

BEE 4750/5750 Homework 3

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Problem 1

Problem 1.1

For this problem, the decision variables are:

1. The installed capacity (MW) of generator type g : x_g
2. The production (MW) from generator type g in period t : $y_{g,t}$
3. The nonserved load (MW) in each period t : nse_t

Here, generators types include geothermal, coal, CCGT, CT, wind, and solar. Periods include every hour from 1 to 24.

We can begin to implement our model in Julia:

```
julia> using JuMP
julia> using HiGHS
julia> gencap = Model(HiGHS.Optimizer);
julia> generators = ["geo", "coal", "ccgt", "ct", "wind", "solar"];
julia> G = 1:length(generators);
julia> T = 1:length(hours);
julia> @variable(gencap, x[G]>=0);
julia> @variable(gencap, y[G,T]>=0);
julia> @variable(gencap, ns[T]>=0);
```

Problem 1.2

The objective function is to minimize the total cost of generation, which is the sum of the investment cost and the operating cost. If C_g^{INV} is the investment cost for generator g , C_g^{OP} is the operating cost for generator g , and L_t is the length of time period t :

$$\min Z = \sum_g C_g^{INV} x_g + \sum_g \sum_t L_t C_g^{OP} y_{g,t} + \sum_t NSE_{cost} nse_t$$

In Julia, this becomes:

```
julia> @objective(gencap,Min,investment_cost'*x + 365*(22*sum(y[2,:]) +  
35*sum(y[3,:]) + 45*sum(y[4,:]) + 1000*sum(ns)));
```

Problem 1.3

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?

The constraints of this problem include installed capacity and availability, the need to serve the load in all time frames, and nonnegativity. These can be written out as follows:

1. **Installed Capacity and Availability:** In a given time period, our $y_{g,t}$ cannot exceed the installed capacity multiplied by the capacity factor, as it is not possible for the generator to produce more than that quantity. When CF_g is the capacity factor for a given generator,

$$y_{g,t} \leq CF_g * x_g$$

2. **Serving Load:** The sum of the generated electricity and the nonserved load should equal the demand for that time period, D_t .

$$\sum_g y_{g,t} + nse_t = D_t$$

3. **Nonnegativity:** Our installed capacities, productions, and nonserved loads cannot be negative (this is physically not possible).

$$x_g \geq 0, y_{g,t} \geq 0, nse_t \geq 0$$

.

In Julia, this translates to:

```
julia> # Availability Constraints  
    avail = zeros(length(G),length(T));  
  
julia> avail[1,:] = thermal_cf[1]*ones(length(T));
```

```
julia> avail[2:4,:] = thermal_cf[2:4]*ones(length(T))';
julia> avail[5,:] = wind_cf;
julia> avail[6,:] = solar_cf;

julia> @constraint(gencap,availability[g in G, t in T], y[g,t] <=
    avail[g,t]*x[g]);

julia> # Load Constraints
    @constraint(gencap,load[t in T], sum(y[:,t]) + ns[t] == demand[t]);
```

Problem 1.4

```
julia> optimize!(gencap)
Presolving model
156 rows, 162 cols, 420 nonzeros
156 rows, 162 cols, 420 nonzeros
Presolve : Reductions: rows 156(-12); columns 162(-12); elements 420(-24)
Solving the presolved LP
Using EKK dual simplex solver - serial
  Iteration      Objective      Infeasibilities num(sum)
           0      0.0000000000e+00 Pr: 24(60321.5) 0s
        120      9.1214221224e+08 Pr: 0(0) 0s
Solving the original LP from the solution after postsolve
Model status      : Optimal
Simplex iterations: 120
Objective value     : 9.1214221224e+08
HiGHS run time      : 0.00
```

Problem 1.5

Answering the relevant questions using the following block of code:

```
julia> # Installed Capacity for Each Generating Plant
    installed_capacity = value.(x);

julia> # Total Cost
    total_cost = objective_value(gencap);

julia> # Nonserved Energy
    nonserved_energy_total = sum(value.(ns));
```

Therefore we get that the installed capacities for geothermal, coal, CCGT, CT, wind and solar are 0 MW, 0 MW, 1704 MW, 881 MW, 1238 MW, and 2729 MW respectively. The total cost for the expansion in this case would be 912,142,212 dollars, and the nonserved load would be 0 MW.

