Financial Analysis of Energy Savings

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Introduction

The topic of energy savings is an important and relevant one. Not only is the issue important from the point of view of conserving valuable non-renewable energy resources, but its role in abating greenhouse gas emission (the cause of Global Warming) is significant. Energy savings is a fairly generic term encompassing on the one hand housekeeping measures and conservation and on the other advanced technologies. However, the fundamental issue in all energy savings is that it will invariably involve some costs to implement. The financial and economic implications arise out of the fact that investment funds always entail opportunity costs. The fact that funds to implement energy savings are subject to interest payments implies that formal costing methodologies must be employed to judge the advisability of implementing a particular energy saving scheme.

As a result of the Kyoto Protocol, which imposes binding greenhouse gas reduction commitments on developed countries, energy saving has acquired a new dimension. In the usual case, energy savings can only be implemented if it makes financial and economic sense, i.e. at the very least the costs of implementing a particular scheme are recovered. But in the regime of compulsory carbon dioxide emission reduction requirement, energy savings can and will probably be implemented even if the costs are not recovered. However, the cheaper an option the more (or earlier) it would be favored. Thus, the cost effectiveness of an energy savings scheme is a crucial issue.

A fundamental concept in evaluating projects is the life cycle costing. With energy savings this concept is particularly significant because often due to the high initial cost of an efficient technology, it is difficult to appreciate that on the long run (due to the accumulated energy savings) the project would be beneficial. This aspect of the benefits of energy efficiency projects not being readily apparent (because advanced technologies have long lives and the annual energy savings are deceptively small) is probably the single largest barrier to implementing efficiency projects.

This article will treat the topic of financial analysis of energy savings under several headings. At the very outset, the concept of interest rate, discounting and costing of energy savings projects will be dealt with. After that the optimization of particular schemes will be discussed. The presentation will end with examples of energy savings options for Bangladesh.

Fundamental Principles of Costing Energy Savings

Key element of dynamics [1]

Interest Rate

The **Interest Rate** (often called the *Discount Rate* in resource contexts) is the fraction of the value of a borrowed resource paid by the borrower to the lender. The (simple) interest rate of the loan, denoted **r**, can be found by solving the following equation for r:

> Principal + Interest = (1 + r) Principal
> For example: \$110 = (1 + r) \$100
> So, we find: r = 10/100 or 10%
> Hence, the interest rate on the loan was 10%.
> Generally, we can find the interest rate by noting that:
> $B1 = B0 + r\,B1 = (1+r)\,B0$
> where B0 = Benefit today, and B1 = Benefit tomorrow

Discounting

Discounting is a mechanism used to compare streams of net benefits generated by alternative allocations of resources over time. There are two types of discounting, depending on how time is measured. If time is measured as a discrete variable (say, in days, months or years), discretetime discounting formulas are used, and the appropriate real interest rate is the "simple real interest rate". If time is measured as a continuous variable, then continuous-time formulas are used, and the appropriate real interest rate is the "instantaneous real interest rate". We will use discrete-time discounting in this course. Hence, we will use discrete-time discounting formulas, and the real interest rate we refer to is the simple real interest rate, r. Unless stated otherwise, assume that r represents the simple real interest rate.

From a lender's perspective, 10 dollars received at the beginning of the current time period is worth more than 10 dollars received at the beginning of the next time period. That's because the lender could lend the 10 dollars received today to someone else and earn interest during the current time period. In fact, 10 dollars received at the beginning of the current time period would be worth \$10(1 + r) at the beginning of the next period, where r is the interest rate that the lender could earn on a loan.

Viewed from a different perspective, if 10 dollars were received at the beginning of the next time period, it would be equivalent to receiving only \$10/(1 + r) at the beginning of the current time period. The value of 10 dollars received in the next time period is discounted by multiplying it by 1/(1+r).

Discounting is a central concept in natural resource economics. So, if \$10 received at the beginning of the next period is only worth \$10/(1 + r) at the beginning of the current period, how much is \$10 received *two* periods from now worth? The answer is $\$10/(1 + r)^2$. In general, the value today of \$B received t periods from now is $\$B/(1 + r)t$. The value today of an amount received in the future is called the Present Value of the amount.

