LIFE CYCLE COSTING: AN ANNOTATED BIBLIOGRAPHY AND EVALUATION OF ITS POTENTIAL AS A NEW FORM OF CONSUMER INFORMATION

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PREFACE

This work was carried out with the financial support of Consumer and Corporate Affairs (CCA) Canada. It represents a part of this department's continued efforts to monitor and analyze developments in the consumer energy policy field. The report focuses on life cycle cost, a useful tool in government and industry decision making for capital assets and a potential aid to consumer decision making for durables.

The authors would like to acknowledge the encouragement and guidance provided by Dr. Geoffrey Hiscaks, Mr. Lee McCabe and Mr. Carman Cullen of CCA's Consumer Research and Evaluation Branch.

Though the present report is written separately it does not represent the only work accomplished. A portion of the resources were devoted to assist in a broad review of behavioral energy research which will appear as a separate document (C. Dennis Anderson and Gordon H.G. McDougall, <u>Consumer Energy Research: An Annotated Bibliography</u>, forthcoming, 1980).

TABLE OF CONTENTS

1. INTRODUCTION

Energy conservation is a major challenge today. Reductions in the absolute amount of energy consumed or the rate of increase in energy consumption is viewed by many to be as vital a task as the pursuit of additional or new energy sources. Conservation appeals and programs have been implemented in consumer, industrial, commercial, transportation and public sectors of developed economies throughout the world.

This report provides a state of the art assessment of one tool in the battle to achieve energy conservation - life cycle cost.

1.1 The Concept of Life Cycle Cost (LCC)

LCC is a relatively new concept used to measure the major cost elements associated with the lifetime of a physical product.[1] The basic dimensions of LCC are product cost and product life. Various definitions of LCC have been offered depending on the nature of the product. In simple form LCC is the sum of all (discounted present value) dollars expended in the acquisition, operation, servicing and disposal of a product over its lifetime. The costs, therefore, are considered to go beyond simple initial acquisition; LCC is a multi-dimensional view of product costs.

[1] Product is used in the broad sense. It includes any capital investment or asset item, for example, buildings, equipment or systems, consumer durables, etc.

The potential of LCC as a conservation tool rests in its ability to facilitate trade-offs among product cost components, especially purchase price and energy costs of operation. Product purchases based on the unidimensional view of cost = purchase price (thus, based on the criterion of minimizing price) might not result in the lowest energy cost choice. In fact the lifetime energy cost of operation for a product chosen using this simple criterion might far exceed that of a higher priced unchosen alternative. Often it turns out that the lowest price option is not the most economical.

Thus, a purchase decision based on the LCC view of product costs might not only result in a reduction in units of energy consumption (and a saving of a nations energy resources), but might also result in a financial gain to the buyer. The LCC view of product costs also facilitates trade-offs between initial price and non-energy cost components. As with the price energy cost trade-off, the buyer is often rewarded for taking a multidimensional view of product cost.

1.2 Project Objectives and Overview

There are two major objectives for this study. The first is to summarize the pertinent evidence on LCC applications and research in both public and private sectors. This is accomplished via preparation of an annotated bibliography of LCC literature which is discussed in part 2 of the report. The annotations themselves appear in the Appendix.

The second major objective is to assess the potential of LCC as a form of consumer information for durable products. This is achieved in part 3 of the report where examples of LCC model specifications for durables (appliances) are presented. This presentation illustrates some of the complexities of developing a LCC information base. The potential for consumer reaction to LCC information provision and the policy relevance of an LCC information system for the consumer durables sector are also discussed.

It must be recognized that a relatively advanced state of LCC analysis exists in government and industrial settings. Unfortunately this situation does not apply to the consumer durables sector due to unpredictability of costs resulting from the general lack of control over data on the durables' use environment. However, the total body of technical knowledge for the applicability of LCC to consumer durables is growing. Further, there is evidence that consumers will use LCC information to achieve financial and energy savings. These factors encourage the pursuit of LCC as a new form of consumer information.

Part 4 of this report contains a summary of the state of the art on LCC and includes recommendations for future directions in the study of LCC for consumers.

2. AN ANNOTATED BIBLIOGRAPHY OF LCC LITERATURE

A major effort was made to survey existing applications and discussions of LCC. The search encompassed public, private and academic settings and included published and unpublished materials. A total of 89 documents were reviewed and annotated. The annotations themselves appear in the Appendix to this report. The remainder of this section will outline the annotation format and present a summary classification of the studies.

2.1 Annotation Format

The annotations in the Appendix are arranged alphabetically by author. Each study is identified by author, title, source and date, all of which are indicated at the top of the first page of a given annotation. Further, for ease of reference and to allow for possible updating of this annotated bibliography, each annotation is assigned a four digit study code number which appears in the top right hand corner opposite the authors name.

The study code numbers are prefaced by a letter corresponding to the beginning letter of the (first) authors surname. Each letter of the alphabet, with the exception of the last two, is assigned 400 numbers.

The body of the annotations contain two sections: objectives/ scope and abstract. The former typically includes a statement of study purpose and setting while the latter mentions details of methodology and content (findings/implications). Sufficient detail is given to enable the reader to select those documents of particular relevance to his/her work.

2.2 Classification of Studies

Table 1 presents a classification of LCC studies by the sector and asset type upon which they focus or to which they have relevance. The sectors are public (eg. military, general procurement offices), industrial/commerical and residential (individual consumers). Asset types include buildings/houses, equipment and systems, space heating, appliances and other durables. A particular study may be classified under more than one category.

Several noteworthy features appear in Table 1. First, LCC studies have been carried out in and or have relevance to all sectors: 60 studies relate, at least in part, to consumers (residential sector) and the corresponding figure is 34 and 33 for the public and industrial/commercial sectors, respectively. This is concrete evidence of the broad range of applicability of the LCC concept. The diverse settings covered makes the annotations valuable to practioners in many areas.

It must be cautioned that the relatively large number of consumer sector studies does not indicate a more advanced state of application of the LCC concept here than in public and industrial sectors. In fact the opposite is the case; there is considerable history and sophistication in the use of LCC in the latter sectors, particularly for military and other government procurements, while the state of LCC analysis/use in consumer settings is much less advanced. Many of the

Table 1

Classification of Life Cycle Cost Literature by Sector and Asset Focus[1]

Sector and Asset	Study Code Numbers
PUBLIC:	
Buildings	B0650, M4810, N5205, P6086, R7118, R7119, R7120, R7121, S7345, W8877
Equipment/Systems	B0643, D1287, D1288, D1289, D1437, F2145, G2487, G2488, M4810, N5205, 05895, 05912, R7118, R7119, R7120, S7345.
Appliances	B0675, G2485, G2486, L4631, M4949, S7505.
Other	L4630, S7505.
INDUSTRIAL/COMMERCIAL:	
Buildings	H3030, M4810, R6887, R7118, R7122, W8877.
Equipment/Systems	B0482, B0643, D1289, F2275, H3030, H3035, L4485, M4810, 05812, R7118.
Appliances	B0725, B0930, D1290, H3036, K4010, L4720, L4723, M4949.
Other	D1435, K4145, K4325, L4412, L4485, P6012, P6077, P6322, W8940.
RESIDENTIAL:	
Home - general	H2945, M4852, M4945, P6085, P6087, R7122.
Space Heating	G2490, H3120, H3121, 05812, 05813, R7118.
Appliances	A0215, B0725, B0930, D1290, G2410, H2812, H2880, H3035, H3036, H3123, H3124, H3125, K4010, L4720, L4721, L4723, L4724, M4852, M4945, M4946, M4947, M4948, M4949, M4950, M5147, P6089, R6800, R7124, S7505, S7507, S7508, S7509, S7510, S7511, Y9680.

(continued)

Other Durables
B0725, C1030, D1285, H21812, K4145, L4724, M4810, P6089, R6800, R6925, S7505, S7507.

Other
C0981.

<u>BIBLIOGRAPHY/REVIEW PAPERS</u>:

B0650, B0643, B0725, D1437, F2148.

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[1] Some studies are classified in more than one category.

materials addressing consumer sector applications of LCC are exploratory discussions or deal with a very limited concept of LCC.

A second important feature of Table 1 is the differences in asset focus of LCC studies for the different sectors. Public sector applications of LCC are dominated by building and equipment/system (usually military) capital investment decisions; only a small number of applications are for appliances. In contrast, studies referencing residential sector applications focus primarily on major appliances; occasionally other household durables, insulation and space heating systems are addressed. Industrial/commercial applications of LCC reference no one asset category in particular.

Table 2 contains further detail on the nature of the LCC related literature reviewed. It presents a breakdown of studies by LCC issue dealt with. The issues arise because LCC includes future costs over time. Particular issues and some of the topics of concern are:

- Product life/durability - How long will products (assets) last or be used? Can accelerated life tests be developed and implemented?
- Discount rate - What is the appropriate time value to place on money?
- Pay back period - How long will it take for operating energy savings to compensate for a higher initial price?
- Energy prices - What future price changes for energy should be incorporated into the LCC calculations? How can future energy prices be estimated?

Table 2

Classification of Life Cycle Cost Literature by Issues Addressed[1]

Issues	Study Code Numbers

<u>PRODUCT LIFE/DURABILITY</u>:

A0215, B0482, B0650, B0675, B0725, C1030, C1033, D1287, D1289, D1435, K4010, L4412, L4720, L4723, L4724, P6012, P6089, P6322, R6800, R6925, R7124, S7507, S7508, S7509, Y9680.

