GENERATE: The Game of Energy Choices

Teachers Guide: Middle School

www.epa.gov

Middle School Instructional Support Document

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 electricity can affect emissions of carbon dioxide (CO_2) and water use. The game also has the potential to explore different energy contexts specific to geographic regions as well as socio-political considerations.

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, and college/university. 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 Next Generation Science Standards as well as North Carolina Essential Standards for a variety of subjects and levels; below is a sampling.

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

Primary Alignment in Science is with Grade 8

- 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

- 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.

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

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),(MS-ESS3-5)
- 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),(MS-ESS3-2),(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),(MS-LS2-2),(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 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. (MS-ESS3-3),(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)

Essential Questions for Middle School

- What energy system would you design for the future to meet the needs of people yet protect the environment?
- How do we classify basic types of energy and what are their basic characteristics?
- Why are energy systems different across the world?
- What are challenges facing us in trying to change energy systems and how could they be met?
- How does the energy system impact climate change and water resources?

Student Task Objectives

Students will be able to:

- Create a model of contributing resources to electricity generation.
- Explain similarities and differences between basic sources of electricity.
- Evaluate sources of energy for their environmental impact.
- Adapt an energy model to minimize impacts on factors such as CO_2 and water usage.
- Manipulate an energy system model for the future that considers financial costs/investments and overall environmental impacts.
- Evaluate geographic differences in terms of implications for energy resources and sources for generation of electricity.

Core Literacy Exposure

Financial Literacy, Environmental Literacy, Technological Literacy, Health Literacy, 21st Century Decision Making, Group Communication, Global Citizenship

Materials

- This Teacher's Guide*
- Game board and energy pieces* (1 game board and 1 bag of pieces per group, see table below)
- Full-size game boards – (optional) this can be used for printing and mounting on foam board*
- Separate energy efficiency pieces to pass out for later rounds (4 small and 4 large pieces per group)
- 1 Score Card per team*
- Introductory presentation slides*
- Excel spreadsheet for scoring and team rankings (see website below for instructions on accessing)
- Computer and Projector that can display PowerPoint and Excel Spreadsheet
- Set of Red Light, Green Light, Yellow Light cards for each group (optional, see explanation under "Differentiation")
- Calculators for each group (optional)

*Printable PDFs located at: https://www.epa.gov/air-research/air-quality-and-energy-choice-stem-activities-educators

Assembly of Team Materials

The printable boards and pieces provided on the website are designed for approximately 5 teams. There will be some extra pieces for each type of energy. The number of pages that need to be printed for each type of energy are shown at the top of the page, for example, for nuclear, "Print x2" will give 6 total pieces to be distributed to teams as shown below. Additional teams can be created by simply printing additional pieces and boards. For assembly, use one plastic zipper storage bag per team (and a bag for the extra pieces), print the team piece lists below, cut them out, and include the list in the storage bag for reference.

Piece can be printed on regular printer paper. For more durable versions, it is recommended to print on cardstock and laminate the pieces as well as the boards. The score cards and calculation sheets can also be printed/laminated to that students can use dry erase markers on them.

TEAM 1		TEAM 2		TEAM 3	
Nuclear	0	Nuclear	2	Nuclear	1
Coal	8	Coal	6	Coal	5
Coal - Existing	5	Coal - Existing	4	Coal - Existing	6
Coal - CCS	5	Coal - CCS	5	Coal - CCS	9
Natural Gas	11	Natural Gas	9	Natural Gas	6
Wind Small	7	Wind Small	12	Wind Small	10
Wind Large	4	Wind Large	5	Wind Large	5
Wind with Battery	2	Wind with Battery	4	Wind with Battery	4
Solar Small	10	Solar Small	9	Solar Small	8
Solar Large	6	Solar Large	5	Solar Large	4
Solar with Battery	6	Solar with Battery	4	Solar with Battery	2
TEAM 3		**TEAM 4**		**TEAM __ ***	
Nuclear	1	Nuclear	0	Nuclear	
Coal	5	Coal	8	Coal	
Coal - Existing	4	Coal - Existing	3	Coal - Existing	
Coal - CCS	5	Coal - CCS	9	Coal - CCS	
Natural Gas	10	Natural Gas	7	Natural Gas	
Wind Small	11	Wind Small	12	Wind Small	
Wind Large	6	Wind Large	7	Wind Large	
Wind with Battery	6	Wind with Battery	3	Wind with Battery	
Solar Small	10	Solar Small	10	Solar Small	
Solar Large	5	Solar Large	5	Solar Large	
Solar with Battery	5	Solar with Battery	2	Solar with Battery	

*For additional teams, you can duplicate a team or create your own distribution of pieces!

