Energy Management & Utilization

Chapter 4

Economic Decisions for Energy Projects

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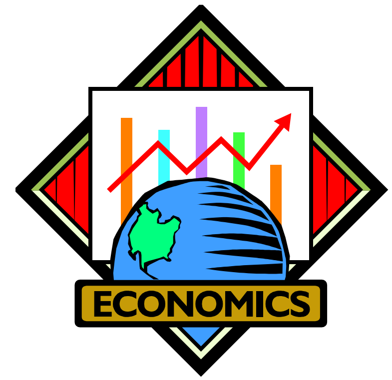
The Need for Economic Analysis

- The decision on whether management will invest in an energy savings project – or energy conservation measure (ECM) - often hinges on how successfully the energy manager communicates with the decision makers using their rules, words and decision criteria.
- The energy manager must present projects in economic terms in order to help the decion makers to make their decisions.

The Need for Economic Analysis (continued)

- The energy manager must learn to speak management's language.
- To do this he/she must present the project in economic terms.



- There are many measures of project economic analysis, and many businesses and industries use their own methods or procedures to make their decisions.
- This chapter presents the basic elements used to determine the cost-effectiveness of projects and a few of the most popular measures of cost-effectiveness.

Simple Payback Period

- Simple Payback Period or Payback Period does not include the time value of money.
- It is simple and easy to use, and that is why many organizations use it.
- For periods of one to two years, this is mostly OK for some people.
- SPP is not an acceptable method for longer time periods.

What is «Pay Back Period» ?

- Payback period is the time required to cover the cost of investment.
- Simple payback period (SPP) ignores the time value of money.

$$\text{Simple Payback Period} = \frac{\text{Investment}}{\text{Cash inflow per year}}$$

- Usually periods larger than a few years do not make any sense.
- It is simple and easy to use, and that is why many organizations use it.
- For periods of one to two years, this is mostly OK for some people.
- SPP is not an acceptable method for longer time periods.

SPP Example

A lighting improvement costs $1000. The improvement saves $500 each year. What is the Simple Payback Period?

$$SPP = \frac{\$\,cost}{\$\,savings\ /\ yr} = \qquad\qquad =$$

SPP Example -- Solution

A lighting improvement costs $1000. The improvement saves $500 each year. What is the Simple Payback Period?

$$\text{SPP} = \frac{\$\,\text{cost}}{\$\,\text{savings/yr}} = \frac{\$1000}{\$500/\text{yr}} = 2 \text{ yrs}$$

Decision Rule for Payback Period

- Project is feasible if the payback period is less than the target payback period

- Example: An energy project requires an investment of $250 million and expected to return $75 million/year for **5 years**. The simple payback period is

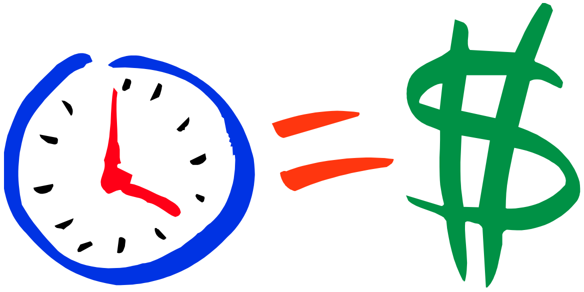
$$= \frac{\$250 \text{ million}}{\$75 \text{ million/year}}$$

$$= 3.33 \text{ years}$$

- The project is accepted as feasible

Time Value of Money

- A dollar tomorrow is not worth as much as a dollar today because money has earning power.
- The dollar today could be placed in a bank and earn interest so that it is worth more than a dollar tomorrow.
- This relationship between interest and time is called the **time value of money**.



Time Value of Money

- This time value of money means that equal dollar amounts at different points in time have different values as long as the interest rate that can be earned exceeds zero.
- The fundamental approach to correctly account for cash inflows and outflows at different times is called **discounted cash flow analysis**.

Discounted Payback Period

- It calculates the present value of each cash inflow assuming the start of the first period as zero point
- The discounted cash inflow:

$$\text{Discounted Cash Inflow} = \frac{\text{Actual Cash Inflow}}{(1+i)^n}$$

where

i = discount rate

n = period of cash inflow (years)

$$\text{SPP} = \frac{\text{Investment}}{\text{Cash inflow per year}}$$

- The cash inflow value for each year is inserted into the equation and a more realistic payback period is obtained.

