualized life-cycle costs as a research vehicle. Such research is needed because information provision has become a central theme in consumer protection policies, and yet little is known about the most effective ways of framing and delivering product information to consumers. The LCC approach offers a unique opportunity to investigate how consumers process and respond to new and potentially useful information; it also merits study as an innovative method of consumer information with enormous possible benefits. This is conceived as a two year study, calling on the multidisciplinary skills of specialists in consumer behavior and information processing, computer-based information systems, communications psychology, and consumer information policy. The project will begin with a background inquiry into consumer receptivity for LCC information, based on the use of focus-groups, depth interviews, and a national telephone survey. Attention will also be given to adapting previous work in developing a computer-based LCC computational model for major home appliances to become a tool for consumer decision-making. The project will culminate in a field experiment to evaluate consumer reactions to individualized LCC information delivered under natural purchasing conditions.

Lund, Robert T.
1977 — Life-Cycle Costing As A Societal Instrument. Cambridge, Massachusetts: M.I.T. Centre for Policy Alternatives.

Objectives/scope: (1) To describe the LCC concept as it applies to consumer products; (2) to provide a preliminary assessment of its direct use by the consumer.

Abstract: There are four elements of total cost implicit in purchase: (1) acquisition; (2) operating; (3) repair and maintenance; (4) disposal. Two products (color television and refrigerators) are considered as examples in an examination of the entire system of costs. Purchase, service and power costs for televisions make up 53%, 35% and 12% of total cost, respectively. Similar figures for refrigerators are 35%, 6% and 58%. Disposal costs are 1% or less. The energy consumption of appliances could be reduced without sacrificing many of their desirable features (ex. refrigerators - 50%). Cost factors influencing the LCC of an appliance in a given household vary so much that any national average or typical LCC figure may be virtually meaningless for the individual consumer. These influences may be appliance-specific (capacity, warranty), region-specific (climate, energy prices) or consumer-specific (usage rates, discount rate). LCC cost information must be tailored as closely as possible to the consumer's own particular situation. Some form of centralized public or private collection and dissemination of LCC information is required, since it is not economical for consumers to collect such information on their own. We need to understand how consumers most readily acquire and use information, if the system is to work. LCC should reduce the need for legislated product requirements, with the ultimate beneficiary being our society.

Manzo, Joseph P.
1976

Life Cycle Costing...What is It? How Does it Affect the Engineer?
Specifying Engineer (September) 71-78.

Objectives/scope: To describe the uses of life cycle costing in building construction.

Abstract: The foremost factor spurring current interest in life cycle costing in building construction is the rapidly rising cost of energy. In the past, annual energy costs averaged 10 percent or less of the first cost of the installed system. Now enery costs are approaching 20 percent of the first cost in most areas and will probably be more than 30 percent within a few years. The data requirements for a life-cycle cost analysis of a proposed building are provided in the report. The appropriate approaches for government projects, privately owned buildings, and nonprofit organizations are also discussed. Examples of life-cycle costing analysis are given for a luxury apartment tower and an office building. The use of life-cycle costing provides the systems design engineer with more incentive to specify energy saving products and systems rather than those based on low first cost. Further, it provides an incentive to use existing computerized equipment-selection programs to obtain equipment selections based on low operating cost rather than only on low first cost. One problem is that the present tax structure does not justify or encourage lower owning or operating costs for privately owned buildings.

Metcalf, Sir Robert Matthew, and Partners.
1974 Life Cycle Costing at the University of Alaska: Feasibility Report.
Prepared for the University of Alaska.

<u>Objectives/scope:</u> To investigate the application of building life cycle costing (LCC) concepts which will enable the University to adequately meet space requirements, while minimizing the total cost of space acquisition, maintenance and operation.

<u>Abstract</u>: The report deals with building and equipment and their operation, replacement and maintenance and does not address the relationship between building space and quality of education. Current life cycle costs at the University of Alaska (UA) are reviewed in order to underline the magnitude of the costs involved. Life cycle costing is defined, its uses explained, and its components described. The current decision structure at UA (for acquiring space) is explained, so that the LCC uses can be properly integrated for tha decision structure. It is recommended that the UA incorporate an LCC program into its planning, design, procurement and construction procedures, in four stages: (1) LCC I - planning; (2) LCC II - design analysis; (3) LCC III - an LCC plan; (4) LCC IV - LCC procurement. A theoretical LCC model is developed, its objective being to minimize applied resources to achieve a desired result. Three types of cost and descriptive data required to implement the models are: (1) user activity; (2) physical description; (3) maintenance and operation. Data sources are identified. The computer will be an essential element in the development and implementation of the LCC building analysis.

M.I.T. Centre for Policy Alternatives

1978 — Consumer Durables: Warranties, Service Contracts and Alternatives. Volume I: Policy Alternatives for the Problem of Product Failure.

Objectives/scope: To report on warranties and service contracts for major household appliances used in the United States for the purpose of increasing public understanding of these mechanisms, and of generating policy alternatives to current practices.

Abstract: In this volume the major policy-related findings of the research project are summarized and options are examined for modifying the means of providing consumer information and protection. The analysis of alternatives draws upon all of the research reported in the other volumes, so this volume serves to integrate the research results. The policy recommendations are summarized by discussing eleven major issues related to warranties, service contracts, and life-cycle costing that emerged during the two years of the study. Each issue is posed as a question followed by a discussion and, where a conclusion is reached, by one or more recommendations. In the concluding chapter a more thorough evaluation of a number of possible alternatives to current warranty and services contract arrangements is pursued. Each alternative is considered on the basis of criteria identified at the start of the chapter, and evidence from the research findings is cited.

