The Engineering Economics of Energy Use and Capital Investment

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Abstract

A potential capital investment involving energy use or energy conservation is always in competition with other possible uses of the same available capital. The competition may come from other energy related projects, or from proposals for, say new production equipment. The situation of "Pay Now - Save Later" is common for energy related decision problems. The comparison of competing energy-related projects is often complicated with unequal useful lives and typically includes substantial initial investments and a variety of recurring costs. Methods of comparison that are frequently used include payback period, return on investment (ROI), and net present value. Further, unit costing methods are needed to account for unit costs of electricity and steam, and are used to determine incremental change in the busbar price of electricity that is sold to consumers (i.e., the price of electricity from the plant excluding outside factors such as transmission lines or local distribution services). Clearly, energy use and energy related capital investment decisions require good skills in economic analysis. They also provide intuitive and rich examples for teaching the basics of engineering economics. This paper provides a primer that can be used to teach the basic principles of economic analysis necessary to understand and evaluate energy-related alternatives. The paper includes an introduction to the concepts of time value of money, present worth, effects of escalating energy costs, levelized cash flows, project life, depreciation, taxes, and interest rates. Methods used to rationally compare alternatives such as simple payback period, discounted payback period, internal rate of return, net present worth analysis, and annualized costs are presented on a basic level, and then applied to energy examples in the paper. While the methods of analysis pertain specifically to situations where energy-related alternatives are being considered, the paper serves as primer that can be used as a module on basic principles of economics applied to a variety of topics for practitioners or university students.

1. Introduction

A potential capital investment involving energy use or energy conservation is always in competition with other possible uses of the same available capital. The competition may come from other energy related projects, or from proposals for, say new production equipment. In any case, it is always important for managers and engineers to be able to evaluate and justify energy related proposals on economic grounds.

The economic situation is one of "Pay Now – Save Later", and so the main issue is: Are the future savings worth the present cost of the investment? A method of analysis is required that can rationally compare alternative projects with different initial costs and different lifetimes. Is it, for example, better to invest in a ten-year energy conservation project costing $150,000 that returns $20,000 of energy savings the first year with 10% per year in energy escalation costs, or to purchase a new production machine costing $120,000 that returns $30,000 annually for six years?

Such questions are a major topic of discussion in courses and texts on engineering economics with several methods presented to support analysis and selection among alternatives[1-5]. Often in energy related discussions, the concept of Payback (or payout) period is prominent. In this paper, alternate methods of computing the so-called Payback time will be discussed. The concept of return on investment (ROI), however, provides much more consistent and accurate economic comparisons of alternative projects. Moreover, ROI is better respected by accountants and managers. Thus, though Payback is presented, ROI and Net Present Value methods are advocated and stressed in this review.

In other situations it is necessary to determine the on-going cost of the project to the corporation, the individual, or the process being modified. For example, if we are evaluating a cogeneration project in a plant that will produce electricity for the plant and process steam for a production line, it may be necessary to determine the unit costs of electricity and steam separately in order to allocate costs of production within the plant. Similarly, electrical utilities must evaluate projects on the basis of the incremental change in the busbar price of the electricity that they market to consumers (i.e., the price of electricity from the plant excluding outside factors such as transmission lines or local distribution services). For these situations, determining the New Present Value (NPV) of the project and then the Levelized Cost per unit of output is more useful than finding the ROI. It may be the ROI was used initially by management to evaluate the distribution of available capital to alternative projects, but then Levelized Cost is used to allocate resources in the company.

In order to conduct and interpret analyses, some of the basic tools of economic analysis are presented in Section 2. Section 3 builds on this basic foundation with methods of economic analysis for energy-related problems.

2. Notation

In this review the following symbols and notation will be used:

- i = Rate of Interest or Discount Rate (expressed as a decimal);
- n = Number of Interest Periods (usually years);
- P = Present Value of Money, or Present Value of some Future Sum;
- F = Future Value of Money, or Future Value of some Present Sum;
- A = Uniform Periodic (usually annual) Transfer of Money.

Most often, financial considerations involved in capital projects occur over time. Discounting is the concept used to relate cash transactions occurring over a period of time. It takes into account that the value of money changes with time (due to the effects of interest earned, inflation, etc.). Discounting is essential for the translation of cash flows to one point in time for equitable comparison of alternatives. Some terminology commonly used in economic analysis follows.

Time Horizon. The time period over which financial decisions are being made–often the project life. The time horizon is divided into time periods, such as years or months. Here we will usually use years as the time period.

Cash Flow. The magnitude of the cash expenditures over a series of time periods. Positive cash flows are *receipts*, and negative cash flows are *disbursements*. Cash flows occur at various times. They may be continuous, at the beginning of time periods, or at the end of time periods. The most common convention is to use end of period cash flows. For instance, t=1 is the end of period 1 or the beginning of period 2. Similarly, t=2 is the end of period 2 or the beginning of period 3, and so on.

Discount Rate. The rate that money earns interest or the rate that money is discounted into the future. Usually this rate is the best opportunity rate. For an individual this may be the rate that is paid by the bank for money kept in a savings account. For a company it may be the rate that the company can borrow from a bank or from investors.

Equivalent Cash Flows. Two cash flows occurring at different time periods are said to be equivalent when, based on the discount rate used, they are of equal value to an investor when compared at a common time period.

Net Cash Flow. In many cases in financial decision making, we do not need to know absolute values of cash flows, but rather the relative values. For example, if we are comparing the two alternatives: 1) add air pollution equipment to a boiler plant, or 2) use low sulfur oil in the boiler plant, in order to meet emissions requirements. All we need consider is the difference in costs between the two alternatives and not the absolute costs.

Annualized or Levelized Costs. The equivalent uniform (annual) cash flows equivalent to a series of discrete non-uniform cash flow over the time horizon.

2.1. The Time Value of Money

In this discussion, the notion that money has a time value is attributed to the investment value or interest return from its use. Although also affecting the value of money over time, the effects of inflation (or deflation) will be incorporated into analyses later. Thus if we start with a present amount of money P, and invest that amount with annual interest i, then the amount of money F in the future will be:

After 1 year: $F_1 = P + iP = P(1 + i)$
After 2 years: $F_2 = P(1 + i)^2$
After n years: $F_n = P(1 + i)^n$

EXAMPLE 1: \$1000 is invested at 10%. What is the future amount of money received after 7 years?

SOLUTION:
$$F_n = P(1 + i)^n$$
$$F_7 = 1000(1 + .10)^7$$
$$F_7 = 1000(1.94871) = \$1948.71$$

An interesting rule of thumb makes it possible to quickly compute the effects of such compound interest. The "rule" computes the number of interest years needed for an amount of money to double. That is, it computes the so-called "doubling period":

Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition

Number of Years for a Sum to Double = 70/Interest Rate Expressed in %.

