**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* andafter-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.

*dk =* Capital allowance (depreciation) in year *k,* for *k* = 1, 2, 3.

*Ek* = Operations & maintenance cost in year *k*, for *k* = 1, 2, …, *N*.

*BVN* = Book value of project at end of year *N*.

*MVN =* Market or Salvage value of project at end of year *N.*

*i =* After-tax *MARR.*

*t* = Tax-rate.

*rk* = Annual PV panel degradation rate in year *k*, for *k* = 1, 2, …, *N*-1.

η*k* = System efficiency in year *k*, for *k* = 1, 2, …, *N*.

*pk* = Price of electricity in the energy market in year *k*, for *k* = 1, 2, …, *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

*Sk* = *Sk*-1 (1 – *rk*-1) for *k* = 2, …, *N*. (1)

Annual total electricity sold in year *k* is

*Qk* = *Sk*η*k* for *k* = 1, 2, …, *N*. (2)

A more convenient recursive formula to compute *Qk* in Excel is

 (3)

Annual revenue from sale of electricity in year *k* is

*Rk*= *Qk**pk* for *k* = 1, 2, …, *N*. (4)

After-tax *PW* of project is

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

 (6)

Hence

 (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

Financially feasible / Not financially feasible.

**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:**

After-Tax *PW* Risk Analysis

**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* ≥ $40,000 = \_\_\_\_\_\_\_\_\_\_\_\_

Probability that after-tax *PW* ≥ $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?