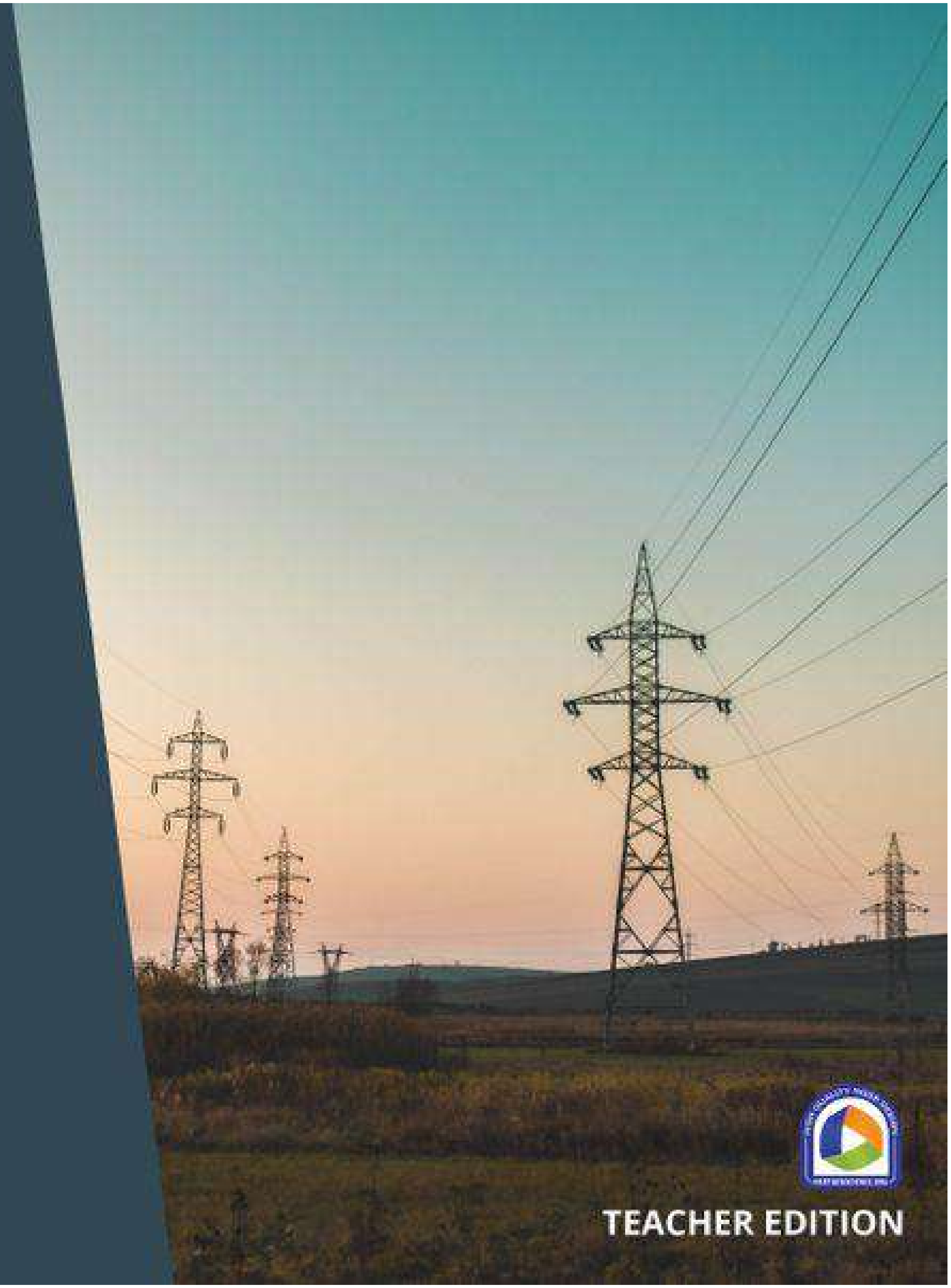
**PHYSICS**

Energy Flow from Earth's Systems

# How can we design more reliable systems to meet our communities' energy needs?

OpenSciEd

HIGH SCHOOL SCIENCE



TEACHER EDITION

# How can we design more reliable systems to meet our communities’ energy needs?

## Energy Flow from Earth's Systems: Electricity

OpenSciEd Unit P.1

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## Energy Flow from Earth's Systems: Electricity

