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Life Cycle Costing of Energy Systems

William R. Baker

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William R. Baker, P.E.

Assistant Professor of Engineering

University of Wisconsin-Extension

Abstract

Determination of true costs of ownership and the proper evaluation of savings are extremely important with regard to the purchase of energy efficient systems. It is the purpose of the following paper to discuss the application of the life cycle costing process as applied to the evaluation of capital expenditures.

In today's cost-conscious economy individuals responsible for the design, construction, and operation of engineering facilities are called upon to provide services in a cost-effective manner that has not been demanded in the past. We have entered an era where today's decisions have a dramatic influence on future operation costs. This is particularly true in the area of energy consumption. Of one thing we can be certain--the cost of energy will increase with the passage of time. No longer can we simply rely upon the low bid or cheapest initial cost when selecting a construction method or purchase of an equipment item. Many organizations now insist that cost-effectiveness studies be incorporated into the design process to insure the wise investment of capital funds.

Life cycle costing is a procedure for computing the total cost of possession of an item over a time span of ownership. Properly applied, it correctly provides a blend of an initial purchase price along with all future anticipated expenditures. In addition, the process becomes a powerful tool for the comparison of alternate construction and purchasing options.

When considering the design of an engineering system or the purchase of an item of equipment, two basic factors must be considered. Obviously, of paramount importance, is the performance of the item under consideration. It must accomplish the intended task within the parameters anticipated by the owner. This is the case regardless of the physical characteristics of the system being considered and would apply equally to a boiler plant design or the purchase of diesel truck.

In addition to performance, cost is an equally important factor of consideration by both public and private organizations. The total "price" of ownership is made up of several categories of individual costs. This includes the initial purchase amount and/or total cost of construction; all future maintenance, operation, and mortgage payment amounts; any salvage, trade-in, or sale value of the item at the end of its useful life; any and all lost interest earnings on money used to purchase the item under investigation. The effect of Federal and State income taxes must also be considered in the cost analysis process.

The cost attributed to lost interest earnings perhaps deserves some additional comment since it is a somewhat subtle or indirect ownership cost. One must appreciate that the possession of money automatically implies the potential for earning additional dollars in the form of interest payments upon investment. Now, if instead of investing available dollars in some form of interest yielding account such as at a bank, these same dollars are used to purchase an item of equipment, it is only reasonable to include the "lost earnings" as a part of the equipment ownership. In essence, by purchasing the equipment item, one has elected to forego or sacrifice future earnings.

Life cycle cost analysis is usually performed by one of two methods--the computation of the total present worth cost of ownership or the conversion of all costs associated with an item to a series of uniform end-of-year dollar amounts. For the purposes of the following discussion only the present worth approach will be used. Computation of total present worth cost of ownership involves discounting all future cash flow amounts "backwards through time" to the date at which the item under investigation is purchased. The discounting process is much the same as one would employ to determine the purchase price of a bond or treasury note. For example, a bond with a face or maturity value of $10,000 one year from the date of purchase, would be bought for a discounted amount dependent upon the rate of return or interest rate offered by the seller. If the annual yield was set at 7 percent, the discounted purchase price would be $9345.79 (10,000 ÷ 1.07). In investment analysis terminology, $9345.79 is the present worth of $10,000 one year in the future, providing the interest rate is set at 7 percent.

In life cycle costing analysis, the anticipated future ownership costs of an item are discounted to the time of purchase and added to the initial purchase price of the item to obtain a total present worth cost of ownership. The discounting mechanism, or interest rate used, is the investment worth of capital to the owning organization. Such a dollar amount is an exceedingly valuable item of information to the decision maker for several reasons. Of most importance, all costs are expressed in the value of present dollars. In addition, however, the present worth value of several alternatives that are potential options for performing a specific function will enable the selection of the most economical alternative. This is of particular importance in the area of equipment purchases.

