ENERGY ECONOMICS

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Background notes for Energy Policy Analysis

Introduction

Any decision on investing money in a renewables or energy conservation option will finally be taken based on its economic viability. Assessing the economic viability of an energy option is similar to the methods used for any investments in new projects. Before carrying out an economic analysis, it is essential that all technically feasible options that are likely to be viable are included. Economic evaluation may help answer two types of questions:

1. Is a particular option worthwhile?
2. Which is the best possible option amongst the options being considered? Ranking of different options based on some economic criteria.

In most cases the renewables option requires an additional capital investment. What are the factors that determine the cost-effectiveness of the additional investment? The amount of investment involved and the amount of money saved annually will definitely affect the cost effectiveness. For renewables money savings are predominantly due to energy savings and are affected by the amount of energy saved and the price of energy. In general an option is likely to be more viable if the additional investment is low, the energy savings are high and the energy price is high. The life of the option also affects its viability with a higher life option more likely to be viable than a comparable option with a lower life. Economic evaluation also has to consider the time value of money. Different companies and individuals adopt different criteria while making decisions related to investments. We will examine different criteria and illustrate their applicability. We will start by examining the simple payback period before discussing the concept of the time value of money.

Simple Payback Period

The simple payback period (SPP) is the number of years in which the investment pays for itself. The SPP is defined as

$$SPP = \frac{\text{Initial Investment}}{\text{Annual Savings}} \qquad (1)$$

In an Energy Conservation Option (ECO)/renewables option usually the annual saving is only due to energy savings and hence is the product of the energy saved and the price of energy.

Example 1: Cost Effectiveness of Insulation.

An energy auditor recommended additional insulation on a boiler. The cost of the insulation is Rs 200000. It is estimated that installing the insulation will result in savings of 5 kilo-litres of Light diesel oil priced at Rs 32/litre. What is the SPP for this ECO?

$$SPP = 20000/(5000 \times 32)$$

$$= 1.25 \text{ years (1 year 3 months)}$$

In most cases the SPP is to be compared with the acceptable maximum SPP. For instance a company may accept any project with a SPP less than 2 years. In this case the company will agree to put additional insulation on the boiler. However if a company is only willing to consider ECOs which have SPPs less than a year, then this ECO will not be implemented.

What are the limitations of this criteria? In example 1 the life of the ECO did not affect our calculation. Suppose we were choosing between two ECOs which had different lives, as illustrated in example 2.

Example 2: Options with different lives

Two energy conservation options (A and B) have been identified as technically viable for a process. Only one of the ECOs can be implemented. Option A has a cost of Rs 100,000, annual savings of Rs 50,000 and a life of 3 years while option B has a cost of Rs 120,000, annual savings of Rs 40,000 and a life of 8 years. The SPP for option A is 2 years and for option B is 3 years. In terms of the SPP, it appears that option A is preferable to option B. Is this the right decision in view of the different lives of A and B?

Analysis of example 1 reveals one drawback of the SPP. The SPP does not consider cash flows after the payback period. Hence it is not a useful criteria in comparing between options which have different lives. The advantage of the SPP is its simplicity and ease of calculation. This also treats cash flows in different years as equal and does not consider the time value of money. The SPP may be suitable for assessing low investment projects with relatively small payback periods. Before we present the other criteria for assessing the economic viability of projects, we will discuss the time value of money.

Time Value of Money

The main issue in assessing the viability of an investment is comparing a investment made today with benefits which are expected in the future. Money now is valued more by individuals or companies than the same amount of money in the future. In general the money today can be used productively to create goods and services in the economy and can hence grow to a larger amount in the future. This effect is usually represented by an index called the discount rate. The discount rate represents how money is worth more now than in the future. The discount rate determines how any future cash flow is discounted or reduced to make it correspond to an equivalent amount today. If the discount rate is d, the values of unit cash flows in different years is given below:

	2019	2020	2019+k
Value in year	1	1	1
Present Value	1	$1/(1+d)$	$1/(1+d)^k$

The choice of the discount rate is critical in the evaluation of the project. The availability and value of capital varies depending on the individual or organisation making the investment so that there is no theoretically correct value of the discount rate. The discount rate would always be higher than the bank interest rate as the bank interest rate represents the minimum returns available by placing the money in a bank account.