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# UNIT OVERVIEW

## How can we design more reliable systems to meet our communities' energy needs?

This unit is anchored by the Texas power crisis of February 2021. Students read articles and wonder about the complex social, environmental, and physical realities that led to such a crisis. In the first lesson set (Lessons 1-8), students develop models for energy flow through our electrical infrastructure systems, from a generator to our communities. By the end of this lesson set, students can explain what happened in Texas at multiple scales, from the electrons in the wires to the power companies making difficult decisions. In the second lesson set (Lessons 9-11), students consider engineering trade-offs, criteria, and constraints inherent in making decisions about our energy systems, and apply them in a culminating task: design a reliable energy solution that meets our communities' needs, as articulated by interviews with friends and family members. The task is designed to support students in taking agency and to give students the tools to speak up in their local and global community for a better energy future, one that aligns with their own values, and those of their families.

Throughout the unit, students will do the following:

- Develop and use both physical and conceptual models related to our energy transfer systems, including a small wired city that is powered by a homemade generator, energy transfer diagrams that include field interactions, and a computational spreadsheet model to test out design solutions against criteria for success.
- Use simulations to model and understand particle and field interaction in and around a wire, and to investigate the impact of changing certain variables on energy transfer through the wire.
- Analyze, synthesize and interpret data about what happened in Texas in February 2021, highlighting an imbalance in energy inputs and outputs, and using the correlation coefficient to disprove a hypothesis.
- Obtain and communicate information about energy flow, electricity, engineering, and power outages from a variety of different kinds of texts.
- Defind a design problem, and develop design solutions related to the use of Earth's resources for electricity production and energy storage 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.

**Focal Disciplinary Core Ideas (DCIs):** ETS1.A: Defining and Delimiting Engineering Problems, ETS1.B: Developing Possible Solutions, PS2.B: Types of Interactions, PS3.A: Definitions of Energy, PS3.B: Conservation of Energy and Energy Transfer, PS3.C: Relationship Between Energy and Forces, ESS3.A Natural Resources

**Focal Crosscutting Concepts:** Patterns; Cause and effect: Mechanism and explanation; Systems and system models; Energy and matter: Flows, cycles, and conservation; Stability and change

**Focal Science and Engineering Practices:** Asking questions and defining problems, Developing and using models, Analyzing and Interpreting Data, Constructing Explanations and Designing Solutions, Engaging in argument from evidence, Obtaining, Evaluating and Communicating Information

Building towards NGSS Performance Expectations (PEs)

- **HS-PS3-1*** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- **HS-PS3-2** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).
- **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.
- **HS-PS3-5*** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the changes in energy of the objects due to the interaction.
- **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.
- **HS-ESS3-2†** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

*This performance expectation is developed across multiple units. This unit reinforces or works toward these NGSS PEs that students will develop more fully in future units.
†This performance expectation is developed across multiple courses. This unit reinforces or works toward these NGSS PEs that students will have previously developed in the OpenSciEd chemistry and/or biology courses.

## Building Toward NGSS Performance Expectations

HS-ESS3-2:
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [

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, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

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.

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.

HS-PS3-1:
Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2:

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

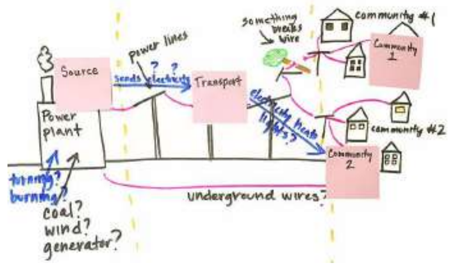
HS-PS3-3:
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

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.