Student Preparation for Play

The teacher can make connections to their instructional flow of content in many ways. The game can be utilized as a “stand-alone” or summative activity. It may also be used as a classroom activity or “energy lab” to enhance student consideration of a complex problem in science. Generate can also be used as a central activity in a problem-based learning unit with other student tasks extending around it. Depending on how the teacher is utilizing the game, the students can be formatively assessed for prior knowledge. Students will likely have varying levels of knowledge regarding energy sources, so pre-assessments may be necessary. These formative assessments can be conducted in numerous ways such as: basic entrance ticket describing chosen prior knowledge related to energy and climate change, short quiz on the basic energy system, sticky note pre-discussion, contrast board between renewable and non-renewable energies.

After conducting any formative assessment activities, the teacher can then use the power point provided to introduce the basics of the energy system to students. The basic pieces, goals and way the game board works can be explained to students with the support of the provided hand-outs for student groups. It is suggested during implementing the game to the classroom to minimize deeper teaching before the game begins to allow students to become engaged in Generate! The need to advance in the game inherently draws students to question energy concepts and prepares them to listen to background material to become more successful in the competition. Alternating between short bursts of needed instruction and the continuation of “rounds” of play has proven to be the most effective method of utilizing Generate in student groups of all ages and backgrounds. Setting up the game in “teams” of 4 to even 7 students allows for lively discussion and cooperative working of the energy piece game board (the “scoreboard” Excel document provides columns for 6 groups).

Cooperative Learning Team Strategies

The teacher may assign group member "roles" to facilitate the cooperative learning aspect of the game. It is important for students to share ideas and verbally reason through the modeling processes during the game. Prior classroom group structures can be used or suggested roles for students could include: leader, energy banker, recorder, calculator person. A runner or "share-out" person to facilitate collecting data sheets or sharing during small group to whole group discussion can also be added.

A three color card system Green- Yellow- Red works well to help groups communicate with the teacher on group status and be responsible for their own learning to a further degree. In this basic system, Green would indicate when the group is finished with an assigned task or round. Yellow would indicate that a group is "working" and Red would visually clue the teacher that help is needed. Other task management systems for cooperative groups may be better established in the classroom and work well.

Considering any extended instructional objectives (such as math, technology or social studies) in the implementation, teachers may want to create extended questions or prompts, add calculators, group whiteboards, or other written products to enhance instruction and assessment during the game and in between rounds when the teacher is inputting to the Excel spreadsheet. Teacher resources/activity sheets to support the regular game implementation and other suggested extensions are found in the **Differentiation** and **Power point extension activities** section.

Duration

60-90 minutes (extensions can vary)

Procedure

1. Divide students into teams of 4-5 students. Present each team with a game board, bag of pieces, and student score card. Depending on your goals, you may also allow use of a calculator.

2. **Prior to playing the game, use the PowerPoint presentation to review or introduce the U.S. Energy System**. Actively engage students in the review or introduction, asking question such as:
   a. Show the slides available here: https://www.epa.gov/air-research/air-quality-and-energy-choice-stem-activities-educators
   b. **Slide 2**: Energy can take many forms. Primary energy resources including fossil fuels as well as renewables. We use energy in residential and commercial buildings (homes, offices, stores, etc), industrial facilities and in the cars and trucks we drive as passengers and heavy duty freight. In between, we have to convert those primary resources to useable forms, like electricity, gasoline, and diesel. Is there a form of energy that we both convert to electricity but often use directly in our homes for space heating, water heating, and cooking? [Answer, natural gas].
   c. **Slide 3**: This diagram is called a Sankey diagram, and it connects all of our resources from primary resources to end use. The width of the connecting flows represents the relative amounts of energy. All flows of energy are represented here. What do we start with, all the way to the left? [The actual primary energy resource]. What do we have, all the way to the right? [End-use demand sectors, or how and where we use that energy]. What do we need, in between the energy resource and end use, to enable us to flip a switch and have the light turn

on? [Technologies to convert the energy into useable resources, i.e., electric power plants to make electricity].