Implications: One of the findings of significance from a computer based life cycle model is that there is a great variation in life-cycle costs that will be experienced by different consumers in different circumstances. These variations are so great as to make average or typical life-cycle cost values useless to the individual consumer for any form of decision making. Individualized life-cycle cost information from a computerized system could radically change consumer purchasing behavior and reduce consumer expenditures.

M.I.T. Centre for Policy Alternatives

1978 — Consumer Durables: Warranties, Service Contracts and Alternatives. Volume II: Appliance Warranties and Service Contracts: Description, Pricing and Legal Aspects.

Objectives/scope: See Volume 1.

Abstract: In this volume, attention is focused on the nature of warranties, the kinds of protection they provide to consumers and how this protection has changed in recent years, the significance of the Magnum-Moss Act and its implementation by the Federal Trade Commission, and the cost of warranties to consumers. Finally, the legal aspects of service contracts are examined. The terms of 691 warranties for television sets, ranges, refrigerators, room air conditioners, and clothes washing machines were examined and the results presented for the period of 1965 through 1975. This is followed by a discussion of the legal framework of warranty protection. The warranties previously examined are then assessed against standards established by the Magnum-Moss Act and rules promulgated by the Federal Trade Commission. This is followed by an examination of the Magnum-Moss Act to uncover ambiguities, or inconsistencies in the statute's language which may be in need of revision and/or clarification and to consider evidence which sheds light on the extent to which the act is fulfilling its intended goals. In the next chapter hedonic price analysis is used to estimate mean implicity prices of individual warranty characteristics. In general warranty prices appear to be high when compared to the expected costs of repairing appliances. In the last chapter the legal aspects of service contracts are explored. In contrast to warranty law, where an identifiable body of legislation has developed, service contract law rests primarily on common-law doctrines.

M.I.T. Centre for Policy Alternatives
1978 — Consumer Durables: Warranties, Service Contracts and Alternatives. Volume III: Appliance Warranties and Service Contracts: Consumer Experience.

Objectives/scope: See Volume 1.

Abstract: This volume presents two empirical studies of consumer experience with appliance warranties and service contracts. The first study relates to all five of the major consumer appliances included in the project, colour television sets, refrigerators, room air conditioners, clothes washers and cooking ranges. The data was gathered from a national consumer telephone survey conducted in the spring of 1975 of 1317 demographically representative households. The survey was designed to (a) elicit new information regarding consumer expectations of appliance reliability and repair cost, actual consumer repair experience, and the tendency of consumers to purchase service contracts, and (b) relate this information to household characteristics. The second study was conducted in the spring of 1976 on 483 Syracuse, New York families who had recently purchased a television set. Shortly after the major provisions of their warranties expired, consumers were asked about their use of the sets, repairs, satisfaction with service, and their complaint behaviour during their warranty period. They were also asked about the extent to which warranty provisions affected their purchase decisions. The results of these studies are presented and analyzed in only a preliminary descriptive way in this volume as multivariate analysis had not been completed at the time of publication.

M.I.T. Centre for Policy Alternatives

1978 — Consumer Durables: Warranties, Service Contracts and Alternatives. Volume IV: Analyses of Consumer Product and Warranty Relationships.

<u>Objectives/scope:</u> See Volume 1.

<u>Abstract:</u> This volume presents two quite dissimilar modeling efforts. The first is an application of the life-cycle cost concept to the five major appliances in the study. A computer model is developed which provides flexibility in testing life-cycle costs in a variety of cost, usage and product performance situations. A key finding is that the values of the components of life-cycle cost vary widely among consumers, among types of appliances and among regions of the country. The authors conclude that life cycle cost information should be individualized by using a computer based model as national averages could be very misleading. The second model developed mathematically derives the conditions for joint optimization of appliance price, appliance reliability, and warranty scope, when consumers lack full information regarding product reliability. The results of the analysis depend critically on whether consumer misperceptions of reliability are pessimistic (Type I solution) or optimistic (Type II solution). A Type I solution yields full warranty scope offered by producers and an optimal tradeoff between the cost of increased reliability and the benefits consumers gain from fewer product failures. A Type II solution, however, yields only partial warranty scope offered by producers and a non optimal level of reliability; either too much or too little reliability could result. If a Type II solution is produced, the authors argue that the simplest and most effective policy action is to mandate full warranty scope. There is a problem in applying this as retail appliance prices include a series of markups of warranty costs that make the cost of full warranty coverage to consumers greater than its benefit. The final chapter includes an analysis of product failure data. The results indicate that there is a large amount of variability in failure experience among different owners of the same appliance type, but that much of this variability disappears when usage, misuse, and brand are held constant.

M.I.T. Centre for Policy Alternatives

Consumer Appliances: The Real Cost.
Prepared for the National Science Foundation.

Objectives/scope: To examine and evaluate the consumer appliance industry, and to find alternatives for increasing the productivity of service in the context of what the consumer pays for a product during its useable life. While the scope of the study ranged widely from general household appliances to entertainment and communication products, it concentrated specifically on color televisions and refrigerators.

