

Physics and Mathematics of Sustainable Energy

Finance Exercises

College of the Atlantic

Due Friday, November 4, 2022

Guidelines

- You can work on this with a partner and hand in only one writeup. If you opt for this route, I strongly recommend that one of you write the spreadsheet for scenario B and the other of you write the spreadsheet for scenario C. (Scenario A you have basically already done in lab last week.) Don't have the same person in the duo write both of the models.
- This should be typed up (not handwritten) and should be reasonably well explained. In particular, but be sure to clearly enumerate the various assumptions that you make in your models.
- Please use google docs for your spreadsheets and include a link to your spreadsheets in the submission you upload on google classroom.
- Your spreadsheets should use the techniques that I demonstrated last week. Namely, all the parameters (system cost, capacity factor, discount rate, etc.) in your model should be in their own cells—nothing should be hidden in a formula. This way you can easily adjust these parameters and see what happens. Also, anything that is a dollar amount should be indicated as such with a "\$", and you should round everything to the nearest dollar or perhaps the nearest ten dollars.

The Situations

Below are three situations for you to analyze and compare: purchasing solar cells, replacing an oil furnace with a heat pump system, and insulating and air sealing a house. The basics of each are described below.

Option A: Solar PV

- 16 solar panels, 450 Watts (nameplate) each.
- Capacity factor is 0.14.
- Installation cost: \$3/Watt.
- The electricity you generate is worth 23 cents per kWh.
- Run your analysis for two scenarios: with and without a 30% rebate.
- Assume that the solar panels last for 25 years.

Option B: Insulating Cottage

- Insulating the attic and air sealing Cottage will cost \$15,000.
- Doing so will reduce heat loss by between 25 and 35%.
- Cottage uses 875 gallons of fuel oil a year.
- Oil prices in Maine for the last 18 years can be found at <https://www.maine.gov/energy/heating-fuel-prices>.

- Assume that the insulation and air sealing will last for 25 years.

Option C: Installing Heat Pumps in Cottage

- Cottage uses 875 gallons of fuel oil a year. The efficiency of the furnace is around 70%.
- You will use the heat pumps to generate as much heat as the oil furnace delivered to Cottage. (I.e., the caloric value of 70% of 850 gallons.)
- The cost of electricity is 23 cents per kWh.
- The heat pump, installed, will cost \$11,000.
- Oil prices in Maine for the last 18 years can be found at <https://www.maine.gov/energy/heating-fuel-prices>.
- Assume the heat pump lasts for 15 years.
- Assume that the COP of the heat pump is 3.

Things to do and Figure Out

Once you have the spreadsheet set up, use it to answer the following questions.

1. For each of the investments, build a spreadsheet model that you can use to analyze it.
2. For each investment, calculate the payback time, ROI, NPV, and IRR for the solar cells. Determine the NPV for a discount rate of 5%.
3. For the solar panels, calculate the above quantities with and without factoring in the 30% rebate.
4. Estimate the emissions saved per year due to each investment. Assume a carbon intensity of 0.35 kg per kWh of electricity from the grid, and a carbon intensity of 0.04 kg per kWh of electricity generated from the solar panels you install.

Your Report

Suppose that COA is trying to decide among the scenarios you analyzed. There is only funding to do one of these projects. Write a report that will help inform this decision. Assume that your reader understands ROI, NPV, and IRR, and understand why reducing emissions is important.

Your report should be structured as follows:

1. Analysis of solar PV. Write a few paragraphs summarizing your analysis of this project. This summary should include not only your values for IRR, payback, NPV, and IRR, but the assumptions that went into these calculations. Include some assessment of risk. How confident are you of your analysis? What are some ranges or bounds for the quantities you calculated? Your analysis should include analysis both with and without the 30% rebate.
2. Repeat the above for attic insulation and air sealing. Be sure to include a discussion of how you handled the uncertainty around the price of heating oil.
3. Repeat the above for the heat pump. Be sure to include a discussion of how you handled the uncertainty around the price of heating oil.
4. Recommendation. Which investment do you recommend, and why? Your recommendation does not need to be based solely on financial considerations.

Your report should be typed/word-processed (i.e., not handwritten) and will probably be around two pages. Write in the style of a technical report. You do not need long, flowery prose. It is fine to use bulleted lists.

Things I am Looking For

When giving feedback on your report, here are some of the things I will be looking for:

- Are the spreadsheets clearly formatted (using the guidelines given above) and understandable to a viewer who is not you.
- Are your calculations accurate?
- In your report, do you clearly outline the assumptions that go into your calculations?
- Do you address the uncertainty associated with your calculations? Your approach of uncertainty should involve more than simply taking an average of oil prices. Consider a few different scenarios and get a sense of the range of possible outcomes.
- Does your report include a recommendation about which project the college should pursue?

Other, Optional things to Consider

If you have time and the inclination, there are some other considerations you could add to your analysis.

- Electricity prices in Maine are expected to jump to around 30 cents per kWh sometime next year. How does this change the
- What happens if the capacity factor of the solar installation is slightly different?
- What happens if the COP for the heat pumps is closer 3.5? (A COP of 3 is probably a low estimate.)
- What happens if the solar panels only last 20 years? Or if they last 30 years?
- What happens if the output of the solar panels decreases by 0.5 percent a year. (This is the median degradation rate for solar panels according to a report¹ by the US National Renewable Energy Lab.)
- What happens if there is a 2000 state rebate for solar PV? For the attic insulation?

Notes on the Scenarios

The numbers given above are all based on real systems. The solar installation numbers are those for a system I had installed at my house over the summer. I think the installation costs are likely higher now, due to inflation. Also, we needed to upgrade our electrical panel in order to tie our system in to the grid. I didn't include this cost in the scenario.

The Inflation Reduction Act reinstated the 30% tax credit for the next 10 years, and made it available as an upfront rebate for non-profits, schools, and municipalities.

The costs for the heat pumps and insulation/air sealing are approximate actual costs for work that was done in the last year.

¹<https://www.nrel.gov/state-local-tribal/blog/posts/stat-faqs-part2-lifetime-of-pv-panels.html>

As noted above, it is expected that the price of electricity in Maine will jump again in the next year to roughly \$0.30/kWh. The price of heating oil will likely continue to fluctuate.

In general, a lot is in flux economically. So some of the numbers in the scenario will likely soon be out of date. But they're pretty close to the current reality. And the spreadsheet models you built can be easily updated as numbers change.