A discount rate can be calculated from the manner in which people and companies make investments among alternatives that have costs and benefits spread in time. If a consumer's discount rate is 20%, what does it imply? This means that the consumer will make an investment of 100 Rs today only if annual returns of Rs 20 (or more) are expected every year in the future.

Inflation

The economic evaluation of a project depends on the general level of prices. Over a time period, there is often a change in the purchasing price of the Rupee. This effect is denoted as inflation. A rise in general price levels are known as inflation and a fall as deflation. Inflation is usually measured by the change in a price index – either the Consumer Price Index (CPI) or the Wholesale Price Index (WPI). The price index is the ratio of the price of a stipulated basket of goods and services at a particular year to the price in the base year (denoted as 100). Figure 1 shows the variation of the Consumer Price Index for India during the period 1970-1997. It is clear that the CPI increased from 100 in 1970 to 942 in 1997 (The average annual inflation rate during this period was 8.7%). Except one year when prices declined (1976), in all years there has been a steady increase in prices. The normal way of dealing with inflation is to convert all cash flows into units of constant purchasing power. This is illustrated in example 3.

Example 3: Inflation rate

In a state the CPI in 1995 was 140 (with 1990 as the base year). In 1990 an investment was made in a fixed deposit account which had an interest rate of 10%. What is the real interest rate obtained on the investment?

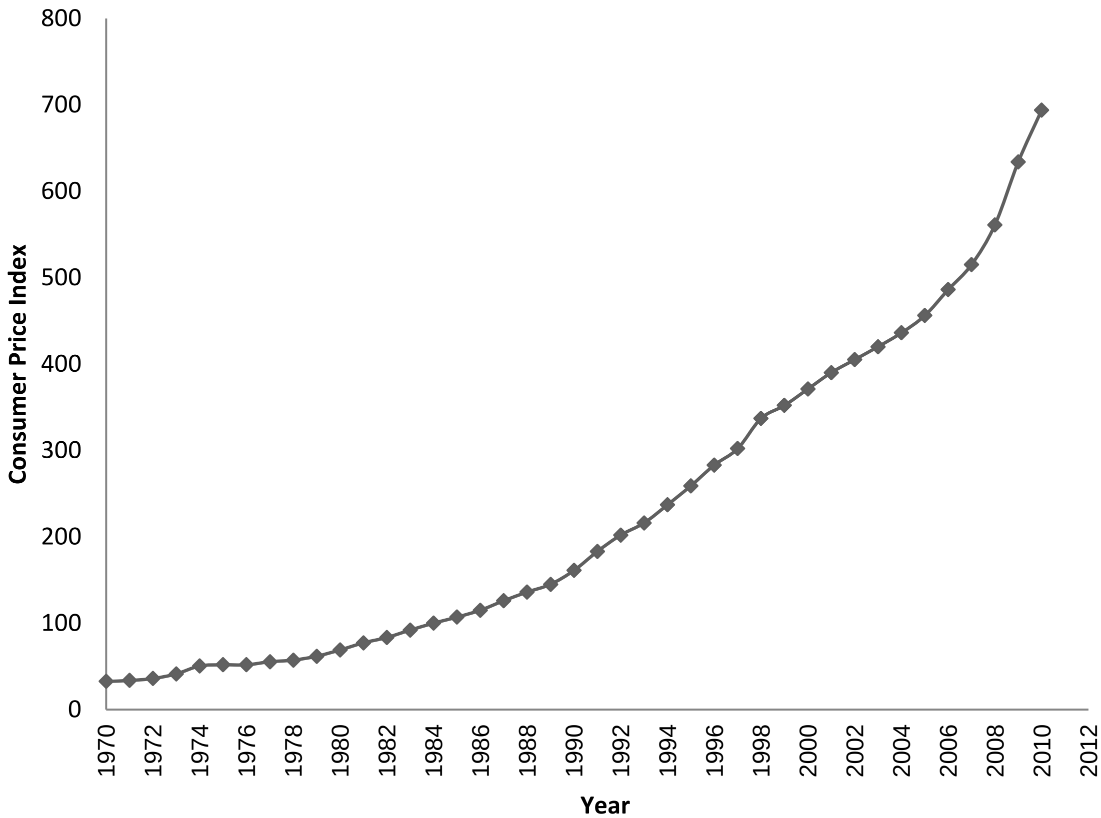

Fig. 1 Variation of Consumer Price Index (1970=100) for India

(Source: www.rbi.org.in › Publications/)