Abstract: While a number of problems were uncovered, notably the abuses in service billing practices and warranty claims, the consumer appliance industry has provided the buying public with increasingly reliable products that do a better job. Nevertheless, the consumer, who looks first to purchase cost, is not aware of the substantial magnitude of servicing and energy costs. As a result, manufacturers have not paid as much attention as they should to reducing these costs. A number of steps that consumers, manufacturers and government agencies could take to improve problem areas are suggested. One major suggestion is that manufacturers respond to the life-cycle concept by designing products that represent an optimal balance between acquisition, operation, and service costs during their lifetime. Manufacturers should also make life-cycle cost data available at the point of sale. It is suggested that government provide incentives that encourage reduced life-cycle costs and resource consumption.

M.I.T. Centre for Policy Alternatives
1977

Consumer Use of Life-Cycle Cost Information. Informal Draft Research Proposal to the National Science Foundation.

Objectives/scope: To outline a proposal for research into the consumer uses of life-cycle cost information, the purpose of which is to investigate and develop the most effective alternatives by which LCC information can be of use to the ordinary consumer.

Abstract: The specific objectives of the research are outlined. Proper use of LCC by consumers could result in: (1) direct savings from wiser long term purchase decisions; (2) better matching of consumer needs and product performance; (3) reduction of information search costs as well as improved information; (4) improving the way people use products. The concept of LCC has been used for purchasing decisions in industry and government, but it is relatively unfamiliar to the average consumer. What is necessary is an LCC information system which is individualized to the particular needs and circumstances of diverse consumers. A computer model could help overcome barriers to access to pertinent information beyond initial acquisition cost of a product and the complexities of the calculations involved in integrating such information. The current state of the art regarding consumer information processing is reviewed. LCC should simplify the information processing that consumers must cope with. The specific work plan for the research is outlined: (1) appraise LCC system capabilities; (2) assess the consumer environment for LCC; (3) characterize other potential LCC areas; (4) develop provisional interface scenarios; (5) improve the LCC computing model; (6) establish a data base management system; (7) collect product data; (8) further assess the consumer environment for LCC; (9) prepare a prototype of an operational LCC system; (10) test and evaluate the prototype; (11) investigate avenues for full scale implementation; (12) design a major field test of the prototype. The project will require a collaborative effort among several research institutions. The organization and division of the effort is outlined.

Mutch, J.J.
1974

Residential Water Heating: Fuel Conservation, Economics and Public Policy., Santa Monica, Ca.: The Rand Corporation.

Abstract:

Investigates the changes that can be made in water heating technology to reduce the energy required to heat a given amount of water to some acceptable temperature, i.e., to reduce heat losses from the system. Each measure is examined in an economic cost-benefit framework in which costs are the incremental dollars that must be invested by the consumer to institute the measure, and benefits are the dollars saved in operating (fuel) expenses over the lifetime of the water heater. Government policies are suggested which would encourage implementation of these measures. The study concludes that thicker tank insulation is perhaps the most effective means of reducing heat losses and overall energy consumption of conventional water heaters. Policies that encourage consumers to install economically optimum equipment may result in end use water heating energy reductions of 26 to 68 percent.

Naramore, Bain, Brady and Johanson.

1975 — Life Cycle Budgeting and Costing as an Aid in Decision Making: Processes and Concepts. Prepared for U.S. Department of Health, Education and Welfare.

<u>Objectives/scope:</u> This report is the second of the study of "Life Cycle Costing as an Aid in Decision Making," the purpose of which is to bring the concept of life cycle costing to bear on health facilities. This report has two specific objectives: (1) to refine the analytical process conceptual model described in the Outline (the first report); (2) to document minimal data needs required for decision making.

<u>Abstract:</u> The report summarizes the basic tradeoff concepts between operational effectiveness, energy consumption, and long term costs, and their interrelationships. The relevant features of each of the conceptual models are described. The operational effectiveness model analyzes resources in terms of their effective use in producing a desired output. The model is in two parts: the first is used to determine the aggregate use of the particular resource under consideration; the second enables determination of operational effectiveness by comparing the resultant aggregate utilization with the total output of the alternative. The long term (life cycle) cost model represents a financial tool through which the time planned costs and revenues identifiable to a project or program over a specific planning horizon can be comparatively evaluated on a consistent basis. The application of the model is described in terms of five systematic tasks. The application of sensitivity analysis to four elements of the model is discussed. The energy consumption model is required to evaluate energy consumption and the interrelationships involved in tradeoff evaluations of use of the resource, operating effectiveness and long term monetary cost. The ever increasing cost of energy has created a need for new procedures and techniques that are applicable from the initial determination of program requirements to final implementation and operation, in which innovation in design, use of new materials and construction and operating techniques will reduce energy consumption and related costs. Linkages between the three models are described. A handbook is being developed which will establish a rational methodology for bringing operational and total cost tradeoffs to bear on the design and choice of energy efficient systems and components for facilities. Data requirements for each of the three models are defined: the two components are facility related data and function related data. Potential sources for these data are provided.

O'Neal, Dennis L.
1978 — Energy and Cost Analysis of Residential Heating Systems.
Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Objectives/scope: The report provides estimates of potential savings in energy and cost that may be achieved through the implementation of several energy conserving options for residential gas, oil, and electric space heating systems. These options include not only changes in current technology, but also new technologies yet to be introduced in the market. The analysis of energy conservation potential is limited to design changes implemented by the manufacturer or installer of new equipment, and does not consider retrofit impacts.

