Energy Economics

Introduction

- **Investment is often essential** for installation of a new energy project-like substituting a conventional system with a renewable energy based system
- **Modifications/retrofitting**, for incorporating new technology
- **Systematic approach for merit rating** of the different investment options compared with the anticipated savings
- **Identify the benefits** of the proposed measures including increased productivity, sustainability, improved product quality etc.
- The cost involved in the proposed measure should be captured in totality!

Economic Analysis

- Any decision on investing money in an energy related project 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:

- Is a particular option worthwhile?
- Which is the best possible option amongst the options being considered?

- In general an option is likely to be more viable if the additional investment is low, the energy savings are high and the prevailing 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

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

$$SPP = \frac{\text{Initial Investment}}{\text{Annual Savings}}$$

- 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

- Two energy conservation options (A and B) have been identified as technically viable for a process. Only one of them 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.

Limitations of SPP

- It fails to consider the time value of money
- It ignores cash flows beyond the payback period.

(This leads to discrimination against projects that generate substantial cash inflows in later years)

Time Value of Money

- 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 :

	2008	2009	2008+k
Value in year	1	1	1
Present value	1	1/(1+d)	$1/(1+d)^k$

Discount rate

- 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

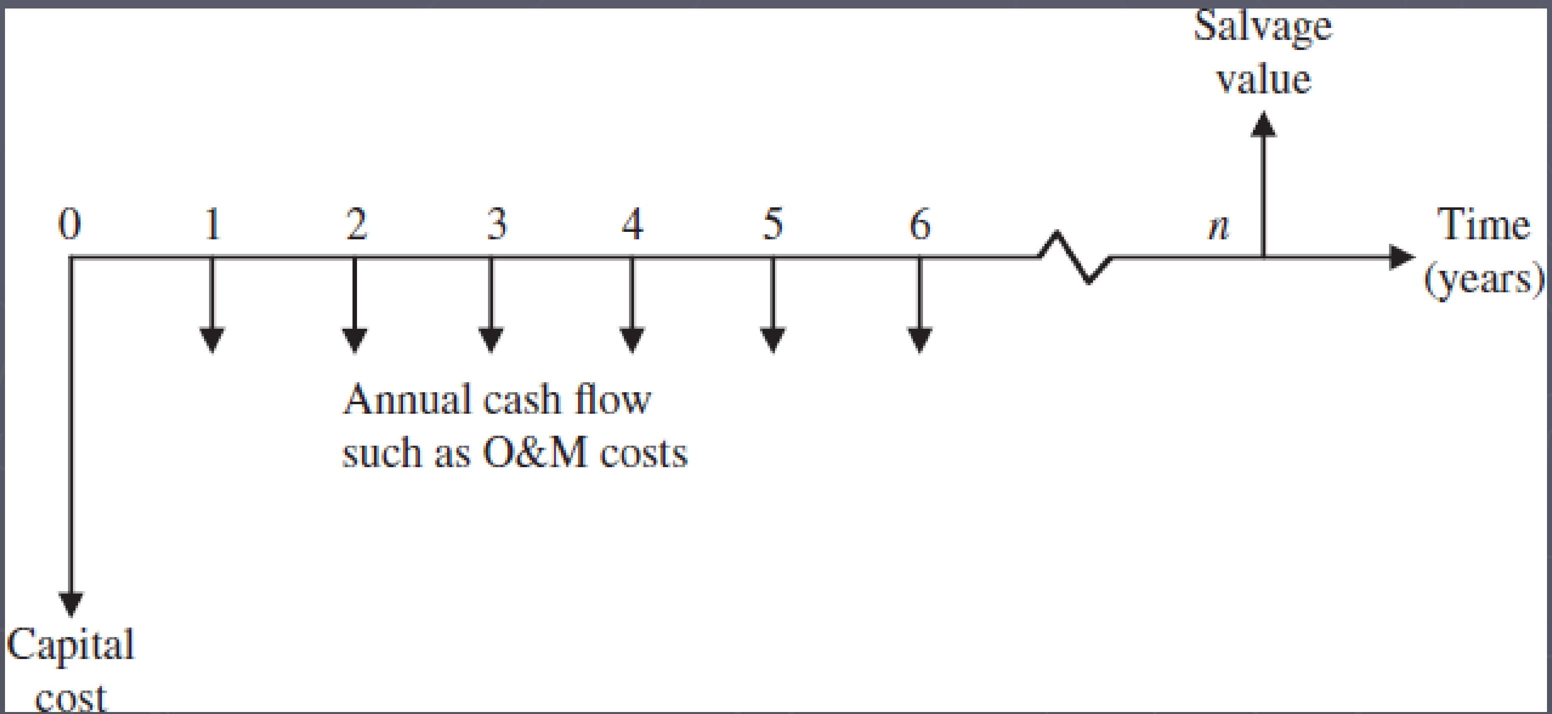
Capital Recovery Factor

- 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 k^{th} year. The present value P of these cash flows is

- $P = \sum_{k=1}^{n} A_k/(1+d)^k$
- $P = A\,[\,(1+d)^n-1]/[d(1+d)^n]$ ....(5)
- P = A [Uniform Present Value Factor]
- $CRF = A/P = [d(1+d)^n]/\,[\,(1+d)^n-1]$

Cash flow diagram



- The capital recovery factor enables the determination of the annualised value equivalent to the initial investment.
- Consider an investment in an equipment with a life of 10 years and a discount rate of 12%.
- 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?