Problem 1.6

```
julia> # Assign generations to generator type
```

```

        served_load = ones(length(G),length(T));
served_load[:,:]=value.(y)[:,:];

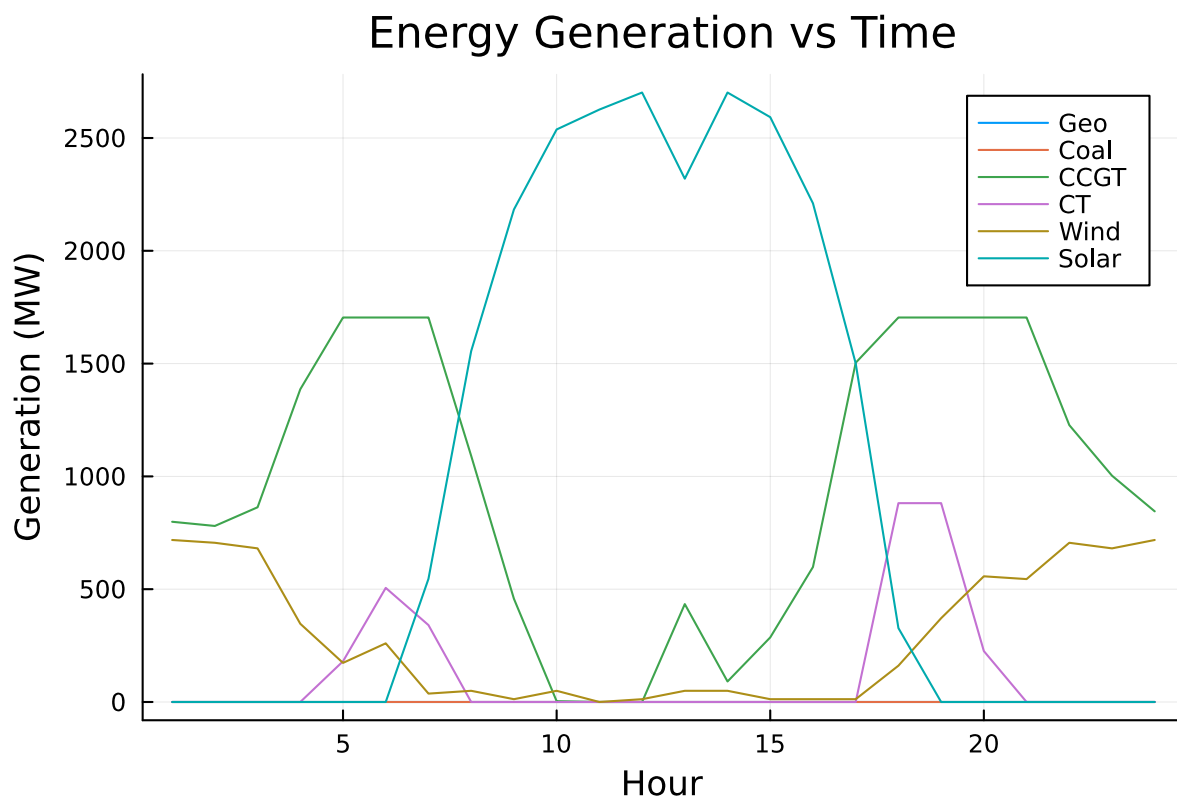
julia> using Plots

julia> # Plotting Line Plots for Raw Amounts

plot(hours,served_load[1,:],label="Geo",xlabel="Hour",ylabel="Generation
(MW)",title="Energy Generation vs Time");

julia> plot!(hours,served_load[2,:],label="Coal");
julia> plot!(hours,served_load[3,:],label="CCGT");
julia> plot!(hours,served_load[4,:],label="CT");
julia> plot!(hours,served_load[5,:],label="Wind");
julia> plot!(hours,served_load[6,:],label="Solar")

