Activity Duration: 90 minutes

Grade Level: 9-12

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EPA Energy Game

Generate: The Game of Energy Choices

Generate is the EPA's interactive game that allows students to explore energy choices and teaches the considerations and costs in deciding what type of energy generation to build.

Download the following resources:

EPA's Generate Game (How To Play the Game of Energy Choices) to learn how to play

Introductory PowerPoint Presentation File to explain the game to your students

Editable Companion Excel File to calculate team scores and show team rankings

PowerPoint How-to Guide for using Google's Jamboard to play the game virtually

Game instructions and printable pieces included in this PDF **Pages**

Generate: The Game of Energy Choices

Instructional Support Document

Summary

- **Players:** 5 Student Teams (approximately 4-6 students per team)
- **Time:** 60-90 minutes (more time with extensions)
- **Format**: Board game with introductory slides and Excel workbook for scoring (virtual/online options described separately)
- **What's New in the 2021 Version**? Updated energy costs, new pieces for existing natural gas and nuclear, new biomass pieces, inclusion of air quality impacts for fossil fuels, and additional renewable energy options in Round 2.

Overview

The objective of Generate: The Game of Energy Choices is to engage students in grappling with the complexities of our energy challenges in order to cultivate a deep and layered understanding of these challenges. The game serves as a dynamic platform for teaching players about the considerations involved in deciding what type of energy generation to build, as well as the costs (financial and otherwise) involved in providing electricity. It examines impacts on the environment, including how different mixes of sources of electricity can affect emissions of carbon dioxide (CO_2), air pollution, and water use. The game introduces the important role of energy efficiency in reducing the need for fossil fuels and has the potential to explore different energy contexts specific to geographic regions as well as discuss how technology change and socio-political considerations determine a region's energy pathways.

This game, which is a powerful engagement strategy to begin a deeper examination of energy issues, is appropriate for use with a variety of age groups including middle school, high school, college/university, informal educational settings like museums, or other community forums. The game is played in a variety of rounds and teachers should select the rounds that are appropriate to age group and course standards. The game aligns with several Next Generation Science Standards (NGSS) and standards for Math and English Language Arts (ELA). Because the in-person development of the Generate game was in Research Triangle Park, North Carolina, Essential Standards for a variety of subjects and levels are also included. The game may align well with other state-level standards, and teachers are encouraged to identify relevant standards and think broadly about the connections to math, science, ELA, and social studies.

Essential Objectives for High School Students

- Understand and evaluate the different sources of electricity generation, and the trade-offs between their cost and their environmental impact.
- Identify potential improvements in energy technologies that could mitigate the trade-offs.
- Create, evaluate, and refine competing design solutions for the electricity generation mix based on total system cost, which includes the financial cost, cost of the environmental damages, and environmental limits.
- Analyze and describe the complexities of designing a cost-effective and environmentally friendly electricity generation mix.
- Explain the impact of constraints in resource availability or the ability to use different technologies on designing optimal electricity generation mixes.
- Evaluate the impact of energy efficiency on design solutions in terms of system cost, environmental impact and competitiveness of renewables, and describe the relevancy of their own actions.

Essential Objectives for Middle School Students

- Identify and classify types of energy and understand their basic characteristics.
- Understand some of the factors involved in designing an energy system to meet the needs of people while protecting the environment.
- Explain why energy systems are different across states, regions and world.
- Describe some of the challenges in trying to reduce the environmental impact of generating electricity.
- Evaluate sources of energy for their environmental impact.

Materials

Printable PDFs located at: https://www.epa.gov/climate-research/generate-game-energy-choices

- This Instructor's Guide
- Game Board and Pieces (1 game board and 1 set of pieces per team, 5 teams, see table below)
- Full-size Game Boards – (optional) this can be used for printing and mounting on foam board
- 1 Score Card per team
- Introductory presentation slides with speaker notes
- Excel spreadsheet for scoring and team rankings

Additional and optional materials:

- Computer and Projector that can display presentation and Excel Spreadsheet
- Set of Red Light, Green Light, Yellow Light cards for each team (optional, see explanation under "Differentiation")
- Calculators for each team (optional)

Assembly of Team Materials

The printable boards and pieces provided on the website (https://www.epa.gov/climate-research/generate-game-energy-choices) are designed for 5 teams. There may be some extra pieces for each type of energy. Additional teams can be created by simply printing additional pieces and boards. For assembly, use one quart or gallon-sized plastic zipper storage bag per team (and a bag for the extra pieces).

Table 1. Initial distribution of pieces to teams

	Team 1	Team 2	Team 3	Team 4	Team 5
Nuclear - New	1	1	1	1	1
Nuclear - Existing	2	1	1	1	1
Coal - New	2	2	2	2	2
Coal - Existing	3	3	1	6	2
Coal - CCS	2	2	2	2	2
Natural Gas - New	2	1	5	1	6
Natural Gas - Existing	3	6	6	1	6
Wind - Small	4	8	2	8	7
Wind - Large	2	3	2	3	2
Wind with Battery	1	1	1	1	1
Solar - Small	4	0	6	0	1
Solar - Large	1	2	3	1	0
Solar with Battery	1	1	1	1	1
Biomass	2	2	2	2	2
TOTAL AREA OF PIECES	640	640	640	640	640

Table 1 shows the initial distribution of pieces. The distribution of pieces for each team will differ, reflecting how different states, regions, and countries have varying resource availability as well as in their existing electricity generation mix. More detail will be provided below. While this is the initial distribution, additional wind and solar pieces are introduced in Round 2. Energy efficiency pieces are introduced in Round 3. Have students return the original number of pieces (shown in Table 1) to the bags at the end of the game and return any extra pieces to the instructor.

Pieces can be printed on letter-size printer paper. For more durable versions of the pieces, it is recommended to print on cardstock and/or laminate the pieces as well as the boards. There are two options for the board. The board that is included in the file with the pieces can be printed on two letter-size pieces of paper and simply taped together or laminated. There is another version of a larger board, for printing at a 13 by 16 inch size, and can be printed and mounted on foam board and or laminated for a larger, more durable version. The score cards can also be printed/laminated so that students can use dry erase markers on them. For additional teams, you can duplicate a team or create your own distribution of pieces!

These files are all available at https://www.epa.gov/climate-research/generate-game-energy-choices and are updated periodically.

Student Preparation for Activity

For the high school level of instruction, students are expected to enter the activity with a *basic* understanding ofthe types of and differences between fossil fuels, non-fossil and renewable energy sources. They should also have an understanding of carbon dioxide (CO_2) emissions and air pollution from fossil fuel combustion and the linkage of CO_2 emissions due to human activities to climate change and its impacts. As the game can be played at a variety of levels, teachers may decide that students need more preparation to play more complex rounds.

Game play and rounds

1. **Game introduction and background**
    a. Divide students into teams of 4-5 students. Present each team with a game board, bag of pieces, and student score card. Calculators are also encouraged. For smaller classes, use fewer teams and for larger classes, team sizes can be increased.
    b. To begin playing the game, use the PowerPoint presentation available here: https://www.epa.gov/climate-research/generate-game-energy-choices
    c. The Power Point presentation includes speaker notes for presenting the game with talking points and additional introductory and background information. The speaker notes also include short summaries of the first three rounds of the game. The sections below describe each round in detail and also show the most likely team results for each round.

