Final Exercise: Making a US Energy Plan

Physics and Mathematics of Sustainable Energy

Fall 2023. College of the Atlantic

Due: Friday, November 17, 2023

- Please feel free to do this in pairs if you wish and hand in only one write-up.
- There is no need to word-process your work; handwritten is fine. But please make your work readable.
- I would recommend doing a fairly thorough write-up. This exercise brings together a number of different things that we've done this term, so writing it up well is a chance for you document to your future self what you've learned.
- For this assignment use the 2022 energy US flow chart at: `https://flowcharts.llnl.gov`.
- (If you want to analyze another country, go for it! But please check with me, first, since we may need to modify the questions below.)
- Along the way you'll need to make some assumptions. Be sure to state what assumptions you make.

Your goal in this exercise is to come up with a plan that electrifies the transportation sector and replaces all the natural gas and petroleum used by the residential and commercial sectors with heat from electric heat pumps. We won't worry about the industrial sector. You'll first figure out how much electricity we'll need to generate, and then you can figure out how you would like to generate this electricity.

1. **An Initial Conversion:** One Quad per year is how many GW? (In what follows, use GW for all powers.) Do this by hand (with a calculator) and show your work.

2. **Transportation:** Assume that an electric car is 75% efficient at converting electrical energy from the grid into the kinetic energy of the car. How much electric power would be needed to electrify the transportation sector?

3. **Heating:** Let's assume that all the natural gas and petroleum consumed in the residential and commercial sectors is used for heat. Assume that the average efficiency of these heaters is 80%. Suppose we were to supply this heat with electric heat pumps instead. Assume that the heat pumps have an average COP of 3.5. How much electric power would this take?

4. **Add up Electric Power:** How much total electrical power will be needed? Add together your answers to the above two questions, and then add to this the electricity that is already used by the residential, commercial, and industrial sectors.

5. **Decide:** How do you want to generate this amount of power without using fossil fuels? Choose among the following non-fossil sources of electricity:

   - Solar PV
   - Nuclear
   - Onshore Wind
   - Offshore Wind

   Assume that hydro power in the US stays[1] at or near its current amount. Ignore grid considerations and seasonal fluctuations.

6. **Calculate Areas:** How much total land, in km^2, is needed for the solar and wind that you choose?

7. **Nuclear Power:** How many nuclear power plants are in your plan? Assume that each power plant can generate 2 GW.

8. **Map It:** Make a map on which you have indicated the land areas you'll use for Solar and on and off-shore wind. Don't worry about making a beautiful map, but try to make it somewhat clear. Rather than plotting each area as one giant square, I'd suggest breaking each area up into several smaller squares. Draw each nuclear power plant as a small dot. You'll want to locate the power plants near a river or coast.

[1] This means that you should subtract the hydropower from the amount of power you calculated in question four. The idea is that in question four you have figured out the total amount of electricity the US will need to generate. Once you subtract off the electricity from hydropower, you then need to decide how to generate the rest of the electricity.