Teaching Electricity Generation and the Smart Grid using the CLEAN-NGSS Unit Planning Template

<table>
<tr><td>Unit Title:</td><td colspan="3">Debating the Grid</td></tr>
<tr><td>Grade Level and Class:</td><td>High School AP
Environmental/Earth Science</td><td>Instructional Time:</td><td>2-3 weeks</td></tr>
<tr><td colspan="4">1. Select the NGSS Performance Expectation(s) (PEs) based on grade level and content-focus and list the learning objectives.</td></tr>
<tr><td colspan="4">HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

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.</td></tr>
<tr><td colspan="4">2. What phenomena, problem, or project would best suit the PE(s)?
(Learn more about phenomena)</td></tr>
<tr><td colspan="4">Students research electricity, its sources, and how energy grids function, how to make grids most efficient, how to bring different types of energy generation together to diversify grids. Students debate the costs and benefits of moving to a modernized “Smart Grid”.</td></tr>
<tr><td colspan="4">3. Describe an overview of how the phenomena, problem, or project would best suit the PE(s).
(Revise, as needed)</td></tr>
<tr><td colspan="4">The electrical grid is the biggest machine on Earth. While it is an amazing feat, it needs an upgrade and there are many factors to consider. Money and politics play a role but so does conservation, technology, and diversification. In this activity, students research how the grid works and debate the following:
Do we need a “Smart Grid”?http://cleanet.org/resources/43478.html
Should the grid continue to be centralized or does it make more sense to have a local and distributed system?
How should renewable resources be integrated?
How should governments from the federal to the local level be involved?</td></tr>
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Driving questions:
What factors determine the best way to generate, distribute, and use electricity? (HS-ESS3-2)
How can different energy solutions be brought together to solve energy problems? (HS-ESS3-4)
Is the Smart Grid really a good idea? (HS-ETS1-3)

4. What type of strategy works best for teaching and learning about the phenomena, problem, or project?
(For ideas, see the Teaching Strategies for Units)

Argument-Driven Inquiry

5. Identify (unpack) the Performance Expectation(s) components embedded in the PE(s) in the NGSS Matrix.
(For guidance, see Access the NGSS Science Standards by Topic):

HS-ESS3-2

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Engaging in Argument from Evidence: Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).	**ESS3.A: Natural Resources** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. **ETS1.B: Developing Possible Solutions** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.	**Connections to Engineering, Technology, and Applications of Science - Influence of Science, Engineering, and Technology on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practice to increase benefits while decreasing costs and risks. Analysis of costs and benefits is a critical aspect of decisions about technology. **Connections to Nature of Science - Science Addresses Questions About the Natural and Material World** Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.

		Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.
HS-ESS3-4		
Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Constructing Explanations and Designing Solutions Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ESS3.C: Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **ETS1.B: Developing Possible Solutions** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts	**Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system. **Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
HS-ETS1-3		
Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Constructing Explanations and Designing Solutions Evaluate a solution to a complex real-world problem,	When evaluating solutions it is important to take into account a range of constraints including cost, safety,	**Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system.

based on scientific knowledge student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	reliability and aesthetics and to consider social, cultural and environmental impacts.	**Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practice to increase benefits while decreasing costs and risks.

6. How will you assess students' learning of the PEs with summative assessments and/or rubrics?

Debate rubrics are the recommended assessment tool. Depending on the classroom environment, any of the following rubrics should be modified to meet the needs of the teacher and students:

- Class Debate Rubric
- Debate Assessment Rubric
- Debate Grading Rubric

7. Create an instructional plan by building a unit storyline:

Assess Students' Prior Knowledge

- Develop a plan to determine students' prior knowledge (e.g. pre-test, class discussion, etc.) based on the NGSS standards listed below that students should have learned throughout elementary school:

Performance Expectations (PE)

4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels. **Assessment Boundary:** none

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
Clarification Statement: none. **Assessment Boundary:** Assessment does not include quantitative measurements of energy.