EXAMPLE 2: At 10%, how many years will be required to double an initial investment of $1000?

SOLUTION: Doubling period = 70/i% = 70/10 = 7 years.

(Note the exact calculation in the proceeding example shows that after 7 years the amount will be $1948.71, which is very close indeed to $2000.)

The expression $(1 + i)^n$ is called the Single Compound Amount Factor and is sometimes abbreviated SCA or in short form notation $(f/p)^n{}_i$. There are tables called Discount or Interest tables which list the values of this and other interest rate factors (described in the next several sections) in all books on engineering and project economics.

Cash Flow Diagrams are an effective means of capturing and visualizing the receipts and disbursements of cash flows. In these diagrams, the y-axis is used to display cash flows, with arrows in the positive direction being used to indicate a positive cash inflow to the organization or individual (receipt), and negative or downward arrows representing negative outflows of cash (disbursement). The length of the arrow is proportional to the magnitude of the cash flow. Time flows along the direction of the positive x-axis. The origin usually represents the beginning of the project or planning period. The divisions along the x-axis represent time periods being considered, often in years. A cash flow diagram corresponding to Example 1 is shown below.

In cash flow diagrams, just as in project economic analysis, it is not necessary to always use total costs or cash flows. In many cases only net values are needed. For example, in evaluating a project such as the addition of a power plant bag house to the smokestack that will allow the power plant to burn coal rather than oil, it is not necessary to use total fuel costs. Only the difference in fuel costs, or net savings, is required. In most cases this simplifies the analysis and gives numerical data that is more easily visualized.

2.2. The Concept of Present Worth

Assuming your available interest rate is 10%, how much will you give now for the promise of receiving $1000 one year from now? Or, in other words, what is the present value of this future sum of money?

To answer this type of question, we assume we have some present sum P that can be invested at the available interest rate, i, such that the required future sum is attained at the end of the given period. Thus, to get a future F = $1,000 one year from now at 10%, we need a present sum P such that:

$$F = P(1 + i), \text{ or}$$
$$P = F/(1 + i); \text{ thus}$$
$$P = 1000/1.1 = 909.09.$$

We say, therefore, that "the present value (present worth or PW) of $1000 one year from now at 10% is $909.09."

If the above reasoning is extended to longer periods (2, 3, …n years), then from $F = P(1 + i)^n$ we get: $P = F/(1 + i)^n$.

EXAMPLE 3: What is the present value of $1,000 four years from now if the interest rate that can be earned by the $1,000 investment is 5%?

SOLUTION: $P = F/(1 + i)^n$

$P = 1{,}000/(1.05)^4 = \$822.70$.

Note again that the reason the present value of a future sum is less than the future amount has not accounted for the effects of inflation. This will be considered later. Here, we view interest as the cost of using capital. Assuming no changes in the prices of goods and services (that is, no inflation or deflation), the present value of a future sum is as computed above.

The factor $1/(1 + i)^n$ is called the Single Present Worth Factor and is abbreviated SPW, or in short form, $(p/f)^n{}_i$. It too is listed in the discount tables of textbooks on engineering economics. It is of course, merely the reciprocal of the Single Compound Amount Factor.

EXAMPLE 4: Find the present value of $1000 ten years from now. The interest rate is 6%.

SOLUTION: Calculating the Single Present Worth Factor SPW from the formula or looking it up in the interest tables, for this case is 0.558. Thus, since

$P = F(SPW)$, therefore

$P = 1000(0.558) = \$558.00$.

2.3. Annuity or Uniform Series of Payments

The concept of present value is extremely important to energy project economics. The way to evaluate the cost effectiveness of a project by comparing the present value of all future savings with the initial outlay required. For proper analysis, it is not total savings over the years that should be compared with the initial cost. Instead, it is the present value of the savings that makes a proper comparison. This takes into account the time value of money. To aid in computing the present value (or future value) of savings over a period of years from an energy related capital investment; the concept of annuity (or uniform series) is introduced in this section.

Suppose an annuity is received, that is, a series of uniform annual payments, of A dollars at the end of each year. Also assume that these dollars, when received, are invested at an interest rate of i. Then what amount F will you have at the end of n years?

We assume in answering this question that the payments are received at the end of each year. Thus:

At the end of year 1: $F_1 = A$

At the end of year 2: $F_2 = A(1 + i) + A$

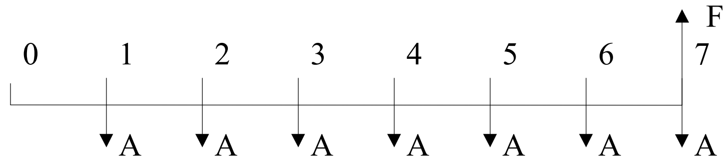
At the end of year 3: $F_3 = A(1 + i)^2 + A(1 + i) + A$

At the end of year n: $F_n = A(1 + i)^{n-1} + A(1 + i)^{n-2} + \text{-----} + A$

This type of series can be simplified to the following expression for F_n:

$$F_n = A[(1 + i)^n - 1]/i$$

The factor $[(1 + i)^n - 1]/i$ is called the Uniform Series Compound Amount Factor (USCA), which in short form is written $(f/a)^n{}_i$. This uniform series can also be visualized easily in a cash flow diagram as shown below:



EXAMPLE 5: You receive an annuity of \$300 per year for 10 years, which can be invested at 5%. What sum of money will you have at the end of 10 years?

SOLUTION:
$$F_n = A[(1 + i)^n - 1]/i$$
$$F_{10} = 300[(1.05)^{10} - 1]/.05$$
$$F_{10} = 300[12.5779]$$
$$F_{10} = 3773.37$$

Of course, the concept of annuity is not limited to actual money received. It can also be used to find the total amount of savings to be expected from an energy conservation project. The built-in assumption, of course, is that the savings will be invested at interest i. This is only fair because dollars saved have a time value just like other cash funds held by the company. (Note: We are not yet dealing with the present value of such annual savings.)

EXAMPLE 6: An energy conservation project saves \$1000 per year over its 15-year life. The interest rate is 10%. What total amount will be accumulated?

SOLUTION:
$$F_n = A[(1 + i^{)n} - 1]/i$$
$$F_{15} = 1000[(1.1)^{15} - 1]/1$$
$$F_{15} = 1000[31.77248]$$
$$F_{15} = \$31,772.48$$

Note the savings by themselves are only \$1000 x 15 = \$15,000. The additional \$16,772.48 is the accumulated interest, which in compounding also receives interest. Also, just as for present and future value calculations, pre-computed factors can be found in interest tables of texts on engineering economics.