Abstract: Several energy-saving design changes in residential space heating systems were examined to determine their energy conservation potential and cost effectiveness. Changes in conventional and advanced systems (such as the gas heat pump) were considered. The energy and cost estimates were developed from current literature, conversations with heating and equipment manufacturers and dealers, and discussions with individuals doing research and testing on residential space heating equipment. Energy savings as large as 26, 20, and 57% were estimated for design changes in conventional gas, oil, and electric space heating systems, respectively. For advanced gas and electric systems, energy savings up to 45 and 67%, respectively, were calculated. The design changes needed to produce these energy savings increased capital costs 80 and 35%. The ORNL energy use simulation model was used to evaluate the effects of space heating improvements on national energy use to the year 2000. Four cases were run with the model, and in one case it was assumed that consumers would minimize life cycle costs (beginning in 1980). This case provided the lowest estimated space heating energy growth rate (.9% vs. 2.1% for the highest of the four). It was recommended that future analysis include life cycle comparisons of all competing heat systems.

O'Neal, Dennis L., and Ken R. Corum

1980 — An Estimate of Consumer Discount Rate Implied in Purchasing Energy Conservation Measures in New Single-Family Residences.
Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Objectives/scope: To describe the analysis used to estimate implied consumer discount rate in purchasing energy conservation in new residences.

Abstract: An important aspect of consumer behavior with respect to energy use is the willingness of consumers to make investments which increase the efficiency of energy use in their residences. These investments may take a variety of forms: increased levels of insulation, storm windows, high efficency air conditioners, etc. In each case, the investment decision involves the evaluation of a first cost and a stream of expected future energy and monetary savings resulting from the investment. Essential to the comparison of the initial costs of the investment and expected future benefits is the concept of a discount rate. While individuals may not consciously employ this concept, their investment behavior can be characterized as though they did. This provides a means of analyzing some important influences on their behavior and prediction of chosen levels of efficiency in future years. While the discount rate used by consumers in investments in energy efficiency is related to the rate of interest (i) the pay for loans, and the rate of return (r) they could get from alternative investments, recent evidence indicates that the discount rate is considerably higher than i or r. While this difference can be attributed to such factors as a lack of knowledge about future performance of conservation investments and future energy prices, we are left without a simple analytical means of estimating the discount rate based on i or r. The results of the analysis described in the paper are based on single family residential construction practices in 1976, together with engineering evaluation of cost and energy use effects of available conservation construction practices. The discount rate is estimated for ten cities and three heating fuels (gas, oil, and electricity). Sensitivity of the results to assumptions regarding financing arrangements and expected energy arrangements is also analyzed. Results indicate that the implied discount rate for investment in improving the thermal integrity of single-family residences averaged 18%, with a range from 8% to 31%. Estimates of the discount rate by fuel type ranged from 14% for gas to 21% for electrically heated residences. All discount rates are given in real terms.

Otto, Thomas W. Jr.
1975

Life Cycle Cost Model.
Fort Monmouth, New Jersey: U.S. Army Electronics Command.

Objectives/scope: To present the details of a better defined and automated LCC model suitable for conceptual or real single channel tactical radio systems or equipment.

Abstract: Recent experience in performing Life Cycle Cost Analyses on single channel tactical radio equipment has shown the need for a complete and computerized LCC model. This report discusses such a model which has been developed by the author. The cost categories and each of their elements are presented initially in broad terms; then the mathematical equations which compute each element are presented. Additionally, a comprehensive discussion of the learning curve and the various methods of applying it are presented.

Pearson, George F.
1974 — Life-Cycle Costing in an Energy Crisis Era. Professional Engineer (July) 26-29.

Objectives/scope: To review life cycle costing, in response to recent interest stimulated by escalating energy costs.

Abstract: In comparing alternative solutions to accomplish a particular goal, the system showing the lowest life-cycle cost will usually be the first choice. Such things as delivery time, installation time, pollution effects, aesthetic considerations, maintainability, and owner preference will temper this hard and fast rule. To maintain a measure of control over the impact of estimating errors on the end result of a life-cycle cost study, the sensitivity of the end result should be tested by varying a questionable element upward and downward and redoing the calculation. When the end result shows significant sensitivity, the value of that element must be determined with as much precision as is practically possible. In general, a system with a high energy efficiency will likely have a higher first cost than a system which is less energy efficient. High interest rates are therefore unfavorable for energy conservation as they force acceptance of low first-cost systems at the expense of energy efficient systems. Formulas are provided for using an escalation factor in the energy cost position of a life-cycle cost analysis.

Implications: The use of an energy escalation factor will help promote the acceptance of more energy efficient systems and counteract the effect of high interest rates to some extent.

Petersen, Stephen R.
1974

Retrofitting Existing Housing for Energy Conservation: An Economic Analysis.
Washington, D.C.: National Bureau of Standards.

Objectives/scope: To examine the economic aspects of energy conservation techniques suitable for retrofitting into existing housing, including insulation, storm windows and doors and weather stripping.