Present worth computations are performed by the use of the interest factor nomenclature shown in Figure 1. The value of an interest factor is dependent upon the two variables i and n. When the symbol notation is used to indicate a specific factor, the interest rate is placed in the exponent location and the number of years in the subscript position. No mathematical significance is attributed to this placement as it merely represents a convenient method of indicating a unique interest factor. Both present worth interest factors are used as multipliers. They convert future cash amounts to equivalent present worth dollars as indicated by the following equipment item example:

First cost....................	$10,000
Yearly M&O costs...............	500
Overhaul at end of 4th year....	2,000
Salvage........................	0
Discount rate used.............	9%
Life (years)...................	8

Present Worth (PW) = ?

$$PW = \$10,000 + 500\left(\frac{P}{A}\right)_{8}^{9\%} + 2000\left(\frac{P}{F}\right)_{4}^{9\%} = \$14,184.$$

In the above example, the discounted present worth amount ($14,184) represents the total cost of ownership expressed in terms of present dollars. The degree of accuracy, of course, is dependent upon the validity of estimated future expenditures and the selected investment worth of capital. A brief comment should be made regarding the selection of the specific interest factor used to perform the dis-

FIGURE 1

FACTOR NAME	INTEREST FACTOR SYMBOL	MATHEMATICAL FORMULA
Present Worth Factor	$\left(\frac{P}{F}\right)_{n}^{\%}$	$\frac{1}{(1+i)^n}$
Series, Present Worth Factor	$\left(\frac{P}{A}\right)_{n}^{\%}$	$\frac{(1+i)^n-1}{i(1+i)^n}$

i denotes discount rate, (usually annually)

n denotes number of compound periods (usually years)

P denotes a present amount of dollars

F denotes a single amount of future dollars

A denotes each expenditure in an annual series of future end-of-year costs counting procedure. A single future amount is reduced to the appropriate present worth equivalency by multiplying by a $\frac{P}{F}$ factor for the designated interest rate and number of years. The $\frac{P}{A}$ factor, in like manner, is used to compute the present worth of a series of end-of-year expenditures. Hence, in the above example the present worth of the series of $500 expenses is multiplied by the factor $\left(\frac{P}{A}\right)_{8}^{9\%}$. The numerical value of this factor is secured by use of the formula previously given for the series, present worth factor.

To apply the life cycle cost methodology in practice it is quite apparent that the simple treatment of future costs as expressed in the above example would not apply. Expenses have a nasty habit of escalating. Federal and State income tax laws also drastically affect cash flow, actual cost of ownership, and hence, in a large measure dictate management decision-making policy. To illustrate the effect of these parameters on the life cycle cost computation process, the following evaluation of two alternate energy systems designed for use in Wisconsin are offered. Two types of ownership, public and corporate, are considered, and it is interesting to note the contrast based simply upon the status of the owner.

A 12,000 S.F. office building is to be equipped with a 30 ton rooftop air cooling unit. Two systems are available--a standard system "A" and system "B" equipped with an economizer. Cost data for the two units is given below:

	Sys. A	Sys. B
Capital Cost	$30,000	$33,000
Salvage	0	0
Life	10 years	10 years
Operation cost per year		
Maintenance	$ 300	$ 350
Energy (current, but will triple at a uniform rate over the next 9 years)	2,360 (1st yr)	1,890 (1st yr) (a 20% reduction)

When computing the true cost of corporate ownership it will be assumed that the organization pays combined state and Federal income taxes at a rate of 55 percent in addition to local property taxes of $15/$1000 of true value. Also, money is considered to be worth 10 percent both to the corporation and the public entity.

PUBLIC OWNERSHIP: As one would expect, the additional $3000 investment is profitable for a publicly-owned, non-taxpaying organization. The present worth ownership cost of System A using a 10 percent discount rate is $56,132 while System B's cost is $54,602. Clearly, a net savings of over $1500 will accrue to the owner in addition to the energy savings benefit. These amounts were computed with the aid of the series present worth factor applied to the M&O costs while each year's adjusted energy cost is discounted individually by use of the standard present worth factor. An alternate discounting method for application to the annual energy cost is to use a present worth factor based upon a geometric progression using a 13 percent rate of escalation and a 10 percent discounting rate. Both approaches will, however, yield identical results.