2. **Round 1**
    a. Explain to the students that their goal for each round is to fill the white area of the board, also called the grid, in a way that achieves the **lowest possible score**.
    b. Using the slides, show the students how to calculate the cost per piece, but also emphasize to students that the pieces have different sizes to take into account. The students should use the least expensive pieces first as they fill out their board.
    c. Assign a CO_2 price of 0, so total costs of CO_2 are not factored into this round. Air quality impacts, the wavy lines in the low-left corner circle, will not be enforced in this round.
    d. Give students about 10-15 minutes to fill in their board. Instruct students to write down how many pieces of each type (including fuel or resource type, size, and new or existing) they used on the score sheet.
    e. When they finish, instruct teams to send up a representative with the score sheet, so that you can begin plugging in their chosen energy mixes into the spreadsheet. Minimize the PowerPoint and project the spreadsheet. Be sure that the CO_2 price is set at 0. Fill in the number of pieces for each team as shown below.
    f. Below is an image of the spreadsheet with a common solution to the first round. Actual solutions will differ depending on the students' decisions. Note that the green check marks appear with a team has correctly filled in their board. If there is a red "X" then they will need to recheck their numbers.
    a. The spreadsheet will show TOTAL COST of each team's electricity mix. This is their score.

Teams will be ranked according to the lowest cost. The rank of 1 is the lowest cost, while 5 is the highest cost. If you play with less than five teams, note that any un-played teams will rank as first because they will have zero costs.

Table 2. Team solutions for Round 1

	Team 1	Team 2	Team 3	Team 4	Team 5
Nuclear - New					
Nuclear - Existing	2	1	1	1	1
Coal - New					
Coal - Existing	3	3	1	6	2
Coal - CCS					
Natural Gas - New	2	1	5	1	6
Natural Gas - Existing	3	6	6	1	6
Wind - Small	4	8	2	8	7
Wind - Large		1		1	
Wind with Battery					
Solar - Small	4	0	6	0	1
Solar - Large	1	2	3	1	0
Solar with Battery					
Biomass					
Efficiency Small					
Efficiency Large					
This is your breakdown of costs, total cost, and rank for each team					
Cost (Build and Operate)	**5530**	**5445**	**5563**	**5477**	**5517**
Total Cost of CO_2	**0**	**0**	**0**	**0**	**0**
TOTAL Cost	**5530**	**5445**	**5563**	**5477**	**5517**
Ranking	**4**	**1**	**5**	**2**	**3**
CO_2 emissions	**585**	**657**	**531**	**882**	**702**
Air Quality Health Impacts	**14**	**16**	**14**	**20**	**18**
Water use	**216**	**150**	**134**	**178**	**154**
Grid squares not covered	✓0	✓0	✓0	✓0	✓0
Small Needed	✓0	✓0	✓0	✓0	✓0

3. Round 1 – Discussion questions

a. Once all teams have finished and been ranked, ask them to compare their scores and rankings. (See Table 2) For the teams ranked 1 and 2, what does your energy mix look like? What was the strategy? *Answer: The strategy was to use existing resources as much as possible, particularly existing natural gas and coal.*

b. At this point, you can also ask students if this reflects the energy mixes any places in the U.S.? *Answer: Yes! It is difficult to have an exact match because the Generate pieces cannot capture small differences in percentages. Generate also does not include hydropower or geothermal. However, generally speaking, the pieces provided to the teams roughly resemble the energy mixes associated with the following states: Team 1 – NC, Team 2 – TX, Team 3 – CA, Team 4 – IA, Team 5 – FL, based on the electricity generating region in which the states are located (see EPA's Power Profiler tool* *https://www.epa.gov/egrid/power-profiler#/ for these regions as well as others for the rest of the United States).*

c. According to 2018 data, North Carolina has a large share of nuclear power, for example, with the rest of the mix split between natural gas and coal. Iowa uses a large share of coal, but also has over 20% share of wind resources. California has a mix of renewables, with a high share of solar, and the lowest percentage of coal of these states. Florida has the largest share of natural gas, with the rest made up of nuclear and coal power, with a perhaps surprisingly low share of solar. Texas has a large wind industry, but also produces natural gas, which makes up nearly half of generation.

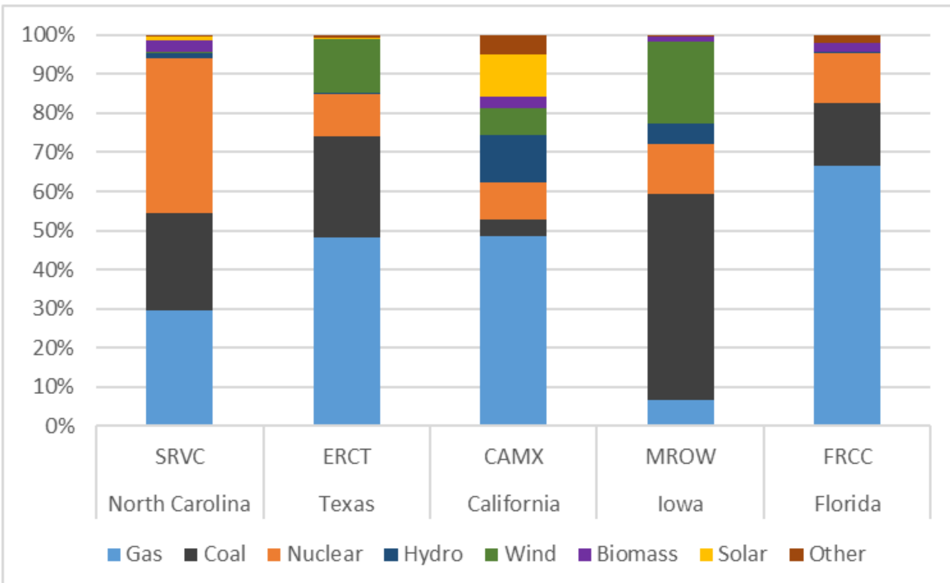

Figure 1. Fuel mix for 5 states (sources not used in Generate are shown as "other"). The region names used in the EPA's Power Profiler are also listed for reference.

d. Did some teams seem to have an advantage for this round because of the types of pieces they had available to them? *Answer: Those with more existing natural gas, coal, and nuclear have an advantage in this round. Table 3 shows the ranking for the 6 lowest cost pieces for Round 1.*

Table 3 Piece Rankings for Round 1 (CO_2 price = 0)

Natural Gas - Existing	1
Coal - Existing	2
Nuclear - Existing	3
Solar - Large	4
Natural Gas - New	5
Wind - Large	6

e. What made each team use the smallest size pieces? *Answer: The small row at the bottom of the board could only use small pieces for wind and solar. This can represent state or regional energy policies. It may also represent a situation in which small generators, like solar and wind, are added incrementally, instead of being constructed as a large power plant, wind farm, or solar farm. Many states have standards for minimum amounts of renewable electricity, sometimes called Renewable Portfolio Standards, which may require a percentage of electricity to come from wind, solar, and possibly biomass, hydropower or geothermal.*

f. The instructor may point out whether the students total scores are very similar or different. Most teams should be able to reach total costs between 5,400-5,600.

g. Which teams had the highest CO_2 emissions? Highest air pollution impacts? What is the relationship between the two? *Answer: The teams with the largest area covered by a combination of coal and natural gas will have the highest CO_2 emissions and air quality impacts. Fossil fuel combustion emits CO_2 as well as air pollutants, like Particulate Matter (PM) that can have negative impacts on human health. For simplicity, biomass pieces may be considered to have zero CO_2, if the biogenic CO_2 from burning that biomass for energy is exactly offset by removal of CO_2 from the atmosphere by growing the trees or crops. While this can result net zero releases of CO_2 to the atmosphere, the reality is often much more complex. That said, like fossil fuels, burning biomass releases air pollutants that are also of concern for human health.*

h. What causes water use for electricity generation? *Answer: Thermoelectric plants like nuclear, coal, natural gas, and coal, rely on water. Water for thermoelectric power is used in the process of generating electricity with steam-driven turbine generators*. This question can be further explored in other variations or extensions of the game – see .