# UNIT STORYLINE


**Unit Question: How can we design more reliable systems to meet our communities' energy needs?**

## Lesson Set 1: How does electricity transfer through systems to power communities, and what causes instability in these systems?

| Lesson Question | Phenomena or Design Problem | What we do and figure out | How we represent it |
|---|---|---|---|
| **LESSON 1**<br>Lesson Set 1<br><br>3 days<br><br>**What can we learn from a blackout in Texas about producing reliable energy for our communities?**<br><br>Anchoring Phenomenon<br><br> | <br>*A winter storm in Texas in February 2021 led to devastating widespread blackouts throughout the state.* | We explore a new phenomenon by jigsawing a series of articles about widespread blackouts in Texas, and by drawing on the experiences of our friends and family. We make an initial consensus model of what happens to our electricity production system when it is stable and during a blackout. We develop questions for our DQB and brainstorm initial ideas about ways we could design more reliable systems to meet our communities' energy needs. We figure out:<br>• There are several components that we agree are important for understanding how energy transfers to power our communities when the system is stable and during a blackout. |  |

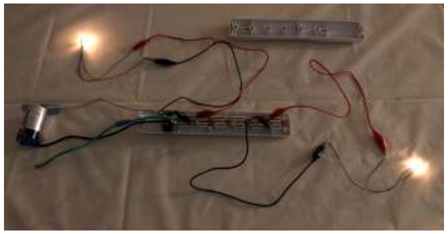
⇓ **Navigation to Next Lesson:** We decide to document the electricity infrastructure in our homes and communities to look for patterns that could help us understand how the system works and identify important design constraints.

## LESSON 2
Lesson Set 1

2 days

**What structures in the system enable energy transfer from one source to multiple devices, buildings, and neighborhoods?**

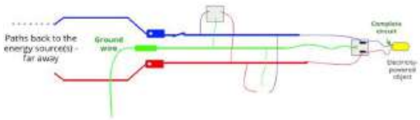
Investigation



*In a power strip, there are three pieces of metal that are each connected to three wires within the plug. Similar structures are found within a house, and even within electrical grid substations.*

We compare photos of structures that provide electricity in our buildings. We dissect a power strip as an analog for what's behind the walls of buildings, and we connect a battery and a couple of small devices. We read about the function of ground wires and circuit breakers. We develop a model to show how systems transfer electrical energy. We figure out:

- Energy will transfer from an electrical energy source to an electronic device when a complete circuit is formed, but will not transfer when there is a break in any of those paths.
- If a short circuit is created, most of the energy will not transfer. through the other circuits. Such small changes in one part of the energy distribution system could cause blackouts across multiple buildings or neighborhoods.




⇓ **Navigation to Next Lesson:** We are thinking that short circuits or broken circuits could have been a cause for the patterns of blackouts we saw in Texas, so we want to investigate this possibility.

## LESSON 3
Lesson Set 1

3 days

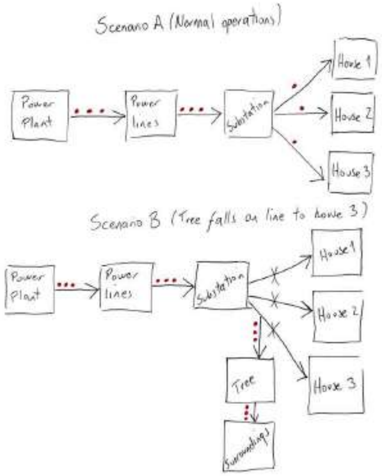
**Could the blackouts in Texas have been caused by a broken or short-circuited circuit?**

Investigation

*Electricity demand forecast data did not match electricity production in Texas during February 2021.*

We read about an energy crisis that began in Ohio, and a strategy used by engineers to prevent short and broken circuits in power lines. We use the *Engineering Design Tracker* to keep track of our ideas. We develop a new representation to model energy transferred in various parts of the system. We analyze electricity demand and supply data in Texas and use this to brainstorm ideas of where to go next. We figure out:

- Engineering constraints can affect the implementation of a possible solution.
- The production of electrical energy must match the demand for electrical energy.
- The cold temperatures during the Texas blackout caused a spike in energy demand, which was accompanied by a drop in the supply of electrical energy.




*US Energy Information Administration*

⇓ **Navigation to Next Lesson:** We saw a mismatch between the amount of energy generated and the amount of energy demanded by communities in Texas, which led us to wonder what could have caused the observed drop in the supply..