Abstract: The combination of techniques which will maximize net dollar savings in life-cycle operating costs for heating and cooling operations in existing homes was determined, subject to specific climatic conditions, fuel costs, and retrofitting costs. Using micro-economic marginal analysis such a combination must be economically balanced and each technique should be utilized up to the point where the present value of the life-cycle savings generated by the last increment will just cover the costs of that last increment. Thermal engineering data is combined with the economic analysis in a computer-assisted model which estimates such optimal combinations for a wide range of climatic conditions and fuel costs. Results of this analysis show that optimal investment levels in the various techniques are quite sensitive both to climatic factors and to energy prices, and that in many cases these levels are considerably higher than those currently recommended by government and industry. This information must be placed in the hands of homeowners and homebuyers if it is to contribute toward any substantial measure of energy conservation. Even today, in a period of rapidly rising energy prices, most homeowners have little feeling for the potential economic return from the energy conservation techniques examined in this paper.

Petersen, Stephen R.
1978

The Role of Economic Analysis in the Development of Energy Standards for New Buildings.
Washington, D.C.: National Bureau of Standards.
Prepared for the Department of Energy and the Department of Housing and Urban Development.

Objectives/scope: To outline the potential role of economic analysis in the development of economically efficient energy conservation standards for buildings.

Abstract: The Federal Government and a number of States are currently developing energy conservation standards for new buildings. This report suggests that economic considerations be incorporated directly into this standards development process. A life-cycle benefit-cost approach to standards development can provide a systematic and objective framework for standards specification. Differences in climate, building type, energy cost, and operational requirements can be directly incorporated into the standards as they impact energy related benefits and costs. It is shown that the life-cycle costs associated with any given overall conservation goal can be reduced by developing an economically balanced standard. In addition, it suggests that a standard which has as its goal the minimization of life-cycle costs will likely lead to greater effective energy savings than alternative approaches. Specific suggestions for the incorporation of economic analysis into the standards development process are made.

Petersen, Stephen R.
1979

Economic Analysis of Insulation in Selected Masonry and Wood-Frame Walls.
Washington, D.C.: National Bureau of Standards.
Prepared for U.S. Department of Housing and Urban Development.

Objectives/scope: To provide a life-cycle cost-benefit analysis of several alternative methods for insulation 8" (200 mm) concrete masonry walls in new single-family residences. In addition, a cost-benefit analysis for insulation in wood-frame walls is provided, consistent with the assumptions used in the masonry.

Abstract: A dynamic load simulation model, NBSLD, was used to calculate the heating and cooling requirements for a 1176 square foot (110 m^2) house with different levels of thermal resistance for both wall types in eight geographic locations. These data are used to calculate the reduction in annual heating and coding requirements due to several different types of insulation of the masonry wall and the cavities of the wood-frame wall. Economic analysis is applied to determine estimates of life cycle savings from insulation for different locations and furnace types in order to determine the most cost-effective insulation level. In general it is found that the maximum economically justifiable level of insulation in the masonry wall is considerably lower than for the wood-frame wall because of the significantly higher cost of insulating masonry walls.

Reynolds, Smith & Hills
1977

Life Cycle Costing Emphasizing Energy Conservation: Guidelines for Investment Analysis.
Prepared for Energy Research & Development Administration.

Objectives/scope: To set forth a life-cycle costing method for dealing with energy conservation design alternatives aimed primarily at retrofitting existing facilities. The procedures are adaptable for use of a broad range of project types, such as experimental facilities, laboratories, production plants, office buildings, and service facilities.

Abstract: Applicable study parameters are provided for capital expenditures emphasizing energy conservation. These parameters quantify such features as discount rates, energy escalation rates, study period, salvage value, BTU measurement, and analysis techniques. By using these analysis concepts, budget requests for energy conservation programs will be standardized and result in a common measurement basis. The format and measurement statistics requested allow a comparable ranking of budget contenders, thus assuring maximum benefit for the funds expended. The guidebook also serves to allow the magnitude and complexity of each individual project to dictate the level of analysis required. Finally, the document is designed to serve as a working desk guide. The methodology is geared toward ease of calculation and the authors estimate that their techniques will be adequate to handle over 90 percent of the economic analysis situations confronting facility engineers. Life Cycle Costing is concluded to be a useful tool for synthesizing data and contributing to a logical decision, but it is only as good as the forecasts, assumptions, and estimates involved in the data inputs.

Ruegg, Rosalie T.
1975

Solar Heating and Cooling in Buildings: Methods of Economic Evaluation.
Washington, D.C.: National Bureau of Standards.

Objectives/scope: To evaluate economic issues important to the design, acquisition, and evaluation of solar heating and cooling systems.

Abstract: The paper explains and illustrates methods for evaluating and comparing the economic efficiency of solar and conventional heating and cooling systems for buidings. It identifies relevant costs, discusses data collection requirements, illustrates the discounting of costs, develops generalized life-cycle costs and benefit-cost models, sets forth techniques for developing models for unique problems, and discusses how the effective life-cycle costs to the owner of a solar equipped building would be altered by current tax laws, insurance, and governmental incentive programs. Assumptions regarding the discount rate, the period of analysis, and the rate of price escalation in nonrenewable energy sources are also discussed. The paper sets for the logic of and identifies an optimality rule for making cost-effective tradeoffs in the design of solar energy projects. For clarity and convenience, much of the discussion and illustration of optimality centers on the optimal tradeoffs between capacity of a heating, ventilating and air conditioning system and investment in energy conservation in the building envelope.

