IE2111 ISE Principles & Practice II
Lab 5 - After-Tax Financial Risk Analysis of Renewable Energy Investment

Learning Objectives

In this lab, you will learn how to:

1. Develop an after-tax cash flow model for a renewable energy investment project using Excel basic functions based on base case data.
2. Perform One-Way Range Sensitivity Analysis using Sensit add-in software to better understand the key uncertainties in the project.
3. Perform Probabilistic Risk Analysis using Monte Carlo Simulation using @Risk.
4. Interpret Risk Profiles and determine risk measures.
5. Evaluate competitiveness of renewable energy and technology.

Problem Description

A company is planning to invest in another solar PV system on the roof top of a shopping mall that it is developing.

Costs: The system will cost $288,000. It will have a useful life 20 years and a salvage value of $2,000. Annual operations and maintenance cost is estimated be $1,500.

Energy output and system efficiency: Based on Singapore geographical location, orientation of the building and weather conditions throughout the year, the PV panels are capable of producing 250,000 kwh of electricity in the first year of operation. However, this output will degrade at a rate of 1% per year through its 20-year useful life. The electricity output from the PV panel is DC and need to be converted to AC via an inverter at an efficiency of 95% before it can be sold at 18 cents per kwh to either the shopping mall's tenants or to the power grid.

Project financing: For this project, the initial investment cost will be fully funded by the company's equity capital. The company computes the *WACC* and determines that the after-tax *MARR* should be 10% for the purpose of evaluating the financial feasibility of this project.

Income tax: The PV system is entitled to the 3-year capital allowances schedule and the corporate tax rate is 17%. Table 1 shows a summary of the relevant data.

Table 1. Data for the PV System

	Solar PV System	Base Value
1	Useful life (years)	20 years
2	Initial cost	$288000
3	Salvage value	$2,000
4	Annual O&M cost	$1,500
5	Energy output in year 1 (kwh)	250,000
6	System efficiency	95.00%
7	Annual degradation rate	1.00%
8	Electricity market price per kwh	$0.180

You have been engaged as a consultant by the company to evaluate and advice on the financially feasibility and risk of investing in this project using a study period of 20 years.

Lab Exercises

1. After-Tax Cash Flow Base Model Development & Analysis

Using Excel, perform after-tax cash flow financial analysis to determine the after-tax *PW* and after-tax *IRR* for the proposed solar PV system investment based on the estimated base values with a study period of 20 years. You may use the Excel template provided.

Notations:

- I = Initial investment cost.
- N = Study period.
- d_k = Capital allowance (depreciation) in year k, for $k = 1, 2, 3$.
- E_k = Operations & maintenance cost in year k, for $k = 1, 2, \dots, N$.
- BV_N = Book value of project at end of year N.
- MV_N = Market or Salvage value of project at end of year N.
- i = After-tax *MARR*.
- t = Tax-rate.
- r_k = Annual PV panel degradation rate in year k, for $k = 1, 2, \dots, N$-1.
- η_k = System efficiency in year k, for $k = 1, 2, \dots, N$.
- p_k = Price of electricity in the energy market in year k, for $k = 1, 2, \dots, N$.

Let S_1 = Total electricity generated by *PV* in year 1.

Due to annual degradation of the PV panels, total electricity generated in year k is

$$S_k = S_{k-1}(1 - r_{k-1}) \qquad \text{for } k = 2, \dots, N. \tag{1}$$

Annual total electricity sold in year k is

$$Q_k = S_k \, \eta_k \qquad \text{for } k = 1, 2, \dots, N. \tag{2}$$

A more convenient recursive formula to compute Q_k in Excel is

$$Q_k = \begin{cases} S_1 \eta_1 & \text{for } k = 1 \\ S_{k-1}(1 - r_{k-1})\eta_k & \text{for } k = 2,\dots,N \end{cases} \tag{3}$$

Annual revenue from sale of electricity in year k is

$$R_k = Q_k \, p_k \qquad \text{for } k = 1, 2, \dots, N. \tag{4}$$

After-tax *PW* of project is

$$PW(i\%) = -I + \left(\sum_{k=1}^{N} \frac{(1-t)(R_k - E_k) + td_k}{(1+i)^k} \right) + \left(\frac{MV_N - t(MV_N - BV_N)}{(1+i)^N} \right) \tag{5}$$

Answer the following questions:

Q1.1 After-Tax *PW* of project = ________________________

Q1.2 After-Tax *IRR* of project = ________________________

Q1.3 The project is financially feasible: . Yes / No .

2. Competitiveness of Renewable Energy

The **Levelized Cost of Energy** (*LCOE*) is a popular measure for assessing the feasibility as well as the overall competiveness of investing in renewable energy systems and technologies, such as for examples solar PV, wind farm, hydroelectric station, geothermal energy, etc.

LCOE is defined as the revenue per unit of electricity generated that would be required to recover the costs of building and operating an energy generating plant during an assumed system useful life or study period. Intuitively, it is also the minimum constant price at which electricity must be sold in the energy market in order to break even over the lifetime of the project.

