LESSON PLAN

The 50 Year Energy Plan Project

Lesson 3: Scaling up to Power Production: Let's Engineer a Wind Turbine

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DESCRIPTION:

After working 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.

ACTIVITY LENGTH

3 x 90 minute periods

LEARNING GOAL(S)

1. Design, build, and refine a wind turbine in order to effectively and efficiently

convert motion into mechanical energy and then into electrical energy

CONTENT BACKGROUND

STUDENT BACKGROUND

- Some familiarity with wind turbines.
- Background on energy, energy transformations and basics of electricity as gathered from prior lessons in this Unit
- Experience using Vernier Labquests; Labquest 2s; or GoDirect Sensors

EDUCATOR BACKGROUND

Educators wanting to be prepared should read through the EMPP Unit Slides for Lesson 3 or found online at https://goo.gl/EYCyT2). Moreover, click through to explore videos and resources embedded within those slides

Have understanding of the basics of Windpower generation and contemporary US power production methods →

- Read the most recent Oregon Energy Plan, as it provides a lot of relevant, real-world background information. Another tool is the official State of Oregon's interactive, online "Electricity Mix in Oregon" map found here (https://www.oregon.gov/energy/energy-oregon/Pages/Electricity-Mix-in-Oregon.aspx).
- Explore the U.S. Energy Information Administration website for more background, including the U.S. Overview map to find information on another state.

Activity-Specific Background Resources:

- Gain or have experience using Vernier Labquests; Labquest 2s; or GoDirect Sensors – information can be found on the provider's website: www.vernier.com/products
- Gain or have prior experience assembling the KidWind Mini Turbine: www.vernier.com/products/kidwind/wind-energy/kw-mwtbd/
- Explore the NOVA Labs website to watch embedded educational videos and try your hand at Playing the Energy Lab Game: http://www.pbs.org/wgbh/nova/labs/lab/energy/
- Gain familiarity with the NOVA Energy Lab Game Educator Guide: http://www.pbs.org/wgbh/nova/labs/about-energy-lab/educator-guide/

MATERIALS NEEDED

HANDOUTS/PAPER MATERIALS

- Student Packets
- Lab Template for Investigating a Parameter of Wind Turbine Design

CLASSROOM SUPPLIES

- General AV Equipment
- 2 box fans (20")
- 4 KidWind Mini Turbines
- 4 Vernier Energy Sensors - either Labquest(2)s or GoDirect sensors (or simple multimeters)
- 4 Variable Loads
- Various additional found materials to make blades (cardboard, foam core, balsa wood, etc.
- Hot glue-guns & glue sticks, liquid adhesive, or strong tape
- Access to internet-connected devices.

LESSON PROGRESSION

PLANNING AND PREP

Review the Unit Slides for Lesson 3 (119-185), familiarize oneself with applicable pages and data sheets in the Student Packet.

Preparing for Wind Energy Engineering Challenge:

- Review background content on wind energy concepts
- Understand and know how to use Vernier data collection tools.
- Understand and know how to use/assemble KidWind Mini Turbines.
- Using box fans, set up wind station with Vernier data collection tools for students to test designs.
- Collect materials for students to build and measure blades for their wind turbine designs:
    - Enough found materials to make many different blades for each team (i.e. cardboard, foam core, balsa wood, cardstock, plastic sheets)
    - Hot glue-guns & glue sticks, liquid adhesive, or strong tape
    - Scissors, Exacto blades, Cutting surfaces, etc.

LESSON SEQUENCE

DAY 1

In this section, students utilize pages 11-16 in their Unit Packet and the Lab handout to track their design progress and following along with EMPP Unit Slides for Lesson 3 (SLIDES #119-185) . At the end of Lesson 3 students should be able to use the big ideas of electricity to explain the design of the United States' power grid.

- Guiding Question –

  "Why is our large-scale power production and distribution the way it is?"
    - Watch Video "The Need for Large Scale Power Production:" www.youtube.com/watch?v=_W1ApWgsIug&feature=youtu.be
    - Share ideas and ask questions
    - Explore local utility and power generation method maps (Oregon state specific map found here: https://www.oregon.gov/energy/energy-oregon/Pages/Electricity-Mix-in-Oregon.aspx)
    - Analyze methods and locations as well as social, economic, and environmental outcomes of these methods (positive and negative)
    - Watch Video to think of other important considerations: "A Better Grid:" https://www.youtube.com/watch?v=MDhgIUduCBI&feature=youtu.be
    - Discuss Power Production as well as TRANSMISSION in the U.S.
        - Why use high Voltage Power Lines?
        - Return to P=IV and consider that with big localized (as opposed to small decentralized power generation – i.e. solar panels on a house or neighborhood) long distance transfer is needed, where

wasted (or dissipated energy) depends on the amount of current in the wires

- CAREER QUESTION – Watch Video: "Crew Repairs High Voltage Power Lines," www.youtube.com/watch?v=EWbBdAeW1m8&feature=youtu.be

- Reintroduce 50 Year Energy Plan Capstone Project
  - ACTIVITY: Watch Intro Video and Play ENERGY LAB SIMULATION GAME: "www.pbs.org/wgbh/nova/labs/lab/energy/"
  - Watch Video and Discuss Battery Storage: "www.youtube.com/watch?v=Vpo0DArodJI&feature=youtu.be"

  ASK – What are three ideas discussed in NOVA's "Solving the Storage Problem?"