d. Stay on slide 3: Each colored line on this infographic represents one of the energy sources listed on the bottom of the slide. Which does the dark green represent? Why? How or where is this energy source used? How can that end use inform us of what type of energy it may be? Now, turn and talk with a neighbor for 2 minutes. Try to match the remaining energy forms with the colors on the graphic. After 2 minutes, bring the class together again and quickly move through the list of colors, asking students to call out their findings. Let's check and see if you're correct. [Answers on next slide].

e. **Slide 4**: What do you notice is happening with the thick gray lines, particularly on the upper right area of the slide? [rejected or wasted energy]. How much is actually used versus wasted? Which types of energies currently contribute to more rejected energy? Why do you think this is? [Answer is: efficiency losses in converting energy from one form to another, a good example is a lightbulb, the heat is considered rejected energy since that is not meeting an energy demand, what we really want is lighting, measured as lumens]. This slide introduces the concept of efficiency. Some of the later rounds of the game include energy efficiency pieces.

f. **Slide 5**: Prior to advancing the slides, ask: Now let's think about environmental impact. In what ways do energy extraction, conversion, and use impact the environment? [air pollution, greenhouse gas emissions, water use]. What percentage of these things do you think are related to our energy use? Advance the slide and share information. Ask students, do these percentages surprise you?

3. Now you are ready to **introduce the game.** The PowerPoint should remain projected as the slides continue to walk students through how to play.

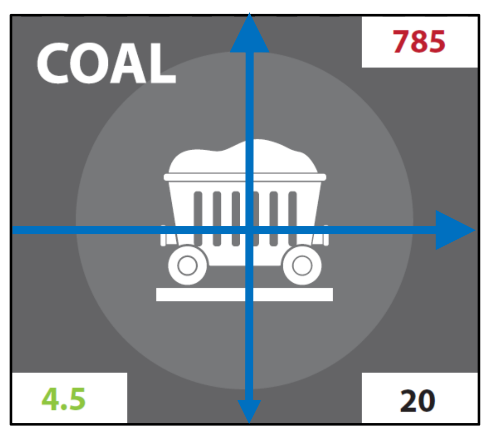
   a. **Slide 6**: Explain that the Energy Game is a simple simulation of our energy system, using values derived from engineering costs of building and operating electricity generating units. We are mainly focusing on electric power generation. *The purpose of the game is to not to tell us the "right answer" but to help us understand the challenges and tradeoffs involved in making energy and policy decisions.* Each team has the same "electric grid" size and the same total energy (area of pieces), but teams do not have the same mix of energy types. The goal, in each round, is to completely fill the grid with energy pieces in order to achieve the lowest total score, or cost, that fulfills the parameters of the round. Pieces may not overlap, and pieces may not extend past the grid or be placed sideways. Your score is determined by adding up the one-time purchase cost, 30 years of annual operating costs, and 30 years of total CO_2 costs for all of the pieces you choose.

   b. **Slide 7**: This is the grid. The name of the game is Generate because we are looking at how to produce, create or "generate" electricity. Generation means to convert one form of energy (chemical, mechanical, etc.) into another (electrical).

   c. **Slide 8**: Show the pieces. Ask students to compare piece sizes. Why is piece size significant? How would you use that to compare the cost per square on the grid, or cost per unit of energy? [Answer: the larger the piece, the more of the grid it covers and the more energy it provides. The largest nuclear piece is 64 squares, the large coal pieces are 32, natural gas and renewables are 16, and the smallest wind and solar are 4]. What units are used in real-life for selling and purchasing electricity? [Our electricity bills measure kilowatt-hours, and we pay in cents or dollars per kilowatt-hours, e.g., $/kWh]. How do we buy liquid fuels like gasoline and diesel [dollars per gallon, or $/gal]?