The concept of present value applies to amounts *paid* in the future as well as to amounts received. For example, the value today of \$B paid t periods from now is $\$B/(1 + r)^t$. Note that if the interest rate increases, the value *today* of an amount received in the future declines. Similarly, if the interest rate increases, then the value *today* of an amount paid in the future declines.

For example, say you win the lottery! You are awarded after-tax income of \$1M. However, this is not handed to you all at once, but at \$100K/year for 10 years. If the interest rate is, $r = 10\%$, net present value:

$$NPV = 100K+(1/1.1)100K+(1/1.1)^2 100K + (1/1.1)^3 100K + \ldots + (1/1.1)^9 100K. = \$675,900$$

The value of the last payment received is: $NPV = (1/1.1)^9 100K = \$42,410$.

That is, if you are able to invest money at $r = 10\%$, you would be indifferent between receiving the flow of \$1M over 10 years and \$675,900 today or between receiving a one time payment of \$100K 10 years from now and \$42,410 today.

Cash flow evaluation [2]

This method is based on discrete discounting. Suppose there is an energy firm. For instance, an IPP (Independent Power Producer)

R: revenue - energy sales
C: costs - operational expenses

π- profit **π = R - C**

In order to find out how much the business is worth we want to know its Net Present Value (NPV), assuming an operational lifetime (t). Start with a steady business, which produces the same revenue every year [3].

Capital Recovery Factor (CRF)

$$\boxed{PV = \frac{B}{r}\left(1 - \frac{1}{(1+r)^t}\right)}$$

Here we have PV as a functionof B but the converse is also useful. How much is PV worth in the future in terms of annual payments invested now?

Suppose you buy a Compact Fluorescent Light (CFL). The cost of the CFL is the PV of the investment. You know that per month you can save X kWh, based on the difference between the power of the CFL and regular light bulbs, the period of use, and the electricity cost. The (CRF)•(PV) shows how much your investment is worth per month, over the life time of the equipment.

(In the case of light bulbs, of course, the lifetime is a function of its usage.)

$$\boxed{PV = \frac{B}{r}\left(1 - \frac{1}{(1+r)^t}\right)} \Rightarrow \frac{(PV)r}{\left(1 - \frac{1}{(1+r)^t}\right)} = B \Rightarrow B = PV\left[\underbrace{\frac{r}{1-(1+r)^{-t}}}_{\text{CRF}}\right]$$

$$\boxed{CRF = \frac{r}{1-(1+r)^{-t}}}$$

Example 1: Electricity cost for a Natural Gas power plant (¢/kWh)

Assumptions:

- $450 per kW of installed capacity = fixed cost
- 80% capacity factor
- 98% of operational costs is fuel
- 1 kWh = 3414 Btu
- natural gas price $3/million BTU
- life time of the power plant is 20 years, η=0.4

Life Cycle Cost -- **The overall estimated cost for a particular program alternative over the time period corresponding to the life of the program, including direct and indirect initial costs plus any periodic or continuing costs of operation and maintenance.**

Analysis:

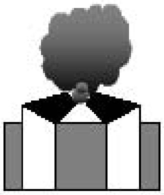
Total cost → PV = fixed cost + PV{of recurring operational costs (O&M)}

Annual Energy Output (AEO) → E = (capacity factor) • (8,760 hrs/yr) • (1kW of capacity/yr)