## LESSON 4

Lesson Set 1

2 days

### What makes an energy source reliable?

Investigation

*Descriptive and graphic data on a variety of energy sources reveal puzzling inconsistencies in each energy source's reliability during the blackout.*

We use informational cards and several data representations from the 2021 Texas energy crisis to seek additional information about specific sources of energy to help us figure out which source might be responsible for the drop in supply we discovered in Lesson 3. We use a new tool called a *Decisions Matrix* to keep track of how well each source meets criteria we think are important. We figure out:

- The energy used to create electricity in a power plant comes from Earth's systems.
- Making decisions about complex societal issues like energy production requires defining criteria for success that might not be straightforward or easy to quantify.

| Energy Source | Energy Sources In | | | |
|---|---|---|---|---|
| | Criterion #1 | Criterion #2 | Criterion #3 | Criterion #4 |
| | High Reliability | High Renewability | High Efficiency | |
| Wind | * | **** | ** | |
| Solar | * | **** | * | |
| Biomass | *** | *** | ** | |
| Coal | **** | * | ** | |
| Natural Gas | **** | ** | *** | |
| Nuclear | **** | *** | *** | |
| Hydroelectric | *** | *** | **** | |
| Geothermal | *** | **** | ** | |

⇓ **Navigation to Next Lesson:** Since we are now wondering why some energy sources are more reliable than others (or efficient, powerful, dispatchable), we want to compare how the electricity from these different sources is produced.

## LESSON 5

Lesson Set 1

3 days

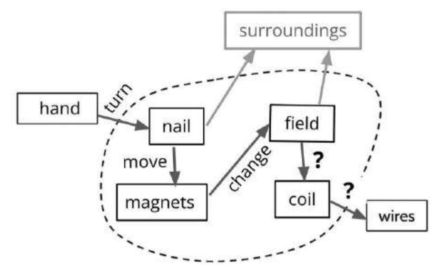
### Where does electrical energy come from?

Investigation

*A light connected to generator glows and nearby compass needles change direction when either the magnet or wires in a generator moves.*

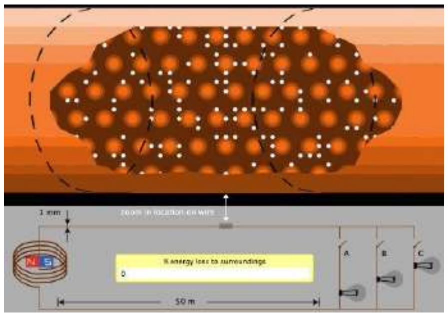
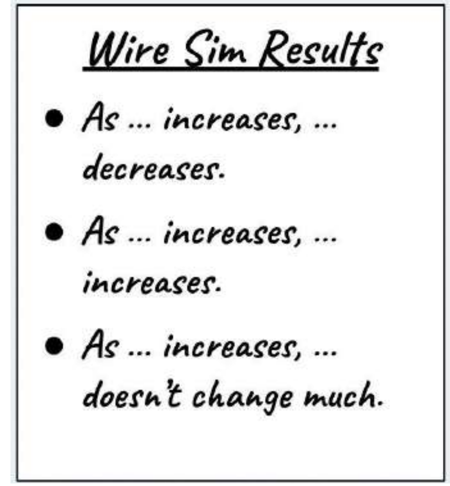
We use diagrams of wind and natural gas power plants to figure out how power plants transfer energy into wires. We dissect a generator and then reverse engineer it. We use compasses to investigate energy transfer between the magnet and wire, and model the energy transfer through fields inside our generators. We figure out:

- Many power plants have generators, which are loops of copper wire and powerful magnets.
- Matter changes and/or motion can cause energy transfer through contact (and vice-versa).
- The motion of a magnet can generate changing fields, which can cause energy transfer at a distance (and vice-versa).
- When moving matter (e.g., pushing wind or steam) moves the magnets inside a generator, that can cause energy transfer into wires



| | | | |
|---|---|---|---|
| | | through changing fields. | |

⇓ **Navigation to Next Lesson:** Though we have a model for how generators transfer energy to wires, we don't know what is happening inside the wires when they transfer energy (electricity) to our communities.