<u>DISCOUNT RATE</u>:

B0650, B0675, D1287, H2812, H3123, H3124, H3125, L4720, L4721, L4724, M4852, M4950, 05813, R6887, R7118, S7505, S7507, S7509.

<u>PAYBACK PERIOD</u>:

G2490, H2810, H3120, H3121, L4721, L4724, M4950.

<u>ENERGY PRICES</u>:

B0650, G2490, H3120, H3121, L4721, L4724, M4810, M4948, M4950, 05813, 05895, P6077, P6085, R6887, R7118, R7119, R7120, S7505, S7507, S7509.

<u>DATA REQUIREMENTS</u>:

B0650, D1285, D1287, D1288, F2148, F2275, L4630, L4631, L4721, L4724, M4810, M4948, M4950, N5205, 05895, R6887, R7118, R7119, R7120, S7345, S7505, S7507, S7508, S7509, S7510.

<u>ACCURACY/RELIABILITY OF LCC MODEL</u>:

B0650, D1287, D1288, F2145, L4724, M4852, M4948, M4950, R6887, R7119, S7507, S7509, S7510.

[1] Some studies are classified in more than one category.

- Data requirements - What data on product life, service (repair, maintenance) costs etc., exists? How can life and cost data be generated or collected?

- Accuracy and reliability of LCC figures - How variable are total LCC figures? To what factors are LCC estimates most sensitive? What situation specific factors must be accounted for in LCC analysis?

As indicated in Table 2, discount rates, product life and data requirements for product cost components are key issues in LCC analysis. It is not surprising that a number of studies deal specifically with the accuracy and reliability of LCC figures since each of the component elements of the LCC model is a variable. The reader is cautioned that the degree of treatment a particular study gives to the various issues is not reflected in Table 2, except in the case of most of the studies dealing with product life. Many of the documents reviewed are extensive treatments of LCC and cover the full range of issues in considerable depth. Other materials are more limited and may only mention an issue briefly (e.g. by way of assumption).

In summary, the classifications in Tables 1 and 2 provide a quick reference to major details covered in the LCC materials reviewed for the annotated bibliography. Readers, whether involved in technical, enonomic and policy aspects of LCC, can use these tabular summaries to identify annotations of relevance to their work. The annotations themselves are quite detailed and will enable the reader to choose those studies of major benefit to his or her continued efforts in the LCC area.

Readers are encouraged to forward copies of their LCC related reports to the authors so that the annotated bibliography might be improved in depth and scope.

3. LCC FOR CONSUMER DURABLES

The objective of this part of the report is to assess the potential of LCC as an information provision for consumer durables. This is accomplished by a review of suggested LCC models for consumer durables and recent studies on the applicability of LCC as a consumer information provision.

The presentation in this section will reveal that there are still technical data problems to be overcome in implementing LCC for consumer durables. However, promising attitudinal and behavioral responses of consumers to an LCC information environment strongly suggest that work in this area should continue.

For purposes of illustrating the application of the LCC concept to consumer durables, major appliances are chosen as the case. The rationale is threefold. First, most discussions of LCC analysis in the consumer sector deals with this product category. Second, major appliances are significant energy consuming devices and present an opportunity for trade-offs between energy costs of operation and initial purchase price. The third factor influencing the choice of major appliances is the fact that governments in the United States, Canada and several European countries have recently adopted, or are in the process of considering, energy labeling schemes for major appliances--labels are a viable vehicle for provisions of LCC information to consumers. Thus, major appliances are a logical setting for consideration of the potential of LCC as a consumer information provision.

3.1 Examples of LCC Model Specifications for Consumer Durables/Appliances

Two somewhat related specifications of LCC models for consumer products (appliances) are presented below in summary form. These are chosen to illustrate the range of issues involved in LCC model specification, to acquaint the reader with the more technical aspects of LCC formulations and to indicate the position reached by two major agencies involved in LCC for consumer durables.

The first LCC model specification to be highlighted is that of the U.S. National Bureau of Standards (N.B.S.). Several reports from this agency are included in the annoted bibliography in the Appendix. These are coded S-7507, S-7508, S-7509, S-7510 and S-7511. The report S-7507 entitled "Life Cycle Costing: An Assessment of Practicability for Consumer Products", is the most relevant to the present objecive of illustrating a LCC model for major appliances. A summary of section 3.2 of the N.B.S. report is presented below.

The basic LCC formula for a durable product is expressed as:

LCC = Fixed Costs + Variable Costs + Disposed Costs.

Fixed Costs (initial purchase price plus transportation and installation costs) and disposal costs (value of scrap/salvage or expenses in disposal) are one-time expenses. Variable costs (consisting of operating, maintenance and repair costs) on the other hand occur over time and are dependent on the outputs or use of the appliance.

The full expression of the LCC formula allows for discounting of costs incurred over time:

$$LCC = PLC + \sum_{t=1}^{N} \frac{1}{(1+r)^t}[(OC)_t + (MTC)_t + (RC)_t] + \frac{1}{(1+r)^N}(DC)$$

where,

LCC = present value of costs incurred during N periods,

PLC = consumer's initial price and logistics (i.e. transportaion and installation) cost,

r = discount rate (per period)

OC = operating (energy, water, etc.) cost for specified maintenance, repair, and use conditions,

MTC = maintenance cost,

RC = repair costs, and

DC = disposal cost (This item becomes negative if a consumer received money when disposing of an old product.)

Further, this general expression must be altered to accomodate specific forms of the variable cost components for different appliance products.

The variable cost component can be affected by the consumer and must be analyzed. For example, the extent and timing of use and servicing are largely determined by the consumer. To specify LCC, some minimum level of performance (via maintenance and repair) must be assumed to be maintained or exceeded throughout the life of the product. Complexity arises in that maintenance cost inversely affects both operating costs and repair cost. Trade-offs among variable cost LCC components, therefore, exists and it is possible for a consumer to arrange these costs in such a way as to reduce overall variable cost, hence overall LCC of a particular product.

There are issues surrounding product life such as how long the product lasts physically, how long it lastS at some minimum performance level and how long it is economical for the consumer to keep it. The latter depends on economic conditions associated with post-purchase product use. LCC does not permit a determination of a repairable products' life but it can be used to determine a product's useful (economic) life.

The study of LCC for consumer products must incorporate external factors, particularly the use environment and user characteristics, both of which can vary from beneficial to determental in terms of overall LCC. Data on these factors is severely lacking, hence there is a need to develop standardized laboratory testing methods to determine product performance on energy consumption and other variable cost components. Important features that must be met in testing are: specification of external condition; detailing of the method used to simulate use and environmental conditions; and, demonstrating the correlation of laboratary tests with actual use data. The most practical approach is to determine the "normal" use and environment for the product and to use manufacturer recommeneded maintenance prodecures.

The development of representative ownership costs requires a combination of data from lab tests and field analysis. The latter is particularly important in order to reflect variances due to geographic, climatic and other use environment and user characteristics. Thus there are very demanding tasks associated with the development of LCC for a durable product.

The position of the authors of the report after reveiwing the state of the art in LCC methodology is:

> ... 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 unavailability of standardized life cycle performance test methods. The inability to gain access to company test methods and field experience for consumer products also hinders LCC development efforts. These data are needed to correlate laboratory test results with actual field experience and to establish the test conditions based upon use and environment conditions in the field. Therefore, additional efforts are required to push the state-of-the-art in order to make LCC practicable for consumer products.

Specifically, in discussing the nature of the work to be done if LCC information is to be made available to consumers, the authors mention:

> At the present time, elements of LCC available for consumer products include initial purchase price and installation costs, a projection of maintenance costs (based upon manufacturers recommendations), and for certain appliances energy costs when units are new. Factors in the LCC formula which are ill-defined and for which information is lacking include: product life, operating cost, repair cost, discount rate and salvage value. Efforts intended to provide manufacturers with a basis for testing consumer products and estimating cost of ownership must address both the definitions for the above factors and provide techniques for assigning values. The basic areas requiring future investigation in order to develop the capability to generate LCP (life cycle performance) and LCC information include: information on consumer product use, laboratory test development and validation, rules for test application, and techniques for cost estimation.
>
> For the purpose of planning long-term research, both engineering and economic disciplines must be utilized. Engineering research should be oriented toward simulation of use and environmental factors, the automation of test prodecures and the development of a basis for accelerated testing. A successful program requires development of techniques for gathering operational information relative to a product's use, use environment, maintenance, repair and "life" for non-repairable products.
>
> Economic research essential to the translation of LCP information into LCC information is the valuation of the LCP input factors. Tasks must be directed toward the development of procedures to yield cost estimates for operating cost factors, repair requirements and consideration of the use of the discount rate for consumer product cost characterization. Another area for future research concerns the question of how "best" to provide consumers LCC information. This question relates to product selection,

information content, complexity, format and the vehicle for presentation of comparative LCC information, and impact assessment.

The last issue mentioned includes the likely attitudinal and behavioral responses of consumers to LCC, the new form of product information provision. This is dealt with in greater depth in sub-section 3.2 below. A second LCC model for consumer appliances will now be outlined.

The Center for Policy Alternatives at the Massachesetts Institute of Technology has produced a number of reports on conceptual and technical LCC issues. These are represented in the annotations of the Appendix and are coded M-4945,M-4996, M-4947, M-4948, M-4949, M-4950, L-4720, L-4721, L-4723, and L-4724. The document of particular relevance to LCC modeling for appliances is M-4948 entitled "Consumer Durables: Warrantees, Service Contracts and Alternatives - Volume IV, Anaylses of Consumer Product and Warrantee Relationships". Chapter 2 of this MIT document contains a discussion of LCC concepts and modelling. The essence of the LCC model developed by the authors for major appliances is presented below.