Discounted Payback Period

- Example: An energy project requires an investment of $250 million and expected to return $75 million/year with a discount rate of 3% for **5 years**. The simple payback period is

$$\text{Discounted cash flow:}$$

$$= \frac{\$75\text{ million}}{(1+0.03)^5} = \frac{\$75\text{ million}}{1.159} = \$64.71\text{ million}$$

$$\text{Discounted payback period}$$

$$= \frac{\$250\text{ million}}{\$64.71\text{ million/year}} = 3.86\text{ years}$$

- The project is accepted as feasible

Minimum Attractive Rate of Return

- To compare cash flows occurring at different times, we need an interest rate at which to discount the cash flows.
- Management at every firm generally has a target rate of interest that represents the lowest rate of return that will be considered acceptable for any investment.
- This interest rate is termed the **minimum attractive rate of return**, **MARR**.

Minimum Attractive Rate of Return

- The MARR can be viewed as a rate at which the firm can always invest, since it has a large number of opportunities that yield such a return.
- This is why the MARR is commonly referred to as the opportunity cost of capital.

Life Cycle Costing

- US government often requires Life Cycle Costing using the time value of money.
- Use Present Value (PV) analysis to find lowest life cycle cost (LCC)

$$LCC = PV\begin{bmatrix} \text{Purchase Cost} + \text{Operating Cost} \\ + \text{Disposal Cost} \end{bmatrix}$$

- Need interest tables, a computer, or a calculator to find these PVs

Life Cycle Costing (continued)

- Present Value (PV) and Present Worth (PW) are the same thing
- A good project has a Net Present Value (NPV) greater than zero

$$NPV = PV\left(savings\right) - PV\left(\text{cost}\right)$$

- The Internal Rate of Return (IRR) is the interest rate (I) at which the PV of the savings equals the PV of the costs

Solve PV(savings) = PV(cost) for I=IRR

Time Value of Money Analysis

Formulae

<u>Life Cycle Net Savings (Net Present Value)</u>

NPV = Σ PV Annual Savings - Σ PV Life Cycle Investments

<u>Savings-to-investment ratio:</u>

SIR = Σ PV Annual Savings / Σ PV Life Cycle Investments

<u>Internal rate of return:</u>

IRR = Discount rate, where SIR = 1.0, or NPV = 0

<u>Simple pay back period:</u>

SPP = Initial investment / annual savings

Determining the Feasibility of Energy Projects

In energy projects we have:

- A reference application (usually referred to as the "old" system)
- A challenging technology (usually referred to as the "new" system)
- We need to determine if the life cycle costing of the challenger (new system) is less than the reference application (old system)
- In the analysis the capital cost, the energy savings and the O/M costs play an important role

Determining the Feasibility of Energy Projects

A simple "Ten steps" method:

1. Determine "old" costs (existing baseline conditions).
2. Determine "new" costs (implementation and beyond).
3. Calculate differences.
4. Choose discount rate.
5. Choose analysis period.
6. Estimate residual value of equipment at end of service life.
7. Calculate present value of annual savings.
8. Calculate present value of investments.
9. Calculate net present value.
10. Calculate savings-to-investment ratio and internal rate of return.

Life Cycle Cost Analysis: Inputs

Input in BLUE cells only.

TABLE 1

Life Cycle Investment Schedule, from Steps 1, 2, and

Year	New	Old	Net Amount
0			$0
1			$0
2			$0
3			$0
4			$0
5			$0
6			$0
7			$0
8			$0
9			$0
10			$0
11			$0
12			$0
13			$0
14			$0
15			$0
16			$0
17			$0
18			$0
19			$0

TABLE 2

Annual Savings		(from Step 3)
Discount Rate		(from Step 4)
Analysis period (years)		(from Step 5)
Residual value		(from Step 6)

Life Cycle Cost Analysis: Calculations & Outputs

TABLE 3: Savings Calculations

<u>Formula:</u> PV Annual Savings = Annual Savings / (1 + Discount Rate)^{year} (from Step 7)

Year	0										
Annual Savings	$0										
PV Annual Savings	$0										
□ PV Annual Savings	$0										

TABLE 4: Investments

<u>Formula:</u> PV Life Cycle Investment = Life Cycle Investment / (1 + Discount Rate)^{year} (from Step 8)

Year	0										
Net Life Cyle Investments	$0										
PV Life Cycle Investments	$0										
□ PV Life Cycle Investments	$0										

Net Cash Flows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

TABLE 5: Results	OUTPUTS	
Net Present Value (NPV)	**$ 0**	(from Step 9)
Savings-to-Investment Ratio		(from Step 10)
Internal Rate of Return (IRR)		(from Step 10)
Simple Payback (years)		

Step 1 - Determine Old Costs (Baseline Conditions)

a) **Life cycle re-investments**

b) **Annual energy costs**

c) **Annual operations & maintenance (O&M) costs**

d) **Other annual costs**

Step 1a
Old Re-investment Table

- Old equipment probably needs periodic re-investment to keep going.
- Assume:

  Old re-investment costs

  = $50 000 every 4 years

  (*from maintenance records*)
- Assume:

  Last replacement was two years ago, so next replacement is in year 2.
- Enter data in "Old" column.

