Homework 3

BEE 4750/5750

Due: Oct 20, 2022 by 9:00pm ET

1 Overview

1.1 Learning Objectives

Homework 3 is focused on assessing your ability to formulate and implement linear programming models.

1.2 Background Information

You have been asked to develop a generating capacity expansion plan for the utility in Riley, NY, which currently has no existing electrical generation infrastructure. The utility can build any of the following plant types: geothermal, coal, natural gas combined cycle gas turbine (CCGT), natural gas combustion turbine (CT), solar, and wind.

Each of these plant types has the following generation data (**disclaimer**: these are not real), given in Table 1.

Assume that all 365 days in a year are equivalent in terms of demand and wind and solar capacity factors (**disclaimer**: this is obviously stylized and not reflective of reality, but it makes the problem simpler). These are given in Table 2.

The utility will also penalize any non-served demand at the cost of non-served energy, which is set at \$1000/MWh.

Type	Investment Cost (\$/MW-yr)	Operating Cost (\$/MWh)	Capacity Factor	CO_2 Emissions (tCO_2/MWh)
Geothermal	457000	0	0.95	0
Coal	268000	24	1	1
CCGT	85000	35	1	0.43
CT	62580	45	1	0.55
Wind	92000	0	see below	0
Solar	90000	0	see below	0

Table 1: Generation data for the available plant types.

Hour	Demand (MW)	Wind CF	Solar CF
1	1517	0.58	0
2	1486	0.57	0
3	1544	0.55	0
4	1733	0.28	0
5	2058	0.14	0
6	2470	0.21	0
7	2628	0.03	0.20
8	2696	0.04	0.57
9	2653	0.01	0.80
10	2591	0.04	0.93
11	2626	0.04	0.99
12	2714	0.01	0.99
13	2803	0.04	0.99
14	2842	0.04	0.99
15	2891	0.01	0.95
16	2821	0.01	0.81
17	3017	0.01	0.55
18	3074	0.13	0.12
19	2957	0.30	0
20	2487	0.45	0
21	2249	0.44	0
22	1933	0.57	0
23	1684	0.55	0
24	1563	0.58	0

Table 2: Demand (MW) and solar and wind capacity factors by hour for the representative day.

2 Problems

2.1 Problem 1: Minimizing Cost

Your first task is to find a capacity expansion plan which minimizes total costs of investment and operation.

2.1.1 Problem 1.1: Identify Decision Variables

Identify and define all relevant decision variables and their notation.

2.1.2 Problem 1.2: Formulate Objective

Formulate the objective function. Make sure to include any needed derivations or justifications for your equation(s).

2.1.3 Problem 1.3: Formulate Constraints

Derive all relevant constraints (you don't need to write them all out, but they should all be represented through your notation). Make sure to include any needed justifications or derivations. Why is your set of constraints complete?

2.1.4 Problem 1.4: Implement in `JuMP`

Implement your optimization problem in `JuMP`. For this sub-problem, you only need to provide a code block with the problem formulation.

2.1.5 Problem 1.5: Find the Solution

Find the optimal solution. How much should the utility build of each type of generating plant? What will the total cost be? How much energy will be non-served?

2.1.6 Problem 1.6: Visualize the Solution

Plot how much electricity will be generated under this plan each hour by each type of plant. Make both a line plot for the raw amounts (using `plot`) and a stacked area plot to show relative contributions to the total demand (using `areaplot`). What are your take-aways?

2.2 Problem 2: CO_2 Limits

The NY state legislature is considering enacting an annual CO_2 limit, which for the utility would limit the emissions in its footprint to 1.5 $MtCO_2$/yr.

2.2.1   Problem 2.1: Identify Changes from Problem 1

What changes are needed to your linear program from Problem 1? Formulate any different variables, objectives, and/or constraints.

2.2.2   Problem 2.2: Implement in `JuMP`

Implement your optimization problem in `JuMP`. For this sub-problem, you only need to provide a code block with the problem formulation.

2.2.3   Problem 2.3: Find the Solution

Find the optimal solution. How much should the utility build of each type of generating plant? What is different from your plan from Problem 1?

2.2.4   Problem 2.4: Visualize the Solution

Plot how much electricity will be generated under this plan each hour by each type of plant. Make both a line plot for the raw amounts (using `plot`) and a stacked area plot to show relative contributions to the total demand (using `areaplot`). What is different from your plan in Problem 1?

2.2.5   Problem 2.5: Value of Relaxing the Constraint

What would the value to the utility be of allowing it to emit an additional 1000 tCO_2/yr?

2.3   References

List any external resources consulted, including classmates.