# Decarbonization Project Assignment, Part 2

EES 3310/5310 Global Climate Change

Report due Monday, November 6

## Top-Down Decarbonization

For this part, you will use a top-down approach to figure out how much new energy infrastructure you would need to install for each country to meet the emissions reduction goals for 2050.

## Working with R

Because of the difficulty everyone had last week with the interactive tool, I am taking a different approach this week. You I have made a new package called `kayadata` that loads the Kaya identity data for 66 countries plus the whole world and the collective properties of the 34 OECD countries (members of the Organization for Economic Cooperation and Development). This package is much simpler and does not rely on Java or on other packages that might pose problems. The template for the assignment automatically loads the package. If you want to load it yourself, you just do

```
library(pacman)
p_load_gh("gilligan-ees-3310/kayadata")
```

The packages contains the following functions:

- `get_kaya_data(country_name)`: Get Kaya identity data for a country.
- `get_fuel_mix(country_name)`: Get the fuel mix for a country
- `top_down_trend(country)`: Get trends (percent-per-year rate of change) of Kaya identity variables for a country according to top-down projection models.
- `top_down_values(country)`: Get top-down values of Kaya identity variables for a country for 2015 and projected into the future at five-year intervals from 2020–2050.
- `project_top_down(country, year)`: Get top-down projection of Kaya-identity variables for a country at a specific year between 2015 and 2050.
- `emissions_factors()`: Get emissions factors (million metric tons of $CO_2$ per quad) for different energy sources.
- `generation_capacity`: Get the nameplate capacity (in megawatts) and capacity factor for different kinds of electrical generating plants. The actual average power a plant produces over a typical year is nameplate capacity × capacity factor
- `kaya_country_list()`: A list of countries in this package's database.
- `megawatts_per_quad()`: Returns the number of megawatts required to produce a quad of energy per year. When converting from electrical generation capacity (from `generation_capacity()`) to quads, the number of quads a power plant produces in a typical year is nameplate capacity × capacity factor/megawatts per quad.
- `plot_kaya(kaya_data, variable)`: Plot Kaya data for a country. Optionally, change the start and stop year for highlighting and trend fitting, add a trend line, plot on a logarithmic scale, and use a custom $y$-axis label.
- `plot_fuel_mix(fuel_mix)`: Plot the mix of energy sources that a country gets its primary energy supply from.

You can get help on the functions from inside RStudio by typing `?function_name` at the RStudio console (where you use the actual function name instead of `function_name`) by highlighting a function name and pressing the F1 key, or by typing the function name into the search box at the top right of the help window inside RStudio.

Just in case there are problems with this package, I have put the data files and the plotting scripts in the lab project repository: You can load the raw data with the following commands:

```
load("data/kaya_data.rda")
load("data/fuel_mix.rda")
load("data/td_trends.rda")
load("data/td_values.rda")
```

You should only do this if you have trouble with the `kayadata` package.

## Assignment

Undergraduates should do each of the following exercises for the whole world, the United States, and China. Graduate students should do the exercises for the World, the United States, China, India, and Brazil.

1. Get the top-down projections for Kaya identity variables for the year 2050. How many quads of energy does this predict that the country will require in 2050?

2. Get the fuel mix for the country and determine the amount of energy (in quads) from each source (coal, gas, oil, nuclear, and renewables) the country used in 2016.

3. If the country uses the same mix of fuels in 2050 that it does in 2016, calculate how many quads from each source it will use, how much $CO_2$ will it emit from each source, and the total $CO_2$ emissions.

4. Calculate the target emissions for 2050 using the following table of target reductions below 2005 for different countries and regions:

| Country | Year | Emissions Reduction from 2005 |
|---|---|---:|
| Africa | 2050 | 28% |
| Australia_NZ | 2050 | 82% |
| Canada | 2050 | 72% |
| China | 2050 | 78% |
| India | 2050 | 73% |
| Japan | 2050 | 66% |
| South Korea | 2050 | 67% |
| Latin America | 2050 | 40% |
| Middle East | 2050 | 32% |
| Southeast Asia | 2050 | −17% |
| USA | 2050 | 73% |
| Western Europe | 2050 | 74% |
| World Total | 2050 | 36% |

5. If we wanted to cut emissions in the country to the policy target you found in question #4, by replacing fossil fuels with renewable energy, calculate how many quads of clean energy would we need to supply?

6. How many clean generating plants we would need to build to produce the amount of clean energy you calculated in part 5? (Use the `generation_capacity()` and `megawatts_per_quad()` functions from the `kayadata` package).

   (a) If we used only nuclear power, how many large nuclear power plants would we need to build?
   (b) If we used only solar energy, how many large solar thermal plants would we need to build?
   (c) If we used only wind, how many wind turbines would we need to build?

7. Suppose that instead of trying to cut emissions, your countries just use coal to provide all the additional energy that they will need in 2050? (That is, the difference between $E(2016)$ and $E(2050)$ ).

   How many new coal-fired power plants would the country need to build between 2016 and 2050 to supply the growing demand for energy?

8. Express your energy infrastructure equivalents (coal plants, nuclear plants, solar plants, wind turbines) in a manner that makes sense—such as installations per day or per week between now and your target date.

9. Comment on the challenges of simply providing enough energy to meet your country's demand and the challenge of trying to do this while also cutting $CO_2$ emissions.