Instructions for Top-Down Decarbonization Policy Analysis Lab

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Reading for Lab on Monday Oct. 29

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1 Introduction

In this lab, you will use a top-down approach to figure out how much new energy infrastructure you would need to install for each country or region in order to meet the emissions-reduction goals for 2050.

You will analyze the same countries and regions you did in the bottom-up lab last week:

class	region
Undergraduates	World, United States, China
Grad Students	World, United States, China, India, Brazil

2 The Assignment:

2.1 Outline:

1. For each country, examine the top-down projections for the Kaya variables for the year 2050. How many quads of energy does the Energy Information Administration preduct that the country will use in 2050?
2. Examine the mix of energy sources that the country used in 2017.
3. If the country uses the same percentages of each energy source in 2050 that it did in 2017, calculate how much energy the country would use from each energy source in 2050 and how

much CO_2 each energy source would emit. Add these up to get the total CO_2 emissions F in 2050 under a "business-as-usual" scenario.

4. Calculate the policy target for F in the year 2050.
5. Calculate how much the country would have to reduce its CO_2 emissions in 2050 below business-as-usual to meet its policy goal.
6. Allocate the emissions reduction from step 5 across the different fuels and calculate the amount of fossil fuel energy the country would need to replace with clean energy by 2050 to meet its policy goal.
7. Calculate how many clean power plants the country would need to build between now and 2050 to produce this clean energy.

   Report this as the total number, the number per year, and the number per week or per day if appropriate.

   Start by doing this calculation for nuclear energy plants, then repeat the calculation for solar, and then for wind.
8. Suppose instead that the country or region supplied its growing energy demand with coal. Calculate how many new coal power plants it would have to build between now and 2050 to supply the growing energy demand.

   Calculate the number of new coal power plants the country would have to build and how much additional CO_2 that would put into the atmosphere every year.

2.2 Detailed Instructions:

For each country:

1. Use the function `get_top_down_values()` from the `kayadata` package to examine the top-down projections for the Kaya variables for the year 2050. How many quads of energy does the Energy Information Administration preduct that the country will use in 2050?
2. Use the `get_fuel_mix()` function to get the mix of energy sources that the country used in 2017.
3. If the country uses the same percentages of each energy source in 2050 that it did in 2017, calculate the number of quads and the greenhouse gas emissions from each energy source in 2050, if the total energy consumed in that year is the value for E that you looked up in step (1).

   First, multiply the total energy demand E in 2050 by the percentages in the fuel mix to get the number of quads for that energy source. Then multiply the number of quads for each energy source by the emissions factor for that fuel to get the emissions from that energy source.

   Finally, add up the emissions from all of the fuel sources to get the total emissions for 2050, under a "business-as-usual" scenario, where the mix of energy sources does not change.

Hint: You can combine data frames using `join` functions to make this easier. Here is an example, which I have worked for Mexico. You can do the same thing for other countries or regions:

```
E_2050 <- get_top_down_values("Mexico") %>% filter(year == 2050) %$% E
fm <- get_fuel_mix("Mexico")

# Calculate the mix of energy sources for 2050
fm_2050 <- fm %>% mutate(quads = E_2050 * pct)
# Get the emission factors
factors <- emissions_factors()

# Combine the emission factors data frame with the fuel mix data frame:
fm_2050 <- fm_2050 %>% left_join(factors, by = "fuel") %>%
  # This line is to fix a problem with the kaya_data package,
  # because I forgot to put an emissions factor for Hydro power.
  mutate(emission_factor = replace_na(emission_factor, 0))

fm_2050 <- fm_2050 %>% mutate(emissions = quads * emission_factor)

# Summarize by adding up the emissions from each fuel source.
total_emissions_2050 <- fm_2050 %>%
  summarize(emissions = sum(emissions)) %$% emissions
```

4. Get the Kaya identity data for the country from `get_kaya_data()` and look up the CO_2 emissions F in 2005. Then use the policy goal for emissions reduction from the data frame `rcp_26` to calculate the policy target for F in the year 2050. You did this calculation last week as part of the bottom-up analysis.

5. Compare the projected "business as usual" emissions from step (3) to the policy target from step (4) to figure the total amount of emissions you would need to cut by converting fossil fuel energy sources to clean sources.

6. Use the top-down procedure I presented in class last week to allocate the emissions reduction that you calculated in step (5) across the different energy sources for 2050, that you calculated in step (3).

   How many million metric tons of CO_2 would you cut from coal, natural gas, and oil? How many quads of energy from that fuel would you need to replace with new clean energy?

   Add up all of the clean energy requirements to calculate the number of quads of clean energy that the country would need to add between now and 2050 to meet the policy goal.

7. Calculate how many clean generating plants you would need to build between now and 2050 to produce this clean energy. Report this as the total number, the number per year, and the number per week or per day if the number is large.

   Start with nuclear, then do the calculation for solar and then for wind.

You can look up the nameplate capacity and the capacity factor for different kinds of power plants (clean and dirty) from the function `generating_capacity()`.
Remember that the average number of megawatts a power source supplies over a year is the nameplate capacity times the capacity factor. Remember that one quad equals 11,000 megawatts.

8. Suppose instead that the country or region supplied its growing energy demand with coal. Calculate how many new coal power plants it would have to build between now and 2050 to supply the growing energy demand.

   Calculate the number of new coal power plants the country would have to build and how much additional CO_2 that would put into the atmosphere every year.