TABLE I

CORPORATE OWNERSHIP OF SYSTEM A

YEAR	PROP TAX & MAINT	ENERGY	GROSS CASH FLOW	ST. LINE DEPR.	TOTAL TAX DED.	TAX RTN. @ 55%	NET CASH FLOW	PW @ 10%
1	$750	$2360	$3110	$3000	$6110	$3361	$+251	$+228
2	"	2667	3417	"	6417	3529	+112	+93
3	"	3013	3763	"	6763	3720	- 43	- 32
4	"	3405	4155	"	7155	3935	-220	-150
5	"	3848	4598	"	7598	4179	-419	-260
6	"	4348	5098	"	8098	4454	-644	-364
7	"	4913	5663	"	8663	4765	-898	-461
8	"	5552	6302	"	9302	5116	-1186	-553
9	"	6274	7024	"	10,024	5513	-1511	-641
10	"	7090	7840	"	10,840	5962	-1878	-724
								-2864

Discounted Yearly Cash Flow

Initial Acquisition Cost		$30,000
Plus Discounted Cash Flow		2,864
Less Discounted Investment Tax Credit		-2,727
Life Cycle PW Ownership Cost	=	$30,137

TABLE II

CORPORATE OWNERSHIP OF SYSTEM B

YEAR	PROP. TAX & MAINT.	ENERGY	GROSS CASH FLOW	ST. LINE DEPR.	TOTAL TAX DED.	TAX RTN. @ 55%	NET CASH FLOW	PW @ 10%
1	$845	$1890	$2735	$3300	$6035	$3319	$+584	$+531
2	"	2136	2981	"	6281	3456	+475	+393
3	"	2413	3258	"	6558	3607	+349	+262
4	"	2727	3572	"	6872	3780	+208	+142
5	"	3082	3927	"	7227	3975	+ 48	+ 30
6	"	3482	4327	"	7627	4195	-132	- 75
7	"	3935	4780	"	8080	4444	-336	-172
8	"	4446	5291	"	8591	4725	-566	-264
9	"	5024	5869	"	9169	5043	-826	-350
10	"	5678	6523	"	9823	5403	-1120	-432

Discounted Yearly Cash Flow = + 65

Initial Acquisition Cost	$33,000
Less:	
Discounted Cash Flow	65
Discounted Investment Tax Credit	3,000
Life Cycle PW Ownership Cost	$29,935

CORPORATE OWNERSHIP: A study of Tables I and II will show that little advantage is realized by the corporation for appropriating additional capital to purchase the energy saving item of equipment. This is the case even with a yearly savings in energy equal to 20 percent! The reason for this, of course, is due to the income taxing structure. Energy savings have the net effect of increasing taxable income thus resulting in an additional cost to the owner that may be greater than the savings achieved.

Planning for the wise management of our energy fuel resources should incorporate adjustments in our Federal and state taxing structures that offer incentives for energy saving capital investments. This could be accomplished by an increase in the investment tax credit and/or depreciation schedules that would allow for rapid recovery of capital costs.

Very few organizations actively resist a program of energy conservation. It is, however, ironic to be confronted with potential situations whereby conscientious energy saving efforts, coupled with good engineering design can result in increased costs to manufacturers.

WILLIAM R. BAKER
Assistant Professor
University of Wisconsin-Extension

Department of Engineering

432 North Lake Street

Madison, Wisconsin

Professor Baker is a civil engineer by background and his professional career includes association with municipal governmental organizations and private consulting in the area of public works engineering.

In addition to his responsibilities for the development of continuing education programs for public works engineers at the University of Wisconsin, he teaches courses in the areas of engineering economics and municipal engineering practice.

He is the author of numerous papers and articles on the subject of Life Cycle Costing and is particularly interested in this application to government purchasing. At the present time Professor Baker is Project Director for the Wisconsin Local Government Energy Audit program.