UNIT PLAN

The 50 Year Energy Plan Project

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DESCRIPTION

Throughout this creative, hands-on Unit, students are challenged to scale up every Disciplinary Core Idea and Science & Engineering Practice they've learned - from simple electricity generation, to building their own stereo speakers and DIY electric guitars – in order to think independently and develop a 50-Year Energy Plan for their local community. To complete this final challenge, students incorporate concepts and findings they explored throughout the unit: electromagnetism, motors and generators, amps and electric guitars, optimizing solar energy production, wind turbine design, climate change, as well as human impacts on the environment when generating energy. This unit is only part of a series of units housed on PatternsPhysics.org, the web-based home for a collaborative group of Oregon physics teachers working to develop rigorous, phenomena driven units aligned to Next Generation Science Standards (NGSS).

GRADE LEVEL(S)

9; 10; 11; 12

SUBJECT AREA(S)

Physics, Physical Science, Earth Science, Electromagnetism, Energy Planning, Power Grid, Wind Energy, Environmental Policy, Solar Energy, Climate Science

LEARNING GOAL(S)

1. Explore causes and effects of climate change as related to energy production.
2. Develop a working understanding of varying stakeholder perspectives on the causes and effects of climate change.
3. Through hands-on exploration, build a working speaker that can connect to a cellphone.
4. Use DIY speakers as a model to observe the process of producing electrical currents with a simple generator.
5. Design, build and refine a wind turbine to efficiently convert mechanical energy into electrical energy.
6. Design, build and refine a system that is the most effective at converting the sunlight into electrical energy.
7. Students develop models to study the relationship between the Earth's atmospheric composition and the Earth's surface temperatures using simple diagrams.
8. Students reflect on the impact of energy sources and power production on the environment.
9. Students utilize their knowledge of how energy generation processes impacts the environment to inform how and why they develop a 50-year Energy Plan for their local community.

UNIT EXPERIENCES

Lesson/Experience	**Time**
Engage/Explore	
L1: Intro the 50-Year Energy Plan Project	90 min x 2 = 180 min (3 hrs)
Explain	
L2: Diving into Motors and Generators L2: Investigation into Power Production (Electric Guitar and Generators)	90 min x 6 = 540 min (9 hr)
Elaborate/Evaluate	
L3: Scaling up to Power Production Let's Engineer a Wind Turbine L4: Scaling up to Power Production L5: How do we Evaluate Energy Sources? L6: What is Our Plan?	L3 90 min x 3 = 270 min (4.5 hrs) L4 90 min x 2 = 180 min (3 hrs) L5 90 min x 4 = 360 min (6 hrs) L6 90 min x 2 = 180 min (3 hrs)
Total	**90 min x 16 = 1440 min (24 hr)**

NEXT GENERATION SCIENCE STANDARDS

Guiding Phenomenon	The American power grid and its relationship to global climate change.
Supplementary Phenomena	L2: Building a speaker L2: Electrify an acoustic guitar L3: Engineering wind turbines L4: Optimizing solar cells

Table 1. Next Generation Science Standards Assessed in This Unit

Performance Expectation	How is this Assessed?
HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	L3: Students design a wind turbine that optimally generates an electrical current. Students utilize background knowledge from the exploration of motors and generators.
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	L3: Students design a wind turbine that optimally generates an electrical current. Students utilize background knowledge from the exploration of motors and generators.
HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	L2: Students explore amplifiers and electric guitar microphones as a method to visually/physically model and explain the concept of electromagnetism.
HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.	L4: Students use their understanding of solar radiation and position of the sun to inform decision making while designing an effective solar array.
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.	L6: Students develop a 50 Year Energy Plan for their local community, taking into account the science of energy generation, environmental challenges, and societal needs.
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,	L6: Students develop a 50 Year Energy Plan for their local community, taking into account the science of energy generation, environmental challenges, and societal needs.

cultural, and environmental impacts.	
HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	L5: Students construct a model demonstrating interactions and relationships between the Earth's atmosphere and pollutants coming from traditional energy generation practices.
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.	L5: Students construct a model demonstrating interactions and relationships between the Earth's atmosphere and pollutants coming from traditional energy generation practices.
HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*	L6: Students develop a 50 Year Energy Plan for their local community, taking into account the science of energy generation, environmental challenges, and societal needs.

THREE DIMENSIONAL LINKAGES

NGSS focuses not only on content, but also on process and building bridges between concepts within and across disciplines. The following tables outline the way in which this unit addresses this three-dimensionality as is essential to NGSS.