The inflation rate i can be calculated as

$(1+i)^5 = 140/100$

Hence i = 7.0%.

The true interest rate obtained on the investment (r) is given by

$(1+r)(1+0.07) =(1+0.1)$

Hence r = 2.8%.

In economic evaluation of projects it is necessary to distinguish between the real and nominal discount rates. If cash flows are adjusted for inflation and expressed in constant money terms, the discount rate used is the real discount rate (d_r). If the cash flows are not corrected for inflation, the discount rate used is termed the nominal discount rate (d_n). The real and nominal discount rates are related by the equation

$$1+d_n = (1 + d_r)(1+i) \qquad (2)$$

$$\text{Hence } d_r \sim d_n - I \qquad (3)$$

As the inflation in a country varies, so does the nominal discount rate. The real discount rate tends to be more stable and reflects the real scarcity of capital. Normally in calculating the viability of a project, it is better to use the real discount rate. The annual savings computed are based on present prices. An assumption is made that the annual savings escalate at the inflation rate. Using a nominal discount rate would involve explicitly assuming the inflation rate and the increase in the energy prices (inflation rate for the annual savings). Unless otherwise specified by a discount rate we will refer to the real discount rate. Real discount rates for private companies may range between 15-20% while the public sector (especially the infrastructure sector) may have lower discount rates. There is no theoretically correct discount rate for a company. The discount rate depends on the availability of capital. Depending on the total capital available to a company it will choose the investments with the highest rates of return. Figure 2 illustrates this. Consider a company that has a fixed amount of total capital available for investing C. The company has a number of possible projects in which it can invest in. Different projects will require different amounts of investments and have different expected rates of return. The company would choose projects with the highest rates of return till the total capital available is exhausted. The discount rate is the lowest rate of return of the project in which the company invests.

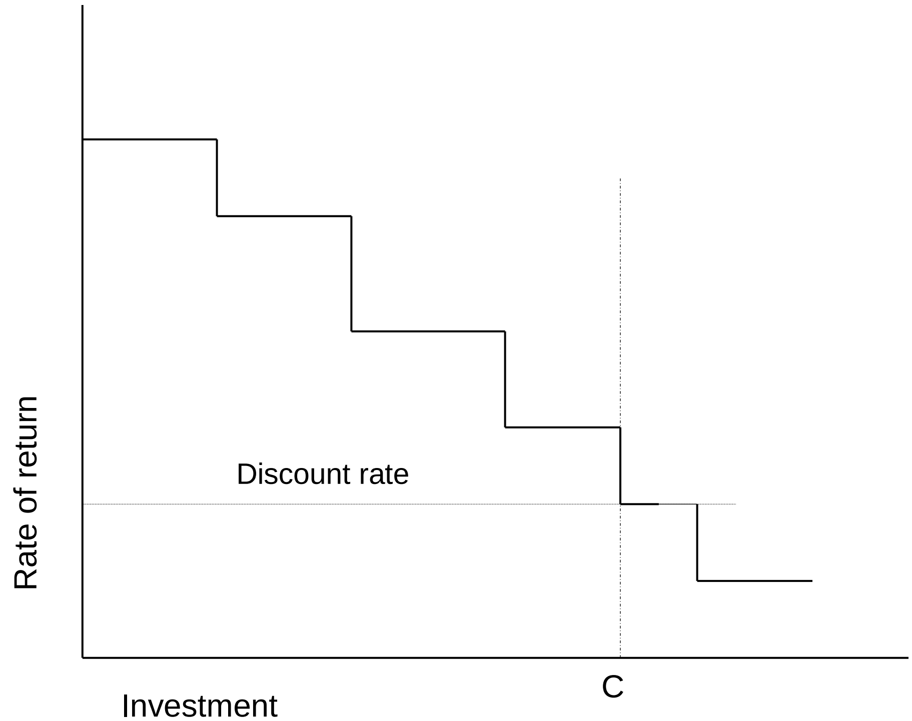

Fig. 2 Schematic showing discount rate for a company.