- The Net Present Value of a project is the present value of the savings (benefits) minus the costs and is obtained as

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

where C_0 is the initial capital investment.

For uniform cash flows this simplifies to

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

For viablity, the NPV should be greater than zero.

- 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 :

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

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

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

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

- where AC_k is the annual cost or expenditure in the k^{th} year.
- For constant annual costs, this reduces to

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

- 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. It is difficult to apply this index to options with different lives.

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.

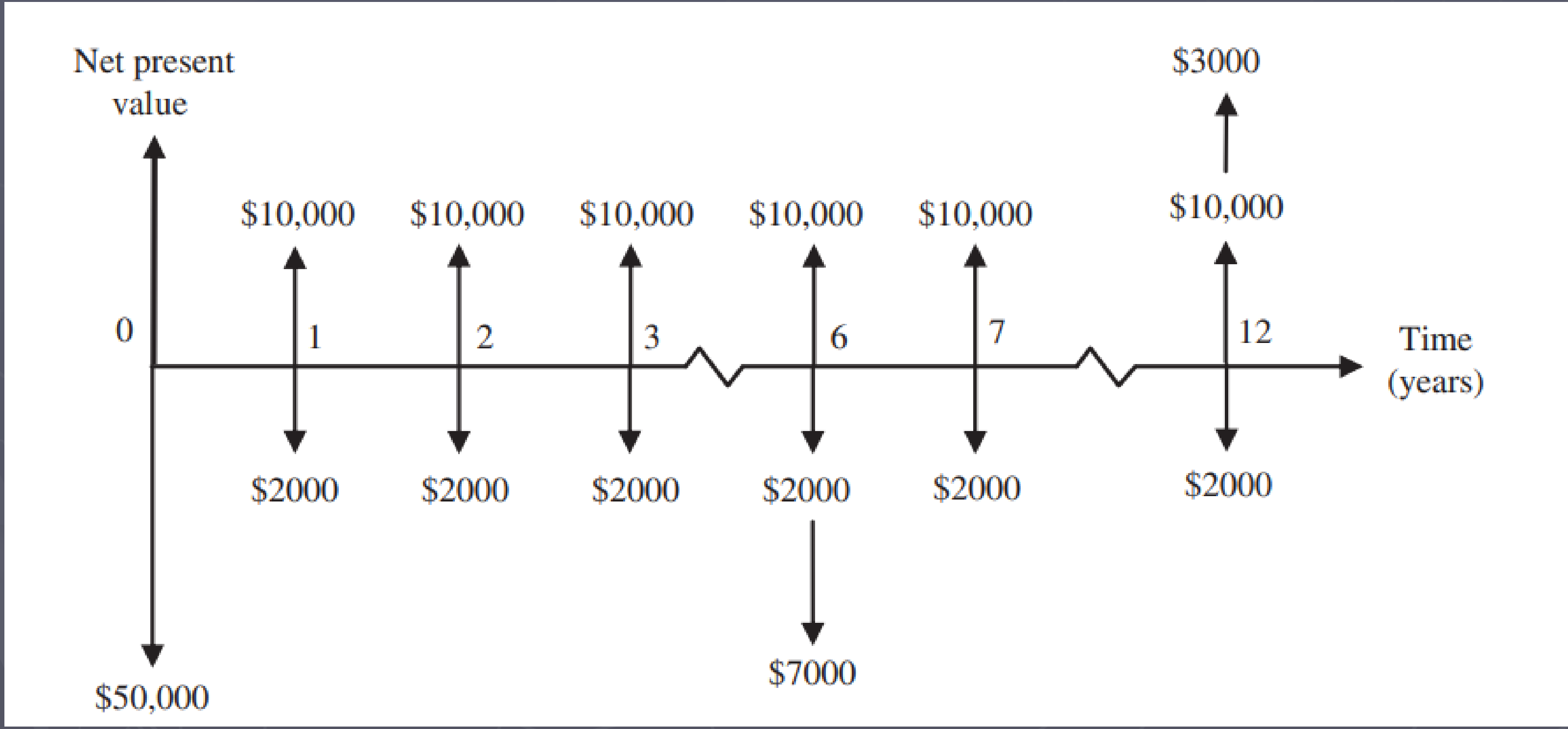
  $ALCC = C_0 \times CRF(d,n) + AC$

The ALCC is related to the LCC as:

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

- Economic viability of an ECO is sensitive to a number of factors – energy prices, equipment life, number of hours of operation etc.
- The choice of a discount rate affects the viability of projects, especially those with long lives.
- 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.