d. Stay on slide 8: Students should have some basic background on fossil fuels, renewable energy, and energy efficiency. Review the different types of energy pieces.
   i. Why are there three types of coal pieces?
      1. "Coal" could be a new coal power plant, while "Existing Coal" would be power plants that are already built and operating, so only annual operating costs are needed.
      2. What is "Coal with Carbon Capture and Storage (CCS)"? How is it different? This is coal with technology to capture CO_2 emissions so that they can be stored instead of emitted to the atmosphere. How do the CO_2 emissions differ? Is it cheaper or more expensive than the other coal power plant pieces?
   ii. What other fossil fuel pieces are there? Answer: natural gas.
   iii. Why is nuclear so large? Does it have CO_2 emissions? Why not? There is no fuel combustion to produce CO_2.
   iv. There are also different types of renewables: wind and solar.
      1. Some have battery technologies and a higher cost. Why do renewables need batteries to store power? Renewables are sometimes called intermittent. Their electricity generation is not continuous, but depends on when the sun is shining and the wind is blowing. They need batteries to store electricity for when it's needed at different times of day.
      2. Also, some renewable energy installations may be large, and some may be small (think of a solar farm with acres of solar panels compared to smaller solar panels on rooftops of individual homes).

e. **Slide 9**: Explain the parts of the pieces and how to calculate the score. The **size** is the amount of energy it produces. Point out that the one-time **purchase cost** is in red, located on the upper right-hand corner. Make the analogy that this is similar to the up-front cost of purchasing a car. What else does it take to run a car? [Answer: gasoline or diesel, maintenance, insurance, registration and taxes, inspection]. These are similar to the annual costs to operate a power plant. Point out that the **annual cost** is noted in black, located on the bottom right-hand corner. If the power plant functions for 30 years, what would you multiply this number by to get its lifetime cost? Point out that **CO_2 emissions** are located on the bottom left-hand corner in green. These annual CO_2 emissions will also be multiplied by 30 years. However, we will then put a cost on the emissions, to reflect environmental damages



or possible policy decisions. This is done as a CO_2 multiplier, which is set by the instructor on the Excel Spreadsheet for each round and will also need to be multiplied by a specific CO_2 cost given in each round.

f. Slide 9 also shows the full equation, and how it would calculate for one coal piece. Remember, these all last for 30 years so annual costs and emissions are multiplied by 30.
Cost per piece = Purchase cost + (Annual Cost x 30) + (CO_2 emissions x 30 x CO_2 cost)

4. **Slide 10: Let's play the game!** For round one, assign a CO_2 multiplier of 0, so CO_2 costs are not factored into this round. Remind students that their goal is to achieve the lowest possible score. Instruct students to write down how many pieces of each type they used on the score sheet. Minimize the PowerPoint and project the spreadsheet. Be sure that the CO_2 cost (highlighted in yellow) is set at 0. Instruct teams to send up a representative with the score sheet, as they finish, so that you can begin plugging in their chosen energy mixes into the spreadsheet. Once all teams have finished and been ranked, ask them to compare. The spreadsheet will show TOTAL COST of their electricity mix. They will be ranked according to the lowest cost for the full board. For the teams ranked 1 and 2, what does your energy mix look like? [Existing coal favored, natural gas]. For those of you ranked toward the bottom, how is your mix different? [more renewables, perhaps nuclear, less existing coal]. Were some teams given an unfair advantage for this round? [Yes, those with more existing coal and natural gas are at an advantage in this first round]. That advantage will shift as we start considering CO_2. What challenges did you encounter? [Had to diversify so that coal, even if you had enough, was not completely covering the board (note that the grid is created in a way that forces diversification)]. Why do you think the grid is created in order to force diversification? What made you use the smallest pieces [Answer: it can represent state or regional energy policies, for example, 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].

   * Please note that you may choose to delete or expand upon some of the rounds below based on student needs/standards. In order to introduce an understanding of trade-offs, at least one round of CO_2 cost and one round of energy efficiency should be played.