4. Next rounds

a. The following rounds can be modified based on time available and student needs and teaching objectives.

b. At least one round with a CO_2 price and one round of energy efficiency should be played.

5. Round 2

a. Inform students that they will play another round. This time, teams will have to take CO_2 prices and costs[1] into consideration. They must rethink their strategy and will redo their boards. The instructor can also introduce the health and economic costs of air quality impacts[2] at this point and make a rule that the air quality impacts for the board must be less than a given number, typically 10-15.

b. The slides describe the changes in the calculations. The goal still is to achieve the lowest total cost or score. However, now teams must consider the cost of CO_2 emissions, and limitations on air quality impacts, if used for this round. These CO_2 prices reflect the damages associated with climate change, while placing an upper limit on the air quality impacts will further reduce the health and economic impacts of air pollution.

c. Set the CO_2 price multiplier at 1 on the spreadsheet. Let the students see how their total costs and even rankings would change even before redoing their grid. It may help to show this different a few times.

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[1] While these are distinct terms, CO_2 price and CO_2 cost are used somewhat interchangeably for the purposes of this game. However, in general, the price is the CO_2 multiplier that is applied (0, 1, 4, etc.) while the CO_2 cost is the product of multiplying CO_2 emissions by the CO_2 price per unit of emissions, by the 30-year lifetime.

[2] https://www.epa.gov/air-research/research-health-effects-air-pollution

d. Now give the students additional solar pieces and wind pieces as shown in Table 4. The reason these pieces are not all given in the first round is that the goal is to show the Round 1 results in a way that reflects <u>current</u> energy mixes for states in the U.S. (with generally lower levels of wind and solar). Therefore, solar and wind are more restricted in Round 1. In Round 2, we assume growing supplies of renewable technologies.

Table 4. Number of additional pieces per team for Round 2	
Solar	4
Solar with Battery	2
Wind	3
Wind with Battery	3

e. Let the teams redo their boards taking into account the purchase and operating costs, plus the CO_2 price and air quality limits, if used. Remind them to multiply their annual CO_2 emissions by 30 years and then multiply by the CO_2 price. That will give them the total cost associated with their CO_2 emissions.

f. Give students about 10 minutes to find their new energy mix. They should now be more familiar with the game, but the calculations with CO_2 are more complex. Remember: the total costs only change for the fossil fuels.

Table 5. Team solutions for Round 2, assuming CO_2 price = 1, but no AQ limits

	Team 1	Team 2	Team 3	Team 4	Team 5
Nuclear - New					
Nuclear - Existing	2	1	1	1	1
Coal - New					
Coal - Existing	2	2	1	5	2
Coal - CCS					
Natural Gas - New					
Natural Gas - Existing	3	6	6	1	6
Wind - Small	4	8	2	8	7
Wind - Large			1		2
Wind with Battery					
Solar - Small	4	0	6	0	1
Solar - Large	5	6	7	5	4
Solar with Battery					
Biomass					
Efficiency Small					
Efficiency Large					
This is your breakdown of costs, total cost, and rank for each team					
Cost (Build and Operate)	**5606**	**5494**	**5570**	**5526**	**5551**
Total Cost of CO_2	**378**	**486**	**351**	**711**	**486**
TOTAL Cost	**5984**	**5980**	**5921**	**6237**	**6037**
Ranking	**3**	**2**	**1**	**5**	**4**
CO_2 emissions	**378**	**486**	**351**	**711**	**486**
Air Quality Health Impacts	**9**	**12**	**9**	**16**	**12**
Water use	**192**	**130**	**114**	**158**	**130**

6. Round 2 – Discussion questions

a. Compare the new team rankings. What do the cheapest energy mixes now look like? *Answer: With a relatively low CO_2 price of 1, existing coal and natural gas are still viable, and nuclear and renewable costs do not change, as there is no CO_2. However, no new natural gas or coal are built* *because they cost too much in this round. Table 5 shows the solutions to this round.*

a. How are team costs divided between the cost to build and operate and the total cost of CO_2? *Answer, the total cost of CO_2 ranges from about 300 to over 700.*

b. What pieces did teams start to swap? *Answer: Most teams will have removed all new natural gas plants. It is cheaper now to build solar and wind.*

c. See the piece rankings in Table 6. Solar is now cheaper than existing coal, so most teams will use their additional solar pieces from this round to displace existing coal. Most teams will reduce at least some, but not all, of their existing coal. Wind is now cheaper than new natural gas.

Table 6. Piece Rankings for Round 2 (CO_2 price = 1)

Natural Gas - Existing	1
Nuclear - Existing	2
Solar - Large	3
Coal - Existing	4
Wind - Large	5
Natural Gas - New	6

d. Students may want to discuss what the CO_2 price multiplier represents. Ask them for any examples of impacts related to climate change. *Answer: Some examples include sea level rise and storm surges along coastal areas causing property damage, loss of life due to extreme heat events, changes in temperature and precipitation patterns leading to inland flooding, changes in the frequency and intensity of droughts, among others*. How could these impacts lead to economic costs? *Answer: Some examples include impacts on agricultural production, human health, labor, and transportation and other infrastructure*? The CO_2 price reflects the damages associated with climate change and calculates those additional damages for each additional unit (e.g., ton) of CO_2 emissions.

e. If air quality limits are set, for example, to 10, there will be a somewhat different mix. As shown in Table 5, three of the teams have air quality health impacts greater than 10. Those teams would further reduce their fossil fuel pieces, using less coal and natural gas. Teams 1 and 3, however, would reach the same solution with or without the air quality limits.

7. Round 3

a. Increase the CO_2 price to 2, 3 or 4 (or higher, for illustrative purposes). Changing the number on the spreadsheet, while letting the students see how the rankings change, allows them see the tipping points., For example, when is the price is high enough to substantially change the rankings of the teams, or when does the total CO_2 cost becomes even higher than the cost to build and operate?

b. For a CO_2 price of 4, the changes in costs will lead to a complete shift to renewables. The only remaining existing pieces will be the nuclear pieces.

Table 7. Team solutions for Round 3, assuming CO_2 price = 4

	Team 1	Team 2	Team 3	Team 4	Team 5
Nuclear - New					
Nuclear - Existing	2	1	1	1	1
Coal - New					
Coal - Existing					
Coal - CCS					
Natural Gas - New					
Natural Gas - Existing					
Wind - Small	4	8	2	8	7
Wind - Large	5	6	5	6	5
Wind with Battery		1	1	2	4
Solar - Small	4	0	6	0	1
Solar - Large	5	6	7	5	4
Solar with Battery	2	3	3	3	3
Biomass					
Efficiency Small					
Efficiency Large					
This is your breakdown of costs, total cost, and rank for each team					
Cost (Build and Operate)	6230	6459	6385	6535	6648
Total Cost of CO_2	0	0	0	0	0
TOTAL Cost	6230	6459	6385	6535	6648
Ranking	1	3	2	4	5
CO_2 emissions	0	0	0	0	0
Air Quality Health Impacts	0	0	0	0	0
Water use	148	74	74	74	74

c. Additional rounds can be played increasing the CO_2 price, depending on time. Make sure with each round the students look at how their total score was affected by the cost to build and cost of CO_2. Maybe they had a grid that was expensive to build and operate but with a low CO_2 price. Or, alternatively, their grid was cheaper to build and operate but their CO_2 price was high. Let the students discuss the different strategies they used to reduce CO_2 emissions.