Ruegg, Rosalie T.
1976 — Life-Cycle Costs and Solar Energy. Ashrae Journal (November) 22-25.

<u>Objectives/scope:</u> To explain the use of life-cycle cost analysis to evaluate and compare the economic efficiency of solar and conventional energy systems.

<u>Abstract:</u>

Widespread use of solar heating and cooling systems in buildings depends on their economic performance relative to conventional systems. Economic evaluations and cmparisons of alternate solar and conventional energy systems are essential in determining the economic merits of solar systems. Reliable and consistent procedures are needed to collect and analyze costs and benefits associated with the various sytems. Life-cycle costing is concluded to be a useful evaluation method because investment in a solar energy system involves expenses and savings that spread out over the life of the system. A major consideration in assessing the life-cycle costs of a solar energy system is the impact of property taxes, income taxes, and any applicable state, local, or federally sponsored incentive programs. An abbreviated version of a life-cycle annual cost model for evaluating the profitability of a solar energy system is presented.

Ruegg, Rosalie T.
1976 — Evaluating Incentives for Solar Heating. Washington, D.C.: National Bureau of Standards.

Objectives/scope: To provide a life-cycle cost model and a computer program for measuring the dollar impacts of alternative incentives on the private costs of a solar heating system.

Abstract: A review of current legislative activity aimed at developing solar energy incentives showed interest centering primarily on property tax exemption, grants, income tax credits, income tax deductions, sales tax exemptoins, loan interest studies, and taxes on conventional energy sources. Because the impact of an incentive policy on the desire of people to own solar energy systems depends on the pre-incentive economic performance of the system, a life-cycle cost model was developed which allows an overall net measure of the cost effectiveness of a system before and after an incentive is provided. A computer program in BASIC language was written to exercise the model. Six case study evaluations were performed using the program, based on climates typical of Madison, Wisconsin and Albuquerque, New Mexico, and on representative solar equipment costs, fuel prices, and tax rates. The results indicate that the effectiveness of a given incentive program will differ by region, by type of building, and by fuel prices; that in some states the incentives programs now being enacted will not be worth their administrative costs; and that an indepth assessment of policy implications should be made of the differential impact of incentive programs on residential versus commercial use of solar energy.

Ruegg, Rosalie T.
1978

Life-Cycle Costing: A Guide for Selecting Energy Conservation Projects for Public Buildings. Washington, D.C.: National Bureau of Standards. Prepared for the Office of Conservation and Solar Applications.

Objectives/scope: To provide a step-by-step guide for conducting life-cycle cost evaluations of energy conservation projects for public buildings.

Abstract: The report explains the use of life-cycle costing analysis to evaluate and rank the cost effectiveness of alternative energy conservation retrofit projects to existing public buildings, and to select the most cost effective design for new buildings. Worksheets illustrated with a computer program are provided. Based on the view that it is desirable to have comparability of results, the report concludes by proposing a list of uniform LCC criteria that might be adopted by public agencies and organizations. Because it does not include tax effects, the report will be less useful to the owners, managers, and operators of privately-owned buildings.

Ruegg, Rosalie T., and Robert E. Chapman
1979 Economic Evaluation of Windows in Buildings: Methodology.
Washington, D.C.: National Bureau of Standards.

Objectives/scope: To improve the cost effectiveness of window selection and use in buildings.

Abstract: A life-cycle costing evaluation model and computer program is developed for assessing for alternative window systems the net dollar impact of acquisition, maintenance and repair, heating and cooling, energy gains and losses, and artificial lighting and daylighting tradeoffs. The method is applicable to the evaluation of many different window sizes, designs, accessories, and uses, both for new and existing residential and commercial buildings. Two step-by-step examples of evaluating selected window alternatives in a residence and in an office building in Washington, D.C. serve to illustrate the application of the method. The results indicate that window size, orientation, thermal resistance, accessories, and use, particularly the substituting of daylight for electric lighting, can affect significantly the energy consumption and life cycle costs of windows. Development of easy to use, reliable guides to energy efficient and cost-effective windows could result in better decisions by the building community and in energy and dollar savings to the nation.

Ruffin, Marilyn D., and Katherine S. Tippett

1975 — Service-Life Expectancy of Household Appliances: New Estimates From the USDA.
Home Economics Research Journal, 3, 3 (March). 159-170.

Objectives/scope: To develop current estimates of average service-life expectancy under one owner for widely owned household appliances by using the actuarial or current life table method.

Abstract: Information on year of acquisition of selected appliances in use and on those discarded within the previous year was collected from a national sample of about 12,000 households. Actuarial tables were constructed to develop service-life expectancies for ranges, refrigerators, freezers, dishwashers, clothes dryers, washers and televisions. When the estimates developed from this study were compared with estimates developed by the USDA in 1957 throughout 1961, service life for most acquired new remained about the same. The service-life expectancy of items acquired used was, in most cases, slightly less in 1972 than in 1957 through 1961.

Stern, Martin O.
1978

Life Cycle Costing, Government Policies and the Diffusion of Energy-Conserving Technology.
Energy, 3, 2 (February). 173-202.

Objectives/Scope: To explain and illustrate the usefulness to public policy makers of the techniques of life cycle costing and of market acceptance estimation.