The reciprocal of the USCA is usually called the Uniform Sinking Fund Factor (USF). It is used to answer the question: What annual payment A is required which will accumulate to an amount F in n years at interest i? Thus:

$$A = F_n[i/\{(1 + i)^n - 1\}]$$
$$A = F_n \text{ x } (USF)$$

Uniform Sinking Fund Factors, abbreviated as $(a/f)^n$.

2.4. The Present Value of an Annuity

The present value of a uniform annual amount received or saved can be determined as follows. If A is the single amount received or saved in, say, the third year, then we know from previous discussion that the present value of A is:

$$P = A/(1 + i)^3$$

(In this case, A is said to be received at the end of the third year for an end of period convention. We will by convention always make our cash flows occur at the end of each period.)

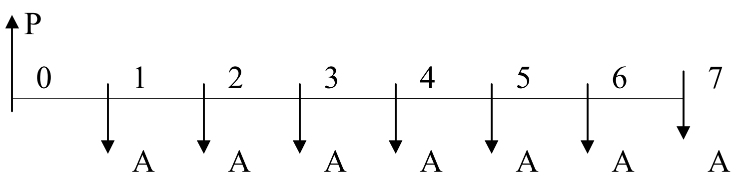
Generalizing this, the present value of uniform annual savings over n years is:

$$P = A/(1 + i) + A/(1 + i)^2 + A/(1 + i)^3 + ---- + A/(1 + i)^n$$

As always, factor out A and multiply both sides by $[1 - 1/(1 + i)]$.
Rearranging and simplifying gives:

$$P = A[(1 + i)^n - 1]/i(1 + i)^n$$

The factor $[(1 + i)^n - 1]/i(1 + i)^n$ is called the Uniform Series Present Worth Factor (USPW), and it, like the others, can be found in existing tables or can be calculated directly. The shorthand notation for USPW is $(p/a)^n_i$. The cash flow diagram for this process is shown below:



EXAMPLE 7 Compute the present worth of expected annual savings of $1000 per year for a project with an expected life of 10 years. Interest i = 8%.

SOLUTION: $$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

$$P = 1000\frac{\left[1.08^{10} - 1\right]}{.08(1.08)^{10}}$$

$$P = 1000(6.71008) = \$6710.08.$$

Note that the total amount saved is 1000 x 10 = 10,000. The present value is less, of course, because each of the amounts saved in the future are discounted to their respective present values by division by $(1 + i)^n$.

EXAMPLE 8: Insulating a building can save $400 per year over the next 20 years. The interest rate in 6%. What is the present value of the savings?

SOLUTION: $P = A[USPW]$
$P = 400[11.470]$
$P = \$4588.00$

Though it may not be obvious from the derivation, it is important to understand that in computing the present value of annuities by the above method, it is assumed that the annual amounts received or saved are invested upon receipt at interest i for the remaining life of the project. To verify this fact, note that the Uniform Series Present Worth Factor (USPW) is simply equal to the Uniform Series Compound Amount Factor (USCA) divided by $(1 + i)^n$. That is,

$$USPW = USCA/(1 + i)^n .$$

Thus another way to find the present worth of the annuity is to first compute the total sum of money that will be accumulated or saved assuming the receipts or savings over n years are invested at interest i. This, of course, is exactly what is found by using the USCA factor. Then, to derive the present worth of this future (n years from now) amount, it must of course be discounted by division by $(1 + i)^n$.

EXAMPLE 9: \$500 per year is saved in an energy recovery project that has a life of 6 years. The interest rate is 10%.

(a) Compute the total amount of money saved not including interest.
(b) Compute the total amount of money saved including interest.
(c) Compute the present value of the total saving found in part (b).
(d) Compute the present value of the total savings using the USPW.

SOLUTION: (a) $500 \times 6 = \$3000$.

(b) $F = A[USCA] = A[(1 + i)^n - 1]/i$
$F = 500[1.1^6 - 1]/.1$
$F = 500[7.71561] = \$3857.81$

(c) $P = F/(1 + i)^n$
$P = 3857.81/1.1^6 = \$2177.63$

(d) $P = A[USPW] = A[(1 + i)^n - 1]/i(1 + i)^n$
$P = 500[1.1^6 - 1]/[0.1(1.1)^6]$
$P = 500[4.35526]$
$P = \$2177.63$

Note that the results of (c) and (d) are the same as expected.

2.5. The Capital Recovery Factor

The reciprocal of the Uniform Series Present Worth Factor (USPW) is called the Uniform Capital Recovery Factor (UCR). It is used to answer the question: What annuity A for n years at interest i is required to give a specified present value P? It is given in abbreviated form as $(a/p)^n{}_i$. The formula is:

$$A = P[i (1 + i)^n]/[(1 + i)^n - 1]$$
$$A = P[UCR]$$

EXAMPLE 10: A heat pump costs \$2000 more than a conventional system and has an expected life of 15 years. How much annual savings are required to produce a present value of savings equal to the added initial cost? Interest rate = 9%.

SOLUTION:
$$A = P\left[\frac{\left[i(1+i)^n\right]}{\left[(1+i)^n - 1\right]}\right]$$

$$A = 2000\left[\frac{\left[.09(1.09)^{15}\right]}{1.09^{15} - 1}\right] = 2000\,(.124059) = \$248.17.$$

3. Methods of Economic Analysis for Energy-Related Problems

This section builds on the basic foundation in engineering economics presented in the preceding section with a closer focus on issues and methods needed for energy-related problems.

3.1. The Effects of Escalating Energy Costs

The preceding discussion of annuities assumes that the annual payment received or amount saved is constant over the life of the project. However, it has been the case that energy costs escalate as a result of world events and the increasing cost of finding and obtaining basic energy resources. Similar cost increases occur in other areas of the economy as well. Thus, annual savings due to reduced energy use should be assumed to escalate rather than to remain constant over the years. This escalation of costs is different from the concept of inflation, which can also occur. Inflation affects all costs and is due to the amount of money in circulation.

If the escalation rate is taken to be an annual rate of increase (e), then the effects of energy price increases can be easily computed. We assume that the price escalation begins immediately. This is a beginning of period convention where the periodic cost A is specified at the beginning of the period A_o so that the first year's savings are:

Receipts or Savings, 1st Year: $A_o(1 + e) = A_1$
Receipts or Savings, 2nd Year: $A_o(1 + e)^2 = A_2$
Receipts or Savings, nth Year: $A_o(1 + e)^n = A_n = A_{n-1}(1 + e)$.

Note, however, that $A_1 = A_o(1 + e)$ so that we could write $A_2 = A_1(1 + e)$ etc., if an end of period cost A_1 were being considered.