5. **Round Two**: Inform students that they will play another round. This time, they will have to take CO_2 costs into effect, and thus, they must rethink their strategy. Their goal is still to achieve the lowest score. Set the CO_2 cost multiplier at 1 on the spreadsheet. Let the students see how their total costs and even rankings change even before redoing their grid. Now, let them redo their strategy to take into account both the purchase and operating cost, but now the CO_2 cost as well. Remind them to multiply their annual CO_2 emissions by 30 years and then multiply by the CO_2 cost. Debrief: Compare the new team rankings. What do the cheapest energy mixes now look like? [Existing coal is no longer up there, wind is very competitive]. What about the teams with higher costs that are ranking toward the bottom?

   Student may want to discuss what the CO_2 cost multiplier represents. Ask them for any examples of impacts related to climate change [Some examples include sea level rise and storm surges along coastal areas, changes in temperature and precipitation patterns, changes in the frequency of droughts, stronger storms, etc.]. How could these impacts lead to economic costs (some examples, impacts on agricultural production, human health, transportation and other infrastructure). The CO_2 cost reflects the damages associated with climate change, and calculates those additional damages for each additional unit (e.g., ton) of CO_2 emissions.

6. **Round Three**: Change the CO_2 cost again, this time to 2, 3 or 4. Changing the number and letting the students see how the rankings change lets them see the tipping points. Don't forget to change the CO_2 cost on the spreadsheet. Additional rounds can be played increasing the CO_2 cost, 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 cost. Or, alternatively, their grid was cheap but their CO_2 cost was high. Let the students discuss the different strategies they used to reduce CO_2 emissions.

7. **Round Four**: Energy Efficiency. Prior to beginning play for this round, hand each team 2 large energy efficiency pieces and 4 small energy efficiency pieces. Tell the teams to leave their existing pieces in place on their grid. 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 power plants on the grid. Note: they should only be replacing pieces with energy efficiency pieces, not making other changes to the mix at this point. Debrief: Look at the projected score sheet. What types of energy tended to be replaced by the energy efficiency?

8. **Round Five**: Water Use. This is an optional round. Water use is only for nuclear (74), existing and coal and coal (16), coal with carbon capture and storage (CCS) (43) and natural gas (4). Looking at the water use levels on the Excel spreadsheet can inform where to set a water limit to force change. Setting the total water use at 100 will force some teams to change their mix; more change will occur by lowering the limit to 80, 60, and so on.

Extensions

Pure Optimization: Distribute the pieces equally among all teams. Then one or more rounds are played (with or without CO_2 costs), 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 very different CO_2 emissions? Can they look to some real-world examples of how different states, countries, or regions have reduced their CO_2 from their electric sector using different energy strategies? Why did they make those choices, and what was the role of resource availability or other economic, social, political or environmental considerations?

Energy Traders: Players may swap pieces between their teams, they can do any number of types of pieces, as long as both teams agree to the trade. A single player should be assigned to be the team 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" or Chance 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 chance cards below.*

Budget Breakers: The game facilitator can set an upper limit on the cost of purchasing and running the electricity grid. This only includes the purchase and annual operating and maintenance costs, not the CO_2 cost. This can be set to anywhere between 8,000 or 10,000. At lower levels, certain teams may not be able to reach this cost. However, it can also be combined with Energy Traders, and lower costs can be set.

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?

Thirsty Energy: Another approach to incorporating water use is to include it in all rounds. The game facilitator can set an upper limit for water use using the graph on the score sheet. Multiple rounds can be played but the teams that run out of water (or exceed the upper limit) 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!

Differentiation

Mathematics Focus

To enhance the mathematics used in the game, teachers may want to develop a math calculation sheet. This would be most valuable for 6^{th} and 7^{th} grade students needing real world application for unit cost and area cost objectives in the alignment. Before proceeding in the CO_2 rounds, where costs are now determined by three factors, each team can have a unit cost calculation sheet. This may be a first exposure to spreadsheets for many middle school students. The sheet presents middle school students with the working advantage of a spreadsheet in Excel and how it can be used to simplify repeated calculations.