8. Round 3 – Discussion questions

a. In this round, the outcomes will differ substantially from earlier rounds (see Table 7). What has happened with the CO_2 costs, CO_2 emissions, and air quality health impacts? *Answer: wih the shift to renewables and nuclear, there is no fossil fuel combustion to create produce either CO_2 or emissions of air pollutants. Total cost of CO_2 is zero because at this point there is no CO_2 to price.*

Table 8. Piece Rankings for Round 3 (CO_2 price = 4)

Nuclear - Existing	1
Solar - Large	2
Wind - Large	3
Solar - Small	4
Solar with Battery	5
Wind - Small	6
Wind with Battery	7

b. How much of the existing pieces are still used? *Answer: In this round, all renewables, including with battery, will be cheaper than existing coal and natural gas.* The top seven cheapest pieces are shown in Table 8.

c. How different are the total costs from one round of the game to another? *Answer: The costs in the last round were in the high 5000s, in this round they are in the low to middle 6000s.*

d. How much energy storage is included in the board? *Answer: Teams will have anywhere from 2-7* *pieces with energy storage. Teams that needed to use more storage will be relatively more expensive. Teams with more nuclear will need to rely less on pieces with battery storage.*

e. Some countries, like Germany, are moving away from nuclear power because of safety concerns associated with spent nuclear material. What would happen if nuclear were not an option? Given the pieces available, what would be used to fill in the gaps? *Answer: At a CO_2 price of 4, it would likely be more wind and solar with battery. At lower a CO_2 price, exclusion of nuclear pieces may lead to more use of natural gas or coal pieces.*

9. Energy Efficiency

a. Hand each team three large energy efficiency pieces and three small energy efficiency pieces. Tell the teams to leave their existing pieces in place on their grid.
b. Keep the CO_2 multiplier set at the same level as the last round. Instruct students that they are to again seek the lowest score, this time substituting energy efficiency for some of the pieces on the grid. Note: they should only be replacing pieces with energy efficiency pieces, not making other changes to the mix of pieces at this point.
c. The energy efficiency round can also be played at an earlier round when CO_2 prices are lower.

10. Energy Efficiency – Discussion questions

a. Look at the spreadsheet. What types of energy tended to be replaced by the energy efficiency? *Answer: The most expensive pieces will be replaced, depending on the round of play*.
b. How did energy efficiency affect the total cost and emissions? *Answer: If energy efficiency is introduced in an earlier round, with a CO_2 price of 1, it will replace either wind or existing coal. If it replaces existing coal, natural gas, or biomass, then energy efficiency pieces with reduce both the cost to build and operate, and the total CO_2 cost and air quality impacts. If energy efficiency is used in later rounds with a higher CO_2 price, it will replace renewables. That will reduce the cost, but not change CO_2.*

11. Wrap up

a. Final discussion can focus on observations for all rounds. How did air quality impacts change over the different rounds and why? How did water use change? What challenges did teams encounter?
b. How did costs change from one round to another? On the spreadsheet, the instructor can copy and paste the total cost for each round to compare.
c. For cleaning up, have students return the original number of pieces (shown in Table 1) to the bags. Return any extra pieces – such as the additional renewable pieces in round two and any efficiency pieces – to the instructor.

The science behind the game

Generate is meant to provide a fun and engaging platform for discussing energy choices and understanding some of the costs and environmental impacts associated with a changing electric power grid. Below are some of the key concepts that are built into the game design, along with resources to learn more. Like any game, however, it does not represent all the nuances of the system, and teachers are encouraged to discuss with students the many factors – technical, economic, social, and political – involved in real-world energy choices.

Capacity: The game is called Generate, but first, we need to look at *capacity*. Capacity is how much electricity can be generated when a power plant is "running full blast."[3] Capacity is the maximum electric output an electricity generator can produce under specific conditions. Capacity is often shown in megawatts (MW) or gigawatts (GW).

Capacity factor: Most power plants do not run 100% of the time. Even if they run most of the time, they might not run at 100% of their maximum capacity. The capacity factor is simply the fraction of actual electricity generated divided by the maximum amount of energy that *could* be generated. If a power plant, wind turbine, or solar panel produced its maximum amount of electricity 100% of the time, the capacity factor would be 100%. However, power plants sometimes need to be taken offline for maintenance, and wind and solar technologies depend on when the wind is blowing and the sun is shining. The highest capacity factors are for nuclear (which runs at close to capacity for 90% of the time) while wind and solar have lower capacity factors (40-44% for wind and 29% for solar).[4]

Electricity generation: As defined by the Energy Information Administration, electricity generation is "the amount of electricity a generator produces during a specific period of time. For example, a generator with 1 megawatt (MW) capacity that operates at that capacity consistently for one hour will produce 1 megawatt-hour (MWh) of electricity. If the generator operates at only half that capacity for one hour, it will produce 0.5 MWh of electricity." [5] On the game board, each square on the grid represents a unit of electricity generation. However, because the game numbers are simplified to calculate scores more easily, each square does not equal an straightforward, easy to show unit, like a MWh or kilowatt-hour (kWh), the goal is to show the relative costs and dynamics of the tradeoffs.

Grid: The electricity grid is the complex system or network that connects electricity production to users. The real-world electricity grid connects the power plants and other electricity generating units through a complex system, including substations, transformers, and power lines that deliver electricity to the consumer. For the game, our "grid" is the space that is divided into rectangular units, and the supply (the pieces) must meet the demand (the available space).

[3] https://www.energy.gov/ne/articles/what-generation-capacity#:~:text=The%20Capacity%20Factor&text=It%20basically%20measures%20how%20often,of%20the%20time%20in%202016.
[4] See Table 1b. https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf
[5] https://www.eia.gov/tools/faqs/faq.php?id=101&t=3

Levelized Cost of Electricity (LCOE): The LCOE represents the cost of generating electricity for a particular system or grid. This number is used in the real world for decision making for building and operating electricity generating units, as well as for policymaking. At a minimum, the LCOE should include all the costs over the system's lifetime: initial investment (or capital cost), operations and maintenance, cost of fuel, and cost of capital (the financial return required to make an investment worthwhile). For the game, we use several components of the LCOE (the *purchase cost*, the *annual cost*, and the *lifetime of 30 years*). While the game does not reflect all complexities of the LCOE, it captures key concepts.

Capital cost: Generate uses a simplified measure of capital costs that are sometimes also called overnight capital costs. This represents the estimated cost of building electricity generating technologies or power plants. It includes the materials (like metals, concrete, etc.) and the costs involved the construction and development of the plant (although it does not really happen "overnight"!). These costs can vary from one region to another, depending on wind and solar resources, or other factors like how expensive the land is where they will build the plant. In the game, these are our purchase costs for each piece.

Operations and maintenance (O&M) costs: These are the recurring costs for operating and maintaining power plants and electricity generating technologies. These can include the cost of labor, maintenance, repairs, and parts, as well as fuel costs. In the game, these are represented as the annual costs. These costs are generally higher for fossil fuel and nuclear pieces, and lower for wind and solar pieces which have lower O&M costs.