As before, the receipts or savings themselves are assumed to be invested at interest i. Thus the future amounts of money are:

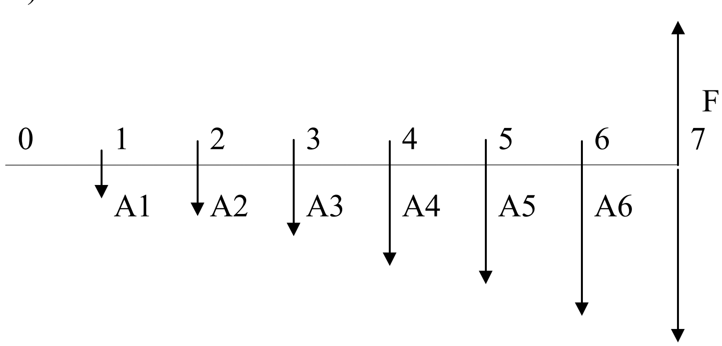
At the end of 1st Year: $F_1 = A_o(1 + e)$
At the end of 2nd Year: $F_2 = A_o(1 + e)(1 + i) + A_o(1 + e)^2$
At the end of 3rd Year: $F_3 = A_o(1 + e)(1 + i)^2 + A_o(1 + e)^2 (1 + i) + A_o(1 + e)^3$
At the end of nth Year: $F_n = A_o(1 + e)^{n-1}(1 + e) + A_o(1 + e)^{n-2} (1 + e)^2 + \text{---} + A_o(1 + e)^n$.

(Note that although our baseline for escalation is the cost A_o at the beginning of our time horizon or planning period, our cash flows are still at the end of each period.)

Simplifying this series result in:

$$F_n = A_o \frac{([f(f^n - 1)](1+i)^n)}{f - 1}, \qquad \text{where} \quad f = (1 + e)/(1 + i).$$

The term $[f(f^n - 1)/(f - 1)](1 + i)^n$ is called the Modified Uniform Series Compound Amount Factor (MUSCA). This non-uniform series can be seen in the cash flow diagram below:



EXAMPLE 11: An energy recovery project will save $1000 annually at current prices when the interest rate is 8%

(a) What will be the savings at the end of 10 years if energy prices remain constant?
(b) If energy prices escalate at 12% per year, what will be the savings?

SOLUTION: (a) $F_n = A_o[(1 + i)^n - 1]/i$

$F_{10} = 1000[(1.08)^{10} - 1]/.08$

$F_{10} = 1000[14.48656]$

$F_{10} = \$14,486.56$

(b) $F_n = A_o \left[\frac{f(f^n - 1)}{f - 1} \right] (1 + i)^n$ where $f = (1 + e)/(1 + i)$

$f = (1 + .12)/(1 + .08) = 1.037037$

$F_{10} = 1000 \left[\frac{1.037037(1.037037^{10} - 1)}{1.037037 - 1} \right] (1.08)^{10}$

$F_{10} = 1000\ (12.28104)\ (2.158925) = \$26,513.84.$

The proceeding analysis enables us to calculate total savings. As before, the present value of these savings can be found easily by discounting the total savings at the end of year n by $(1 + i)^n$. Thus by dividing the previous equations by $(1 + i)^n$,

$$P = A_o[f(f^n - 1)/(f - 1)] \qquad f \neq 1$$

$$P = nA_o \qquad f = 1$$

These equations can be derived in a different way. The present value of the first year's savings is:

$$P = A_o[(1 + e)/(1 + i)] = A_o f = A_1/(1 + i) = A_1 f/(1 + e)$$

For subsequent years, the whole series is:

$$P = A_o f + A_o f^2 + A_o f^3 + \text{---} + A_o f^n$$

Multiply both sides by $(1 - 1/f)$:

$$(1 - 1/f)P = A_o[f^n - 1].$$

Rearranging: $P = A_o[f(f^n - 1)/(f - 1) = A_o[(1 + e)(f^n - 1/(e - i)] \qquad f \neq 1$

$$P = nA_o \qquad f = 1$$

or using an end of the first period cash flow with $A_1 = A_o(1 + e)$:

$$P = A_1[(f^n - 1)/(e - i)] \qquad f \neq 1$$

$$P = nA_1/(1 + e) \qquad f = 1$$

EXAMPLE 12: An energy recovery project will save \$1000 annually at current prices. The interest rate is 8%. Energy prices are assumed to escalate at 21% annually.
(a) How much total money will be saved?
(b) What is the present value of the savings?

SOLUTION: (a) This is the same as part (b) from the previous example. The answer is \$26,513.84.
(b) $P = A_o[f(f^n - 1)/(f - 1)]$ $f = (1 + e)/(1 + i)$ $f = 1.12/1.08 = 1.037037$

$$P = 1000[1.073073(1.037037^{10} - 1)/(1,037073 - 1)]$$
$$P = 1000[12.28104]$$
$$P = \$12,281.04$$

The two factors — $(p/A_o)^n{}_{ie,} = f(f^n - 1)/(f - 1)$ and $(p/A_1)^n{}_{ie,} = f(f^n - 1)/(e - 1)$ — have been used by various authors in describing geometric series escalating cash flows. In their texts it is important to note whether the author is using a beginning of first period A_o or an end of first period A_1 in calculating the tabulated values.

3.2. Levelized Cash Flows

There are times in performing engineering economic analysis when it becomes useful to convert the unequal non-uniform cash flows for a project into an economically equivalent uniform series of cash flows. This concept of a levelized cost (LC) allows us to find a constant level of revenue necessary to recover all expenses of a project over the lifetime considered. To perform this evaluation, all costs (Capital, Maintenance, Replacement, Scrap Value, Energy, etc.) are included at the time they occur. Based on the available discount rate and expected escalation rates, these cash flows are discounted to the present to obtain a Present Worth (or Net Present Worth). The Net Present Worth is then used to find a uniform series cash flow over the project life by applying the Uniform Capital Recovery Factor (UCR). These two factors, Net Present Worth and Uniform Capital Recovery Factor can be combined into one term:

$$LF = UCR*NPW.$$

For costs such as Replacement Costs R_k that occur at some specified period k, the NPW of this cost is just the cost R_k discounted to the present i.e.:

$$NPW(R_k) = R_k(1 + i)^k,$$

and then the Levelized Cost LC is just:

$$LC(R_k) = NPW(R_k)[i(1 + i)^n]/[(1 + i)^n - 1]$$ where n is the project life, or:
$$LC(R_k) = R_k*LF,$$

and:

$$LF = (1 + i)^k[i(1 + i)^n]/[(1 + i)^n - 1]$$ is the levelizing factor for a discrete cash flow at some period k.

For costs such as energy costs A_o that escalate over the project period, the Net Present Worth of the series is the Modified Uniform Present Worth Factor $(UPW)^*$, and the Levelizing factor LF^* is:

$$LF^* = f(f^n - 1)/(f - 1)*i(1 + i)^n/[(1 + i)^n - 1]$$,so that the Levelized Cost LC becomes:

$$LC = A_oLF^*$$

3.3. Project Life, Depreciation, Taxes, Maintenance, and Interest Rates

Before projects can be analyzed for comparison, a number of issues must be decided. These are:

- How is project life determined?
- What is the proper interest rate to be used?
- How shall depreciation be included?
- What are maintenance requirements?
- What will be the salvage value of any equipment purchased?
- What is the marginal income tax rate?

