**Grid Resilience Analysis**

**General Objective**

Compare different energy portfolios against variable demand curves.

**Instructions**

1. Student teams construct 3 different energy portfolios, made up of various energy sources. Inspiration for these sources can come from the Energy Supply opportunities outlined in the En-ROADS simulator.
   1. An example of an energy portfolio may be: 25% solar PV, 25% wind energy, 25% natural gas, 10% bioenergy, and 15% coal.
2. Student teams are provided the variable energy demand curve file included in the project files folder. This dataset shows the energy demand during the day from midnight to midnight in MW.
3. Student teams will research each energy source in their portfolio to determine if it has the ability to produce baseload power (can be turned off and on easily) or intermittent power (conditions must be met for power generation). In addition they will research the emissions factors for these energy sources (i.e., kgCO2/MWh).
4. Student teams will conduct research related to electric grid reliability, stability, and resilience to become familiar with these terms.
5. Students will develop a game of change for each intermittent source. The likelihood of it producing energy is linked to:
   1. Time of day (for example, solar PV will not produce energy until the sun is up)
   2. The outcome of the game of chance (i.e., deck of cards or dice)
6. Students will run simulations, where they will record which energy producers from their initial portfolio provide energy to meet demand throughout the day.
7. Once each hour in the day has been evaluated for the energy source that provides the energy, the following calculations can be completed:
   1. Theoretical CO2 emissions if the initial portfolio were to deliver energy at the stated distribution to meet demand every hour of the day.
   2. Actual CO2 emissions associated with energy produced to meet demand
   3. Difference between CO2 emissions from the initial energy portfolio (theoretical) and the actual responsiveness of the portfolio (actual).
8. Students will evaluate the project and prepare and deliverable that answers the following questions:
   1. How did you decide to implement the intermittency, as a game a chance in your simulations?
   2. Were the energy portfolios you developed able to meet the energy demand consistently over the course of the day? Why or why not?
   3. How does the intermittency factor play into meeting the energy demand consistently?
   4. Thinking about the results from your simulation, how do you think intermittency of energy sources is dealt with on the actual electricity grid? How long do you think energy demand could not be met fully, and still be societally acceptable? Why?
   5. Can you think of anytime in your lifetime where electric grid reliability of stability was at risk? When was it? What were the impacts?
   6. If you were to take these findings and present them to policymakers, what do you think is the most important thing to get across to them, and why?

**Example of Project Simulation for 1 hour**

**Initial Energy Portfolio:** 25% solar PV, 25% wind energy, 25% natural gas, 10% bioenergy, and 15% coal

**Total Energy Demand for Hour 1:** 100 MW

Theoretical Energy Distribution to Meet Demand:

* 25 MW solar PV (0 kgCO2/MW)
* 25 MW wind energy (0 kgCO2/MW)
* 25 MW natural gas (443 kgCO2/MW)
* 10 MW bioenergy (300 kgCO2/MW)
* 15 MW coal (1024 kgCO2/MW)

Total: 100 MW and 29,435 kgCO2

**Intermittent Energy Resources:** Solar PV, Wind

**Baseload Energy Resources that can turn on/off to meet excess demand:** Natural Gas, Bioenergy, Coal

**Game of Chance to Illustrate Intermittency:**

* Solar PV is available when it is day time (6am - 6pm) and dice role is 1, 2, 3
* Wind Energy is available when dice role is an even number.
* (Optional conditions can take a similar form to this:) To make this more realistic and harder, if dice rolled is a 5, energy demand increases by 50%, but renewable energy can only be increased by 10%.

**Actual Energy Distribution to Meet Demand for Hour 1:**

* Dice Roll: 4
  + No solar energy is available, so the 25 MW from the theoretical case is moved into the natural gas category
  + Wind energy is available
* 0 MW solar PV (0 kgCO2/MW)
* 25 MW wind energy (0 kgCO2/MW)
* 50 MW natural gas (443 kgCO2/MW)
* 10 MW bioenergy (300 kgCO2/MW)
* 15 MW coal (1024 kgCO2/MW)

Total: 100 MW and 40,510 kgCO2

**Comparison Between Theoretical vs. Actual Energy Production:**

* Was the energy demand met in both cases?: Yes
  + The answer to this may change if the dice roll condition was 5 and the portfolio was fully renewable energy
* How much was the difference in CO2 generated for the hour?: 11,075 kgCO2 more in the actual scenario
* If the CO2 value was different, why was the CO2 different between the two scenarios?: Natural gas had to turn on to meet demand that could not be met by solar PV.