Renewable Portfolio Standard (RPS): These are policies that may require electricity suppliers to generate a minimum percentage or share of electricity from renewable resources.[6] These RPS may differ across states, and states may include some renewable resources and not others as eligible sources. In the game, the teams discover that they must use a row of the smaller wind and solar pieces in order to correctly fill out the board. This mimics an RPS, because to fill out the grid, a certain number of renewable pieces are required, in addition to coal, natural gas, and nuclear.

Generation mix: Electricity is produced by many different sources of energy, including, but not limited to, wind, solar, nuclear, and fossil fuels. The Generate game includes many of these sources. The CO_2 and air pollutant emissions produced depend on how electricity is generated. The EPA's Power Profiler interactive webpage shows and compares the resource or fuel mix (%) used to generate electricity in different regions of the U.S.[7] In the first round of game play, the teams will each find an optimal resource mix, but each grid will differ. These grid mixes were designed to represent five distinct regions of the U.S. The fuel mix for all other regions in the U.S., and the associated CO_2 and air pollutant emissions can be found on the Power Profiler.

Battery storage: Large-scale battery systems can store excess electricity as it is generated and then redistribute that electricity when and where it is needed. That is particularly important for renewables like wind and solar, since the periods when the renewable generation occurs may not coincide with when the electricity demand is

[6] https://www.eia.gov/energyexplained/renewable-sources/portfolio-standards.php

[7] https://www.epa.gov/egrid/power-profiler#/

the highest. Pairing energy storage with renewable technologies provides a range of benefits and is becoming increasingly common in the U.S.[8] In the game, there are pieces for wind and solar without storage, but the teams will also need to use pieces that include battery storage.

CO_2 (carbon dioxide) emissions: CO_2 emissions occur primarily through the burning of fossil fuels (oil, natural gas, and coal), but can also be emitted from burning of solid waste and biomass (trees, other wood products).[9] Carbon dioxide emissions represented 80% of total U.S. greenhouse gas emissions in 2019.[10] As noted on the EPA's Climate Indicators website: "Greenhouse gases from human activities are the most significant driver of observed climate change since the mid-20th century."[11]

Carbon price: Carbon pricing is one strategy for reducing emissions of CO_2. The idea is to put a price on CO_2 emissions (or on the carbon content of the fuel that is burned). This charges emitters a real-world monetary value for every ton of emissions produced. In this manner, the costs of climate impacts on the public are included in energy choices. Putting a price on carbon or CO_2 reflects the wide range of effects that climate change has on people and ecosystems, including lost agricultural productivity, property damages from storms, like hurricanes, and storm surges, and diminished freshwater availability. In the game, the CO_2 price varies, depending on the round. This shows how energy choices will change when CO_2 prices are factored into decision-making. The numbers in the game are illustrative and do not reflect a specific dollar per ton.

Air quality impacts: In addition to CO_2, combustion of fossil fuels also produces air pollution. The EPA sets standards for six common air pollutants (known as "criteria air pollutants"). These pollutants harm human health and the environment, and include ground-level ozone, lead, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM).[12] In the game, air quality health impacts are described on a scale of zero to three (indicated by wavy lines in the lower left corner of the pieces). Renewables have zero air quality impacts, whereas natural gas, coal, and biomass have air quality impacts due the combustion. For more information on how regional grid mixes affect CO_2, SO_2, and NO_X (an ingredient in ozone formation), use the Power Profiler tool to compare regions.[13]

Water withdrawals: A lot of water is required for nuclear, coal, and natural gas power plants. Water is used as cooling water and, depending on what type of technology is used, can either be used and returned to the water body (such as a river or lake) at a higher temperature, or evaporated to the atmosphere. In 2015, total withdrawals for thermoelectric power (133 billion gallons per day!) accounted for 41 percent of total water withdrawals for all uses.[14] This is even more than irrigation water use or public supplies of water. Water use is calculated on the spreadsheet for each round.

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[8] https://www.eia.gov/todayinenergy/detail.php?id=43775#

[9] https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide

[10] https://www.epa.gov/sites/production/files/2021-04/documents/fastfacts-1990-2019.pdf.pdf

[11] https://www.epa.gov/climate-indicators/greenhouse-gases#sources-of-data

[12] https://www.epa.gov/criteria-air-pollutants

[13] https://www.epa.gov/egrid/power-profiler#/

[14] https://www.usgs.gov/mission-areas/water-resources/science/total-water-use?qt-science_center_objects=0#qt-science_center_objects

Alignment to High School Standards

Alignment to Next Generation Science Standards for High School

Engineering, Technology, and Applications of Science:

- HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade- offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real- world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Human Impacts on Earth Systems

- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soil such as river deltas, and high concentrations of minerals and fossil fuels.]
- HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practice for mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what *can* happen in natural systems, not what *should* happen].
- HS-ESS3-3: Create a computational simulation to illustrate the relationship among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste-management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include levels of conservation and urban planning]. [Assessment Boundary: assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]
- HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban

development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean)].

The game can also align to state-level standards. The original development of the game was based in Research Triangle Park, North Carolina. Examples of state-level standards are below.

Alignment to North Carolina Essential Standards for Earth/Environmental Science:

- EEn2.8.1: Evaluate alternative energy technologies for use in North Carolina.
- EEn2.8.3: Explain the effects of uncontrolled population growth on the Earth's resources.
- EEn1.1.3: Explain how the sun produces energy which is transferred to the Earth by radiation
- (accomplished with extension piece on solar photovoltaic).
- EEn2.2.2: Compare the various methods humans use to acquire traditional energy sources (such as peat, coal, oil, natural gas, nuclear fission, and wood).
- EEn2.4.1: Evaluate human influences on freshwater availability (with water usage round(s)).

Alignment to North Carolina Essential Standards for World History:

- WH.H.8.4: Analyze scientific, technological and medical innovations of postwar decades in terms of their impact on systems of production, global trade and standards of living (e.g., satellites, computers, social networks, information highway).
- WH.H.8.5: Explain how population growth, urbanization, industrialization, warfare and the global market economy have contributed to changes in the environment (deforestation, pollution, clear cutting, ozone depletion, climate change, global warming, industrial emissions and fuel combustion, habitat destruction, etc.)

Alignment to Middle School Standards

Alignment with Next Generation Science Standard for Grades 6-8 Science

- ESS3.C: Human Impacts on Earth Systems:
    - Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
    - Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MSESS3-3),(MS-ESS3-4)
- ESS3.A: Natural Resources
    - Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not

renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1)

- ESS3.D: Global Climate Change
    - Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

Alignment with Common Core Middle School Mathematics and ELA:

Mathematics:

- MP.2: Reason abstractly and quantitatively. (MS-ESS3-2),(MS-ESS3-5)
- MP.4: Model with mathematics. (MS-LS2-5)
- 6.EE.B.6: Use variables to represent numbers and write expressions when solving a real-world or
- mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS3-1),(MS-ESS3-2),(MS-ESS3-3),(MS-ESS3-4),(MSESS3-5)
- 6.EE.C.9 Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. (MS-LS2-3)
- 6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-ESS3-3),(MS-ESS3-4)
- 6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-LS2-5)
- 6.SP.B.5 Summarize numerical data sets in relation to their context.
- 7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-ESS3-3),(MS-ESS3-4)
- 7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-ESS3-1),(MSESS3-2),(MS-ESS3-3),(MS-ESS3-4),(MS-ESS3-5)

ELA/Literacy:

- RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts. (MS-LS2-1),(MSLS2-2),(MS-LS2-4)
- RST.6-8.9: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS2-

1)

- WHST.6-8.9: Draw evidence from literary or informational texts to support analysis, reflection, and research. (MS-LS2-2),(MS-LS2-4)
- SL.8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly. (MS-LS2-2)
- SL.8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (MS-LS2-2)

Alignment with NC Essential Standards for Middle School Science 6-8

- 6.E.2.4 Conclude that the good health of humans requires: monitoring the lithosphere, maintaining soil quality and stewardship.
- 7.E.1 Understand how the cycling of matter (water and gases) in and out of the atmosphere relates to Earth's atmosphere, weather and climate and the effects of the atmosphere on humans.
  - 7.E.1.6 Conclude that the good health of humans requires: monitoring the atmosphere, maintaining air quality and stewardship.
- 8.P.2 Explain the environmental implications associated with the various methods of obtaining, managing, and using energy resources
  - 8.P.2.1 Explain the environmental consequences of the various methods of obtaining, transforming and distributing energy.
  - 8.P.2.2 Explain the implications of the depletion of renewable and nonrenewable energy resources and the importance of conservation.