We will deal briefly with each of these issues in this section.

Project Life. Determining project life is probably the most difficult task facing the project decision-maker. The tax life of the equipment is usually determined by IRS depreciation guidelines[6]. These are guidelines only, of course, and shorter or larger equipment life can often be justified. Nevertheless the guideline life of 12 years for industrial machinery provides a starting place for determining economic life. Ductwork and insulation may well have a longer life. On the other hand, fans and other equipment operating under difficult hot or dirty conditions may well have a much shorter life unless replacement or repair costs are included. *In most cases, however, the economic life of projects is assumed to be the same as the tax life.*

Maintenance. Maintenance costs must not be ignored. Where full maintenance contracts exist, costs can be obtained; they take the guesswork out of maintenance cost estimates. Otherwise, the project analyst must make a guess based on experience, information from equipment suppliers (usually optimistic), or from other sources.

Income Taxes. For projects that are not in the public sector, income taxes can be important to the proper economic evaluation of a project. With the concept of taxes, a firm pays some fraction of its profits to the government. The fraction becomes the marginal tax rate and will include federal, state and local contributions. The amount of profit to be taxed is the annual revenue less deductible expenses. Company accountants are the best source of information to determine the firm's marginal tax rate. In our examples we assume 50% for convenience.

Depreciation. Deduction of expenses from revenues reduces taxes, so it is in a firm's best interest to consider the expense of large capital expenditures such as we are considering here in the analysis. IRS regulations do not allow large capital assets (items that retain value over a long period, such as machinery) to be deducted all in one year. Instead, IRS guidelines require that the asset is *Capitalized*, i.e. the expense must be divided up into parts that are expensed over a series of years. *Depreciation* is an artificial expense that allows a firm to spread the expense of an asset out over a period of years for tax purposes. Depreciation may be computed in a number of ways: straight line, double declining balance, sum of years digits, or the newer methods such as the Accelerated Cash Recovery System (ACRS) or Modified ACRS (MACRS). Whatever method is used for income tax computation should also be used for project comparison analysis. Since straight line is easily understood and computed, it is used in all the examples that follow.

Interest Rate. The choice of interest rate is a particularly difficult problem. Among the possibilities are:

- The current cost of borrowed money.
- The current rate of return available on external investments such as bonds or stocks.
- The current company internal rate of return on capital.

In some cases when projects are competing for funds, a company may use a discount or interest rate called Minimum Attractive Rate of Return (MARR). MARR gives the minimum economic return that the firm expects to achieve in order to do business.

3.4. Multiyear Project Present Worth

In large capital investment projects, such as a power plant or a multistory building, economic comparisons between alternatives often occur during the design process. Evaluation of these projects entails discounting positive and negative cash flows over the total project life back to the present. Sometimes this type of economic analysis is referred to a Life Cycle Costing. To obtain a project Present Worth (PW) or Life Cycle Cost (LCC), all costs and salvage values are forecast over the time horizon being considered, and then these cash flows are discounted to obtain a single equivalent present worth. The present worth can then be easily converted to a levelized annual cost if necessary. The basic formulas developed earlier can be applied to the project costs described in the last section. The costs that are included in typical projects consist of acquisition, replacement, maintenance, salvage and operating costs as well as taxes and depreciation. Because these costs can occur yearly over the complete analysis period, the Present Worth is found by summing the contributions of each cost component over the total project period:

> Cost Components: Net Annual Investments, Salvage of End of Life Equipment, Net Income, Taxes, Maintenance costs, Energy Costs

These annual cash flows must now be combined by discounting to the present to obtain the complete project present worth. This is accomplished by multiplying each term by $(1 + i)^j$, where j is the number of years to be discounted to the present. This is shown in the equation below where the possibility of energy escalation is also included:

$$\mathrm{PW} = -\mathrm{C} + \frac{S}{(1+i)^n} + \sum_{j=1}^{n} \frac{\left(I_j - T_j\right)}{(1+i)^j} - \mathrm{M}\frac{(1+i)^n - 1}{i(1+i)^n} - \mathrm{F}\sum_{j-1}^{n}\left(\frac{1+e}{1+i}\right)^j$$

where:

	PW	=	Present worth of the cost of the project over the project life of n years;
	C	=	Initial investment cost, including costs of acquisition, delivery, and installation;
	S	=	Salvage or remaining value of equipment at end of period of analysis;
	I_j	=	Income or savings generated by project in year j at present prices;
	D_j	=	Depreciation allocation cost in year j at present prices;
	T_j	=	Taxes on net income less depreciation in year j at present prices;
	M	=	Estimated annual maintenance and replacement cost at present prices, here assumed constant over the life of the project. (These could be treated like energy cost, if necessary.);
	F	=	Estimated annual energy cost at present prices—there could be other terms involving energy if more than one energy source is involved;
	i	=	Discount rate or MARR; and
	e	=	Energy price escalation rate.

In many cases it is only necessary to consider differences between alternatives when two or more projects are being compared. For example, when evaluating an energy conservation project, only the project investment and energy savings need be considered. Costs that are common among alternatives, and hence, do not affect the selection decision, can be ignored.

3.5. Methods of Comparing Projects

There are a large number of methods for comparing the economic value of different projects. The ones that will be considered here are:

(1) Simple Payback Period (PP_s),
(2) Discounted Payback Period (PP_{DFC}),
(3) Internal Rate of Return $(IRR)_{DFC}$,

(4) Net Present Worth Analysis (NPW), and
(5) Annualized Cost (AC).

Other methods are used, but the above are common and illustrate the principles and possibilities. The Payback methods have the major advantage of their simplicity and ease of computation. They can, however, very often lead to erroneous or inconsistent conclusions. The reason, of course, is they ignore project life, taxes, and depreciation. Moreover, the simple Payback period also ignores the time value of money — a most serious omission. Payback methods are recommended only for quick, preliminary project evaluation, but not for serious comparison of competing projects. For better comparisons, the return on investment or internal rate of return method is recommended.

Discounted Payback, Net Present Worth, Internal Rate of Return and Annualized Cost methods require an assumption of an interest rate or minimum attractive rate of return (MARR). Comparison of alternatives requires equal study periods for all alternatives. If alternatives have different live spans, the comparison of alternatives will require determining a common study period. One frequently used method is to use a study period determined by the least common multiple of project lives.