Table 2. Three-Dimensionality: Disciplinary Core Ideas (DCIs)

Disciplinary Core Ideas	Linkage in Unit
PS2.B: Types of Interactions Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)	Students are creating their own hand powered motors and generators (in the form of speakers and electric guitars) to construct ideas about force fields and the interrelated nature of electric and magnetic fields, as small-scale version of large-scale power production.
ESS3.D: Global Climate Change Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future	Students explore both a pre-programed simulation and also code their own spreadsheets in order to model large scale power production, energy production's impact on the environment and how those impacts

impacts. (HS-ESS3-5) Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6)	change if utilizing different energy resources over 50 years.
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. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)	Students explore both a pre-programed simulation and also code their own spreadsheets in order to model large scale power production, energy production's impact on the environment and how those impacts change if utilizing different energy resources over 50 years.

Table 3. Three-Dimensionality: Science and Engineering Practices (SEPs)

Science and Engineering Practices	Linkage in Unit
1. Asking questions and defining problems	L1: Students ask questions about large scale power production and its environmental impacts. L3: Students ask questions about what affects a wind turbine's efficiency to generate electricity. L4: Students solve the problem of how to optimize a solar array's power production.
2. Developing and using models	L2: Students create a model of a small-scale electric generator. L6: Students create a model of large-scale power production and environmental impacts from utilizing different energy resources over 50-years.
3. Using Mathematics and Computational Thinking	L6: Students code a spreadsheet that predicts the environmental and municipal effects of various power production plans and observe differing outcomes when utilizing different energy resources over 50-years.

Table 4. Three-Dimensionality: Crosscutting Concepts (CCCs)

Crosscutting Concepts	Linkage in Unit
1. Cause and effect:	L2: Students use cause and effect as they explore and determine how a motor works with various inputs and outputs. L2: Students use cause and effect as they explore and determine how an electric generator works with various inputs and outputs. L6: Student use cause and effect as they code a spreadsheet that predicts the environmental and municipal effects of various power production plans and observe differing outcomes when utilizing different energy resources over 50-years.
2. Scale, proportion, and quantity	L3: Students use scale and proportions as they consider how to move from small-scale electrical generators (in the form of DIY electric guitars) to large-scale systems to power entire.
3. Energy and Matter	L5: Students explore how changes of energy and matter in the earth system can be described in terms of energy and matter flows into, out of, and within that system.

COMMON CORE STATE STANDARDS

WHST.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

CONTENT BACKGROUND

STUDENT BACKGROUND

At the start of this unit, students are expected to have some familiarity with the following concepts and practices:

- The engineering design cycle
- Basics of using spreadsheets (Excel, Google Sheets, etc.)
- Tracking forms of energy through a system

EDUCATOR BACKGROUND

Optimally, educators will have a strong working understanding of basic physics and the basics of how motors and generators work, as well as Earth's climate system.

VOCABULARY

Electricity	A flow of electrons, often through a circuit, used often in our daily lives.
Electromagnet	A circuit with a coil of wire that concentrates and aligns a magnetic field, nearly always with a metal core that acts as the “magnet” that can then be turned on and off
Magnetic Field	A region of space that surrounds a magnet and affects how magnets interact with their surroundings
Renewable Energy	A naturally occurring source of energy that replenishes itself quickly

REQUIRED MATERIALS

ACTIVITY SUPPLIES (PER CLASS OF 24)

- **3** light bulbs (1.5 V)
- **1** Bar Magnet
- **2** Food Coloring – (Blue and Yellow or any two primary colors to mix)
- **2** Magnetic compasses (to react to electromagnets)
- **2** Multimeters
- **2** Spools Enameled Wire – 1lbs 24 AWG (for building speakers)
- **1** Easy to work with 20 AWG wire (for electrical connections)
- **8** Handheld Generators
- **4** 20in Box Fans
- **16** Cylindrical Magnets made of Neodynium (1/2 in diameter x 1/2 in tall)
- **4** KidWind MINI Wind Turbine
- **4** Vernier Energy Sensors
- **4** Vernier Variable Loads
- **4** Solar Cells, anywhere from 1.5-5V
- **4** DC Electric Motors
- **(Optional) 1** Anemometer (used to measure flowing air speed of fans)

UNIT PROGRESSION

LESSON SUMMARIES

LESSON 1: THE 50-YEAR ENERGY PLAN PROJECT

TEACHER TIPS: This lesson follows slides 1-19 of the "Energy, Magnetism and Power Production" ("EMPP") Unit Slides and is aligned with pages 1-7 of the EMPP Unit Packet.

In the first part of this activity, students participate in a role play activity – understanding the needs of different people living and working around the world. Each character express their unique perspective on climate change and impacts to their community. Students are then introduced to the 50-Year Energy Plan project, wherein they work to build an environmentally friendly long-term Energy Plan for the state of Oregon. Finally, students jigsaw together all the different energy generation processes already operating in Oregon as a primer for their future exploration.