The teacher can walk through a sample calculation for all teams. A simple analogy for students to understand the power of calculating the total costs per white rectangle in the grid, is the purchasing of cookies in packages at the store. Trying to compare different size packages with different prices can be made easier by calculating the cost per ounce or per cookie. Each team can be encouraged to complete the full calculation for each type of piece on the board and use these values to make decisions on which pieces are most advantageous to use in maintaining low overall and CO_2 costs in the game. The cost per white rectangle on the grid is as follows:

$$Cost\ per\ square = \frac{(Purchase\ Cost)\ + 30 \times (Annual\ Cost) + 30 \times (CO2\ Cost) \times (CO2\ Emissions)}{Squares\ per\ Piece}$$

For example, a natural gas piece (which covers 16 squares) would cost 26.4 at a CO_2 cost of 0.5.

$$Cost\ per\ square = \frac{(105)\ + 30 \times (10) + 30 \times (0.5) \times (1.2)}{16} = 26.4$$

Further rounds can be used with a cost sheet allowing for the third factor in the sum to be adjusted for the CO_2 cost in terms of a multiplier. Note: Students may attempt to multiply the entire value for the piece by the multiplier rather than adjusting only the CO2 emissions cost.

Calculations: Options include having students work their own calculations for mathematical practice. Students can also enter numbers into the spreadsheet directly rather than work calculations themselves and have those checked off by the teacher. The spreadsheet can be used to verify group calculations.

Writing Integration

Writing components can be added to Generate game play. These writing extension ideas can be done individually or in groups. Assignments can be completed at home or used within group classroom time to help equalize playing time between groups. All groups should have a constructive task to be working on at all times during play or when the teacher is assisting or inputting numerical data for groups.

Option 1: Each group can be assigned a major electricity resource and conduct a mini-exploration with tablets or other internet-connected devices to create a brief group report for sharing. These reports can be given in between rounds or especially before the energy efficiency round. All group members should participate in presenting the information.

Option 2: Group journals introduce writing into every round by requiring groups to write out the reasoning that the group used to make their grid of choice for the round. Students can include any comments about total score for the round, rank within the class and reflection about how other groups may have set up their board. Students can pass the responsibility of writing between group members for each round.

Option 3: (includes peer assessment) Groups can be given a geographical location and after doing research on the features of that region write about the key factors they would consider in creating a grid for that area (see "Resources" below for links to state specific energy information). Existing electricity grid information can be included. Groups can then explain what their grid would include and if it is scored how it would compare to other regions. Groups can create a poster of their key information/geographical facts, their grid composition, and bullets of their reasoning. Posters can be hung in the room and a small gallery walk can be used for students to see the posters leaving sticky note questions/comments on each poster as they move through the room spending two/three minutes examining each poster.

Power Point extension activities

The power point teaching resource can be very advanced for some middle school students depending on grade level and background. The introductory slides in the power point provide a source for rich science concepts/vocabulary as well as small group activities. Directed teaching, notes and activities will support student comprehension of the material presented in the slides and further illustrated in the dynamic exercise of playing Generate. The math concept of a percentage is new to sixth grade students and this resource can help them to see this concept used to analyze a real world situation.

A new generation science standard cross cutting concept in science is that of a "*system*." The first slide is teaching about the U.S energy system and allows teachers to ask probing formative questions about what a system is and what it is not. Whiteboards can then be used to allow student groups to illustrate a basic "*system*" illustration. Groups should label *inputs*, *outputs* and show with arrows how things are connected and be able to explain their choices. Examples: computer systems, human body, stapler, car, or "why is something like a bottle of water not a system?"

The larger energy system on the slide allows students to then see how a very large system like an energy grid has these same parts including the concept of an end user. Students can learn the four energy end use groups and consider which represents the largest overall user of electrical energy. As an application activity, groups can be given a hand-out of the colorful energy system graphic (called a "Sankey diagram") in the power point. Groups should also have access to the projected colored version. Based on analyzing and inferring from the chart (following connections, sizes of lines, colors and end users) groups can be challenged to figure out which energy resource from the word bank fits into the question mark boxes. Whiteboards can be used and teams can compete to see which group can best fill the boxes in a given amount of time. The key of the graphic chart can be revealed to let groups see proper responses.

A second look at the chart takes place with exploring the light and dark gray representations of wasted energy. Students can be asked to infer from the graphic what these colors mean and examine the concept of wasted energy. This is a prime place to introduce the basic concept of *efficiency.* This concept becomes important in the *efficiency* round of the game when *efficiency* pieces are distributed. Students can respond to teacher led questions about *efficiency* in common energy using devices like automobiles. Major appliances also have tags with labels showing energy efficiency. Why are these required? How would efficiency compare between an older house with little insulation and a newer one with think modern insulation? Many other examples are appropriate.