In actual practice the company has the option of borrowing money from banks or financial institutions. The implicit discount rates (as revealed by the actual decisions taken) in ECOs are often higher than the rational values due to market imperfections, energy costs being hidden and because of the perceived uncertainty regarding future energy savings.

Capital Recovery Factor

The problem in economic assessment is usually the comparison of future annual cash flows with an initial investment. Consider annual cash flows A_k in the kth year. The present value P of these cash flows is

$$P = \sum_{k=1}^{n} A_k/(1+d)^k \qquad (4)$$

where n is the life of the equipment or the no of years during which annual cash flow streams exist. If the annual cash flow streams are constant (A), then the present value P of the annual cash flows can be obtained as the sum of a geometric progression with the first term being A/(1+d) and the common ratio (multiplier) for successive terms being 1/(1+d). On simplification this gives

$$P = A\,[(1+d)^n-1]/[d(1+d)^n] \qquad (5)$$

P = A [Uniform Present Value Factor]

The uniform present value factor is defined as the ratio of the present value of the constant annual cash flows to the annual cash flow. For an ECO, the uniform present value factor can be multiplied by the annual cash flow to get the equivalent present value of the benefits (annual cash flows usually represent savings). The Capital Recovery Factor (CRF) is the inverse of the uniform present value factor and is defined as

$$CRF = A/P = [d(1+d)^n]/[(1+d)^n-1] \qquad (6)$$

The capital recovery factor enables the determination of the annualised value equivalent to the initial investment. The CRF is dependent on the equipment life n and the discount rate d. Consider an investment in an equipment with a life of 10 years and a real discount rate of 12%. Substituting in (6) we get

CRF (d=12%, n=10 years) = 0.177.

This implies that an investment of Rs 1000 today is equivalent to annual investments of Rs 177 over the lifetime of the equipment. When will this investment be worthwhile? This will be viable if the expected annual savings are greater than Rs 177.

Criteria (using discounting)

The main criteria used with discounted cash flows are the net present value (NPV), benefit/cost (B/C) ratio and the internal rate of return (IRR). The net present value of a project is the present value of the savings (benefits) minus the costs and is obtained as

$$NPV = \left[\sum_{k=1}^{n} A_k/(1+d)^k\right] - C_0 \qquad (7)$$

where C_0 is the initial capital investment. For uniform cash flows this simplifies to

$$NPV = A/(CRF(d,n)) - C_0 \qquad (8)$$

For an ECO to be viable, the NPV should be greater than zero. While comparing two projects, the project with the higher NPV can be selected. At times the NPVs of two projects may be similar but one may involve a higher initial investment. An alternative criteria which may be preferable in this case is the ratio of net present value of benefits to cost. A B/C ratio greater than 1 is essential for a viable project. In a comparison between two projects, the project with a higher B/C ratio would be preferred.

Another criteria which is commonly used is the internal rate of return. To compute the IRR, the net present value is equated to zero and the following equation is solved:

$$C_0 = \sum_{k=1}^{n} A_k/(1+IRR)^k \qquad (9)$$

This is a non-linear equation and can be solved iteratively (using the bisection, secant or Newton Raphson method) to obtain the IRR. The company usually has a hurdle rate or minimum acceptable rate of return for an investment. For an ECO the IRR is to be computed. If this is more than the minimum acceptable rate of return, the project is considered to be viable. The application of these indices is illustrated in Example 4 (for the data of example 3).

Example 4: Application of Discounted Criteria.