The notation used in this section is as follows:

C	=	Initial Cost ($);
S_1	=	First Year's Net Savings;
PP_s	=	Simple Payback Period (years);
i	=	Interest Rate (decimal);
e	=	Energy Escalation Rate (decimal);
PP_{DCF}	=	Discounted Payback Period (years);
$(IRR)_{DCF}$	=	Discounted Cash Flow Internal Rate of Return (Decimal);
NPW	=	Net Present Worth of Project ($); and
AC	=	Annualized Cost ($).

3.5.1. The Payback Period Methods

A commonly used method of comparing projects is Simple Payback Period. It is computed by summing all cash flows (receipts and disbursements) until there is a net greater than or equal to zero. This simple calculation neglects both the time value of money and the effects of escalating energy costs. It is clearly unfair to include one without the other.

To compute a Payback period that considers both factors, we must find the value of n in the Modified Uniform Present Worth Factor (UPW^*), such that:

$$A_0\,(UPW^*) = C, \text{ or}$$
$$A_0\,[(f^n - 1)f/(f - 1)] = C.$$

Solving for this n and calling it the Discounted Payback Period (PP_{DCF}):

$$PP_{DCF} = \frac{\ln\left[1 + \dfrac{(C/A_0)(f-1)}{f}\right]}{\ln f}$$

EXAMPLE 13: A heat recovery project costs $20,000 and saves $5000 each year. The interest rate is 9%, and energy costs are assumed to escalate at 15% per year. The planned life of the equipment to be installed is 8 years. Compute

(a) The Simple Payback Period, and

(b) The Discounted Payback Period.

SOLUTION: (a) PPs = -20,000 + (5000*4) = 4 years.

(b) $$PP_{DCF} = \frac{1n\left[1+\frac{(C/S_1)(f-1)}{f}\right]}{1n\, f}$$

$$f = (1+e)/(1+i) = 1.15/1.09 = 1.0550459$$

$$PP_{DCF} = .18954189 / .05358427 = 3.54 \text{ years}$$

It is often helpful, and sometimes necessary in more complex cases, to work out Payback periods using tables that show each year's net savings and (discounted) cash flow. Then the cumulative project cash flow is calculated, giving a graphic illustration of the project's Payback. The results for the preceding example are shown in Tables 1 and 2.

Table 1. Determining simple payback period. See Example 13.

YEAR	CASH OUTLAY	NET INCOME BEFORE TAXES AND DEPRECIATION	NET CASH FLOW	CUMULATIVE CASH FLOW
0	20,000	–	(20,000)	(20,000)
1	0	5,000	5,000	(15,000)
2	0	5,000	5,000	(10,000)
3	0	5,000	5,000	(5,000)
4	0	5,000	5,000	0

Table 2. Determining discounted payback period (e = .15; i = .09). See Example13.

YEAR	CASH OUTLAY	NET INCOME BEFORE TAXES AND DEPRECIATION	NET CASH FLOW	DISCOUNTED CASH FLOW	CUMULATED DISCOUNTED CASH FLOW
0	20,000	–	–	(20,000)	(20,000)
1	0	5,750	5,750	5,275	(14,725)
2	0	6,613	6,613	5,566	(9,159)
3	0	7,604	7,604	**5,872**	(3,287)
4	0	8,745	8,745	6,195	2,908

A note of Caution: A favorite "trick" to prove the worth of one's pet idea (or lack of worth of the ideas of others) is to include the effects of either the energy escalation rate or the interest rate, but not both. Energy escalation without interest gives extremely rapid, but false, Payback. On the other hand, including interest effects without energy escalation gives longer, equally false, Payback periods. This is shown in Tables 3 and 4.

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Table 3. False payback period when energy escalation is included and interest is ignored.

YEAR	CASH OUTLAY	NET INCOME BEFORE TAXES AND DEPRECIATION	NET CASH FLOW	CUMULATIVE CASH FLOW
0	20,000	–	–	(20,000)
1	–	5,750	5,750	(14,250)
2	–	6,613	6,613	(7,637)
3	–	7,604	7,603	(33)
4	–	8,745	8,745	8,712

Table 4. False payback when interest is included, but energy escalation is ignored.

YEAR	CASH OUTLAY	NET INCOME BEFORE TAXES AND DEPRECIATION	NET CASH FLOW	DISCOUNTED CASH FLOW	CUMULATED DISCOUNTED CASH FLOW
0	20,000	–	(20,000)	(20,000)	(20,000)
1	–	5,000	5,000	4,587	(15,413)
2	–	5,000	5,000	4,208	(11,205)
3	–	5,000	5,000	3,861	(7,344)
4	–	5,000	5,000	3,542	(3,802)
5	–	5,000	5,000	3,242	(597)
6	–	5,000	5,000	2,982	2,385

3.5.2. The Rate of Return Investment (IRR) Method

Just as there are several definitions of Payback period, there are also several methods of computing return on investment. All rate of return methods involve computing a ratio of some measure of the project profits to some measure of the required investment. The variation in the methods is the result of different ways of measuring profits and/or investment.

We will only consider the discounted cash flow method, called the Internal Rate of Return (IRR) method. No arbitrary discount (interest or MARR) rate is selected at the outset. Instead, the discount rate is computed that makes the net discounted cash flow (after taxes and depreciation) equal to zero over the period of analysis, the $(IRR)_{DCF}$. This can be viewed as a breakeven point, i.e., IRR is the rate of return at which receipts equal disbursements. The computed IRR can then be compared to the firm's minimum attractive rate of return (MARR) to determine if the project is acceptable (i.e., does it meet or exceed the MARR hurdle).

This method is one of the best ways to compare the economic worth of competing projects. In previous years, calculating the discount rate (IRR) required some trial and error and interpolation. Advances in hand-held calculators and spreadsheets have now eliminated this tedious process.

Table 5 shows the longhand computation from example problem 13 used previously. Trial discount rates of 15%, and 20% were computed indicating the IRR, the rate where present value = 0 is somewhere in between these two rates. Through interpolation, it can be shown that the Discounted Cash Flow IRR is 18.85%.

Table 5. Determining IRR for example problem 13.