Alignment with NC Essential Standards for Social Studies and Technology 7-8

- 7.G.1 Understand how geography, demographic trends, and environmental conditions shape modern societies and regions.
  - 7.G.1.1 Explain how environmental conditions and human response to those conditions influence modern societies and regions (e.g. natural barriers, scarcity of resources and factors that influence settlement).
    7.G.1.2 Explain how demographic trends (e.g. population growth and decline, push/pull factors and urbanization) lead to conflict, negotiation, and compromise in modern societies and regions.
- 8.G.1 Understand the geographic factors that influenced North Carolina and the United States.
  - 8.G.1.3 Explain how human and environmental interaction affected quality of life and settlement patterns in North Carolina and the United States (e.g. environmental disasters, infrastructure development, coastal restoration and alternative sources of energy.

Game Extensions

Carbon Cap: The game facilitator can set an upper limit for the CO_2 emissions on the score sheet. Does this lead to different solutions for reducing CO_2? How does setting a cap affect the total costs?

Clean Energy, Clean Air: The game facilitator can set an upper limit for the air quality impacts on the score sheet. Does this lead to different solutions than when just reducing CO_2? Which pieces have impacts on air quality even through they can be considered net zero from a CO_2 standpoint?

Thirsty Energy: The game facilitator can set an upper limit for water use using the H_2O limit on the spreadsheet. The teams that exceed the upper limit (or run out of water) will be eliminated. Keep in mind that nuclear and coal with carbon capture and storage (CCS) are very water intensive. Renewables are virtually water free! Provide students with the numbers shown in Table 9.

Table 9. Water use per piece	
Nuclear	74
Coal	16
Coal with CCS	43
Natural gas	4
Biomass	8

Pure Optimization: Distribute the pieces equally among all teams. Then one or more rounds are played (with or without a CO_2 price), to determine which team can arrive at the optimal solution. Do they all reach the same solution? Are there ways to achieve the same lowest cost solution with different energy mixes? Are there some solutions that are "close" in total cost but with very different CO_2 emissions?

Energy Traders: Players may swap pieces between their teams. Players can trade any number or types of pieces, as long as both teams agree to the trade. A single player should be assigned to be the team's trader. Teams are allowed one chance to trade *before* each round. This can be done any time after the first round of play.

"Give and Take" Cards: *"*Give and Take" either adds new technologies (from the extra pieces), takes away certain types of technologies, or increases or reduces the relative costs. For an additional round, each team can draw a chance card before choosing their mix. See Appendix for cards.

Budget Breakers: The game facilitator can set an upper limit on the total cost, including the purchase and annual costs, but not the CO_2 cost. This can be set to anywhere between 6,000 or 7,000. At lower levels, certain teams may not be able to reach this total cost. However, it can also be combined with Energy Traders.

Number Crunchers: This game is based on a simplified version of the cost of electricity based on capital and annual costs. However, the real-world calculations of metrics such as the "levelized cost of energy"(LCOE) are more complex. One extension following the game play can be for students to research different metrics the cost of energy. The Energy Information Administration has good resources to discuss costs.[15]

[15] See https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf. How do the relative LCOEs here compare to the game? Tax credits were not included in the numbers for this game. How much can those affect relative costs?

Calculations and Differentiation

The supporting calculations can be handled in a variety of ways. Students can be required to calculate their total scores prior to submitting their mixes in each round, or the instructor can calculate by plugging the numbers into the spreadsheet. The benefit of the spreadsheet is the ability of all teams to see each other's energy mix and scores. It is also a useful exercise to have the students watch the scores and ranks change as the CO_2 cost on the spreadsheet is increased to see how the different teams' scores and rankings are affected.

Some students simply guess what the cheapest pieces are based on the relative costs. Other students will compare the pieces of the same size (comparing the different coal pieces or comparing natural gas to large wind or solar) and compare smaller pieces to large pieces (four small wind or solar compared to natural gas).This will give students a quick sense of the cheapest pieces. Other students may try to add up the cost of the entire board, and then readjust and recalculate, which can be time consuming.

The most accurate approach is for students to calculate -- for each energy type – the cost per square and compare all pieces. Then students would use the low-cost pieces first, then the second lowest cost, and so on. This will be more time consuming for the first round. But, in the following rounds, the cost per square will only change for the pieces that have CO_2 emissions (natural gas and coal). Because the CO_2 emissions for wind, solar and nuclear are zero, the CO_2 price does not affect their cost per square. Students can be reminded of this or left to discover it on their own.

$$Cost\ per\ square = \frac{(Purchase\ Cost) + 30 \times (Annual\ Cost) + 30 \times (CO_2\ price) \times (CO_2\ emissions)}{Squares\ per\ Piece}$$

For example, a natural gas piece (which covers 16 squares) would cost 26.4 at a CO_2 price of 2.

$$Cost\ per\ square = \frac{(63) + 30 \times (7) + 30 \times (2) \times (1.2)}{Squares\ per\ Piece} = 21.56$$

If the rounds move quickly, it may be a struggle both for students that are unsure how to approach the math, as well as for students who want to do the math in detail for every round. The instructor can determine how much guidance to give on the approach to calculations, or give feedback to individual teams (e.g., "are you sure that's the cheapest medium-size piece?")

Teachers can select how many rounds and which rounds to assign based on the needs of their classes and whether it is a one class activity or spread over a few days. They may choose to take more time and only run three rounds, only adjusting CO_2 price. They may choose to assign only carbon multipliers that are integers rather than using decimals such as 0.5 in order to facilitate easier calculations.

Red, Green and Yellow "Stoplight" Cards: For classrooms where students may need more help, using these cards is a great way to help students communicate their team's level of frustration and help the teacher quickly see who needs immediate help. Teams can be given red, green, and yellow cards prior to the activity, and can be asked to display a card at all times. The green card signifies that the team is moving along successfully; the yellow card signifies that the team is having difficulty but has not yet come to a complete standstill; the red card means that the team is at a standstill until it receives help.

Resources

To learn more about energy use in the United States, explore the Energy Information Administration's website: www.eia.gov

- State energy comparisons www.eia.gov/state/
- Interactive mapping of U.S. state-level energy resources and facilities www.eia.gov/state/maps

U.S. EPA climate change resources
http://epa.gov/climatechange/

- Mapping GHG emissions from large facilities http://ghgdata.epa.gov/
- Climate change indicators https://www.epa.gov/climate-indicators

Additional climate change resources from other U.S. federal agencies and programs.