Consider a real discount rate of 12% for the company. Let us first calculate the capital recovery factors for the two ECOs

For A, CRF(0.12,3) = $[0.12(1.12)^3]/ [(1.12)^3-1] =0.416$

For B, CRF(0.12,8) = $[0.12(1.12)^8]/ [(1.12)^8-1] =0.201$

Using these values, the NPV and B/C ratio are obtained as shown in Table 1. It is seen that both options have positive NPVs and B/C ratios and are hence viable. Based on either of these criteria, option B seems preferable. Let us now calculate the internal rate of return for these ECOs.

Table 1 NPV and B/C ratios for ECOs

Option	Investment C_0 (Rs)	Present value of savings (Rs)	NPV Rs	B/C ratio
A	100,000	120,092	20,092	1.20
B	120,000	198,706	78,706	1.66

For option A, the equation for the IRR is

$$\sum_{k=1}^{3} 50{,}000/(1+IRR)^k - 100000 = 0$$

This equation can be solved to obtain an IRR of 23%.

Similarly for option B, the equation for the IRR is

$$\sum_{k=1}^{8} 40{,}000/(1+IRR)^k - 120000 = 0$$

which gives an IRR of 29%. If the hurdle rate (minimum acceptable rate of return) for the company is 12%, both A and B are acceptable. B is preferable as it provides a higher rate of return. If the hurdle rate for the company is 30%, then neither of the options is acceptable.

Cost of Saved Energy (CSE)

In many cases, an energy conservation opportunity is to be compared with the cost of additional energy supply. For such a comparison, the cost of saved energy has been devised as an index. The cost of saved energy (CSE) is defined as

CSE = Annualised Investment / Annual Energy Saving

$$= C_0\, CRF(d,n)/ ES \qquad (10)$$

where ES is the annual energy saved. Unlike the other criteria discussed earlier, the CSE has the units of Rs/(energy unit) viz. Rs/kWh, Rs/kJ, Rs/kg of coal, Rs/litre of oil.

Let us compute the CSE for example 1. In order to compute the CSE we need to know the life of the insulation and the discount rate. Taking a life of 10 years and a discount rate of 12%, the CRF is 0.177 and the CSE is

CSE = 200,000 $\times$ 0.177/(5000) Rs/litre of fuel oil saved

= Rs 7.1 /litre of fuel oil

This has to be compared with the price of fuel oil. Since the CSE is lower than the price of fuel oil (Rs 32/litre), the ECO is viable. Example 5 illustrates the CSE for an energy efficient refrigerator.

Example 5: Energy efficient refrigerator

The cost of a standard refrigerator is Rs 10,000 and the expected electricity consumption per year is 450 kWh. The cost of an energy efficient refrigerator of the same capacity (and with the same features) is Rs 10,500. For the same load, the annual electricity consumption is expected to be 400 kWh. What is the cost of saved energy? The life of the refrigerator can be taken as 10 years. The CSE will depend on the customer discount rate. Suppose we were to compare an investment by the utility or the government in an energy efficient programme. We can take a discount rate of 12%.

CSE =(10,500-10,000)$\times$0.177/(450-400)