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Obtaining, Evaluating, and Communicating Information Obtain and combine information from books and other reliable media to explai phenomena. **Planning and Carrying Out Investigations** Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	**ESS3.A: Natural Resources** Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. **PS3.A: Definitions of Energy** Energy can be moved from place to place by moving objects or through sound, light, or electric currents. **PS3.B: Conservation of Energy and Energy Transfer** Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. Light also transfers energy from place to place. Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.	**Influence of Science, Engineering, and Technology on Society and the Natural World** Over time, people's needs and wants change, as do their demands for new and improved technologies. **Interdependence of Science, Engineering, and Technology** Knowledge of relevant scientific concepts and research findings is important in engineering. **Energy and Matter** Energy can be transferred in various ways and between objects.

<u>Identify Learning Activities</u>

- Select learning activities from CLEAN (NGSS and CLEAN at a Glance and Search the CLEAN Collection by NGSS Topic) and other resources that build towards the PEs.

Resources identified:

HS-ESS3-2:

1. How is electricity generated?https://www.eia.gov/energyexplained/index.cfm?page=electricity_generating.
    a. Our Energy System http://cleanet.org/resources/42776.html
    b. Electricity data browser http://cleanet.org/resources/44626.html
    c. Where does your energy come from? Analyzing your energy bill http://cleanet.org/resources/42728.html
    d. Generating electricity: Evaluating the sustainability of today's and tomorrow's energy sources http://cleanet.org/resources/45577.html

HS-ESS3-4:

1. Responding to Climate Change http://cleanet.org/resources/45148.html
2. Much of the Electricity generated is lost to entropy. How can this be minimized to save money and reduce pollution?
    a. Efficiency: The most important thing http://cleanet.org/resources/45169.html
    b. Energy Lab (simulation) http://cleanet.org/resources/49451.html
    c. Zero-Energy Housing (modeling energy efficient design) http://cleanet.org/resources/41890.html
3. Every region is different. Which types of energy production are the best for each region?
    a. The United States of Energy http://cleanet.org/resources/46133.html
    b. US Energy Production and Consumption http://cleanet.org/resources/43492.html
    c. Selecting Sites for Renewable Energy Projects http://cleanet.org/resources/43135.html
    d. Free Energy Data (FRED) visualization tool http://cleanet.org/resources/45147.html
    e. Power for Developing Countries http://cleanet.org/resources/49466.html
4. What is the Smart Grid? https://www.smartgrid.gov/the_smart_grid/; https://www.nrel.gov/grid/

HS-ETS1-3:

1. Have students read and evaluate "The Big Smart Grid Challenges" https://www.technologyreview.com/s/414386/the-big-smart-grid-challenges/
2. Students use the internet to research the cost, safety, reliability, and impacts of building, implementing and maintaining a Smart Grid in the US (https://www.nrel.gov/grid/) (Debate resources: http://www.educationworld.com/a_lesson/lesson/lesson304b.shtml)

Develop Unit Timeline and Formative & Summative Assessments

Week 1: Students develop an understanding of where electricity comes from and how sources vary by region by researching and reporting out.

Day 1 - Put students into pairs and have students read, analyze and take notes on U.S. Energy Information Administration's "How is electricity generated?" https://www.eia.gov/energyexplained/index.cfm?page=electricity_generating and "Electricity in the United States" https://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states.

Have students work together to create flow charts showing energy transformations required to generate electricity from different means. Have students examine the National Academy of Science's, "Our Energy System" http://cleanet.org/resources/42776.html Using a map of the U.S. have students create maps showing the predominant electricity resources (https://nationalmap.gov/small_scale/printable/reference.html#list).
Homework: Where does your energy come from? Analyzing your energy bill http://cleanet.org/resources/42728.html

Day 2: Conduct a whole group discussion or provide direct instruction on the similarities and differences in ways of generating electricity. Give students a chance to correct their diagrams and create new maps.
Homework: Where does your energy come from? Analyzing your energy bill http://cleanet.org/resources/42728.html