- NASA Climate Kids: https://climatekids.nasa.gov/
- U.S. Global Change Research Program: http://www.globalchange.gov/

EPA Air, Climate and Energy Research

- Climate Change Research https://www.epa.gov/climate-research
  Air Research: https://www.epa.gov/air-research

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Appendix: GIVE & TAKE CARDS

Your region is feeling quite a “blow” to its resources—even though you have a great landscape for on-shore and off-shore wind power, local laws are making it hard to invest in new wind power. Place all of your wind pieces (both large and small) back in your bag	Congratulations! Your team has been working hard to improve energy use and sustainability in your region. Show this card to receive extra energy efficiency pieces! (2 large and 2 small pieces).
The damages associated with climate change are becoming more severe. ALL teams must now calculate their energy grid with a CO_2 price of 8.	Although your region has transported and stored used nuclear fuels without any harmful release of radioactive material, there are concerns by citizen about the future of nuclear waste. Remove any nuclear pieces you have used/could use.
Your region’s proposal to increase solar energy resources was approved. Show this card to gain 2 additional large and 4 additional small solar pieces!	Your region’s proposal to increase wind energy resources was approved. Show this card to gain 2 additional large and 4 additional small wind pieces!
Talk about going green! Your region is one of the first to pledge zero carbon emissions—and this year is the year! You may only use pieces with zero emissions, so put all your other pieces to the side.	Your region has been under pressure by surrounding areas (as well as your own population) to take air quality concerns into account. Therefore, you must reduce your air quality impacts to less than 10.
Fossil fuels are becoming cheaper, which means costs are decreasing! For all fossil-fuel based energy resources, use any of your coal and natural gas pieces at the price of existing pieces.	The citizens in your region have been researching nuclear energy and want to build a nuclear plant to decrease the region’s dependency on fossil fuels. You can use one of the new nuclear pieces but at the cost of an existing nuclear piece.

Score Card

Print page 26 on 8.5″ x 11″ portrait paper.

TEAM _____	Round 1	Round 2	Round 3	Round 4
Nuclear - New				
Nuclear - Existing				
Coal - New				
Coal - Existing				
Coal - Carbon Capture & Storage				
Natural Gas - New				
Natural Gas - Existing				
Wind - Small				
Wind - Large				
Wind - with Battery				
Solar - Small				
Solar - Large				
Solar - with Battery				
Biomass				
Efficiency - Small				
Efficiency - Large				
SCORE				
RANK				

TEAM _____	Round 1	Round 2	Round 3	Round 4
Nuclear - New				
Nuclear - Existing				
Coal - New				
Coal - Existing				
Coal - Carbon Capture & Storage				
Natural Gas - New				
Natural Gas - Existing				
Wind - Small				
Wind - Large				
Wind - with Battery				
Solar - Small				
Solar - Large				
Solar - with Battery				
Biomass				
Efficiency - Small				
Efficiency - Large				
SCORE				
RANK				

Game Board and Pieces

Print pages 28-63 on 8.5″ x 11″ portrait paper.

GENERATE

The Game of Energy Choices

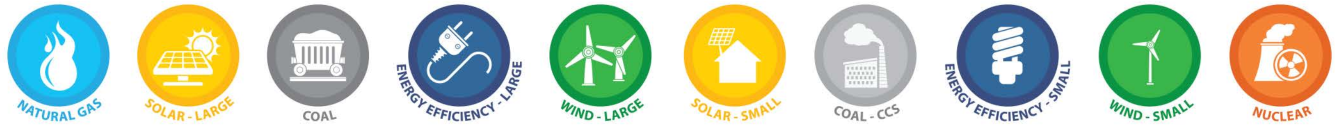
DIRECTIONS

1. Fill the grid with energy sources at the lowest total cost.
2. Energy sources must be horizontal and cover the entire grid. They can not go outside the grid. You may use any combination of energy sources.
3. TOTAL COST = (Purchase Cost) + (Annual Cost x 30) + (CO_2 x CO_2 Cost x 30)
4. The 1st round of the game will not have a CO_2 cost, so this will be zero.
5. Now, go GENERATE!

COMPLETELY COVER THE GRID WITH ENERGY SOURCES

Cut or fold here

Cut or fold here



COMPLETELY COVER THE GRID WITH ENERGY SOURCES

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NUCLEAR

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26

NUCLEAR - EXISTING

168

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29

NUCLEAR - EXISTING

168

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NUCLEAR - EXISTING

168

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168

NUCLEAR -
EXISTING

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COAL - EXISTING

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COAL - EXISTING

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COAL

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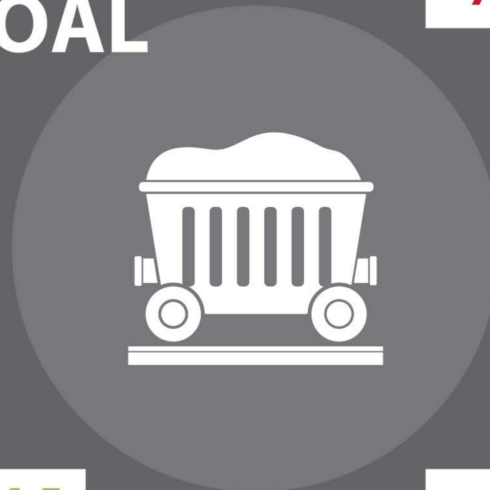

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COAL

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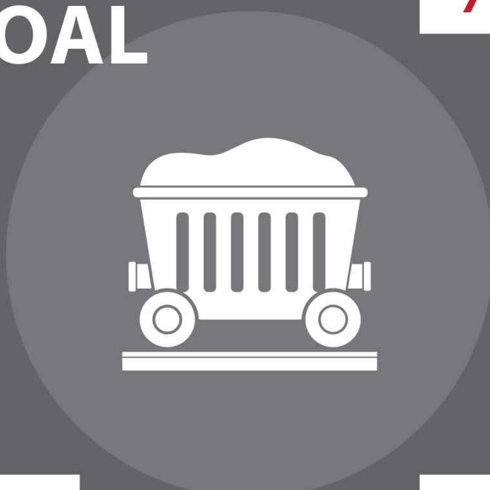

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COAL

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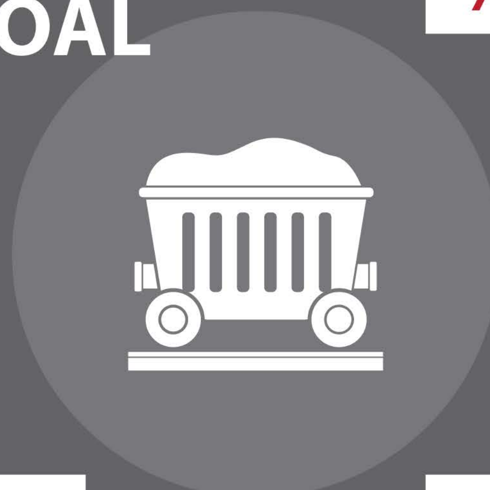

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COAL

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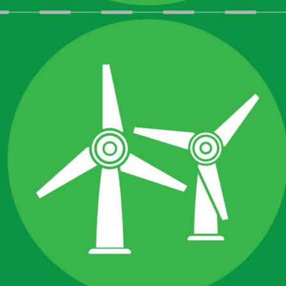

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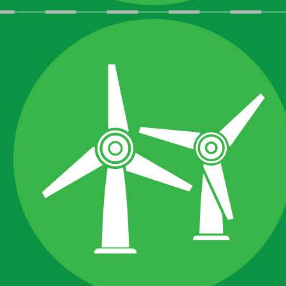
WIND - LARGE