The *Environmental impact* teaching slide offers another teaching opportunity for basic *chemistry* integration (sixth and eighth grade). After students correctly understand the concept of a *pollutant* and an *emission*, the *chemical formulas* (made of *chemical symbols* from the *periodic table*) for *compounds* can be used to show how vital *chemistry* is to protecting the environment. It is important to connect how SO2 and NO2 coming from coal *combustion* then *react* with water in the upper atmosphere to produce *acids* (basic *chemical sentences* can be written displaying these *reactions*) and then return to the Earth in the *water cycle* (review water cycle) in the form of *acid rain.*

The lesson can then include looking at the basics of *greenhouse gases* and how *global warming* is taking place as the *atmosphere* is changing in *composition* (seventh grade). Students will be surprised to see connections between energy production and *impact* in terms of *water pollution*. Students can be asked to speculate which of the resources might be creating the most water system impact and what type of impact it is in general class discussion. Students can then complete basic calculations with the percentages of water withdrawal and total water consumption listed.

Key power point concept/vocabulary terms for middle school cards or notes include: system, input/output, end user, residential, commercial, industrial, transportation, primary resource, refinery, fossil, renewable resource, uranium, efficiency, pollutant, emission, anthropogenic, environmental impact, greenhouse gas, chemical formulas, global warming.

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
- Open Energy Information http://en.openei.org/wiki/Main_Page

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

- Mapping GHG emissions from large facilities http://ghgdata.epa.gov/
- 30 Indicators for climate change http://epa.gov/climatechange/science/indicators/index.html *
- Students guide to global climate change www.epa.gov/climatestudents/ *

*Please note that the EPA climate change webpages are being updated and are currently not available. Archived versions may be available here: https://19january2017snapshot.epa.gov/climatechange_.html

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

Acknowledgments: The teachers instructional support document was developed by Kristen Thomas (Athens Drive High School, Raleigh, NC), Susan Randolph (Wayne School of Engineering, Goldsboro, NC) and Rebecca Dodder (U.S. EPA, Research Triangle Park, NC). Individuals involved in the creation, development, review and maintenance of the game include: Andy Miller, Kelly Witter, Camden Watts Roessler, Dustin Riego, Carol Lenox, and Dana Haine, Whitney Richardson, Nicole Kim and Nicolle Priester. Distribution of the game was supported by the EPA's Air, Climate and Energy (ACE) National Research Program, with special thanks to Dan Costa and Ann Brown.

Appendix: GIVE & TAKE CARDS

There has been a major technological breakthrough! Engineers have discovered a way to drive the cost of solar panels way down, while improving their efficiency. Solar manufacturers have cut the price of their technology by half in order to keep up with the market. Cut your solar purchase and annual costs accordingly.

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! (One large and two small pieces).

CO_2 costs are on the rise as the damages associated with climate change become more severe. ALL teams must now calculate their energy grid with a CO_2 cost 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. On the last election ballot, your town voted "NO" to nuclear power. Remove any nuclear pieces you have used/could use, and place them back in your bag.

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 of 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 limit your fossil fuel use. Reduce the amount of fossil-based generation at least HALF of what it was in the previous rounds.

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 and regulations are making it hard to invest in new wind power. Place all of your wind pieces (both large and small) back in your bag.

Because of issues with initial costs of solar and wind technologies, your regional officials decided that green energy is not the way to go. Please put all of your wind and solar pieces (both large and small) back into your bag. You can only keep 8 small pieces to fill out the grid.

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 1 additional large and 2 additional small wind pieces!

Fossil fuels are becoming cheaper, which means annual costs are decreasing! For all fossil fuel based energy resources, cut the annual costs in half.

The citizens in your region have been researching nuclear energy, and feel the upfront costs of building a new nuclear plant would be justified because they could decrease the region's dependency on fossil fuels. On the most recent election ballot, your region voted YES to help pay HALF of the purchase cost of nuclear energy. Use a nuclear piece on your grid (if you do not have one, please show this card to your moderator).