The LCC components examined are acquisition costs, use costs (primarily energy), service and maintenance costs, contractual costs and disposal costs. Considering these costs elements and appliance life span allows determination of LCC of an appliance to a consumer. Values can be adjusted to accomodate situation specific factors and thus guide consumer decisions in differing use and environment situations.

The MIT summary equation for total LCC is:

$$T = A + P + S + D + C$$

where for each product,

T = discounted total life-cycle cost

A = acquisition cost

P = discounted energy cost

S = discounted service cost

D = discounted disposal cost

C = discounted contractual cost

To bring all future cost components to the same reference point as acquisition costs they are discounted to present value at time of purchase. The suggested procedure when attempting to compare appliances of different model years is to adjust prices using the Consumer Price Index.

Each LCC cost element is defined in turn and complications involved in its measurement are discussed. Initial acquisition costs can vary as much as 20 to 30 percent depending on nature of retail pricing policies (e.g. discount, promotional item or full list), services included (e.g. delivery, installation), and credit and warranty terms offered. In the model presented warranty costs are separated from the initial acquisition cost (price) so warranty alternatives can be analyzed. Also, credit costs are not included in the model.

Estimating useful life of the appliance is difficult since it is dependent on the degree of use or abuse it receives and the consumers preferences for retention. The model incorporates national average appliance life but allows for adjustments to be made for retention spans preferred by different consumers.

The model specification also incorporates these features:

Discount Rates - The market rate of interest is used to discount future costs but provision exists for computation of LCC for user specified discount rates. The point is made that discounting tends to reduce the effects of uncertainities in estimating cost that occur near the end of the life of a long lived appliance.

Energy Costs - On average energy costs represent over 50% of the total LCC for appliances such as refrigerators, clothes washers and ranges, though regional price and energy from variations have a substantial impact on the energy cost component of LCC and these sensitivities are handled in the model. A further important consideration mentioned is that recent federal government programs encouraging reduction in energy consumption of appliances may not be optimal from the viewpoint of LCC. Minimizing operating energy consumption may lead to increases in purchase or service costs that more than compensate for the dollar value of energy saved. The final complication addressed is test methods for measuring appliance energy consumption. The model uses consumption as tested by appliance industry and government standardized test procedures but concerns are expressed for the generalizability of this data to actual use environments.

Service and maintenance cost - These costs have risen dramatically over the past decade (4.25%/yr in contrast to 3% per year for the overall U.S. Consumer Price Index). They form an important component of LCC but data in this area is difficult to obtain. The model employs the first year service incidence rate (defined as the average number of requests for service per 100 appliance units which occur during its first year of ownership) with a downward adjustment to reflect lower expected failure rates for second and subsequent years of appliance use.

Contractual costs - These refer to the possible service contract costs and possible appliance rental costs. The LCC model is adjusted in these situations. For example, in the case of rental, energy is the only cost of operation; the rentee typically is not responsible for appliance service and maintenance, initial price costs.

Disposal costs - This cost may be positive (having to pay to have the appliance discarded) or negative (obtaining dollars for sale as scrap or for remanufacturer). Typically, however, the impact of the disposal component or total LCC is small. Nevertheless, the model allows for calculation of disposal costs for alternative ways of disposing of the product: expense of hauling away; revenue from trade-in; salvage; or, sale as a used appliance.

Though the MIT model does not attempt to examine interdependencies among the five LCC cost components it is sophisticated in many respects. The above description indicates the concerns that were dealt with in specifying the model and should acquaint the reader with some of the technical and data requirement issues that need to be resolved in developing LCC information for major appliances. The authors of this M.I.T. document summarize the discussion of their LCC model as follows:

> The model has demonstrated the usefulness of LCC as a research tool. It forces discipline on the evaluation of consumption costs. Even if the data are frequently difficult to obtain, the requirement that each out-of-pocket cost be identified and quantified adds rigor to consumer policy research. It also provides motivation and/or reinforcement for consumer oriented policies.
>
> The energy component of home appliances is clearly a major aspect of life-cycle cost. Given the almost universal ownership of many of these appliances, Federal policies aimed at reducing the level of energy consumption by these appliances is appropriate. Policies requiring design and manufacture of energy efficient appliances, however, can only be regarded as having long-term benefits. It will take over 15 years to turn over the present stock of refrigerators in this country once all refrigerators offered for sale meet the energy efficiency goals. With additional lags between design and manufacture, and between market introduction and customer acceptance, it will take at least two decades for present energy reduction goals to be accomplished. This points to the need for economic policies, consumer education, and innovative approaches that will motivate the consumer now to use what he or she has more efficiently. Life-cycle costing may be one means of providing consumer education and motivation.

The authors also appeal for consumer specific LCC in information.

> The great variability of life-cycle costs among users, among regions, and among appliances is a most significant finding in terms of consumer product policy. Given the range of factors that may vary for any individual consumer, life-cycle costs are highly idiosyncratic for individual consumers. To minimize the life-cycle costs of owning and using a product, however, these factors must be considered. It is virtually impossible, however for the individual consumer to accumulate all the necessary data on such factors as energy price, service price, usuage rate, energy consumption, product reliability, product life, and service contract price so that these may be properly discounted and combined with acquisition costs to arrive at his or her own expected life-cycle cost. Yet, unless this is done, the variances in these cost factors are ilkely to be so great that national averages have little meaning and may actually misguide the consumer. This concern is particularly appropriate now when there is increasing emphasis on providing more information to the consumer (e.g. energy labeling) at the point of purchase.

In summary, the above review of LCC specifications for consumer durables illustrates that a LCC information system for appliances might be possible with sufficient effort to produce or collect the required input data. It is conceivable that a governmental agency or, indeed, the appliance industry could ensure that the required information is made available. A critical question remains, however. The question is: how will consumers respond to a LCC information environment? This question must be addressed before public policy or industry officials can be expected to support LCC as a system of information provision, specifically, benefits (i.e, shifts in consumer choice behavior) must be demonstrated for LCC before anyone can be expected to undertake the costs involved in producing the data for and implementing a LCC system for consumer durables.

The next section of this report reviews recent discussions on the potential of LCC as a consumer information policy tool and cites available evidence on consumer response to LCC and other product energy information disclosures. This treatment of the policy and behavioral response side of LCC will acquaint the reader with the forefront of knowledge in the area and will provide a basis for assessing future LCC research directions..

3.2 Consumer Response to LCC Information

The greatest portion of activity in the LCC area to date has been technical in nature. In both the public sector (i.e., military, government) and industry, the LCC concept has primarily been used as a way to make better capital investment decisions. Consequently most of the research has focused on modeling the components of LCC and determining feasible methods for their measurement. Very little concern has been given to the question of how consumers are likely to respond to the concept in terms of altering purchase decision processes and choice, if LCC were to become the method of disclosing energy information.

The lack of focus on consumer response is not too surprising given the technical and economic backgrounds of most of the interested parties. This is not to say that past and current research focuses are misplaced or wrong. Certainly, they are crucial, but there has been a considerable gap in the exploration of the usefulness of LCC in general. What is missing is an understanding of the consumers response to LCC, that is LCC can help the consumer make more informed and energy efficient purchase decisions. As discussed below, there is a promising fit between policy goals and objectives in the energy area and the LCC form of consumer information disclosure.

3.2.1 The Policy Setting for LCC Information

A number of programs in recent years have focused on one or more of the components of LCC. Unit pricing in the U.S. was an attempt by the government to provide the consumer with consistent and uniform price information across a variety of products. In the energy area, the most important programs have been the U.S. Voluntary Labeling

Program for Household Appliances and Equipment to Effect Energy Conservation, the U.S. Energy Policy and Conservation Act (EPCA) and Canada's ENERGUIDE program.

There appear to be at least five basic objectives underlying public policies involving energy information. LCC appears to have some potential for meeting each objective.

The first objective is to encourage consumers to utilize energy information by providing the data in a uniform and understandable manner. For example, EPCA is concerned with annual cost provision for most appliances and index numbers for those related to temperature modification, while ENERGUIDE presents energy costs in annual kilowatt hours. In all three cases, the consumer is faced with the task of comparing "total" price to energy costs presented in a non-comparable form. How does the consumer decide whether a higher price is justified by fewer kilowatt hours used or by a lower index number or by a fractional (annual) energy cost figure? The LCC concept may provide some relief for the potential consumer problem since the information is presented in a uniform manner (i.e., dollars) and on the same level of measurement (i.e., total price and total energy cost).

A second objective is to educate the consumer about the significance of operating costs. With LCC, since energy is presented as a total cost, the highest level of aggregation is used. This may increase the probability that the consumer will recognize the significance of energy in the decision process as differences between models will be magnified along the energy cost dimension (e.g., the difference between \$10/year and \$15/year is likely to be perceived as less than the difference between \$100 and \$150, the figures which result from aggregating energy cost over product life--say, 10 years).

A third objective is closely related to the second--to improve comparative shopping on the energy dimension. In order for the consumer to utilize energy in comparative shopping, he must recognize the importance of energy as an attribute. For the consumer, importance is usually a function of two factors: (1) the magnitude of the costs and (2) perception of significant differences between products/ brands on the attribute. Both dimensions are highlighted in an LCC framework.

