Project Greenopia: A Case Study

Your group has been tasked with conducting a pre-feasibility study for **Greenopia**, a site whose development rights your company would like to procure.

You have been provided with a historical year's data for reference renewable production at the site, and some preliminary cost numbers for CAPEX and OPEX of various renewable energy technologies and their variants.

You have made an agreement with the local electricity company (off-taker) who is willing to take all your power production at a fixed PPA price with a connection limit of 25 MW, which is maximum transmission capacity available for the site with shallow costs. Moving beyond that incurs deep costs, as provided in the excel sheet.

Below are the questions related to financial feasibility that you would like to find answers for.

Make reasonable assumptions in addition to those in the excel sheet.
Answer as many as you can.

1. **Base Case:**

   a. For a base case of PV (P1) installed capacity of 25 MW and no wind, assuming a discount rate of 3%, lifetime of 25 years and a fixed PPA of 70 $/MWh, calculate the NPV and IRR of the project. In which year of operation does the project breakeven? What is the LCOE for this plant configuration?
   With only PV of type P1 installed, here are the key financial metrics for the project's feasibility:
   Net Present Value (NPV) = 15.79 M$
   Internal Rate of Return = 7.84 %
   Levelized Cost Of Energy = 44.7 $/MWh
   Break even occurs at Year 13

   To compute the IRR, a neat trick is to use its definition as the discount rate which results an NPV of 0 at the end of the project's lifetime. With everything else fixed, try setting different values of discount rate in the excel sheet and see how the NPV changes. Plug in a few values until you find a nearly 0 NPV value. That should occur around 7.8% discount rate. That is the project's internal rate of return (IRR).

   Do you notice what the LCOE is at this discount rate? It should be equal to the Power Purchase Agreement (PPA) price chosen (70$/MWh). That is no coincidence. It essentially means that now your discount rate (or cost of capital) is exactly equal to the PPA price such that the project makes no money at all at the end of its lifetime, i.e., project's lifetime cost to produce all the MWh it produces equals the revenue it receives from power sale.

   A project is said to break-even when it has recovered all its investment. Therefore, it occurs when the net cumulative cash flows become positive for the first time. To see that add the discounted cash flows in Column H in the 'Cashflows' sheet until you reach a positive number. You'll notice that it happens in Year 13.

   b. What happens to these numbers when you flip the configuration to 25 MW of wind (W1) and no solar?
   With only Wind of type W1 installed, here are the key financial metrics for the

project's feasibility:
Net Present Value (NPV) = 2.75 M$
Internal Rate of Return = 3.475 %
Levelized Cost Of Energy = 66.8 $/MWh
Break even occurs at Year 24

Notice that the project just became less financially attractive (it is still financially feasible since NPV > 0) with the change in technology, since the CAPEX and OPEX of wind type W1 are higher compared to the PV of type P1.

c. What about different variants of PV and wind? Which plant configuration (P1 or P2 or W1 or W2 or W3) gives the highest NPV?
Among the various plant options available with a total installed capacity of 25 MW, a PV plant of type P2 gives the highest NPV at 22.94 M$.

To see why, notice that values for AEP in the 'Production Summary' sheet. You will find that PV with tracking P2 leads to a high AEP (and capacity factor) which comes at a relatively modest increase in CAPEX and OPEX compared to, for example, PV of type P1. Therefore, this plant configuration outperforms other projects, financially speaking.

2. **Hybridisation:**

a. Is it worthwhile to hybridise this plant, i.e., combine wind and solar? What are some good combinations that you found? If you find that hybridisation makes sense, why do you think it is so?
There are several possible combinations of wind and solar installed capacity (with a total of 25MW) that lead to a positive NPV, and are therefore financially feasible. The key word here is "good". Looking at IRR, let us make an assumption that an IRR > 7 % is considered a good investment by our investors.