YEAR	Cash Outlay	Net Income Before Taxes and Depreciation	Depreciation	Income Before Taxes	Tax	Net Income After Taxes and Depreciation	Discounted Net Income
0	(20,000)	–	--	–	-	–	-
1	-	5,000	2500	2500	1250	3750	3440
2	-	5,750	2500	3250	1625	4125	3472
3	-	6,613	2500	4113	2056	4557	3519
4	-	7,604	2500	5104	2552	5052	3560
5	-	8,745	2500	6245	3122	5623	3655
6	-	10,057	2500	7557	3779	6278	3743
7	-	11,565	2500	9065	4532	7033	3847
8	-	13,300	2500	10,800	5400	7900	3965
YEAR	Net Income After Tax	15% Discount Rate	Net Cash Flow	20% Discount Rate	Net Cash Flow	18.85% Discount Rate	Net Cash Flow
0	–	–	(20,000)	–	(20,000)	–	(20,000)
1	3,750	3,261	(16,739)	3,125	(16,875)	3,155	(16,845)
2	4,125	3,119	(13,620)	2,865	(14,010)	2,920	(13,925)
3	4,557	2,996	(10,624)	2,637	(11,373)	2,714	(11,211)
4	5,052	2,888	(7,736)	2,436	(8,937)	2,532	(8,679)
5	5,623	2,796	(4,940)	2,260	(6,677)	2,371	(6,309)
6	6,278	2,714	(2,226)	2,102	(4,575)	2,227	(4,081)
7	7,033	2,644	418	1,963	(2,612)	2,100	(1,980)
8	7,900	2,583	3,001	1,837	(775)	1,984	4

Not all projects return proceeds in equal installments, or even in neatly escalating proceeds as with rising energy costs. When this is the case, the analysis is handled in exactly the same way except, of course, that the annual variations must be entered in the analysis and calculations are a bit more involved.

3.5.3. Comparing Alternatives

To complete this discussion, we will give an example of the use of the methods described in this paper based on a comparison between two vastly different projects.

Project A is a proposed purchase of a new production machine costing \$190,000. Machine maintenance is expected to be \$1,000 per year. Increased productivity as a result of the new machine will yield added revenues of \$35,000 the first year, escalating \$2,500 the second year, and every year thereafter for the life of the equipment (10 years). Depreciation is to be straight line. Salvage value is 0. Money is available at 10%.

Project B is a proposed energy recovery project costing \$160,000. Maintenance is expected to be \$1000 per year except for a major \$4000 replacement in the fifth, tenth and fifteenth years. The life of the project is expected to be 20 years, with an allowed straight-line depreciation over 10 years. Salvage value is 0. First year energy savings are $30,000 per year escalating at an assumed rate of 12%. Money is available at 10%.

Since these are investment alternatives, we must also consider the case where neither project is chosen (i.e., the "Do Nothing" alternative). We will first examine the economic analysis for a public entity, which would not be expected to pay taxes. The two project analyses are given in Table 6. Since the project life duration for the projects are not the same (10 versus 20), we apply the least common multiple rule (assuming repeatability) for a common study period. As such, the Project A cash flow and study period has been extended from 10 to 20 years. This approach assumes that the purchase of a new machine would occur again in year 10, and that the identical cash flow in years 1 through 10 would repeat for years 11 through 20.

Table 6. Cash flow analysis for projects A and B without consideration of taxes.

PROJECT A					PROJECT B			
Periods	Cash Outflow	Cash Inflow	Net Cash Flow	Discounted Cash Flow	Cash Outflow	Cash Inflow	Net Cash Flow	Discounted Cash Flow
0	-190,000	0	-190,000	-190,000	-160,000	0	-160,000	-160,000
1	-1,000	35,000	34,000	30,909	-1,000	30,000	29,000	26,364
2	-1,000	37,500	36,500	30,165	-1,000	33,600	32,600	26,942
3	-1,000	40,000	39,000	29,301	-1,000	37,632	36,632	27,522
4	-1,000	42,500	41,500	28,345	-1,000	42,148	41,148	28,105
5	-1,000	45,000	44,000	27,321	-5,000	47,206	42,206	26,206
6	-1,000	47,500	46,500	26,248	-1,000	52,870	51,870	29,279
7	-1,000	50,000	49,000	25,145	-1,000	59,215	58,215	29,873
8	-1,000	52,500	51,500	24,025	-1,000	66,320	65,320	30,472
9	-1,000	55,000	54,000	22,901	-1,000	74,279	73,279	31,077
10	-191,000	57,500	-133,500	-51,470	-5,000	83,192	78,192	30,147
11	-1,000	35,000	34,000	11,917	-1,000	93,175	92,175	32,307
12	-1,000	37,500	36,500	11,630	-1,000	104,356	103,356	32,933
13	-1,000	40,000	39,000	11,297	-1,000	116,879	115,879	33,566
14	-1,000	42,000	41,500	10,928	-1,000	130,905	129,905	34,208
15	-1,000	45,000	44,000	10,533	-5,000	146,613	141,613	33,901
16	-1,000	47,500	46,500	10,120	-1,000	164,207	163,207	35,519
17	-1,000	50,000	49,000	9,694	-1,000	183,912	182,912	36,188
18	-1,000	52,500	51,500	9,263	-1,000	205,981	204,981	36,868
19	-1,000	55,000	54,000	8,829	-1,000	230,699	229,699	37,558
20	-1,000	57,500	56,500	8,398	-1,000	258,383	257,383	38,258
		TOTAL	525,000	105,500		**TOTAL**	1,969,573	477,293

The evaluation of the "Do Nothing", Project A, and Project B alternatives was conducted using the NPW method without considering the effect of income taxes. These analyses yielded NPW values of approximately $0, $105,500, and $477,293 for "Do Nothing", Project A, and Project B, respectively. Project B is found to be the most attractive alternative due to the highest value of NPW.

If we consider the Cumulative Simple Payback, for Project A the period is 4.9 years and for Project B 4.5 years. If we perform the same type of summing of net savings but with accumulation of the discounted cash flows, the Discounted Cumulative Payback period is 6.7 years for Project A and 5.9 years for Project B. Notice, that when these non-uniform cash flows are considered, the advantage shifts to Project B where the positive net cash flows, relative to Project A, escalate faster as time passes.

The alternatives can also be compared using the IRR method, again taxes are not considered for this public entity. First, the three alternatives are arranged in increasing order of initial invested capital: "Do Nothing", Project B, and Project A. Starting with the lowest investment alternative, the incremental cash flow difference from "Do Nothing" to Project B can be determined. The NPW of this change in cash flow was calculated and then compared to the value of MARR. This analysis was conducted comparing the result to a MARR of 10% indicating the net effect of Project B over Do Nothing is preferable with an IRR = 29.2% (greater than MARR). The next pair-wise comparison would be to compare the "winner" to the next alternative in the ranking. In this case, B to A. Below in Table 7 is the comparison proving that Project B is also preferable to Project A. Even without explicitly calculating the value of IRR, it is obvious from the discounted cash flow of the increment that the IRR will be less than MARR. The cumulative total is quite negative and no where nears the needed breakeven value of a NPW of zero to be equivalent to MARR. Should there have been additional alternatives, these calculations would be carried out in a pair-wise and incremental fashion until all alternatives had been considered. Ultimately, the final selection would be the alternative remaining after all net (incremental) comparisons.

Table 7. IRR analysis for Project A versus Project B without consideration of taxes.