A fourth objective is to encourage energy efficient product design and competition among producers by providing consumers with inforamtion concerning product energy use. There are several alternative strategies for accomplishing this objective. One is to mandate the labels (e.g., EPCA, ENERGUIDE). This, however, does not guarantee increased competition. A second option is to set minimum efficiency standards to which products must be manufactured. It is unlikely that either of the above options will produce maximum effects. What is needed to complement these strategies is the motivation at the consumer level. Standards represent an efficiency tactic aimed at the industry. If implemented, they may achieve a result that is inconsistent with other policy objectives. Manufacturers may move to the same minimum standard, thus producing no differences across models and minimizing the use of energy in the decision process. Consumer information presented in the right format can enhance competition by focusing on energy. Increased concern with energy by the consumer will act as a cue to retailers and manufacturers that energy has become a salient attribute. This process provides the manufacturer with a new competitive dimension, fosters a move toward more energy information, and may result in more efficient appliances being made. In fact, there is evidence that Canadian appliance manufacturers are taking steps to produce more energy efficient refrigerator-freezers, at least partially in response to Canada's new ENERGUIDE program (Anderson and Claxton, 1979).

While not mentioned specifically, it might be assumed that a fifth goal such as improving the consumer's perception of what constitutes product cost and encouraging favorable trade-offs between energy and price are also viable objectives. Product cost being equated with more than price is likely to be accomplished with the LCC framework. The dependence and interactions among the cost components are more clearly defined with an LCC framework thus theoretically making trade-offs between objective dimensions more likely.

For example, it is known that better insulation will result in reduced energy consumption for a refrigerator. The M.I.T. Report (1975) gives an example of how this trade-off may occur. If the value of energy is three cents per kilowatt hour, the cost of insulation is $7, and there is a 2 to 1 markup at the point of sale, the increased insulation will cause a $14 increase in price. However, the reduction in heat leakage will reduce kilowatt hours from 1840 to 1402. Savings in electricity will be $13.14 a year based on $0.03/kilowatt hour.[2] If the savings are discounted at 6% for 10 years, there will be a $99.10 energy savings. The net gain is $85.10; and therefore, the extra insulation material is economically

[2] Savings will vary by area and year depending on utility rate structures.

justified. These costs will already be provided to the consumer by the LCC construct, so that the trade-offs can easily be made. Of course, whatever decision is made will, in the final analysis, also depend on individual and situation specific factors.

One other policy issue should be mentioned. Before deciding which type of energy information to use, the policymaker should decide whether he is interested in promoting lowest LCC or lowest energy cost. Unfortunately, these are not always compatible. Consequently, he must know under which product classes differences are likely to occur and how large the differences will be. Then he will be able to determine the appropriate course of action for the program.

3.2.2 Initial Evidence on Consumer Use of LCC

Though only one consumer study has dealt specifically with the consumer's response to LCC in a durable goods purchase decision there are other studies relevant to the topic of consumer use of energy information. Several studies have been carried out on energy labeling, an area of interest since labels are a likely place for LCC information to be provided should it prove to be better than alternative information. Also several more general studies have investigated the importance consumers attach to energy in purchase decisions. In summary, it has been found that:

(a) energy is not a salient attribute in purchase decisions, at least for appliances (Anderson, 1977; Contemporary Research Centre, 1977; Denham et al., 1977);

(b) appliance consumers show an unwillingness to trade off convenience for energy efficiency, (Anderson, 1977);

(c) appliance consumers show a lack of knowledge regarding energy (Contemporary Research Centre, 1977);

(d) with regard to Canada's ENERGUIDE program, labels appear to impact only the small size-low price segment of the appliance market (Claxton and Anderson, 1980), and

(e) label information can have a positive impact on pre-behavioral consumer measures but are not likely to impact appliance choice after only brief exposure (McNeill and Wilkie, 1979),

(f) appliance consumers don't naturally use discounting (or payback) but they should if energy efficient choices are to be made. Consumers tend to trade down in purchase price when they know the yearly energy cost of appliance operation - this may be a poor trade-off from the point of view of total lifetime costs (Redinger and Staelin, 1980).

Clearly, therfore, consumer use of energy information will not be universal and the use of energy labels may not have the intended effects. The latter is hinted at in the Redinger and Staelin (1980) study where knowledge of energy costs (provided by energy labels) resulted in trade-offs to lower purchase prices. It appears as if consumers become scared on learning the magnitude of energy operating costs and resort to a lower initial price choice to compensate. Unfortunately, this trade-off may be an expensive one since, from a lifetime cost point of view, the lower priced alternative may be an uneconomical choice. The LCC format of providing product cost information may help consumers avoid uneconomical choices. With LCC, all cost components can be presented in dollar units in the same time frame.

The only reported test of the impact of objective LCC information on attitudinal and behavioral dimensions of consumer decision making is a study conducted by Hutton (1977). His results (reported in Hutton, 1977 and Hutton and Wilkie 1980) provide a preliminary assessment of the potential of LCC information. The study involved consumers in a simulated purchasing task for refrigerator-freezers.

Hutton's findings support those of McNeill and Wilkie in that the strongest results in the LCC study occurred in early levels of consumer response (e.g., attitudes, knowledge) as opposed to choice. In addition, it is apparent from Hutton's work that consumer knowledge of energy cost data is lacking. Consumers consistently underestimated energy costs related to price. This supports other studies showing that consumers, when discriminating between brands and when evaluating a single brand, do not consider energy an important dimension for choice.

Hutton found, however, that the presentation of LCC information did improve perceptions of the importance of energy cost. It appeared that consumers will use the LCC information with positive results when it is provided to them. But, while the information is perceived as being helpful, results indicated that LCC does produce some potential dysfunctional consequences in terms of price perceptions; faced with LCC information, consumers recorded a less accurate recall of price. There is also some indication that lower educated consumers have more trouble with the complex LCC format, although even these consumers perform better with the information than without.

Results were somewhat weaker in the areas of attitudes and behavior, although still positive. In the LCC condition, more positive attitudes were recorded in relation to energy saving features while attitudes toward energy using features were less favorable. In terms of behavior, consumers exposed to LCC information appeared more willing to purchase energy saving features, but were not willing to give up the energy consuming convenience features.

Finally, in a simulated purchase condition, consumers were exposed to LCC information purchased appliances that were significanly more energy efficient. This is a promising finding in light of the low impact other energy disclosure formats appear to have had on actual choice behavior.

The results from Hutton's simulated purchase study show some promise for LCC as an information provision at the consumer level. However, it represents only one attempt and was not carried out under actual market conditions.

In summary, there appears to be a number of complexities to operationalizing an LCC information system for consumer durables. However, it also appears that LCC has potential in this area. First, there is an appealing "fit" betweeen policy objectives and and LCC based consumer information system. Consumer response to existing energy labeling schemes appears to be low and at times contrary to policy objectives. Second, though only a small amount of research attention has been directed at consumer use of LCC, it appears that the LCC format of disclosure may be more effective than present energy label disclosures.

References used in Section 3.2

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4. SUMMARY AND RECOMMENDATIONS

4.1 Summary Discussion

It is evident from the materials referenced in this report that LCC is a topic of growing importance in today's energy sensitive environment. Almost 100 studies dealing exclusively or partially with LCC were reivewed annotated and summarized in tabular form. The accomplishment of these tasks enables researchers in the area to benefit from the work of others. Also, policy officials interested in energy information provision, in general, or LCC in particular, are provided a comprehensive perspective on LCC related research.

The mainstream of the LCC research thrust deals with the technical and economic issues of LCC. A relatively advanced state of LCC anlaysis exists in government and industrial settings. Unfortunately, this is not the case for the consumer durables sector.

Though over half of the studies reviewed touch upon the consumer (residential) sector, many of them are exploratory (descriptive) discussions or deal with a very limited concept of LCC (eg. energy cost). The sophistication of LCC application and analysis is much higher in government and industrial settings.

The more comprehensive attempts at consumer sector applications of LCC focus on major appliances. Two such studies, which were reviewed in detail, revealed a number of barriers to implementation of LCC for consumer durables. Many of the barriers relate to issues of data requirements. For example, there is a lack of:

- information on key variables in the LCC model (eg. product life, repair and maintenance costs, energy costs, disposal costs, discount rate)
- externally valid tests for determining product life and energy cost
- knowledge on consumer use environment characteristics

Though these technical and economic issues were cited, the major cost item, and, therefore, the major concern, would appear to be the service (repair/maintenance) dimension (disposal costs are a small percentage of total LCC and can be ignored). The energy data does not appear to be a problem, given the test procedures already in operation for major appliances in Canada and the United States. Certainly, some of the richness of the LCC concept would be lost if all components were not present, but from an energy policy decision standpoint this may be a reasonable alternative.

The use of LCC without the service component (and without disposal costs, a small cost contribution) would leave price and energy costs as the key items. These could be combined into an aggregate figure and presented as such or presented in the disaggregate form. For example:

Aggregate figure

The purchase price and lifetime energy costs for this model total to $1300.

Disaggregate figure

The purchase price of this model is	$600
The lifetime energy costs for this model are	$700
Total lifetime costs	$1300

This more limited concept of LCC, in most cases would still preserve the relative order (rank order) of appliance costs. It is likely that the relative cost among models in the important issue in choosing a model and not the exact (actual) cost. Given this, the finer issues of regional differences in appliance and energy prices, consumers use habits, discount rates and product life become less important. It is perhaps not worth the cost of including components other than price and energy in the LCC model specification. Certainly the MIT suggestion of providing individualized LCC information to consumers is unrealistic. The relative costs based on selling price and average energy rates are much easier and less expensive to generate and, perhaps, are the salient consideration to consumers.