LESSON 2: DIVING INTO THE PHYSICS OF MOTORS AND GENERATORS

(SLIDES

Using energy analysis and applied tinkering, students build hand-cranked speakers to play music from their cellphones. Inventing DIY electronics works as an exciting phenomenon for students to observe and engage in exploring electromagnetism. At this point, they have created a motor, which utilizes electric current to perform work (the speaker itself creating noise). They can then explore the reversal of this process in the next lesson.

Next, students disassemble their DIY speakers and connect them to simple $3 guitars to make their instruments "go electric." This process requires students to reverse engineer systems built previously and find insight into how generators work. Students can spend time optimizing different parts of their electric guitar for as long as they choose in order to make it work more effectively or increase sound quality/clarity.

LESSON 3: SCALING UP TO POWER PRODUCTION – LET'S ENGINEER A WIND TURBINE!

After going through Lessons 1 and 2 of this Unit, students are now familiar with the physics of how generators work. The next step in Lesson 3 is to investigate how existing power generation systems operate and supply electricity to entire geographic regions. Lesson 3 first focuses on engineering wind turbines and using real-life data to inform the design process. After a class-wide brainstorming session to identify what constraints and considerations will improve their projects, students divide into small groups to collect data on those individual design variables. For example, Group #1 tests how changing the number of blades impacts windmill performance, whereas Group #2 measures if/how different blade angles influence power output, Group #3 observes tower height, Group #4 looks at gear ratios, and so on and so forth. After recording information and uncovering patterns, each group shares results with the class. Using everyone's collective findings, each small group designs an "ideal wind turbine." Through the Engineering Design Process, each group will build, test, re-think, alter their designs and launch an evolved iteration at the end of this Lesson based on recorded data rather than just guesswork.

LESSON 4: SCALING UP TO POWER PRODUCTION LET'S USE DATA TO OPTIMIZE THE PERFORMANCE OF A SOLAR CELL ARRAY

Somewhat similar to the first part of the wind turbine project from Lesson 3, students are tasked with optimizing the performance of a photovoltaic system. This objective both allows students to apply the engineering-design process they absorbed in previous lessons, while also addressing NGSS performance expectation **HS-PS4-3** that states:

> *"Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other."*

Students meet this standard by using their understanding of solar radiation and position of the sun to inform decision making while designing an effective solar array.

LESSON 5: HOW DO WE EVALUATE ENERGY SOURCES?

Building on student's understanding of energy production methods developed over previous lessons, Lesson 5 asks the class to identify and measure trade-offs between environmental impacts – human needs – and practical costs of different power generation methods to help inform their capstone project to create a 50-year Energy plan for their community. As a class, students engage in a brainstorming session to deliberate what factors should be included in their evaluation rubric.

After their brainstorming session, educators carry out a lesson looking at the natural functions of multiple Earth Systems, as well as modern energy generation's impact on those systems - including climate. From this, students develop models that demonstrate the flow of Carbon on Earth and use that knowledge to inform their capstone projects.

L6: WHAT IS OUR PLAN?

With all the pieces in place, this Unit's final lesson asks students to code a spreadsheet that calculates and mathematically predicts the environmental impacts of different energy sources and strategies over a 50 year timespan. Divided into five different decades, students input different types of energy generation systems and use this Calculator to see and measure outputs according to the evaluation rubric they self-determined in Lesson 5. Analyzing Net Power Output, Climate Impact, is incorporated into the scoring of each group's overall Energy Plan. Using this spreadsheet tool to computationally think through many scenarios, students create their optimal idea for the future using real-life scientific skills, data analysis tools, team work, and knowledge gained through this Unit's many explorations.

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENTS

Students should be tracking their data and findings in various methods throughout this unit, whether it be in worksheets provided along with the curriculum or through their own engineering notebooks. Teachers are encouraged to determine as many open-ended methods for observing student understanding formatively as they engage with content in an exploratory manner.

SUMMATIVE ASSESSMENT

- **Lesson 3:** *"Engineer a Wind Turbine"* Engineering Portfolio
- **Lesson 4:** *"Optimize a Solar Cell Array"* Engineering Portfolio
- **Lesson 6:** *"Energy Plan Portfolio,"* including student created *"Energy Plan Rubric with Rationale"*

UNIT EXTENSIONS

- **Lesson 2:** Student DIY speakers, as a linear motor, can be extended to be used as a simple cyclical motor as well.
- **Lessons 3, 4, 6:** This is a great opportunity for local utility partners or renewable energy installers to come work with your classroom. Professionals may act as guest presenters, observers, or project judges. Local Electrical Utilities often already have outreach programs in place and will be happy to work with you to determine how to best meet the needs of your students. Try using the online Professional Mentor – Classroom connection tool Oregon Connections from the education group, Nepris, to get in touch with Solar Professionals in your area – either in person or for a virtual classroom meetup. For more information visit www.OregonConnections.nepris.com

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