Abstract: Energy conservation has become a major goal of State and Federal policy. Goverments are called on to play an actual role in identifying promising energy-conserving technologies, and in encouraging their timely and widespread adoption. For their role to be effective governments must have available and be willing to use some economic tools that permit estimation of the costs and benefits of their actions. Costs may consist of funds spent on research, development and public education, of tax revenues foregone, of administrative expenses, or of outright subsidies to producers or consumers. Benefits arise mainly through the earlier adoption of energy conserving technologies with their attendant economic savings. In evaluating these savings, governments may assign shadow prices different from observed market prices to certain energy forms, to reflect more correctly their perceived value to society. They may also want to use discount rates different from those of private businesses or individuals in their benefit-cost calculus, to better take into account the claims of future generations on earth's remaining resources. In order to highlight basic principles of life cycle costing and market acceptance estimation without getting embroiled in excessive algebraic details, certain simplifications are introduced in the course of the paper. Although the tools are general, the development is made concrete by focusing the discussion on consumer durables that use and/or deliver energy in the performance of their service, and that are ready for application without further research and development effort.

Stiefel, S. Wayne, Kim, S. Justin, and Howard Hung.
1976 Life Cycle Costing: An Assessment of Practicability for Consumer Products.
Washington, D.C.: National Bureau of Standards.

Objectives/Scope: To assess the practicability of applying the life cycle costing approach to consumer products.

Abstract: The report provides a basis for understanding: the potential for application, benefits and effects of LCC; the basic concept of LCC; its interaction with performance, and the state-of-the-art of "life" testing as it relates to developing extended performance test methods for consumer products. The report reviews information now obtainable and barriers to labeling consumer products with LCC information. Observation of the state-of-the-art leads to a conclusion that the application of LCC to consumer products is not immediately practicable. Although the elements of technical knowledge are available for such an application, the total body of knowledge is insufficient. This can be characterized by the availability of statistical techniques for testing but the availability of LCP (time trace of performance) test methods. The inability to gain access to company test methods and field experience for consumer products also hinders LCC development efforts. This data is needed to correlate laboratory test results to actual field experience and to establish the test conditions, based upon use and environmental conditions in the field. The basic areas requiring further investigation include: information on consumer products use, laboratory test development and validation, rules for test application and techniques for cost estimation.

Stiefel, S. Wayne, and Theodore Wancy
1977 Service Lives of Major Household Appliances. Proceedings of the 23rd Annual Conference of the American Council on consumer Interests.

Objectives/Scope: To discuss the service lives of major household appliances.

Abstract: Relative to the acquisition or disposal of major appliances the consumer makes substantive decisions on at least two occasions: 1) at the time of purchase, regarding which model to buy, and 2) on the occurrence of some critical event, regarding whether to retain an exsiting appliance or to replace it with another one. The rationale for disposal differs markedly for appliance owner-users and for appliance-owner-renters. In general, owner-renters prefer to hold appliances as long as possible considering the tradeoffs of operating costs, tax benefits, and competitive pressures. On the other hand, a significant fraction of owner-users appear to discard products for newer products with more pleasing aesthetics or with novel features, and they may be only secondarily concerned with service life.

LCC = initial purchase + maintenance + repair + energy ± disposal over an expected use period.

The overall average cost curve is the sum of these components and it has a minimum designated as the optimal economic life of the appliance. To hold it for a longer period or to dispose of it earlier would involve an average annual cost in excess of the minimum value. One problem in the acquisition of service life data for life cycle costing is the extended period of time required to obtain complete records on the performance of a particular appliance type. With suitable compensation for the observed differences it may be possible to develop adequate projections of appliance performance data from accelerated laboratory tests in coordination with short-duration, multiple-family studies.

Stiefel, S. Wayne, Goodman, P. Clare and William B. Beine
1978 Application of Life Cycle Costing to Hand-Held Hair Dryers: A Field Demonstration for Small Appliances. Washington, D.C.: National Bureau of Standards.

Objectives/Scope: To collect information on hair dryers, aid development of life cycle performance test methods and characterize costs as a function of time.

Method: In a pilot field experiment sixty specially instrumented hair dryers were distributed equally among normal users and local hair cutting salons. Usage and repair data were collected from these consumer participants. Repair incidence and repair cost data were also collected by two other methods. First, used hair dryers were collected from volunteers for failure mode analysis. Second, repair agencies were surveyed for repair and service costs data.

Findings: The lessons learned provide insights into the application of the life cycle costing technique to other small appliances. This study indicated that the recall of estimates of dryer use by individuals significantly exceed the metered values. It is important, therefore, that measurement instruments be used as much as possible to collect accurate usage data. Care in design of the measurement package is important to avoid changing usage patterns. The estimated annual power consumption for a 1000 watt blow hair dryer was 30 kwh in normal use. Average ownership costs are graphically presented for different discount rates, electricity costs and retention periods. The importance of developing test methods based upon controlled field use experience was in part substantiated by the inability to obtain failure use-data. Some of the individuals who contributed failed hair dryers still under warranty did not want to be troubled by the nuisance, delay and expense involved with obtaining a repair. If such an attitude is pervasive, feedback of failure rate data for inexpensive appliances will be incomplete even during warranty periods.

Stiefel, S. Wayne, and William B. Beine
1978 Application of Historical Repair Data in Life Cycle Costing Analysis.
Proceedings of Mechanical Failure Prevention Group Conference.