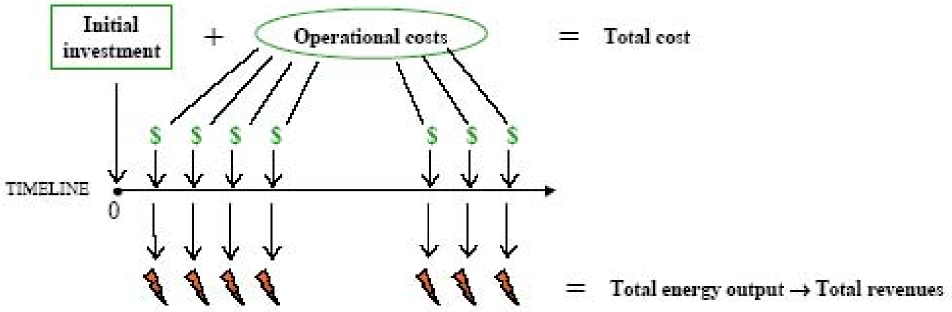
= (0.8) • (8,760 hrs) • (1kW) = 7,008 kWh

$$\text{PV (O\&M)} = \frac{\text{AEO}}{\text{conversion efficiency}} \cdot \frac{\text{fuel cost}}{98\%} \rightarrow$$

$$\text{PV(O\&M)} = \left\{\frac{7{,}008\ \text{kWh}}{0.4} \cdot (3414\ \text{Btu/kWh})\right\} \cdot \frac{(\$3/\text{MMBtu})}{0.98} = \$183$$



Electricity cost for a Natural Gas power plant (¢/kWh)



$$\text{electricity cost} = \frac{\text{PV}}{\text{(Total Energy output)}} \left\{ \begin{array}{l} PV = \$450 + \frac{\$183}{0.07}\left(1 - \frac{1}{(1+0.07)^{20}}\right) \\ \text{total output} = 7{,}008 \times 20 = 140{,}160\ \text{kWh} \end{array} \right\} \boxed{\text{cost} = \frac{\$2388}{140{,}160\ \text{kWh}} = 1.7\text{¢/kWh}}$$

cheap!

- taxes,
- profits,
- externalities

Photovoltaic Plant Calculation

PV Plant capital cost:	\$4000/kW
20 year lifetime, 8% interest rate	
Fixed charge factor:	$= r/[1-(1-r)^{-n}] = 0.13$/year

Annualized payment = (FCF) (capital cost)

Annualized Payment = (\$4000/kW) (0.13/year) = \$520/kW-year

O&M = \$24/kW-y (SEGS, LA County)

Total Annual Cost = \$544/kW-y

If the capacity factor is 0.32, then annual production is

(8760 h/y) x 0.32 = 2766 kWh/kW-y

Levelized cost of energy = (\$540.14/kW-y)/2766 kWh/kW-y) = \$0.19/kWh

Calculation Methodology: Cost of Conserved Energy [4]

An energy-efficient building or appliance is of no economic interest unless the value of the energy savings exceeds the additional cost of the investment. Here, we explain how we calculate the economics of investment in energy efficiency. We assume that the consumer borrows the money for the efficient appliance or building and pays off the loan in a series of equal annual payments. We call the portion of his payments that covers the extra cost of greater efficiency an annual "surcost." Dividing the annual surcost by the annual energy savings tells how much the consumer is spending to avoid buying a unit of energy. This is called the cost of conserved energy (CCE). Where the CCE is less than the cost of buying energy, conservation makes economic sense. The formula for CCE is:

$$\boxed{Cost\,of\ Conserved\ Eneregy\,(CCE) = \frac{annualized\ surcost}{annual\,energy\,savings}}$$

The following example shows how the values for the cumulative net savings can be calculated. Consider solid-state fluorescent light ballasts. One of these ballasts saves 100 kWh per year and last 10 years costing $12 more than conventional ballasts. Are they worth the extra cost? To find the answer to this question, we must first find the cost of conserved energy. Assume the $12 is borrowed from a bank for 10 years at a 7% real interest rate, where "real" means net of inflation. The "annual surcost" (annual bank payment on the loan) is $1.70. The Equation above then gives

$$\boxed{CCE = \frac{annualized\ surcost}{annual\,energy\,savings} = \frac{\$1.70\,/\,yr}{100kWh\,/\,yr} = \frac{1.7cents}{kWh}}$$

A CCE of 2 cents/kWh is far cheaper than purchase price of electricity (7.5-10 cents/kWh). Thus, the more efficient ballast is an attractive investment.