```

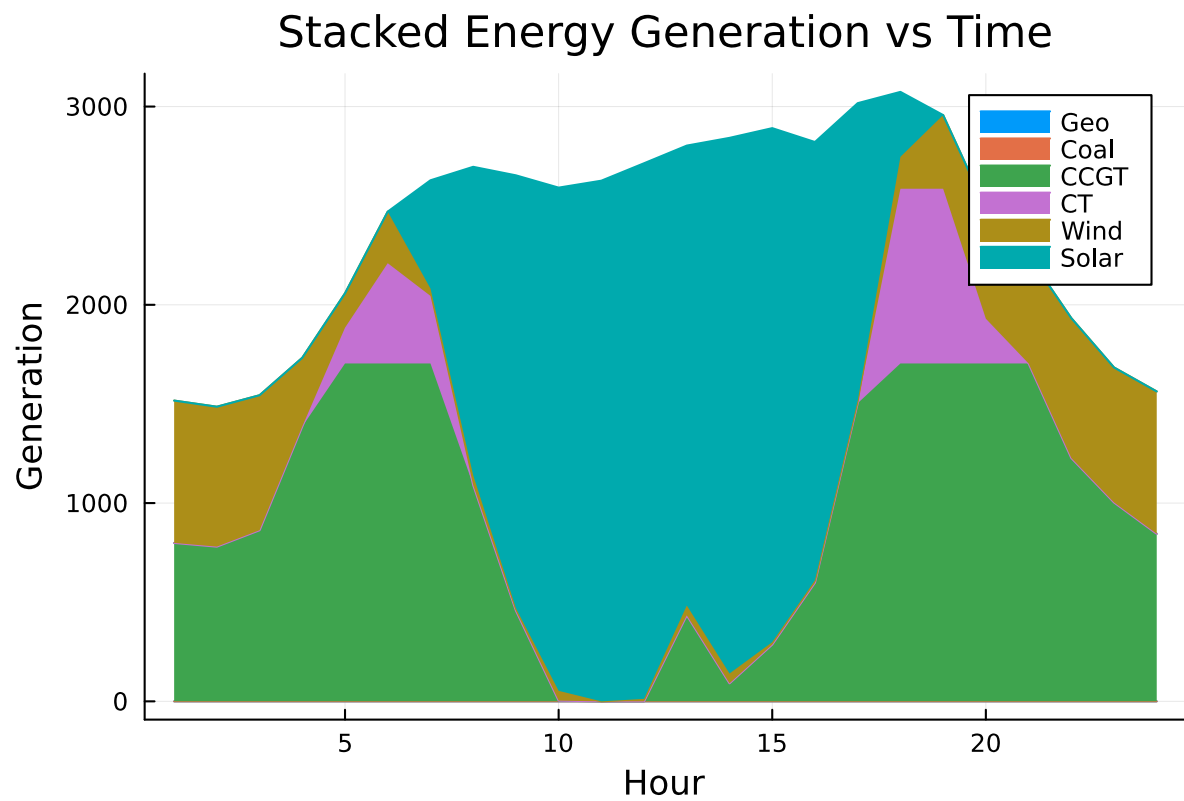


```

julia> # Plotting Area Plot for Overall Contributions

areaplot(hours,served_load',label=permutedims(["Geo","Coal","CCGT","CT","Wind","Solar"]),xlabel="Hour",ylabel="Generation (MW)",title="Energy Generation vs Time")

```



Problem 2

Problem 2.1

Problem 2.2

Problem 2.3

Problem 2.4

Problem 2.5

References