<u>Objectives/Scope</u>: To discuss a general model which integrates available data for electric clothes dryers to estimate repair costs.

<u>Abstract</u>: Historical repair data are useful for estimating life cycle costs as well as guiding development of life cycle performance laboratory tests. The repair cost model is applicable to major household appliances and permits not only computation of a distribution of expected annual repair costs, but also the flexibility to observe the effects of variations in the parameter values of repair rate, service fees and parts cost on expected repair costs. Since the repair data sources located for electric clothes dryers can provide information on other major household appliances, the techniques developed could be extended to those appliances. Historical repair data have application for guiding development of laboratory based testing. Estimates can be derived for expected failure rates by component and average time to first failure. Using usage pattern data together with failure rate estimates it is possible to translate from the field use time to laboratory time. Finally, the use of the LCC approach permits a comparison of the relative share of ownership costs attributable to purchase, repair and energy consumption. These relative costs have implications for addressing the required level of accuracy of test methods intended to generate repair or energy cost estimates.

Stiefel, S. Wayne, et al.

1979 Life Cycle Costing for Major Household Appliances: An Analysis of Ownership Cost Variations. Washington, D.C.: National Bureau of Standards. Prepared for the U.S. Department of Energy.

Objectives/Scope: To provide ownership cost information on major household appliances to support the establishment of minimum energy efficiency standards.

Abstract: The equations presented provide a means of determining the impact on life-cycle cost under a variety of conditions including energy consumption, energy efficiency, energy charge rate, product design, regional effects, and consumer usage. For each appliance type a sensitivity analysis was performed which included presentation in the report of (a) a listing of parameters with typical values, (b) a tabulation of life-cycle costs for specific cases with several discount rates, (c) cost figures over ranges of values of individual parameters, and (d) graphical presentations to display sensitivity effects of individual parameters. In addition, analyses of regional effects are presented for those appliances whose energy costs are appreciably influenced by climatic conditions.

U.S. Department of Commerce
1979 — Experience with the Department of Commerce Voluntary Consumer Product Information Labelling Program.

Objectives/Scope: To describe the origin of the Voluntary Consumer Product Information Labeling Program (CPILP), the problems it encountered, and the reasons why it was suspended before sufficient evidence had been gained so as to adequately evaluate the program on its merits.

Abstract: The Department of Commerce, and its National Bureau of Standards became involved in problems relating to product safety and energy usage. The proposed procedures for the CPILP were developed and published for public comment on May 25, 1976. The comments and hearings showed some concern about the need for the program so the Department initiated the program on an experimental pilot basis. Two products, thermal insulation and smoke detectors were chosen for further investigation. Because of a one year limitation on the pilot program, adequate test methods for rating the performance of these products could not be developed. The absence of productrs for which adequate test methods were available and a funding cutback led to the discontinuance of the program. The following recommendations are made for any future voluntary effort to label performance characteristics of consumer products: (1) A primary concern must be the locating or developing of test methods which are acceptable to both consumer and manufacturers; (2) Provision should be made at an early date to carry on a vigorous public education program; (3) A voluntary labelling program should be allowed five years with guaranteed funding before it is finally judged, because of the time required to develop and implement such a program; (4) Close contacts with manufacturers must be encouraged, particularly with regard to test methods, methods of rating and establishment of a schedule of fees; (5) Consumers and consumer advocate groups must be fully involved in all phases of the program, from product selection to program evaluation.

Weber, Stephen F.
1979 — Historic Preservation Incentives of the 1976 Tax Reform Act: An Economic Analysis. Washington, D.C.: National Bureau of Statistics.

Objectives/Scope: To help corporate investors make cost-effective decisions reagrding historic preservation of non-residential buildings and to provide policy makers with information on the effectiveness of tax incentives for historic preservation.

Abstract: The Tax Reform Act (TRA) of 1976 contains a number of provisions which affect the financial position of owners of income-producing historic buildings. Prior tax law tended to penalize historic preservation by allowing more rapid acceleration of depreciation schedules for new buildings and by permitting demolition costs to be deducted in the year in which they occur. The TRA has provided a more favourable tax environment for historic preservation by removing these tax penalties. This report analyzes the effect of the TRA on the after-tax cost of two basic alternatives facing the owner: (1) rehabilitate the structure; or (2) demolish it and redevelop the site. A life-cycle cost minimization model was developed, programmed in BASIC language, and applied in an after-tax comparison of six alternative situations representing rehabilitation and redevelopment both before and after the TRA. Under the assumptions of the model used in this analysis, the TRA has made the rehabilitation option significantly more attractive than previously. This new information on the economic effects of the TRA should be useful to corporate owners of historical nonresidential properties as well as to anyone interested in tax-incentive policies for the rehabilitation of all types of existing buildings.

Williams, John F.

1977 Data Requirements for Life Cycle Costing. AACE Bulletin, 19, 6 (November/December) 225-236.

Objectives/Scope: To review several of the basic principles and concepts related to the design, implementation, maintenance, and utilization of a large data base for facility life cycle costing.

Abstract: The proposed approach is hierarchical in nature, organized according to the facility decision requirements and specific analytical techniques to be applied. Both engineering theoretic and statistical methods of estimating total costs and quantities using a data base are presented at an elemental level. The paper concludes with an example using State of Alaska data to develop comparative life cycle cost estimates for two facility alternatives.