Day 3-5: Investigating Regional variations in Electricity Production

Day 3: Review homework from Days 1-2 (Where does your energy come from? Analyzing your energy bill http://cleanet.org/resources/42728.html) students answers should be quite similar unless their families have invested in renewable energy technologies. Ask student groups to discuss and identify how and why electricity might be different in different places. Then, broaden the focus to different regions by having students work in small groups and researching other zip codes. Using the Electricity data browser http://cleanet.org/resources/44626.html have students examine the information and complete the worksheet: Analysis of US Electricity Generation

Day 4: Students evaluate the use and sustainability of energy resources (renewable or nonrenewable) used to generate electricity by completing "Generating electricity: Evaluating the sustainability of today's and tomorrow's energy sources" http://cleanet.org/resources/45577.html. Students could also use "Responding to Climate Change" http://cleanet.org/resources/45148.html

Day 5: Student groups come to class ready to report out on their findings in the format of short presentations (5 minutes) or posters. This allows for quick feedback from the instructor.

Day 6: Students examine where the energy we do NOT use goes. Much of the electricity generated is lost to entropy. How can this be minimized to save money and reduce pollution?

1. 3 minute Video -- Efficiency: The most important thing http://cleanet.org/resources/45169.html
2. Complete the Energy Lab (simulation) http://cleanet.org/resources/49451.html (finish as homework) or have students make models of energy efficient housing using "Zero-Energy Housing" http://cleanet.org/resources/41890.html (this will add on a couple of days)

Day 7: Every region is different. Which types of renewable/alternative energy production are the best for each region? Assign student groups different regions. Have them use the following resources to research and take notes on the following in preparation for the debate:

1. The United States of Energy http://cleanet.org/resources/46133.html

2. Free Energy Data (FRED) visualization tool http://cleanet.org/resources/45147.html
   Alternatively, students could conduct this more focused and structured activity:
3. (1 day activity) US Energy Production and Consumption http://cleanet.org/resources/43492.html

Day 8-9: Students begin to identify sustainable energy solutions. Students should work in small groups to complete "Selecting Sites for Renewable Energy Project" http://cleanet.org/resources/43135.html which is focused on the distribution of renewable energy sites in the United States (2 days).

Homework: students read the following articles and complete the following (due Day 10)

1. Write a summary and make a flowchart showing your understanding of "What is the Smart Grid?" https://www.smartgrid.gov/the_smart_grid/
2. Make a T-Chart of the pros and cons of a Smart Grid based on "The Big Smart Grid Challenges" https://www.technologyreview.com/s/414386/the-big-smart-grid-challenges/

Extension: If there is interest in how developing countries are creating distributed electricity generation systems, students could complete "Power for Developing Countries" http://cleanet.org/resources/49466.html.

Day 10-11: In a short whole-class discussion, identify the stakeholders that should have a voice in the development of a Smart Grid. The US Department of Energy has identified the following Smart Grid stakeholder groups: Consumer Advocates, Utilities, Regulators, Technology Providers, Environmental Groups, and Policymakers (https://www.smartgrid.gov/the_smart_grid/index.html). Divide students up into small teams representing these stakeholder groups. Students work in teams to prepare arguments and use the internet to research the cost, safety, reliability, and impacts of building, implementing and maintaining a Smart Grid in the US. (https://www.nrel.gov/grid/)

Day 12: Summative Assessment -- Students debate the cost, safety, reliability, and impacts of building, implementing and maintaining a Smart Grid in the US. (Here are some recommended resources to help the teacher structure the debate http://www.educationworld.com/a_lesson/lesson/lesson304b.shtml and http://www.teachhub.com/classroom-activities-how-hold-classroom-debate)

Homework: Students write a one page evidence-based argument advocating for or against the development of a Smart Grid.

8. Unit Reflection:

- What parts of the unit were a success?
- What were some challenges about the unit?
- How could the unit be changed or improved?

(To be completed after unit instruction)