Year	Old
0	
1	
2	$50 000
3	
4	
5	
6	$50 000
7	
8	
9	
10	$50 000
11	
12	
13	
14	$50 000
15	
16	
17	
18	$50 000
19	

Step 1b
Annual Energy Costs

- Old annual energy costs

  = Old annual energy * cost of energy

- Example

  Old annual energy costs

  = $177 000/yr (*from energy audit*)

Step 1c
Annual O&M Costs

Example

- In this case, assume poor maintenance at low cost.
- Operations and Maintenance (O&M) = $2 500/yr.

Step 1d
Other Annual Costs

- List other annual old costs that will be affected by the project, such as

  - productivity

  - penalties for pollution

Step 2
Determine New Costs

New Costs (Implementation and Beyond)

- Initial investment
- Life cycle re-investments
- Annual energy costs
- Annual operations & maintenance (O&M) costs
- Other annual costs

Step 2a - Initial Investment

- Initial investment = Basic project cost
  + engineering
  + profit
  + contingency
  + taxes
  + other

- For estimation purposes, add costs as %.

Step 2a - Initial Investment (cont.)

Basic project cost	=	$78 000 (*from energy audit*)
Initial investment	=	Basic project cost + engineering + profit + contingency + taxes
	=	Basic project cost * (1 + 0,2 + 0,1 + 0,1 + 0,2)
	=	$78 000 * 1,6
	=	$124 800

- **Enter data in year 0 of "New" column of investment table..**

Step 2b
Life Cycle Re-investments

Five year replacement costs	=	25% of the initial investment (*from manufacturer's recommendation*)
	=	0,25 * $124 800
	=	$31 200

- Enter data in years 1 to end of "New" column of the investment table.

Steps 2a and 2b
New Investment and Re-investment

- There is no 20th year for reinvestment, even with 20 year analysis.
- Investments are considered to be made at the end of each year.
- At the end of the last year of analysis, the project is over.
- Further investment requires a new project with new analysis.

Year	New
0	$124 800
1	
2	
3	
4	
5	$31 200
6	
7	
8	
9	
10	$31 200
11	
12	
13	
14	
15	$31 200
16	
17	
18	
19	

Step 2c - Annual Energy Costs

- New annual energy costs

  = New annual energy * cost of energy

Example

New annual energy costs = $132 000/yr (*from energy audit*)

Step 2d
Annual O&M costs

Example

- New O&M = $5 000/yr

    (*from manufacturer's recommendations*)

Step 2e - Other Annual Costs

- List other annual new costs that will be improved by the project, such as

  - improved productivity

  - reduced penalties

Step 3
Calculate Differences

a) **Life cycle investments**
b) **Annual savings**

Step 3a – Life Cycle Investments

- Investments and re-investments
- Only non-annual costs
- Spreadsheet subtracts old costs from new costs.
- Net = new – old

Year	New	Old	Net Amount
0	$124 800		$124 800
1			$ 0
2		$50 000	-$50 000
3			$ 0
4			$ 0
5	$31 200		$31 200
6		$50 000	-$50 000
7			$ 0
8			$ 0
9			$ 0
10	$31 200	$50 000	-$18 800
11			$ 0
12			$ 0
13			$ 0
14		$50 000	-$50 000
15	$31 200		$31 200
16			$ 0
17			$ 0
18		$50 000	-$50 000
19			$ 0

Step 3b – Annual Savings

Annual cost savings

= (old energy cost - new energy cost)

+ (old O&M - new O&M)

+ (old other - new other)

Example

Annual cost savings

= ($176 000 - $132 000)

+ ($2 500 - $5 000)

+ ($0 - $0)

= $41 500

Annual Savings	$41 500
Discount Rate	
Analysis period (years)	
Residual value	

Enter in appropriate input cell.

Step 4 - Choose Discount Rate

- Choose a discount rate r = 12%
  (*from lender interest rate*)
- Enter discount rate in appropriate input cell.

Annual Savings	
Discount Rate	12%
Analysis period (years)	
Residual value	

Step 5 - Choose Analysis Period

- Choose analysis period T = 15 years.
- Enter analysis period in appropriate input cell.