In addition to the above points in favor of proceeding with a more limited LCC model specification there is the issue of price energy and trade-offs. It is not clear that the present mandated label disclosures are used by consumers to make accurate price-energy cost comparisons. Indeed, one study suggests the disclosure of energy costs alone leads to poor tradeoffs (ie. choice of lower price items) which are not necessarily of financial benefit to the consumer in the long run (Redinger and Staelin, 1980). Presenting price and energy costs in common dollar units and in the same time frame (product life) should encourage accurate tradoffs. This conceptual benefit should not be treated lightly for it is likely that as products become more energy efficient their initial purchase prices will rise. LCC presents a good opportunity to communicate the long term benefits of more energy efficient products.

Regardless of the manner in which LCC is specified there is uncertainty over the behavioral response it might produce. That is, it is not known how consumers might respond to a LCC information environment per se. Nor is it known how responses to LCC will differ from those reactions (or lack of same) produced by existing energy disclosure formats.

Despite the technical and behavioral barriers discussed above, the review of prospects for LCC in consumer sector settings suggests efforts should continue. It is conceivable that a governmental agency in co-operation with the appliance industry could generate the input data necessary for a LCC model specification. The motivation to do so, however, will likely be contingent on evidence of positive consumer response to the LCC form of information. Only if LCC is demonstrated to be a superior form of information provision is it conceivable that major effort will be devoted to overcoming the technical and data requirement barriers involved in its application to consumer durables.

The brief review of consumer response to energy information, presented in sub-section 3.2.2 above, illustrated that consumer use of energy in decision making is far from universal. The impact of energy information as presented in recent energy label requirements appears to be low, especially in terms of choice as opposed to more subjective aspects of decision processes.

The evidence on consumer use of information in the LCC format, though limited, points to a potential role for this new form of disclosure. LCC also appears promising in terms of its "fit" with consumer information policy objectives.

4.2 Recommendations

The state-of-the-art of LCC applications is still evolving. LCC is an important tool in the energy conservation battle, though it is more solidly entrenched in industry and government asset decision making than in decisions for consumer durables.

Based on the present investigation the following actions are recommended:

1. Because of LCC's relevance to government procurement and its fit with consumer conservation policy objectives, the Canadian government should continue to monitor LCC related literature. Periodic annotated reviews, similar to the one present in this report, should be carried out and disseminated to those active in LCC applications and research.
2. LCC has proven to be a sound tool for decision making in the public sector (eg. buildings, equipment systems, other government procurements of durables). The government or its departments (eg. Energy Mines and Resources, Canada) should

initiate a seminar on LCC applications and issues at which LCC users and researchers can present their works and exchange information and ideas on improving applications of LCC in particular asset decision contexts. In particular, it appears that the quite advanced LCC work of U.S. researchers and agencies (witness the dominance of U.S. materials in the LCC annotations) should form a part of the seminar.

3. Though LCC for consumers does not appear practical in the short term, the government should undertake a preliminary exploratory study of the availability of data required to operationalize the components of a LCC based information provision for consumer durables. In this regard, major appliances would be logical product class to investigate as the government is already committed to an improved consumer information environment for these durables and information already exists on the energy component for some appliances (witness ENERGUIDE). In particular, the study should work in co-operation with Canada's appliance industry who should be of major assistance in supplying infomration on repair and service costs, product life, and disposal costs for individual product categories if not model types. It must be emphasized that this recommendation is for an exploratory study only.

4. Since the conservation benefit of LCC for consumer durables depends on consumer use of the information when choosing

among competing models, and since initial evidence on Consumer reaction to LCC disclosures reveals some promising results, further studies of the behavioral response to LCC should be carried out. Specifically, it is imperative that the relative impact of LCC and existing (required) energy label disclosures be determined. There is strong conceptual support for disclosures in the LCC format rather than in the format of present mandated energy labels, such as ENERGUIDE but there is insufficient empirical evidence to state conclusively that LCC <u>is</u> a superior information form. The proposed study of Consumer response should incorporate:

- an experimental design using various LCC disclosures (eg. total LCC) and current mandated energy label disclosures as information treatment
- several product categories (eg. refrigerators, freezers, air conditioners)
- a field as opposed to laboratory research setting. This is particularly important as product (label) information disclosures impact the consumer at point of sale, a setting far removed from laboratory conditions.

This final recommendation is made on the assumption that the government wishes to improve its provision of information, particularly energy information, to consumers. The conceptual appeal of LCC and evidence that it might be a superior form of product information provision (including energy) strongly suggest it is too early to dismiss it entirely. Further behavioral impact research is the quickest way to determine whether there are sufficient benefits to LCC information provision to warrant the obvious cost of implementing such a system for consumer durables.

APPENDIX

AN ANNOTATED BILIOGRAPHY OF LIFE CYCLE COST LITERATURE

Andrews, Laurel, and Craig McDonald A-0215

1980 Information and Consumer Appliance Purchase Choice
Bellevue, M.A.: Mathematical Sciences Northwest

Paper proposal submitted to the International Conference on Consumer Behavior and Energy Use, Banff Canada (September 17-20).

Objectives/scope: It is often asserted that consumers do not make optimal choices when purchasing appliances because they do not pay sufficient attention to the cost of energy to operate the models they are choosing between. Thus the appliances purchased have higher operating costs and use more energy than the optimal mix of appliances. If this assertion is true, it could occur because operating cost information is not available to consumers or because they are not using the information available.

The objective of this research is to estimate the extent to which consumers consider energy efficiency of appliances in their purchase decisions when efficiency ratings are available and if they behave differently when ratings are not readily available.

Abstract: The test is being carried out by first estimating demand functions for central and room air conditioners whose labels have included EER ratings over the past few years. The tradeoff between capital and operating costs estimated will then be compared with the tradeoff for refrigerators, an appliance that has not generally been labelled for energy efficiency. The analysis is limited to these appliances because they are the only ones for whcih efficiency ratings by manufacturer and model are available. Both demand functions are estimated for appliances purchased between 1973 and 1976 using data from EPRI (collected by the Midwest Research Institute) and from appliance trade associations. The estimation technique used is the structured logit, which allows for the modeling of discrete consumer choices.

The criteria used to judge the optimality of consumer decisions is the minimization of the present value of appliance services. An optimal decision has been made if, at the going interest rate, the consumer chooses the appliance which minimizes the net present value for the level of appliance services desired. The demand functions estimated will yield an estimate of the interest rate implicitly used to make the purchase decisions. If the interest rate estimated for air conditioners is near the market rate, then we will conclude that the lack of

information has affected the choice of refrigerators.

This analysis is especially relevant in these times of concern about the level of energy consumption in this country. An understanding of how consumers make decisions can aid in policy formation which addresses national conckerns in an effective manner. If we find consumers ignore EER ratings, a case for appliance efficiency standards could be made as a way for achieving a more desirable appliance mix. If, on the other hand, EER information is used if available, then an effective appliance labeling program may be sufficient to achieve the goal of optimal new appliance mix.

Bensch, L.E. B-0482
1977

Hydraulic Pump Containment Life Evaluation, Stillwater, Oklahoma: Oklahoma State University, Fluid Power Research Centre.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To discuss accelerated test methods of the Fluid Power Research Centre.

Abstract: The hydraulic pump is one of the most critical components in any fluid power system. It is also generally thought to be one of the most sensitive to abrasive wear. The Fluid Power Research Centre has been investigating accelerated test methods for evaluating pump contaminant sensitivity for several years. An associated wear theory has also been developed for predicting long-range pump contaminant service life based upon these accelerated tests and field operating conditions. During the past two to three years, a number of tests have been performed to verify the contaminant life predictions by conducting extended life tests under controlled contaminant environments. Tests were conducted over a broad range of service lives, ranging from 22 to 1430 hours utilizing both gear and piston pumps.

This paper presents the results of an extensive research investigation of accelerated and extended life including details of the life evaluation methods. Also included are brief descriptions of the accelerated test methods and contaminant life prediction techniques. It discusses the expected accuracy of the life predictions revealed by the test results.

Boeing Company 1974

B-0643

Life Cycle Cost/System Effectiveness Evaluation and Criteria.

Alexandria, Va.: Defence Document Center. Doc. No. D180-17648-1

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.

Booz-Allen and Hamilton Inc. B-0650

1975 Life-Cycle Costing in the Public Buildings Service. Prepared for General Services Administration, Public Buildings Service, Washington, D.C.

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 Public Buildings Service 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; 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 General Services Administration (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. A bibliography of LCC literature and models is reviewed.

Briggs, Warren G., DeWolf, J. Barton, and Robert T. Lund B-0675
1975 Life-Cycle Costs: Concepts, Considerations, and Cases.
Cambridge, Massachusetts: MIT Centre for Policy Alternatives.

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

B-0725

The Economics of Product Life - A Critical Bibliography.
Manchester, England: University of Manchester.

Prepared for the OECD Environment Directorate.

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

<u>Abstract</u>: 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.

Chow, Wing S., and George C. Newton C-0930

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 electrical 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, McDougall, Gordon G.H., and Brent Ritchie C-8215

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.

Cohen, J.
1977

C-1030

Methodology of Product Testing
Washington D.C.: National Bureau of Standards, Centre for Consumer Product Technology.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To discuss a laboratory testing procedure for determining useful product life.

Abstract: This paper outlines a methodology formulated for estimating, through laboratory testing, useful life and associated performance of consumer products. Excerpts from two key parts -- concepts of reliability engineering and procedure to guide the formulation of tests -- are given. Criteria for assessing tests are presented.