The CCE tells us that the ballasts are a good investment. Next we want to calculate our net annual saving, which is simply the energy cost savings minus the annualized surcost.

Net Savings = Energy Cost Saved – Surcost

For ballast, the energy savings are 100 kWh/yr. Assuming electricity prices of 7.5 cents/kWh, the gross savings are

100 kWh/yr × 7.5 cents/kWh = $7.50/yr

We already calculated that the annualized surcost for the ballast is $1.70/yr. Thus,

Net savings = $7.50/yr - $1.70/yr = <u>$5.80/yr</u>

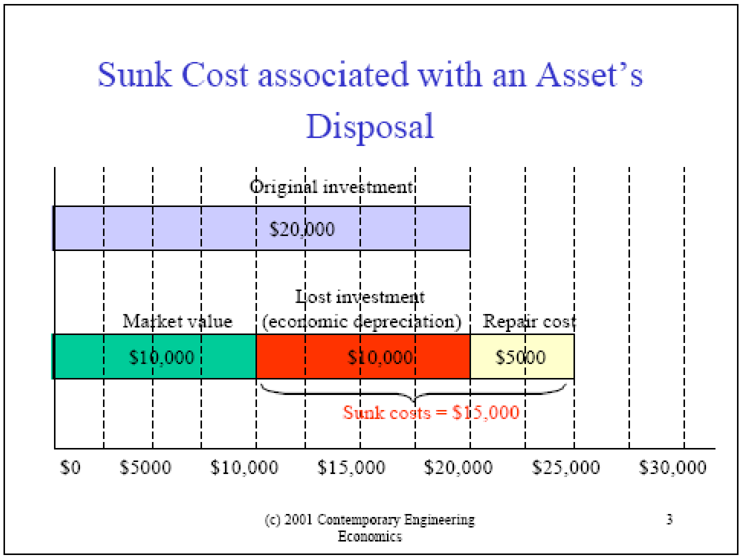
Replacement Decisions [5]

- The role of technological change in asset improvement should be weighed in making long-term replacement plans
- In replacement analysis, the **defender** is an existing asset; the **challenger** is the best available replacement candidate. Ultimately, in replacement analysis, the question is not whether to replace the defender, but when to do so
- The **current market value** is the value to use in preparing a defender's economic analysis. **Sunk costs**—should not be considered in a defender's economic analysis

Replacement Terminology

Sunk cost: any past cost unaffected by any future decisions
Trade-in allowance: value offered by the vendor to reduce the price of a new equipment

Defender: an old machine
Challenger: new machine
Current market value: selling price of the defender in the market place



Sunk Cost associated with an Asset's Disposal

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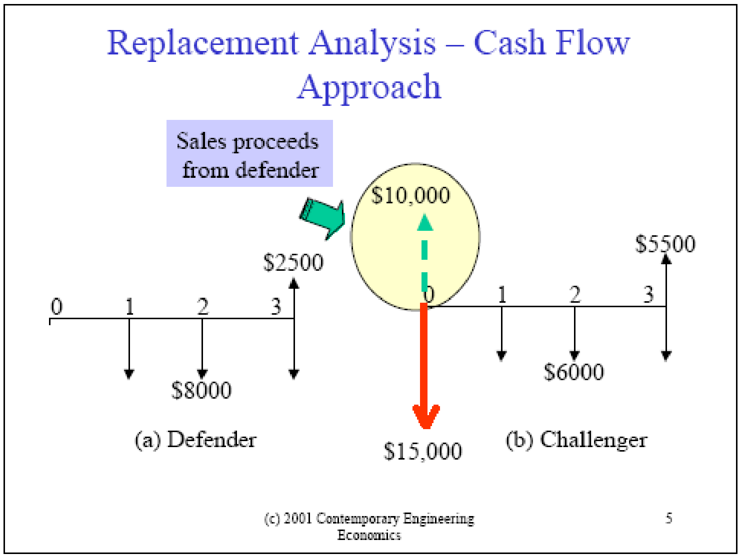
Replacement Analysis Approaches