Annual Savings	
Discount Rate	
Analysis period (years)	15
Residual value	

Step 6 - Estimate Residual Value of Equipment

- What is equipment worth at end of analysis period?
- Rule of thumb:

  Residual value = 10% of purchase price
- Residual value acts as a credit to the project in the final year.
- Estimate

  residual value = $16 000
- Enter residual value

  in appropriate input cell.

Annual Savings	
Discount Rate	
Analysis period (years)	
Residual value	$16 000

Step 7 - Calculate Present Value of Annual Savings

Let: PV_{AS}	=	Total present value of all annual savings
T	=	Total number of the years in the analysis
AS_t	=	Annual savings in the year *t*

- **For each year:**

PV of savings = year's savings divided by (1+ discount rate)

raised to the power of the year when the savings occur

- **Total PV of savings during analysis period is the sum of all annual PVs.**

$$PV_{AS} = \sum_{t=1}^{T} AS_t * \frac{1}{(1+r)^t} = AS_1 * \frac{1}{(1+r)^1} + AS_2 * \frac{1}{(1+r)^2} + \ldots + AS_{15} * \frac{1}{(1+r)^{15}}$$

Step 7 - Calculate Present Value of Annual Savings

For T = 15 years

PV_{AS} = \$282 651

Year	0	1	2	3	4	…	13	14	15
Annual Savings	\$ 0	\$41 500	\$41 500	\$41 500	\$41 500	…	\$41 500	\$41 500	\$41 500
PV Annual Savings	\$ 0	\$37 054	\$33 084	\$29 539	\$26 374	…	\$9 511	\$8 492	\$7 582
Σ PV Annual Savings	\$282 651								

Step 9
Calculate Net Present Value (NPV)

- The net present value (NPV) of a project is its life cycle net savings.
- It is the absolute monetary value of a project.
- $NPV = PV_{AS} - PV_{I}$

Example **NPV = $282 651 - $58 105**
= $224 546

- NPV shows the total potential earnings of a project.
- NPV considers the effect of interest on future net savings.
- If NPV > 0, a project is profitable (economically feasible).
- NPV is a major decision making tool for project owners.

Step 10a - Calculate Savings-to-Investment Ratio (SIR)

- Savings-to-investment ratio (SIR)

  = present value of savings / present value of investments

  = PV_{AS} / PV_I

Example SIR = \$282 651 / \$58 105

= 4,9

- If SIR > 1,0 a project is profitable (economically feasible).
- SIR may also be important for project owners.

Step 10b - Calculate Internal Rate of Return (IRR)

- IRR is a hypothetical discount rate that causes SIR = 1,0 or NPV = 0.
- IRR requires an iterative calculation, easy for a computer.
- If the IRR ≥ the discount rate used in the analysis, the investment is worthwhile (economically feasible).
- A high IRR earns more profit per investment dollar.
- IRR is a major decision making tool for lenders, usually the first question they ask.
- Investors may each arbitrarily set their own minimum acceptable IRR, called a "hurdle rate."

Outputs

- A positive NPV (net present value) shows how much money the project will make in its lifetime.
- A negative NPV shows how much money a project will lose.
- NPV shows a project's absolute feasibility in terms of money.
- **Example: NPV = $ 224 546**

Outputs (cont.)

- **SIR = 4,9**
- The SIR (savings-to-investment ratio) is the same as a benefit / cost ratio.
- With *SIR* > 1,0 the project makes more money than it costs.
- With *SIR* < 1,0 the project costs more than it makes. *SIR* shows a project's relative feasibility.

Outputs (cont.)

- **IRR = 42%**
- IRR (internal rate of return) is the interest in percent that the project's investment will earn.
- Calculated by finding the theoretical discount rate for which *NPV* = 0, or *SIR* = 1,0.
- Theoretically, any project with an *IRR* greater than the company's cost of capital is profitable (and will have positive NPV).
- Companies set "hurdle rates" for *IRR*. A hurdle rate is an arbitrary minimum *IRR* that the company will accept for implementing projects. Hurdle rates are normally higher than a company's cost of capital, so only higher profit projects are selected.

Outputs (cont.)

- **SPB = 3,0**
- Simple payback (SPB), expressed in years, does not discount its input or consider future re-investment costs. *SPB* is only useful for projects with very quick return.
- If a project can pay back in a year, for example, there is little need to calculate discounted future values.
- For longer paybacks, *SPB* becomes inaccurate.

Extra Reading:

- C. O. Okoye, U. Atikol. A parametric study on the feasibility of power plants in North Cyprus Conditions. *Energy Conversion and Management* 2014; Vol.80: pp178-187
- U. Atikol et al. A feasibility integrated approach in the promotion of solar house design. *International Journal of Energy Research* 2013; Vol.37: pp378-388.