Conn, W. David
1977

C-1033

Factors Affecting Product Lifetime
Los Angeles, Ca.: University of California, School of Architecture and Urban Planning.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To present preliminary results of information from a consumer survey, questioning manufacturers and second hand markets regarding life of consumer products.

Abstract: A possible method of reducing solid waste (to alleviate problems of solid waste management, resource depletion, and environmental degradation) is to increase the lifetimes of durable products. Recognizing that in practice these lifetimes are determined not only by a variety of other factors, an NSF-sponsored research project at UCLA is currently seeking information to assist government decision-makers in developing cost-effective policies. Consumers have been surveyed to obtain data about their acquisition and disposal of small household appliances (such as irons, toasters, etc.); manufacturers have been asked about their actions affecting product lifetimes; and the nature and extent of second-hand markets have been examined. Preliminary results are presented.

Department of Commerce 1979

D-1285

Experience with the Department of Commerce Voluntary Consumer Product Information Labelling Program. Washington, D.C.: U.S. Department of Commerce.

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.

Department of Defense, U.S. D-1287
1970 Life Cycle Costing Procurement Guide (Interim)

Objectives/scope: This is the first attempt by the Dept. of Defense (DOD) 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.

Abstract:

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 training 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 numerical 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 against 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, U.S. 1973

D-1248

Life Cycle Costing Guide for Systems Acquisitions.

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

Chapter 1: Introduction

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

Chapter 2: 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 preference for a different alternative than if only initial costs were considered in decision making.

Chapter 3: 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.

Chapter 4: 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) as in 7, 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.

Department of Industry, U.K. D-1289
1975

Management Aspects of Terotechnology: Life Cycle Costing.

London, U.K.: Committee for Terotechnology, U.K. Department of Industry.

Objectives/scope: One of a series of booklets to help explain "Terotechnology" - a combination of management, financial engineering and other practices applied to physical assets in pursuit of economic life cycle costs.

Abstract: The booklet outlines the sequential stages of decision making involved in asset (building, piece of equipment, etc.) planning: specification, design, manufacture, installation, startup, operation, maintenance and disposal. The objective is to minimize total life cycle costs. The concept of terotechnology accepts that costs start from the inception of specification and design. It is for management to consider the economics and accordingly relate the life cycle costs to decisions. Details are given on costs and tradeoffs at each stage in the asset planning process.

Dewees, D.N. D-1290
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.

Abstract: 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.

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.

Dorney, Andrew W. D-1435
1977

Control of Design Quality
New Brunswick, N.J.: American Standard Inc.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To emphasize the function of quality control (product reliability section) in the manufacture of consumer goods.

Abstract: Manufacturers often find that even though their products have been processed utilizing stringent manufacturing controls, their customers are still receiving and reporting poor quality. The function of an independent reliability section is discussed covering its relationship with design, manufacturing and quality control. This section does not fully utilize the statistical aspects of reliability, but controls the quality of the design as required, by determining the end use of the product and testing accordingly. Responsibility for the design and manufacturing in the various stages is discussed as is the testing and decision making associated with it. Typical consumer products are followed from marketing concept through acceptance for shipment to the customer.

Dover, Lawrence E., and Billie E. Oswald D-1437

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. F-2145
1975

Getting 'Real' Data for Life-Cycle Costing.
Santa Monica, California: The 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, anticipating 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. F-2148
1974

The State-of-the-Art: Life Cycle Costing. Washington, D.C.: 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

F-2275

Terotechnology and Life-Cycle Costing: An Introduction.
National Terotechnology Centre.
London, U.K.: Committee for Terotechnology
U.K. Department of Industry.

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. G-2410
1979

Energy and Economic Cost of a Washing Machine: Statistical Life Cycle Analysis for Energy Savings. In Smith, Craig B. and Rocco A. Fazzolare, Changing Energy Use Futures, Proceedings of the International Conference on Energy Use Management, Los Angeles, Ca. (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 economics 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. Since uncertainties come from scattered data and variability in the conditions of operation of the machine, 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, U.S. G-2485

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.

Abstract: 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.

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, U.S. G-2486

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.

Abstract: 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.

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, U.S. G-2487

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.

Abstract: 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.

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 was reexamined in the next procurement, to avoid, if possible, rejecting clearly superior products.

General Services Administration G-2488

1977 Life Cycle Costing Workbook.
Washington, D.C.: Federal Supply Service.

Objectives/scope: Review of the highlights of the Federal Supply Service workshop on LCC, as well as cases and examples of contract clauses successfully used in the past.

Abstract:

Topic I: Concept and Theory of Life Cycle Costing.

The screening procedure for determining if a competitive procurement should be based on price or LCC is discussed.

Topic II: Legal Foundations and General Accounting Office Decisions on Life Cycle Costing.

If a contracting officer can show a reasonable basis for his actions in the conduct of an LCC procurement, the General Acccounting Office will not upset the award. LCC is a legally acceptable procurement technique provided bidders are advised of the basis on which the bids will be evaluated.

Topic III: Life Cycle Costing in Industry.

The widespread use of LCC in industry is discussed.

Topic IV: Life Cycle Costing in the Federal Supply Service.

The administrative and research aspects of developing an LCC contract in the Federal Supply Service are discussed.

Topic V: Answers to Frequent Questions on Life Cycle Costing.

Topic VI: Life Cycle Costing for Equipment Procurements.

This section presents guidelines for applying the LCC concept in the procurement of material and hardware other than complete systems.

Topic VII: Use of Warranties in Life Cycle Costing.

The use of warranties presents an opportunity to transfer some elements of LCC and the attendant risks to a manufacturer or supplier and to reduce the amount of in-house maintenance effort. However, warranties are not free and they should be carefully examined.

Topic VIII: Cost Modeling for Life Cycle Costing.

Equations for LCC and its various cost elements are presented.

Topic IX: Structuring Procurements.

There is no universal contract for use in all LCC procurements. The factors which can impact on the structure of an individual LCC procurement are discussed.

Topic X: Life Cycle Costing in Systems Acquisition.

The LCC of a system consists of the iterative summation of the LCC of the components of that system. Applying LCC to systems is complex only in that a number of LCC calculations must be performed and any synergistic effects of equipment working together must be examined.

Topic XI: Appendix Section.

Appendix 1 - Selected Case Studies in Equipment Procurement.

Appendix 2 - Examples of Appropriate Contract Clauses.

Appendix 3 - Item Criteria Screen and Procurement Plan.

Gery, Frank W. G-2490
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 Solar Assisted Heating Systems (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 SAHS (including domestic hot water) 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.

Hanna, Sherman H-2810
1978

Evaluation of Energy Saving Investments.
Journal of Consumer Affairs, 12, 1 (Summer), 63-75.

Objectives/scope: To discuss the need for a uniform disclosure method so consumers can more easily evaluate energy saving instruments.

Abstract: Disclosure for energy conservation is related to the use of disclosure policies in Truth-in-Lending and other areas. Five methods of evaluating energy saving investments are analyzed: apparent payback method, present value method, actual payback method, loan payment method, and rate of return method. in terms of simplicity and understanding, the apparent payback method may be the best, but since any method should be related to a rate of return or present value method to be used validly, the rate of return method is probably the best choice for a uniform disclosure method. An alternative to a disclosure requirement is a product standard. The best policy for reaching energy conservation goals might be a combination of energy efficiency standards, special assistance for low income households, uniform disclosure requirements using rates of return, and a massive educational and advertising campaign to increase consumer awareness and understanding of energy alternatives.

Hausman, Jerry
1979

H-2812

Individual Discount Rates and the Purchase and Utilization of Energy using Durables.

Bell Journal of Economics, Vol. 10, 33-54.

Objectives/scope: To study individual behavior in the purchase and utilization of energy use durables, and to determine the effects of tradeoffs between capital costs for more energy efficient appliances and operating costs.

Abstract: The methods used include:
(1) An econometric estimate of the home market for air conditioners based on a survey of 409 models of 1979 air conditioners to determine the degree of purchase price per operating cost substitution available for air conditioners and, (2) a survey of 1985 households from cities across the United States in 1976 with a sub-sample of 46 homes with individual appliances metered separately. Variables include:

Dependent: consumer demand.

Independent: price/operating cost; durability; fuel prices; income.

Tradeoffs between initial purchase price and operating costs were substantial. It was found that on a general energy efficiency ratio of 7.5% or 8.0%, the reductions in operating costs would be 6.4% with only a 3.8% increase in the initial price. As one moves from a less efficient unit to a more efficient unit, the percentage increase of the initial price decreases while operating costs are reduced. It was estimated that there would have to be significant reduction in operating costs in order to have people purchase a more efficient air conditioner. Furthermore, if the savings are small and the interest payments are high, the net result would be increased costs. Some of the main implications of the study concern educating the public about price/cost relationships, the need for setting standards of efficiency, and the possibility of having utility companies lease air conditioning units which are energy efficient.

Herendeen, Robert A. H-2880
1975

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

<u>Objectives/scope:</u> 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.

<u>Abstract:</u> 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 durability. 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. H-2945
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.

Hollander, Gerald M. H-3030
1979

Cost Studies and Engineering Economy: A Review of Terms.
Specifying Engineer 38, 79-81.

Objectives/scope: (1) To define the term, life cycle costing, (2) to relate it to the practice of engineering economy or engineering economic analysis and (3) to discuss the origins/objectives and methodologies of the activities they describe.