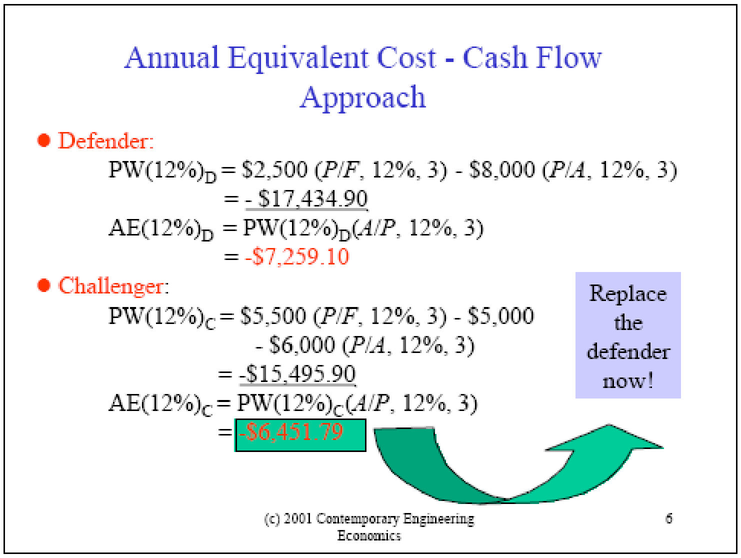
Cash Flow Approach
Treat the proceeds from sale of the old machine as down payment toward purchasing the new machine

Opportunity Cost Approach
Treat the proceeds from sale of the old machine as the investment required to keep the old machine



Replacement Analysis – Cash Flow Approach

Sales proceeds from defender



Annual Equivalent Cost - Cash Flow Approach

- Defender:

$PW(12\%)_D = \$2{,}500\ (P/F, 12\%, 3) - \$8{,}000\ (P/A, 12\%, 3)$
$= \underline{-\ \$17{,}434.90}$
$AE(12\%)_D = PW(12\%)_D(A/P, 12\%, 3)$
$= -\$7{,}259.10$

- Challenger:

$PW(12\%)_C = \$5{,}500\ (P/F, 12\%, 3) - \$5{,}000$
$- \$6{,}000\ (P/A, 12\%, 3)$
$= \underline{-\$15{,}495.90}$
$AE(12\%)_C = PW(12\%)_C(A/P, 12\%, 3)$
$= \boxed{-\$6{,}451.79}$

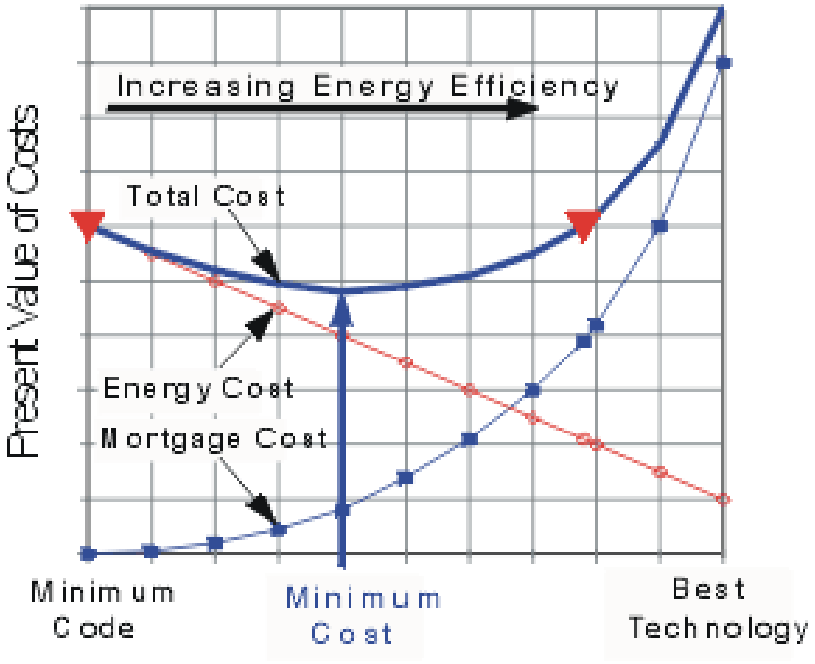
Replace the defender now!

