EPA GENERATE:

Teachers Guide: High School

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

1. EEn2.8.1: Evaluate alternative energy technologies for use in North Carolina.
2. EEn2.8.3: Explain the effects of uncontrolled population growth on the Earth’s resources.
3. EEn1.1.3: Explain how the sun produces energy which is transferred to the Earth by radiation (accomplished with extension piece on solar photovoltaic).
4. 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).
5. EEn2.4.1: Evaluate human influences on freshwater availability (with water usage round(s)).

Alignment to North Carolina Essential Standards for World History:

1. 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).
2. 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 Next Generation Science Standards:
Engineering, Technology, and Applications of Science:

1. 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.
2. 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.
3. 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.
4. 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

1. 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…]
2. 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].
3. 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.]
4. 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).

Essential Questions for High School

- Understand and evaluate the different sources of electricity generation, and the trade-offs between their cost and their environmental impact [comparison of different pieces].
- Identify potential improvements in energy technologies that could mitigate the trade-offs [how to reduce cost of renewables and reduce CO2 and water impact of fossil fuels].
- Create, evaluate, and refine competing design solutions for the electricity mix based on total system cost, which includes the financial cost and the cost of the environmental (climate, water, etc) damages [comparing grid solutions throughout consecutive rounds].
- Analyze and describe the complexities of designing a cost-effective and environmentally-friendly electricity mix.
- Explain the impact of constraints in resource availability [such as limited wind, solar, natural gas] or the ability to use different technologies [constraints on nuclear or coal] on designing optimal electricity 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.

Materials

- 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 Activity

For the high school level of instruction, students are expected to enter the activity with a *basic* understanding of the types of and differences between fossil fuels and sustainable energy sources. As the game can be played at a variety of levels, teachers may decide that students need more preparation to play more complex rounds. The middle school instructional support document provides some of that additional background.

Duration

90 minute block period or two 45 minute shorter periods; options to extend.

Procedure

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 CO_2 cost.

Climate Friendly: The game facilitator can set an upper limit for the CO_2 cost on the score sheet.

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

The supporting calculations can be handled in a variety of ways. Students can be required to calculate their scores prior to submitting their mixes in each round, or the teacher can calculate by plugging the numbers into the spreadsheet. Teachers can choose to give students the calculation support sheet to help scaffold this work.

Teachers can select how many rounds and which rounds to assign based on the needs of their classes. They may choose to take more time and only run three rounds, only adjusting carbon. 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 groups of students who tend to need more help, using these cards is a great way to help students communicate their group'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 one 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 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

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 and development of the game include: Andy Miller, Bernine Khan, Kelly Leovic, Camden Watts, Dustin Riego, Carol Lenox, and Dana Haine. 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.