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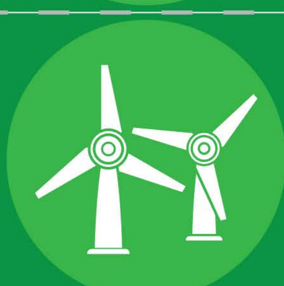

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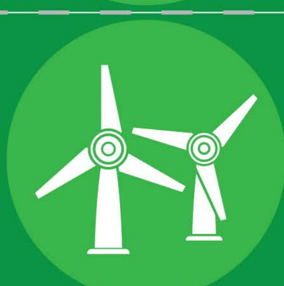

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WIND -
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SOLAR - LARGE

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SOLAR - LARGE

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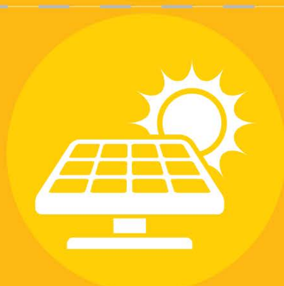

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SOLAR - LARGE

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SOLAR - WITH BATTERY

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ENERGY EFFICIENCY - LARGE

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ENERGY EFFICIENCY - LARGE

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ENERGY EFFICIENCY - LARGE

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SOLAR	49	SOLAR	49	SOLAR	49	SOLAR	49
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EE	10	EE	10	EE	10	EE	10
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Game Board – Large Version

Print pages 65-69 on large format paper.

GENERATE
The Game of Energy Choices

TEAM 1

DIRECTIONS

1. Fill the grid w˙th energy sources at the lowest total cost.
2. Energy sources must be hor˙zontal and cover the ent˙re gr˙d. They can not go outs˙de the gr˙d. You may use any comb˙nat˙on of energy sources.
3. TOTAL COST (Purchase Cost) + (Annual Cost x 30) + (CO_2 x CO_2 Cost x 30)
4. The 1st round of the game w˙ll not have a CO_2 cost, so th˙s w˙ll be zero.
5. Now, go GENERATE!

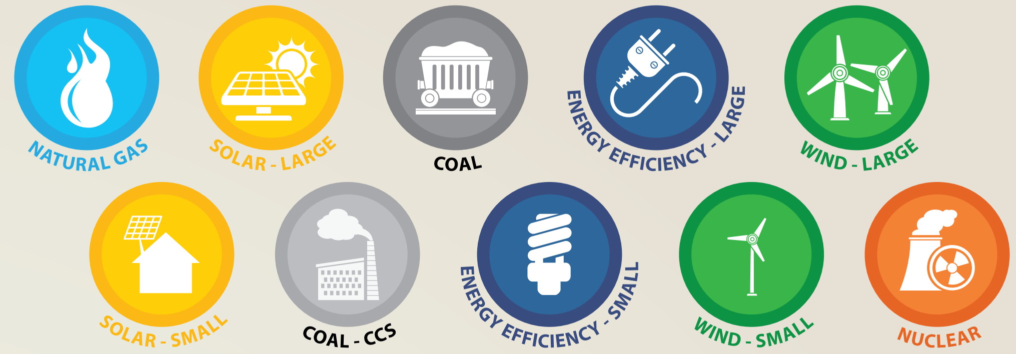
NATURAL GAS
SOLAR - LARGE
COAL
ENERGY EFFICIENCY - LARGE
WIND - LARGE
SOLAR - SMALL
COAL - CCS
ENERGY EFFICIENCY - SMALL
WIND - SMALL
NUCLEAR

COMPLETELY COVER THE GRID
WITH ENERGY SOURCES

TEAM 2

DIRECTIONS

1. Fill the grid w˙th energy sources at the lowest total cost.
2. Energy sources must be hor˙zontal and cover the ent˙re gr˙d. They can not go outs˙de the gr˙d. You may use any comb˙nat˙on of energy sources.
3. TOTAL COST (Purchase Cost) + (Annual Cost x 30) + (CO_2 x CO_2 Cost x 30)
4. The 1st round of the game w˙ll not have a CO_2 cost, so th˙s w˙ll be zero.
5. Now, go GENERATE!



COMPLETELY COVER THE GRID
WITH ENERGY SOURCES

GENERATE

The Game of Energy Choices

TEAM 3

DIRECTIONS

1. Fill the grid with energy sources at the lowest total cost.
2. Energy sources must be horizontal and cover the entire grid. They can not go outside the grid. You may use any combination of energy sources.
3. TOTAL COST (Purchase Cost) + (Annual Cost x 30) + (CO_2 x CO_2 Cost x 30)
4. The 1st round of the game will not have a CO_2 cost, so this will be zero.
5. Now, go GENERATE!

NATURAL GAS
SOLAR - LARGE
COAL
ENERGY EFFICIENCY - LARGE
WIND - LARGE
SOLAR - SMALL
COAL - CCS
ENERGY EFFICIENCY - SMALL
WIND - SMALL
NUCLEAR

COMPLETELY COVER THE GRID
WITH ENERGY SOURCES

GENERATE
The Game of Energy Choices

TEAM 4

NATURAL GAS
SOLAR - LARGE
COAL
ENERGY EFFICIENCY - LARGE
WIND - LARGE
SOLAR - SMALL
COAL - CCS
ENERGY EFFICIENCY - SMALL
WIND - SMALL
NUCLEAR

DIRECTIONS

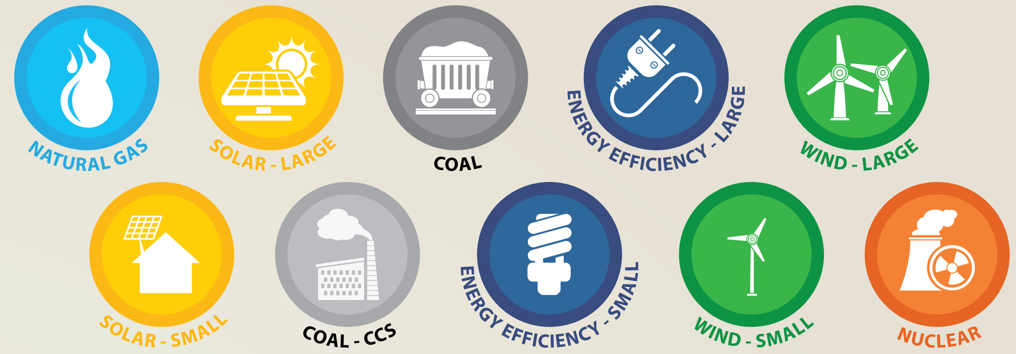
1. Fill the grid with energy sources at the lowest total cost.
2. Energy sources must be horizontal and cover the entire grid. They can not go outside the grid. You may use any combination of energy sources.
3. TOTAL COST (Purchase Cost) + (Annual Cost x 30) + (CO_2 x CO_2 Cost x 30)
4. The 1st round of the game will not have a CO_2 cost, so this will be zero.
5. Now, go GENERATE!

COMPLETELY COVER THE GRID
WITH ENERGY SOURCES

TEAM 5

DIRECTIONS

1. Fill the grid with energy sources at the lowest total cost.
2. Energy sources must be horizontal and cover the entire grid. They can not go outside the grid. You may use any combination of energy sources.
3. TOTAL COST (Purchase Cost) + (Annual Cost x 30) + (CO_2 x CO_2 Cost x 30)
4. The 1st round of the game will not have a CO_2 cost, so this will be zero.
5. Now, go GENERATE!



COMPLETELY COVER THE GRID
WITH ENERGY SOURCES