= Rs 1.77/kWh

This can be compared with the price of electricity. If the household is paying

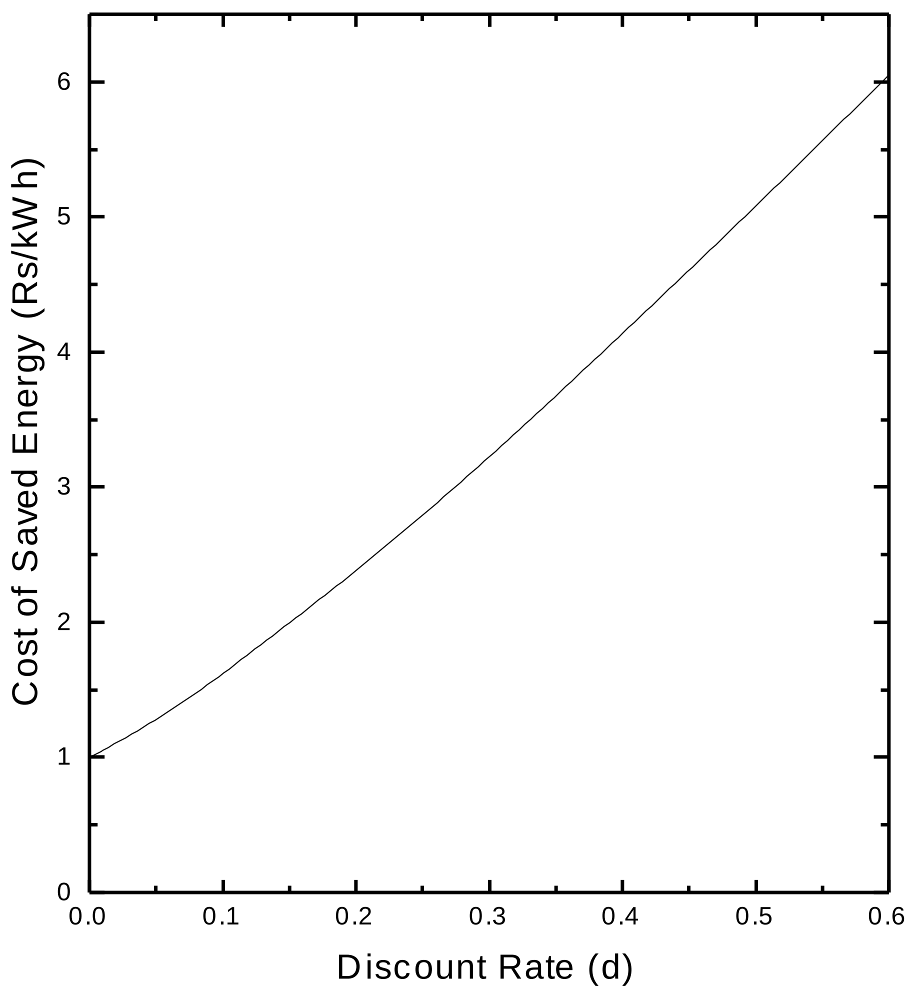

Fig. 3 Variation of CSE with discount rate

Rs 2.50/kWh, then the energy efficient refrigerator seems viable. However if the discount rate is higher than 12% the cost of saved energy increases as shown in Figure 3. If the consumer discount rate is 30%, the CSE is Rs 3.23/kWh and the energy efficient refrigerator is not viable. Studies have shown that the implicit consumer discount rate is as high as 60%. The CSE increases to Rs 6.06/kWh. Thus an ECO which seems viable to an utility (d=12%) is not viable to a household with higher discount rates. This forms the basis for utilities providing rebates/incentives in demand side management programmes.

Depreciation

Depreciation is an accounting concept. This attempts to distribute the cost or basic value of a tangible asset, less salvage value, over the estimated useful life of the asset in a systematic manner. For most assets, the market value of the asset decreases with time. For accounting purposes, depreciation is subtracted as an expense from the profits to obtain the net profits which is taxable. In the indices considered, the initial investment is considered as a cost. Hence depreciation should not be separately accounted for in the annual cash flows. Otherwise, this would lead to double counting. For many ECOs the government provides for accelerated depreciation, as an incentive. In the evaluation of an ECO, the tax benefits from depreciation should be considered.

A commonly used method of depreciation is the straight line method. In this method the annual depreciation (A_D)is computed as

$$A_D = (C_0 - S)/n \quad (11)$$

where S is the salvage value at the end of the life of the equipment. If the salvage value is zero, the annual depreciation is

$$A_D = C_0 /n \quad (12)$$

If the company is making profits and the corporate tax rate is t, there is an annual reduction in tax equal to t A_D . This may be included in the annual cash flows especially for large projects, but is often negligible. For ECOs where accelerated depreciation is permitted, this needs to be considered. Example 6 shows the effect of accelerated depreciation for a solar feedwater heating system.

Example 6: Solar Water Heating System

An industry wishes to install a solar water heating system to preheat the make-up water supplied to the boiler. The cost of the system is Rs 2 lakhs and the annual savings are expected to be Rs 30,000. If we neglect depreciation, take a life of 20 years and a real discount rate of 12%, the indices obtained are shown in Table 2. If the corporate tax rate is 40% and 100% depreciation is permissible in the first year, the project appears to be more attractive. In this case this results in a tax saving of Rs 80,000 in the first year. Since this occurs at the end of the first year this is discounted to the present by multiplying by 1/(1+d).

