EPA GENERATE:

Teachers Guide: Middle School

www.epa.gov

Middle School Instructional Support Document

Overview:

The objective of Generate 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 group contexts 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 ELA and Math

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 man 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 (please see embedded links to files in Teacher Resource section for printing)

- This Teacher's Guide
- Game board and Energy pieces (1 game board and 1 bag of pieces per group) *printable PDFs located at: www.epa.gov/research/airscience/hands-on.html
- Separate Energy Efficiency pieces to pass out for later rounds (4 small and 4 large pieces per group)
- 1 score card per group
- 1 calculation support sheet per group
- Introductory PowerPoint presentation
- Excel spreadsheet for scoring and team rankings
- 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)

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. Formative assessment 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)

Basic Procedure for Play

1. Divide students into groups of 4-5. Present each group with a game board, bag of pieces, and score card. Depending on your goals, you may also wish to give each group a calculation support sheet and calculator.

2. **Prior to playing the game, use the PowerPoint presentation to review or introduce the US Energy System**. Actively engage students in the review or introduction, asking question such as:
    a. Slide 1 and/or 2: Three phases 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 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, refineries to turn crude oil into diesel, gasoline and other useable fuels).
    b. Slide 2: 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).
    c. Slide 3: What do you notice is happening with the thick gray lines, particularly on the upper right area of the slide? (Wasted energy). How much is actually used versus wasted? Which types of energies currently contribute to more waste? Why do you think this is? (The answer is: efficiency)
    d. Slide 4: Prior to advancing the slides, ask: Now let's think about environmental impact. In what ways do energy extraction, refinement and production, and use impact the environment? (air pollution, greenhouse gas emissions, water use). What percentage of these things (air pollution, greenhouse gas emissions, and water use) do you think are related to our energy use? Advance the slide and share information. Ask students, do these percentages surprise you?
    e. Slide 5: at what point in the process do these emissions typically occur?

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 real-life costs and values. The purpose of the game is to help us understand the challenges and tradeoffs involved in making energy and policy decisions. Each team has the same grid 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. Your score is determined by a one-time purchase cost, 30 years of annual operating costs, and 30 years of total CO_2 costs.

b. Show slide 7: the grid.

c. Show slide 8: the pieces. Ask students to compare piece sizes. Why is piece size significant? [The larger the piece, the more of the grid it covers and the more energy it provides].

d. Show slide 9: Explain how to calculate the score. 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? [Gas, maintenance, insurance, etc.] These are similar to the annual costs to operate a power plant. Point out that the annual operating 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? Point out that CO_2 emissions are located on the bottom left-hand corner. These annual CO_2 emissions will also be multiplied by 30 years. However, we then put a cost on the emissions. 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.

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 calculate their scores on the <u>score sheet</u>, and if you choose, hand out the <u>calculation support sheet</u>. Minimize the PowerPoint and project the <u>spreadsheet</u>. 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. For the teams ranked 1 and 2, what does your energy mix look like? [A lot of coal; existing coal favored over new coal or coal with CCS]. For those of you ranked toward the bottom, how is your mix different? [more renewable, perhaps nuclear, less existing coal]. Were some teams given an unfair advantage for this round? [Yes, those with more coal, especially existing, are at an advantage]. Don't worry, 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? [Represents current policies for diversification].

* 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 carbon and one round of energy efficiency must 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 multiplier at 0.5 on the spreadsheet. Debrief: Compare the new team rankings. What do the cheapest energy mixes now look like? [Existing coal is no longer up there]. What about the teams ranking toward the bottom?

6. **Round Three**: Change the CO_2 again, this time to 1.0. Don't forget to change the CO_2 multiplier on the spreadsheet. Additional rounds can be played increasing the CO2 multiplier to 2, 3, etc. depending on time.

7. **Round Four**: Energy Efficiency. Prior to beginning play, hand each group 4 large energy efficiency pieces and 4 small energy efficiency pieces. Keep the CO_2 multiplier set to 1.0. 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. Debrief: Look at the projected score sheet. What types of energy tended to be replaced by the energy efficiency? [renewables such as solar].

8. **Round Five**: Water Use. This is an optional round. Hand out to each a sheet with the water use for each type of piece. 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 or 125 will make some teams have to change their mix, particularly if they have nuclear and or coal with CCS.

Extensions

Pure Optimization: Distribute the pieces equally among all teams. Then one or more rounds are played (with or without CO2 costs), so see which team can arrive at the optimal solution. Are there different ways to achieve the same cost solution with different energy mixes?

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.

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 O&M costs, not the CO2 cost.

Climate Friendly: The game facilitator can set an upper limit for the CO2 cost on the score sheet.

Thirsty Energy: The game facilitator can also set an upper limit for water use using the graph on the score sheet. Multiple rounds can be played but the team that runs out of water will be eliminated. Keep in mind that nuclear and coal with CCS are very water intensive. Renewables are virtually water free!

Differentiation

Mathematics Focus

To enhance the mathematics used in the game teachers may implement the Math Calculation sheet in the Teacher Resources section. This sheet is most valuable for 6th and 7th 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 the nuclear energy sample calculation for all teams. An example 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 piece on the board and use these values to make decisions on what form of energy is most advantageous to use in maintaining low overall and CO_2 costs in the game.

Further rounds can be used with the cost sheet allowing for the third factor in the sum to be adjusted for the CO_2 value in terms of a multiplier. Note: Students will attempt to multiply the entire value for the piece by the multiplier rather than adjusting only the third term in the Sum by the multiplier and then dividing by the square rectangular area of the piece.

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 chart*) 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 ALL energy resources and facilities www.eia.gov/state/maps
- Open Energy Information http://en.openei.org/wiki/Main_Page

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/

EPA Air, Climate and Energy Research

- Climate Change Research http://www.epa.gov/research/climatescience/index.htm
- Air Quality Research : http://www.epa.gov/research/airscience/index.htm

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