With that assumption, a good combination is for example considering types P2 and W2, for example, a combination of 20MW solar and 5MW wind leads to an IRR of just around 7%. You can find many such combinations.

b. What if the fixed PPA price was 60$/MWh instead? Does hybridisation still makes economic sense?
If the fixed PPA price was 60$/MWh, for the example above of P2 and W2 of 20MW and 5MW respectively, the IRR reduces to 5.24 %, which is no longer "good" according to our assumption of requirement of >7% IRR. Therefore, in that case hybridisation no longer makes economic sense.

c. For what kind of a revenue structure, would hybridisation make economic sense, broadly speaking?
Broadly speaking, hybridisation makes sense if you have a requirement to improve the capacity factor of the plant. This could be, for example, a requirement to provide a certain percentage of your total (daily/monthly/annual) generated energy during the night hours when the sun is not shining. Or it could be to ensure a minimum base-load supply to your off-taker during all hours of the day. However, that would also require investing in storage of some sort to increase the chances of your ability to fulfil that part of the contractual agreement.

Additionally, if you have flexible PPAs wherein you get paid different amounts based upon hours of delivery (and therefore load in the system), it might make *economic sense to combine wind and solar to take advantage of better prices, depending on the location and the PPA structure.*

To learn more about the hybridisation process, situations where it makes economic sense, and to follow another case study, refer to this article (open-access): https://doi.org/10.1088/1742-6596/2507/1/012009

3. **Sensitivity studies:** Characterise the sensitivity of the NPV to the following and rank them according to the degree of impact on the financial feasibility (NPV) of the project:

    a. fixed PPA price

    b. discount rate

    c. solar and wind degradation factors

    d. Solar and wind AEP overestimation
    Let's revisit the previously discussed plant configuration with types P2 and W2 having installed capacity of 20 MW and 5 MW, respectively. With all other parameters values at the Base Case, we now compute the NPV. That comes out to be 10.08 M$. This plant configuration and the corresponding NPV defines a ***reference point*** *around which we will characterise the parameter sensitivity.*

    To do that, vary the above parameters one-by-one in reasonable steps, keeping all other parameters at the Base Case level, to study the rate of change in NPV. Table 1 below shows the results for changes of +/-10% for all parameters. Notice how some parameters are aligned with NPV in the directional sense of the change while others aren't. Also, notice how some of the sensitivities are asymmetric, i.e., +10% change in parameter leads to a different % change in NPV vs. -10% change. For such asymmetric cases, you can take the average of absolute value of those sensitivities for comparison purpose.

    As can be seen, for the plant configuration chosen (4 times as much solar installed capacity as wind), here is the ranking of NPV sensitivity to parameters:

    Fixed PPA price > Solar AEP overestimation > Discount rate > Wind AEP overestimation > Solar Degradation factor > Wind Degradation factor

    The exact order will depend on the plant configuration you have chosen as your reference point.

4. Intuitively, what kind of a site is Greenopia do you think? Is it in a largely sunny area or a largely windy area?
Looking at capacity factor values for the two renewable resources as well as the NPV values for the plant configurations, it appears the Greenopia is dominated by solar production rather than wind power production. Therefore, it must be a largely sunny area.

    In fact, it is a location in Samburu County in Kenya, which validates the above inference. The exact GPS coordinates of the site from where wind and solar production data are retrieved is (-1.2836, 36.8172)

    Bonus Activity: *If you now go to GlobalWindAtlas (*https://globalwindatlas.info/en*) and navigate to these coordinates, you will notice there is an area with a hilly terrain and therefore, high wind speeds and greater wind production potential about 10km to the left* *of this location. Reflect on the above questions and in the general context of the financial feasibility for the project, if Greenopia site was located there instead.*

Parameter, P	Value of P	ΔP	NPV	ΔNPV
PPA price	60	0	10.08	**0**
	66	10 %	15.34	**52.18 %**
	54	-10 %	4.82	**-52.18 %**
Discount rate	3	0	10.08	**0**
	3.3	10 %	8.51	**-15.57 %**
	2.7	-10 %	11.72	**16.27**
Solar degradation factor	1	0	10.08	**0**
	1.1	10 %	9.66	**-4.17 %**
	0.9	-10 %	10.51	**4.27**
Wind degradation Factor	0.5	0	10.08	**0**
	0.55	10 %	10.03	**-0.5 %**
	0.45	-10 %	10.13	**0.5 %**
Solar AEP overestimation	0	0	10.08	**0**
	10	10 %	5.84	**-42.06 %**
Wind AEP overestimation	0	0	10.08	**0**
	1	10 %	9.06	**-10.12 %**

Table 1: Results of sensitivity study