A geothermal space heating system is to be installed for a commercial building to support natural gas heaters. The initial cost of the system is $50,000. It is estimated that the system will save the building $10,000 per year from the natural gas it saves. It will take $2000 per year to operate and maintain the geothermal system. The system will require a major cleaning after 6 years at a cost of $7000. The lifetime of the system is 12 years after which the geothermal system will have a salvage value of $3000 (Fig. 11-4). Determine the net present value of this project. Take the inflation-adjusted interest rate as 4 percent. Also, calculate the benefit-cost ratio.



SOLUTION The cash flow diagram in Fig. 11-4 gives all the cash flows during the lifetime of the project. The capital cost is already expressed in present time:

$$P_1 = \$50{,}000$$

The present value of annual savings is [Eq. (11-4)]

$$P_2 = U\left[\frac{1-(1+i)^{-n}}{i}\right] = \$10{,}000\left[\frac{1-(1+0.04)^{-12}}{0.04}\right] = \$93{,}851$$

The present value of the operating and maintenance expenses is

$$P_3 = U\left[\frac{1-(1+i)^{-n}}{i}\right] = \$2000\left[\frac{1-(1+0.04)^{-12}}{0.04}\right] = \$18{,}770$$

The major cleaning cost that will occur after 6 years can be expressed in present time as [Eq. (11-2)]

$$P_4 = \frac{F}{(1+i)^n} = \frac{\$7000}{(1+0.04)^6} = \$5532$$

The salvage value that will occur after 12 years is expressed in present time as

$$P_5 = \frac{F}{(1+i)^n} = \frac{\$3000}{(1+0.04)^{12}} = \$1874$$

The net present value is determined by adding benefits and subtracting expenses from it:

$$\begin{aligned}
\text{Net present value} &= \text{Benefits} - \text{Expenses} \\
&= (P_2 + P_5) - (P_1 + P_3 + P_4) \\
&= (\$93{,}851 + \$1874) - (\$50{,}000 + \$18{,}770 + \$5532) \\
&= \$95{,}725 - \$74{,}302 \\
&= \mathbf{\$21{,}400}
\end{aligned}$$

The installation of this geothermal heating system will provide a monetary benefit of \$21,400 over the entire lifetime of the project expressed in present time value. If we did not consider the time value of money and just added benefits and subtracted expenses, the net value of the project would be

$$\text{Net value} = (\$10{,}000 \times 12 + \$3000) - (\$50{,}000 + \$2000 \times 12 + \$7000) = \$42{,}000$$

This is the twice of the amount calculated above, indicating the importance of considering the time value of money.

The benefit-cost ratio is calculated from Eq. (11-10) to be

$$\text{Benefit-cost ratio} = \frac{\$95{,}725}{\$74{,}302} = \mathbf{1.29}$$

This ratio is significantly greater than unity, and thus this project should receive a green light. ▲

11-38 A food manufacturing plant decides to add another type of cookies to its production line. The plant spends $220,000 for the purchase and installation of the equipment. Other estimated costs on an annual basis include the followings:

$$\text{Operating and maintenance cost} = \$7000$$

$$\text{Electricity cost} = \$48{,}000$$

$$\text{Natural gas cost} = \$37{,}000$$

$$\text{Raw material cost} = \$260{,}000$$

$$\text{Staff cost} = \$240{,}000$$

The lifetime of the equipment is estimated to be 12 years after which it will have a salvage value of $22,000. The plant is to produce 250,000 kg of cookies per year. Taking the interest rate to be 6 percent, determine the unit product cost.

- It is proposed to setup a solar thermal energy based heating system in a medium size process plant. The proposed investment is Rs. 12,00,000. Annual savings for the first four consecutive years are Rs. 3,50,000, Rs. 4,00,000, Rs. 4,00,000 and Rs. 4,50,000 respectively. Comment on the economic feasibility of the project. A discount rate of 12% may be assumed.

- A small 1 kW wind turbine system has a capital cost of Rs. 2,70,000. Assume that the capital cost is to be paid with a 15 year loan with an interest rate of 7%. The operational and maintenance costs for the plant are Rs. 12,000 per year. Estimate the cost of energy (in Rs/kWh), if the capacity factor of the plant is 0.3.

- A biomass briquetting plant requires an initial investment of Rs. 35,00,000. The average yearly income from the plant is estimated as Rs. 6,00,000 during its life time of 10 years. Find the internal rate of return of the project. Company has a hurdle rate of 12%. Is the project viable?