Cost Minimization [6]

As you improve the efficiency of a new home, the present value of its "price" (mortgage cost) increases - more and more rapidly as you approach the best available technology. Simultaneously, however, the operating cost (energy cost) decreases. There is a point, which is much more energy efficient than Minimum Code, at which the sum of the mortgage and energy cost (**total cost**) is minimized. This point is labeled on the horizontal axis of chart as *Minimum Cost* with an *arrow* pointing to the lowest point on the total cost curve. It is worth noting that the cost of owning the minimum code home is greater than the cost of owning a more energy efficient home until the point indicated by the large triangle on the right side of the total cost curve is reached. Thus, substantial improvements in efficiency (and quality and comfort) are typically very cost-effective.

Most homes, new or existing, can be substantially improved and return money to their owner from day one!

The chart below illustrates how these savings occur, even in proposed new, "code-compliant" homes.



A Real-Life Example of Energy Efficiency Improvement Possibility

ElectroFlow^{TM} system developed by Electenergy Technologies Inc. of USA, helps industries and governments to optimize the use of electrical energy which results in up to 34% energy savings. ElectroFlow^{TM} is a microprocessor based control system, operating on ladder logic principle, will insure continuous monitoring of system's reactive power/power factor (X/R), and threshold current. An automatic system, equipped with variable high and low adjustments, whose control employs data inputs other than that of the system's reactive current component will perform during its corrective process in a damped or tuned RLC network response to an indicative or relative manner.

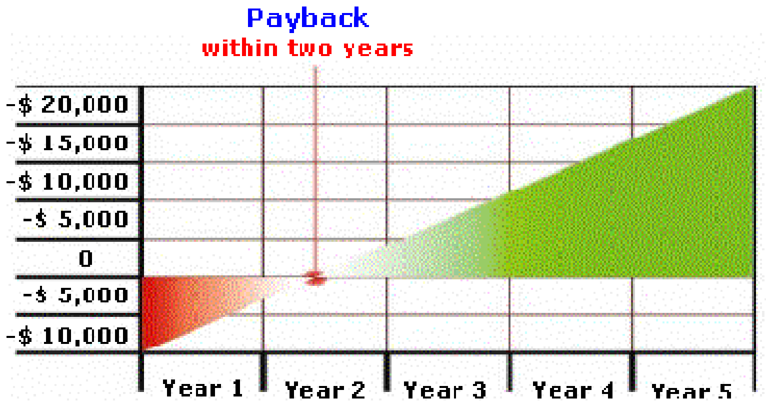
Engconsult Ltd., Canada and Prokaushal Upodeshta Ltd., Bangladesh have jointly undertaken a study in February-March 2003 to explore and perform practical experimentation on the effectiveness of the use of ElectroFlow^{TM} system in Bangladesh conditions. The study team researched the technical and financial feasibility of ElectroFlow^{TM} an Energy and Environmental Conservation system at Youngone Dying and Spinning Industry in Dhaka Export Processing Zone (DEPZ), Savar, Bangladesh.

An energy baseline has been calculated using past 12 months energy consumption data. The potential on-site emission reductions associated with the installation of ElectroFlow^{TM} system are calculated using emission coefficients for natural gas. Based on a preliminary assessment on the observed data in Youngone by the system manufacturer, it is proposed that ElectroFlow^{TM} system has the potential to conserve 10% energy use in this industry. And the simple payback period for this industry is calculated to be 34 months. The final emission reduction will be calculated using the energy conservation data after the system installation.

Electroflow^{TM} Benefits

ElectroFlow^{TM} offers savings of up to 34%; while it improves and stabilizes voltage, balances the three phases, filters harmonics, improves power factor up to 100%, filters surges/transients, and releases balanced KVA capacity.

ElectroFlow^{TM} power quality enhancement protects and increases longevity of equipment and machinery, resulting in reduced overhead, maintenance, and downtime.



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