Abstract: The term life cycle cost was coined by systems analysts in operation research sessions and popularized in the mid-1960's. Its objectives are the same as those of an engineering economy study. The econcepts of rate of return, cost/benefit analysis, cost effectiveness and value analysis are differentiated and discussed with examples. In any of these procedures there is a need to depend on historical cost data, statistical methods and forecasting of future events. Sensitivity analysis (i.e., asking: "What will happen IF") should be used to increase the degree of confidence in the raw numerical results of life cycle cost and other analyses.

Hoskins, Robert A., Hirst, Eric, and W.S. Johnson H-3035

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.

Abstract: 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.

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%.

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 — H-3036

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 H-3120
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 H-3121
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 H-3123
1977

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

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 C. Dennis Anderson H-3124
1980 Energy Information for Consumer Decisions: Public Policy and Life Cycle Costing.
Journal of Consumer Policy 1 (Winter) 17-29.

Objectives/scope: To introduce the concept of life cycle costing as a potential basis for consumer information provision.

Abstract: This paper advocates that life cycle cost (defined as "the total dollars that will be expended over the product's useful life") is very applicable as a means of achieving the objectives of recent energy information policies in the U.S. and Canada. LCC's strength is that it presents a multidimensional view of product cost in contrast to the unidimensional perception of cost being equated to price. The critical dimensions of LCC are product life and product cost, the latter being composed of three major components; purchase price, energy costs in operation and service costs. A fourth component, disposal costs, typically account for a small percent of appliance LCC and are not included. In fact the article focuses on the energy component of LCC with only brief treatment of the price component. The paper is divided into major sections:

Consumer Information and Public Policy Objectives

- This section includes a description of recent energy labeling programs in the U.S. and Canada;

Applicability of LCC in Meeting Public Policy Objectives

- Here the underlying objectives of energy information policies are summarized and the extent to which an LCC based information format fits these objectives is discussed;

LCC in the Public and Private Sectors

- A review is given to illustrate the frequent use of the LCC methodology in government and private industry procurement and design/build decisions; a situation which should enhance the utilization of LCC in the consumer sector;

Consumers Use of Energy in Decision Making

- This section contains a review of a number of studies investigating consumer response to or utilization of energy consumption information (which overall has been quite low) and one study investigating the impact of LCC formatted information on consumer decision making (which indicated positive impact at least in terms of cognitive as opposed to behavioral responses);

Potential Energy Savings Resulting from Use of LCC as a Pruchase Criterion

- Data presented here indicates that while LCC information may encourage consumers to make trade-offs between initial price and costs of operation, the total energy consumed by products (at least refrigerators) purchased using a "lowest energy consumption" criterion is less than that obtained using a "lowest LCC" criterion.

The paper concludes with (1) a brief discussion of some of the complexities that would be involved in operationalizing a LCC based consumer information system for durable products and (2) an appeal for more behavioral research into consumer response to LCC information.

Hutton, R. Bruce, and William L. Wilkie H-3125
1980 "Life Cycle Cost": A New Form of Consumer Information.
Journal of Consumer Research, 6, 4, 349-60.

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 of 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.

Kaliwoda, Frank E. K-4010

1977

Accelerated Testing of Compressors
Sidney, Ohio: Copeland Corporation
Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To discuss procedures for testing compressors used in refrigerators and freezers.

Abstract: It is imperative that a high volume producer of components such as compressors have the capability of identifying expected field failure rates rapidly in order to minimize exposure. This paper describes a program designed to provide the necessary reliability information in a timely manner by means of laboratory testing of significant numbers of these compressors.

There are a number of factors which complicate accelerated tests of compressors used in refrigeration and air conditioning systems. One of these is the long expected life of these compressors and the large number of operating hours expected during that life. This is at least an order of magnitude greater than can be expected in automotive useages. Another is the difficulty in accelerating the test conditions through high temperatures and pressures without the introduction of new failure modes which would invalidate the test results. And this must be done in a competitive climate which requires fast reactions and short development cycles.

To accomplish these tests, special test stands have been designed to permit the operation of significant numbers of compressors under closely controlled conditions. An analysis of the compressor operating conditions has resulted in a test design for the simulation of field conditions under accelerated conditions. These tests have been validated by comparison with field data and reproduction of field failure modes.

This program has permitted the release of new or significantly changed models with a high degree of confidence.

Kirkwood, T.F., and A.D. Lee K-4145

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 | K-4325
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.

Abstract: 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.

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 cores 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.

Larsen, Hugh W., and C.J. Brady L-4412
1977 Automobile Durability
Milford, Michigan: General Motors Corporation

Paper presented at 27th Meeting of Mechcanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To describe GM's process for estimating service life of autos.

Abstract: The automobile industry is designing and testing vehicles to meet increasing requirements for durability, safety, emission control, and fuel efficiency. Recent technical developments at General Motors have provided previously unavailable quantitative information on usage of vehiclies by customers.

This presentation discusses an electronic field data collection program and the way GM is combining the resulting information with modern design analysis and test methods to estimate the service life of vehicles.

Lerman, Paul
1977

Economic Considerations and Product Life
Rutherford, New Jersey: University of Rutherford.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: This paper discusses the economic and financial considerations that must be recognized in determining the viability of an improvement in product durability. Included in this discussion are current accounting and tax policies that affect the decision.

Abstract: The economic and financial considerations associated with all product decisions has become increasingly important in recent years due, in large part, to relatively high cpaital costs and the resulting desire on the part of corporate decision makers to invest their capital funds in those projects yielding acceptable returns.

Most cases involving an imporovement in product durability will require a commitment of managerial, engineering, and production resources, all of which will ultimately be measured in financial terms. Thus, the final decision regarding product durability would seem to be based on economic and financial considerations, assuming technological feasibility.

Logistics Management Institute L-4630

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 L-4631

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.

Abstract: 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.

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 | L-4720

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. L-4721
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.

Lund, Robert T., and W. Michael Denney L-4723

1977 Opportunities and Implications of Extending Product Life.
Cambridge, Massachusetts: M.I.T. Centre for Policy Alternatives.

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 L-4724
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.

Manzo, Joseph P. M-4810
1976

Life Cycle Costing...What is It? How Does it Affect the Engineer?
Specifying Engineer 36, 3 71-81.

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.

McMahon, James E. M-4852

1980

Consumer Behavior In Energy Simulations for Policy Analysis

Berkley, California: Lawrence Berkley Labs

Paper proposal submitted to the International Conference on Consumer Behavior and Energy Use, Banff, Canada (September 17-20).

Objectives/scope: To describe modifications to the Hirst Residential Energy Use Simulation Model.

Abstract: Proposed government policies designed to affect energy demand are often analyzed with the help of energy use simulation models. One of the crucial variables in any such exercise is the assumed behavior of consumers, both in decisions about which equipment or conservation option to purchae and in decisions about subsequent usage of a purchased product.

An ongoing effort at Lawrence Berkeley Laboratory is to provide analysis of the major Department of Energy programs affecting residential energy use, specifically the Building Energy Performance Standards and Consumer Products Energy Efficiency Standards. One of the principal tools utilized is the Hirst Residential Energy Use Simulation Model (originally developed at Oak Ridge National Laboratory). This paper will describe 1) the methodology programmed into the Hirst model to simulate consumer decision making; 2) the implicit discount rates implied by typical usage of the Hirst model with national (USA) data, specific to several end uses and fuel types; 3) sensitivity of this methodology to various important inputs (technological characteristics, fuel prices); and 4) the effects of an alternate methodology for simulating consumer decision making.

The Hirst model was designed with a life cycle costing algorithm. Using assumed discount rates, the minimum life cycle cost is calculated (in a given year for a particular end use and fuel type). Then, the actual purchase choice is moved away from the minimum to a lower capital cost option. The distance from the minimum is assumed to vary in inverse proportion to the fuel price (calibrated to some initial year). So, as fuel prices increase, consumers choose options with efficiencies and equipment costs closer to the life cycle cost minimum.

The implicit discount rate that actually describes

the consumer purchase decision is implied in this formulation, but masked by the separation of the two calculations (minimum life cycle cost and distance from the minimum). The discount rate used in Hirst's life cycle cost calculation determines a curve on which the consumers' choice does not coincide with the minimum. The resultant implicit discount rate is not the same as the input discount rate. By a back calculation, the resultant discount rates have been derived and are presented in this paper. Their variation over time (as a result of changing fuel prices) is also described.

One area in which further analysis is required is in how consumers base their choice of fuel and what are the major factors (and their quantitative relationship) affecting fuel switching. Improvements to this aspect of demand modeling will enable better analysis of proposed policies. In the Hirst model, the choice among different fuel types is made subsequent to the choice of efficiency level for each fuel. The fuel split is dependent on the income, equipment cost, and operating cost. While standards may be imposed to constrain consumers' choice about efficiency, this must be done carefully. Otherwise, in one hypothetical case, a too strict standard for one fuel type may drive equipment costs up disproportionately. Such a choice could cause a shift to an alternative fuel such that the overall energy consumption increases (for example, switching from gas to electric water heaters would cause increased consumption of source energy).

The Hirst model has been modified to produce a new version at Lawrence Berkeley Laboratory with an alternate consumer decision making algorithm. This modification replaces the Hirst methodology with direct utilization of implicit discount rates that are input. Data requirements for optimal utilization of this feature are described, as are the methodology and some preliminary results.

M.I.T. Centre for Policy Alternatives M-4946

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

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.

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 M-4946

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

Objectives/scope: See Volume 1, above.