PROJECT A vs. PROJECT B				
Periods	Net Cash Flow (B)	Net Cash Flow (A)	Incremental Change (B-A)	Discounted Cash Flow for MARR=10%
0	-160,000	-190,000	-30,000	-30,000
1	29,000	34,000	5,000	4,545
2	32,600	36,500	3,900	3,223
3	36,632	39,000	2,368	1,779
4	41,148	41,500	352	241
5	42,206	44,000	1,794	1,114
6	51,870	46,500	-5,370	-3,031
7	58,215	49,000	-9,215	-4,729
8	65,320	51,500	-13,820	-6,447
9	73,279	54,000	-19,279	-8,176
10	78,192	-133,500	-211,692	-81,617
11	92,175	34,000	-58,175	-20,390
12	103,356	36,500	-66,856	-21,303
13	115,879	39,000	-76,879	-22,269
14	129,905	41,500	-88,405	-23.280

15	141,613	44,000	-97,613	-23,368
16	163,207	46,500	-116,707	-25,399
17	182,912	49,000	-133,912	-26,494
18	204,981	51,500	-153,481	-27,605
19	229,699	54,000	-175,699	-28,728
20	257,383	56,500	-200,883	-29.860
		TOTAL	-1,444,573	-371,793

When taxes are included, the case for a private company, the analysis becomes slightly more involved. Depreciation is used in order to account for the business expense of the investment costs and taxes reduce the net savings. Tables 8 and 9 show the analysis for each project.

For the situation where taxes are included, the NPW and IRR methods are reevaluated to include the effects of depreciation and income taxes. Assuming straight-line depreciation, an income tax rate of 50%, and a study period of 20 years for both alternatives, the NPW method yields the following results: $0, $2,002, $207,803, for "Do Nothing", Project A, and Project B, respectively. Again it is determined that Project B is the selected alternative. This can be reconfirmed with an incremental IRR calculation (taking the difference of each after-tax cash flow and calculate IRR).

The Cumulative Simple Payback is 6.4 years for Project A and 4.5 years for Project B. When the cumulative cash flows are discounted, the Payback period becomes 9.9 years for Project A and 8.2 years for Project B.

Table 8. Cash flow analysis for Project A with consideration of taxes.

PROJECT A							
Periods	Cash Outflow	Cash Inflow	Depreciation	Net Cash Flow	Tax(50%)	After Tax Net Cash Flow	Discounted Cash Flow
0	-$190,000	$0		-$190,000		-$190,000	-$190,000
1	-$1,000	$35,000	$19,000	$34,000	$7,500	$26,500	$24,091
2	-$1,000	$37,500	$19,000	$36,500	$8,750	$27,750	$22,934
3	-$1,000	$40,000	$19,000	$39,000	$10,000	$29,000	$21,788
4	-$1,000	$42,500	$19,000	$41,500	$11,250	$30,250	$20,661
5	-$1,000	$45,000	$19,000	$44,000	$12,500	$31,500	$19,559
6	-$1,000	$47,500	$19,000	$46,500	$13,750	$32,750	$18,487
7	-$1,000	$50,000	$19,000	$49,000	$15,000	$34,000	$17,447
8	-$1,000	$52,500	$19,000	$51,500	$16,250	$35,250	$16,444
9	-$1,000	$55,000	$19,000	$54,000	$17,500	$36,500	$15,480
10	-$191,000	$57,500	$19,000	-$133,500	$18,750	-$152,250	-$58,699
11	-$1,000	$35,000	$19,000	$34,000	$7,500	$26,500	$9,288
12	-$1,000	$37,500	$19,000	$36,500	$8,750	$27,750	$8,842
13	-$1,000	$40,000	$19,000	$39,000	$10,000	$29,000	$8,400
14	-$1,000	$42,500	$19,000	$41,500	$11,250	$30,250	$7,966
15	-$1,000	$45,000	$19,000	$44,000	$12,500	$31,500	$7,541
16	-$1,000	$47,500	$19,000	$46,500	$13,750	$32,750	$7,127
17	-$1,000	$50,000	$19,000	$49,000	$15,000	$34,000	$6,727
18	-$1,000	$52,500	$19,000	$51,500	$16,250	$35,250	$6,340
19	-$1,000	$55,000	$19,000	$54,000	$17,500	$36,500	$5,968
20	-$1,000	$57,500	$19,000	$56,500	$18,750	$37,750	$5,611

Table 9. Cash flow analysis for Project B with consideration of taxes.

PROJECT B							
Periods	Cash Outflow	Cash Inflow	Depreciation	Net Cash Flow	Tax(50%)	After Tax Net Cash Flow	Discounted Cash Flow
0	-160,000	0		-160,000		-160,000	-160,000
1	-1,000	30,000	16,000	29,000	6,500	22,500	20,455
2	-1,000	33,600	16,000	32,600	8,300	24,300	20,083
3	-1,000	37,632	16,000	36,632	10,316	26,316	19,772
4	-1,000	42,148	16,000	41,148	12,574	28,574	19,516
5	-5,000	47,206	16,000	42,206	13,103	29,103	18,071
6	-1,000	52,870	16,000	51,870	17,935	33,935	19,155
7	-1,000	59,215	16,000	58,215	21,107	37,107	19,042
8	-1,000	66,320	16,000	65,320	24,660	40,660	18,968
9	-1,000	74,279	16,000	73,279	28,639	44,639	18,931
10	-5,000	83,192	16,000	78,192	31,096	47,096	18,158
11	-1,000	93,175		92,175	46,088	46,088	16,153
12	-1,000	104,356		103,356	51,678	51,678	16,466
13	-1,000	116,879		115,879	57,940	57,940	16,783
14	-1,000	130,905		129,905	64,952	64,952	17,104
15	-5,000	146,613		141,613	70,807	70,807	16,951
16	-1,000	164,207		163,207	81,603	81,603	17,759
17	-1,000	183,912		182,912	91,456	91,456	18,094
18	-1,000	205,981		204,981	102,491	102,491	18,434
19	-1,000	230,699		229,699	114,849	114,849	18,779
20	-1,000	258,383		257,383	128,691	128,691	19,129

4. Summary and Recommendations

It is critical to recognize the importance of engineering economic analysis for energy-related problems of energy usage and capital investment decisions. Indeed, the economic impact of decisions for such decisions can be significant for the public and private sectors. The intent of this paper has been to provide a primer that can be used to teach the basic principles of economic analysis necessary to understand and evaluate energy-related alternatives. It can also serve as a primer that could be used as an introduction to engineering economy for the many engineering disciplines providing brief coverage rather than a full course on the subject. It is our intent that this primer could be helpful for those situations where coverage is limited and textbooks are not required. It has also been used by the authors in undergraduate and graduate courses on engineering economy as a supplement to stimulate discussion and provide examples that are readily understood and of interest to students.

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Biographies

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