  - EDUCATOR NOTE – although malleable, this Lesson will most likely span more than one classroom session. After playing the NOVA Energy Lab, students will complete day one of Lesson 3 in this Unit.

DAY 2

- Intro to Wind Energy
  - Watch Video: "NOVA Wind Power: www.youtube.com/watch?v=SQpbTTGe_gk&feature=youtu.be
  - As a class or in groups completing Think – Pair – Share activities, fill out the "Thinking Through Wind Energy" Pros & Cons worksheet
  - Analyze the US Wind Resource Map – as a class or in small groups – What patterns are observable?
- Engineering Design Process
  - **Introduce** steps of the engineering design process leading from the Problem to the Solution - Define the Problem; Design Exploration; Design Optimization; Design Communication.
  - **DEFINE THE PROBLEM:** Using Page 11 of the EMPP Unit's Packet, Students read the mock Request for Proposals from the City of Beaverton, record three big ideas from the letter, complete some reading comprehension questions, and follow prompts to identify their team's design CONSTRAINTS and CRITERIA.
  - **DESIGN EXPLORATION:** In teams, students brainstorm blade-related parameters that impact a wind turbine's power output. Students record data and ideas in their packets.
    - Based on class discussion, student teams create an initial design drawing.

- As a class, review how Wind Turbines Work – View Animation from the U.S. Department of Energy: https://www.energy.gov/eere/wind/animation-how-wind-turbine-works
- Graph and Track Energy Flow with Energy Bar Charts using different times and parameters as laid out in the EMPP Student Packet
- Writing Exercise – Students describe the basic physics of a wind turbine
- CLASSWIDE BRAINSTORMING SESSION – As smaller groups completing Think-Pair-Share of information, or as a single class, identify what constraints and considerations will improve their projects. There can be more variables tested, but push students to pinpoint Blade SHAPE, Blade ANGLES, NUMBER of Blades, and total AREA of all Blades combined.
- Class divides into their teams to design, build, test and collect data on those "Initial Parameters" and, post investigation, share their findings.

- **DESIGN OPTIMIZATION:** After class-wide brainstorming session, students identify best performing criteria and uncover patterns. Using everyone's collective findings, each small group designs an "ideal wind turbine" using the KidWind Mini Turbines and Vernier Sensor tools to build and record findings/power output.
  - Through the Engineering Design Cycle, each group builds, tests, re-thinks, and re-launches improved iterations of their designs based on data rather than just guesswork. Students will go on to finalize this first version of their designs after testing in real life.
- **DESIGN COMMUNICATION –** Use whiteboards to **graph** data points and think about what type of graph best communicates group findings in a clear and effective manner.
  - Encourage student teams to verbally communicate their graphed data, why they chose the variables and design they chose, and what trade-offs were made between project costs and energy output
  - Writing Exercise– Have individual students or teams compose an "Engineering Rationale for Final Design."

DAY 3

- **Analyzing Info Graphics:**
  - Two-part Question: 1. (According to this graphic) What explains the trend in higher power output? *(Have students use the technical terms to describe energy transfer, energy transformation, E_k, $E_{electrical}$, Watt (W), which is a J/s.)*
  - Part 2: "A farmer is looking into buying wind turbines for their farm. They have space to put blades with a total diameter of 150m and a loan from the bank for $400,000 ($400K). Using the infographic above, write your claim, evidence, and reasoning for the wind turbine or combination of wind turbines that would work best.
- **BUILD!**
  - As a group bring your Final Design to life, improving the wind turbine's performance based on results from earlier tests. ****Teams need to justify design decisions using evidence based arguments and data later on.****
- **Question**:

  As we listen to this story from NPR, write two things that you found interesting: "Tiny Spanish Island Nears its Goal: 100 Percent Renewable

Energy by Lauren Frayer, September 28, 14th (www.npr.org/sections/parallels/2014/09/17/349223674/tiny-spanish-island-nears-its-goal-100-percent-renewable-energy)

- **QUIZ**: At the end of this project they complete the quiz on wind energy fundamentals.

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENT

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

"Engineer a Wind Turbine" Engineering Portfolio

EXTENSIONS

Students can continue to modify their design in an out-of-school setting to compete in a local KidWind Challenge.