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 M-4947

1978 Consumer Durables: Warranties, Service Contracts and Alternatives. Volume III: Appliance Warranties and Service Contracts: Consumer Experience. Cambridge, Mass.

Objectives/scope: See Volume 1, above.

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 M-4948

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

Objectives/scope: See Volume 1, above.

Abstract: 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 M-4949

1975 The M.I.T. Report: Consumer Appliances, The Real Cost.
National Science Foundation.
Washington, D.C.

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 M-4950

1977

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

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. M-5147
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 Johanson, and Loring-Meckler Associates Inc. N-5205

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

Objectives/scope: 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.

Abstract: 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. 0-5812

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 0-5813
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) they 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.

Ostrum, Tony
1979

0-5895

Life Cycle Cost Analysis: Appendix A
Ottawa: Department of Energy Mines and Resources, Office of Energy Conservation (September). Mimeographed Material.

Objectives/scope: To describe LCC analysis to be used to develop a savings-to-investment (SIR) for Canadian government procurement of solar energy systems.

Abstract: The procurement of solar systems by the Canadian government is to be based in part on the comparative economics of solar systems with conventional energy alternatives. The economic analysis is to be based on a life cycle cost analysis which will produce a SIR for the proposed solar project. The methodology to be used is as follows:

1. Energy Savings
- Determine the annual "conventional" energy requirements of each system over a common period (usually the lifetime of major hardware).
- Put these time profiles of energy demand into monetary terms using present market prices at the project site plus the appropriate reference cost premiums (to adjust the prevailing market energy prices to reflect the full economic value to Canada of such conventional energy supplies).
- Discount the two time profiles of energy costs back to the start of the project using a 10% real discount rate.
- Subtract the "solar" present value total from the "conventional" present value total.

2. Differential Non-Energy Costs
- Develop time profiles, based on present day costs at the project site, for the non-energy costs that will be incurred for each system over the evaluation period.
- Allow credits (i.e. negative costs) for any scrap value at the end of the evaluation period arising from these expenditures.
- Discount the two time profiles of non-energy costs back to the start of the project using a 10% real discount rate.
- Subtract the "conventional" present value total from the "solar" present value total.

3. Savings-to-Investment Ratio - divide (1) by (2). The SIR is an indicator of the cost-effectiveness of the proposed solar project. This indicator can be used to select the more cost-effective proposals, and perhaps more importantly, it provides a means of tracking the evolution of the cost-effectiveness of solar systems over time.

Otto, Thomas W. Jr. 0-5912

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.

Passaglia, Elio P-6012
1977

Technical Durability of Products
Washington, D.C.: National Bureau of Standards

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To discuss economic vs. technical durability of a product.

Abstract: When considering durability, it is useful to make a distinction between two different aspects of it. These aspects may be called economic durability and technical durability. Economic durability means the length of time a durable good lasts in service. Technical durability may be defined as the number of services embodied in the durable good. Examples of technical durability are the number of shaves in a razor blade, or the number of miles of travel in an automobile tire. Economic durability is thus the quotient of technical durability and the rate of use of the services embodied in the durable good. Technical durability is not always easy to define, and one of the main technical challenges is the determination of its magnitude. When the physical basis for loss to service is known, technical durability can in principle be determined quite easily. An example is the number of cycles a spring will operate before failure by fatigue. In other cases, when the physical basis is not known, technical durability is more difficult to determine. In such cases, simulated service tests or exposure tests, which are a special case of simulated service tests, are used to determine technical durability. In both cases the reliability of the durable good (the ability to perform in service) must be considered. One problem of design is to increase durability and reliability within the constraints of economics.

Pearson, George F. P-6077

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 portion of a life-cycle cost analysis.

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. P-6085
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 microeconomic 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. P-6086
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

P-6087

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 of 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 cooling 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.

Peterson, M.B. P-6089
1977

Materials Conservation Through Increased Durability Washington, D.C.: U.S. Congress, Office of Technology Assessment.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To examine materials savings resulting from extending product life.

Abstract: The Office of Technology Assessment (OTA) has been conducting a study on materials conservation in which it is considering ways in which materials could be saved if and when it becomes necessary to do so. At the beginning of this study it was felt that extending product life would result in substantial savings of material. Figuratively speaking, if all products lasted forever, no more materials would be needed. More realistically, even one year of extended life would on the surface appear to save appreciable materials. For this reason, a considerable amount of time was spent investigating the potential for product life extension. Basic approaches were followed:

(1) A workshop was held to discuss product durability. To provide a focus, wear control was chosen as the means of achieving improved product durability.

(2) A contractual study was undertaken to investigate materials savings using refrigerators, automobiles, and containers as case examples.

(3) A study was conducted of the product end uses of a variety of metals. From this, an analysis was made of the potential metal savings possible.

The general conclusion from all of these studies was that increasing product durability would not be an efficient means of saving materials. Products are retired from service for many reasons other than poor durability. The material savings which would result would not be fully realized until all existing products had been retired (construction machinery, electrical equipment, etc. already have long lives). A more effective strategy would appear to be the reuse of discarded parts and components.

Pugh, N.R.
1977

P-6322

Product Life Testing and Durability
Chicago, Illinois: Sears, Roebuck and Co.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: This paper considers Product Failure Prevention from the standpoint of a retail organization's laboratory with emphasis on private label merchandise.

Abstract: The point of view on product design evaluation and testing programs of a retail laboratory is described briefly.

The relationship of design quality evaluation to conformance quality, (both as-manufactured and after extended use) is explored.

Some of the challenges in predicting durability, and minimizing failures, through laboratory and field test programs, are described, with examples.

The interaction of factual information and consumer receptivity, and their imact on durability and life information, is considered.

Lastly, some opportunities for real accomplishment through better teamwork among various elements-government institutions, academe, and the private sector, are described.

Raabe, Marke J. R-6800
1977

Labelling Products for Durability
Washington, D.C.: House Committee on Interstate and Foreign Commerce.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To review U.S. Congressional action in the area.

Abstract: This paper presents a review of U.S. Congressional Action with respect to past consideration and current bills dealing with labeling products for durability, as well as for other characteristics. It discusses present governmental action in the overall product labeling area, including comments on primary problems being encountered and focuses specifically on durability labeling along with comments on prospects for future Congressional action.

Reynolds, Smith & Hills R-6887

1977

Life Cycle Costing Emphasizing Energy Conservation: Guidelines for Investment Analysis.
Jacksonville, Florida: Report
Prepared for Energy Research & Development Administration, Washington, D.C.

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.

Rhee, S.K.
1977

R-6925

Break Wear
Southfield, Michigan: Bandix Corp., Research Laboratories.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To discuss factors affecting service life of passenger car brakes.

Abstract: Friction materials for passenger car and truck brakes usually consist of an organic binder (typically phenolic resin), and various organic, inorganic and metallic fillers. When a constant amount of work is performed under a fixed set of braking conditions the wear rate of a typical friction material is found to increase slowly with respect to brake rotor temperature up to about 220°C, and exponentially above this temperature. This exponentially increasing wear rate has been attributed to the thermal decomposition of organic ingredients. In other words, the wear rate is strongly dependent upon brake temperature. Thus, predicting the durability (or service life) of a friction material under a "typical" set of driving conditions becomes difficult since brake temperatures are influenced by many variables such as vehicle weight, brake size, brake design, driver, traffic pattern, weather, and previous braking conditions among others. Suggestions and recommendations are made for minimizing these difficulties.

Ruegg, Rosalie T. R-7118
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. R-7119
1976

Life-Cycle Costs and Solar Energy.
ASHRAE Journal (November) 22-25.

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

Abstract: 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. R-7120
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. R-7121
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 R-7122
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 R-7124

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.

Sir Robert Matthew Metcalf and Partners, Nad Hauscomb Associates S-7345

1974 Life Cycle Costing at the University of Alaska: Feasibility Report.
Washington, D.C., Report.
Prepared for the University of Alaska.

Objectives/scope: 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.

Abstract: 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.

Stern, Martin O.
1978

S-7505

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. S-7507
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 inavailability 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 Wang S-7508

1977 Service Lives of Major Household Appliances. Paper presented at the 23rd Annual Conference of the American Council on Consumer Interests. Washington, D.C.: National Bureau of Standards.

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 $\pm$ 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 S-7509
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.

Abstract: 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.

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 S-7510
1978 Application of Historical Repair Data in Life Cycle Costing Analysis.
Washington, D.C.: National Bureau of Standards.
Paper Presented at 27th Meeting of Mechanical Failure Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

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

Abstract: 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. S-7511

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.

Weber, Stephen F. W-8877
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 regarding historic preservation of nonresidential 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. W-8940
1977 Data Requirements for Life Cycle Costing.
AACE Bulletin, 19, 6 (November/December) 225-237.

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.

Yee, Kenneth
1977

Y-9680

Small Appliance Life Testing
Washington, D.C.: Centre for Consumer Product Technology, National Bureau of Standards.

Paper presented at 27th Meeting of Mechanical Failures Prevention Group, National Bureau of Standards, Gaithersburgh, Maryland (November 1-3).

Objectives/scope: To describe product life testing work underway at the National Burea of Standards.

Abstract: This paper describes work underway at the National Bureau of Standards, Centre for Consumer Product Technology to determine the feasibility of and methodology for, developing standard test methods to estimate the useful life of consumer products. Initial efforts have been on small appliances. The hand-held blow hair dryer was selected for the demonstration product. The status of current work on the hair dryer is described. A similar effort on a major appliance has been undertaken and is described.