Setting p_k = LCOE for all year k in Equation (4), and letting after-tax PW = 0 in Equation (5), we obtain

$$\text{After - tax LCOE} = \frac{I + \left(\sum_{k=1}^{N} \frac{(1-t)E_k - td_k}{(1+i)^k} \right) - \left(\frac{MV_N - t(MV_N - BV_N)}{(1+i)^N} \right)}{(1-t)\sum_{k=1}^{N} \frac{Q_k}{(1+i)^k}} \tag{6}$$

Hence

$$\text{After - tax LCOE} = \frac{\text{After - tax Present Equivalent Cost of Project}}{(1-t)\left(\text{NPV of Energy (kwh) sold}\right)} \tag{7}$$

Answer the following questions:

Q2.1 Present Equivalent life-cycle cost project =

____

Q2.2 NPV of Energy sold =

____

Q2.3 After-tax Levelized Cost of Energy of the project =

______________ cents/kwh

Q2.4 Compared with the price of electricity (18 cents/kwh), the proposed investment is

<u>Financially feasible / Not financially feasible.</u>

3. One-Way Range Sensitivity Analysis

You have identified seven factors in the base model that are subject to uncertainty. After extensive data collection and analysis including consultation with experts, the possible variation of values for these seven factors are shown in Table 2.

Perform one-way sensitivity analysis buy rainbow and spider diagrams for after-tax PW and after-tax IRR to better understand and identify the key uncertainties impacting the financial feasibility of the project.

Table 2: Possible variation in values of each uncertain variable.

	Variables	Low Value	Base Value	High Value
1	Initial cash flow	-$347,000	-$288,000	-$229,000
2	Salvage value	$1,000	$2,000	$3,000
3	Annual O&M cash flow	-$2,000	-$1,500	-$1,000
4	Energy output in year 1 (kwh)	240,200	250,000	259,800
5	System efficiency	93.00%	95.00%	97.00%
6	Annual degradation rate	0.50%	1.00%	1.50%
7	Electricity selling price per kwh	$0.1610	$0.1800	$0.2000

Answer the following questions:

Q3.1 The 3 most sensitivity variables are:

_______________, ________________, ______________

Q3.2 The least sensitivity variable is:

____

Other sensitivity analysis

Optional: Perform one-way range sensitivity on after-tax LCOE by plotting a tornado and spider diagram.

We will skip the rainbow diagrams plotting in this lab, but in practice, it should also be carried out as in Lab 3.

4. Project Risk Analysis using Monte Carlo Simulation

While the one-way sensitivity analysis performed in the previous step is useful for understanding how the uncertainty in each variable impacts the financial feasibility of the project, further analysis is needed to better understand the project's overall risk profile. Table 3 shows the probability distributions of the key uncertain factors and their parameters.

Table 3: Probability distribution for the top seven sensitive variables

	Variable	Distribution	Parameters
1	Initial cash flow	normal	mean= -288,000, sd= 30,000
2	Salvage value	Fixed	2,000
3	Annual O&M cash flow	triangular	min= -2,000, mode= -1,500, max= -1,000
4	PV output in year 1 (kwh)	normal	mean= 250,000, sd=5,000
5	System efficiency	truncated normal	mean=95.0%,sd=1.0%,min=93.0%,max=97.0%
6	Annual degradation rate	uniform	min= 0.50%, max= 1.50%
7	Electricity price per kwh	lognormal	mean= 0.180, sd= 0.010

Perform Monte Carlo simulations to generate the risk profile for the project's after-tax *PW*, after-tax *IRR*, and after-tax *LCOE*.

Answer the following questions:

<u>After-Tax *PW* Risk Analysis</u>

Q4.1 Basic Statistics:

Expected After-tax *PW* = ________________

Std Dev of after-tax *PW* = ________________

Q4.2 Downside Risk:

Probability that the project will be infeasible = ________________

Q4.3 Upside Potentials:

Probability that after-tax $PW \geq$ \$40,000 = ____________

Probability that after-tax $PW \geq$ \$80,000 = ____________

Q4.4 Value-at-Risk:

Present equivalent value-at-risk at 95% confidence = ____________

Present equivalent value-at-risk at 99% confidence = ____________

After-Tax IRR Risk Analysis

Q4.5 Basic Statistics:

Expected After-tax *IRR* = __________________

Std Dev of after-tax *IRR* = __________________

Q4.6 Downside Risk:

Probability that the project will be infeasible = __________________

Q4.7 Upside Potentials:

Probability that after-tax *IRR* ≥ 12% = _____________

Probability that after-tax *IRR* ≥ 14% = _____________

After-Tax LCOE Risk Analysis

Q4.8 Descriptive Statistics:

Expected After-tax LCOE = __________________

Std Dev of After-tax LCOE = __________________

Q4.9 Downside Risk:

Probability that LCOE ≥ $0.18 per kwh = __________________

Q4.10 Upside Potentials:

Probability that after-tax LCOE ≤ $0.14 per kwh = _________________

Probability that after-tax LCOE ≤ $0.16 per kwh = _________________

5. Conclusion & Recommendation

What is your final recommendation to the company?