Table 2: Economic Indices for the solar water heater

Assumption	SPP years	NPV (Rs)	B/C	IRR
No Depreciation	6.7	24,083	1.12	13.9%
100% Depreciation- year1	4.0	95,512	1.48	21.9%

If the minimum acceptable rate of return for the company is 20%, if we neglect depreciation the rate of return is lower than the hurdle rate and the ECO seems unviable. However with accelerated depreciation the rate of return is more than 20% and the project can be implemented. If normal straight line depreciation was permitted, the annual tax saving is Rs 4000 and the IRR is 16.1%.

Life Cycle Costing

The life cycle cost (LCC) is the present value of all expenses related to a specific option during its lifetime. To compute this the present value of the annual expenditures is added to the initial investment. The annual expenditures will include the energy, maintenance, labour and other costs. The LCC can be written as

$$LCC = C_0 + \sum_{k=1}^{n} AC_k/(1+d)^k \qquad (12)$$

where AC_k is the annual cost or expenditure in the kth year. For constant annual costs, this reduces to

$$LCC = C_0 + AC/(CRF(d,n)) \qquad (13)$$

To use this index, it is necessary to compare the LCCs of different options that perform the same function. The option with the lower LCC is preferable. For the refrigerator example (Ex.5.5) the LCC is obtained, considering only the electricity bill as the annual operating expenses and taking a discount rate of 30%, as

LCC(std refr) = 10000 + 450×2.5/0.323 = Rs 13,478.

LCC(eff refr) = 10500 + 400×2.5/0.323 = Rs 13,592.

It is clear that at this discount rate the LCC for the energy efficient refrigerator is higher than the standard refrigerator. Hence the customer should choose the standard refrigerator. However if the customer discount rate is 20% , the LCC for the energy efficient refrigerator is lower than the standard refrigerator. It is difficult to apply this index to options with different lives. An alternative that is preferable for such cases is the annualised life cycle cost (ALCC). Normally the annual operating expenses are estimated at the start of the project. Hence we deal with constant annual costs. The initial investment is added to the annual operating cost to obtain the ALCC.

$$ALCC = C_0 \times CRF(d,n) + AC \qquad (14)$$

The ALCC is related to the LCC as shown

$$ALCC = LCC \times CRF(d,n) \qquad (15)$$

The ALCC represents the annual cost of owning and operating the equipment.

For the refrigerators (with d=30%)

ALCC(std refr) = 10000×0.323 + 450×2.5= Rs 4360.

ALCC(ee refr) = 10500×0.323 + 400×2.5= Rs 4393.

In equipments which have components with different lives the ALCC can be easily computed as

In equipments which have components with different lives the ALCC can be easily computed as

$$ALCC = AC + \sum_{m=1}^{p} C_{0\,m} \times CRF(d,n_m) \qquad (16)$$

where there are p sub-components with initial investments $C_{0\,1}$, $C_{0\,2}$, ….,$C_{0\,p}$ and lives n_1, n_2, ….,n_p. . Example 7 illustrates this for a lighting retrofit.

Conclusions

It should be understood that the economic viability of an ECO is sensitive to a number of factors – energy prices, equipment life, number of hours of operation. The choice of a discount rate affects the viability of projects, especially those with long lives. If energy prices are expected to escalate at rates higher than the general inflation rate, the future inflation rates can be explicitly assumed and the economic criteria computed using a nominal discount rate. The criteria discussed in this note can also be used when the company takes a loan to pay for the ECO.

The payments for the principal and the interest can be included in the yearly cash flows. Tax deductions for loan repayments can also be added as a benefit in the cash flow stream. In such cases, it is better to explicitly put down annual cash flows before discounting and calculating the NPV,B/C ratio, IRR or LCC. For dealing with uncertainty in energy prices (or any other parameter which affects the economic viability) discrete future scenarios can be constructed to check the robustness of the decision. Any cash flow due to carbon credits can also be included in a similar fashion in the economic analysis.

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