| | | | |
|---|---|---|---|
| **LESSON 6**<br>Lesson Set 1<br><br>3 days<br><br>**How does energy transfer in wires?**<br><br>Investigation<br><br> | <br>*A simulation of electrons in a wire shows their motion with various circuit configurations and power sources, and it provides a measure of energy and current in various parts of the system.* | We read about electric and magnetic fields to help us model energy transfer involving fields more closely, focusing on transfers inside a wire. Using a simulation, we explore how various characteristics of an electrical system could influence the transfer of electrical energy, as well as their relation to energy loss, and check our results using classroom equipment. We figure out:<br>● Electric and magnetic fields change when energy transfers into or out of them.<br>● Electric fields can push electrons. "Electrical energy" is the energy of the movement of electrons transferring through pushes from fields.<br>● A turbine transfers energy through electric and magnetic fields to the electrons in a wire, causing them to slosh back and forth continuously.<br>● Electrons cause the atoms of the wire material to heat up, transferring energy from the system to the surroundings as "heat". | <br> |

⇓ **Navigation to Next Lesson:** Since we figured out that cold weather does not affect energy loss from wires much, we think we can model in greater detail how insufficient supply can account for the affects on people in Texas.

## LESSON 7
Lesson Set 1

2 days

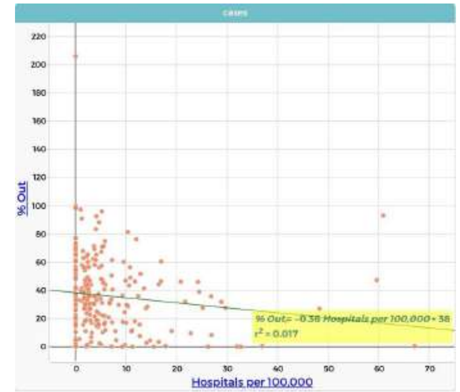
**What could have caused the disparities we saw in the blackouts in Texas?**

Problematizing

*A data set shows disparities between counties impacted by the energy crisis in Texas that is not well explained by our model.*

We develop a model showing how insufficient supply entering the system could lead to buildings losing power during a crisis. We test our models using Electric City, and we notice that to keep the lights on in one building, we need to cut power to others. We use data to test for correlations with county-level factors, and we consider limitations on this analysis. We figure out:

- Power companies in Texas probably had to make decisions about who lost power in some places in order to keep the lights on in others.
- There is no one factor that explains why some counties in Texas lost power and others did not.




*Concord Consortium*

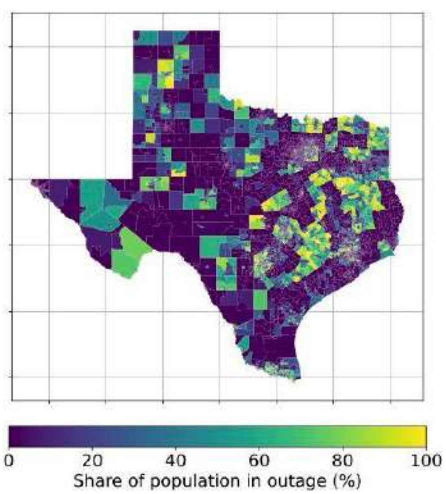
⇓ **Navigation to Next Lesson:** We figured out limitations associated with analyzing data grouped by counties because the scale of a single county is large. We wonder what those data look like at a smaller scale.

## LESSON 8
Lesson Set 1

2 days

**Why do design solutions affect some people differently than others?**

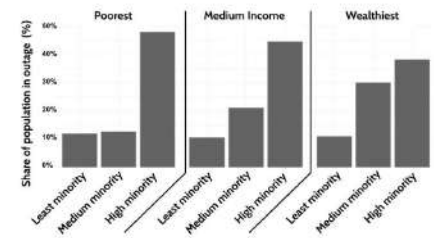
Putting Pieces Together




*Scientists looking at satellite data uncovered*

We listen to (and read the transcript of) a podcast featuring a scientist whose research group used satellite data to investigate patterns in who lost power in Texas. We read about two fictionalized families in Texas and consider how existing disparities can make the impact of a power outage inequitable across communities. We figure out:

- An imbalance of energy supply and demand was the primary cause of the blackouts in Texas in February 2021.
- There are design solutions for avoiding this in the future, but they come with tradeoffs.
- Across Texas, what neighborhood people lived in made an impact on whether they lost power.
- Power outages have an inequitable impact on people in communities where there are existing disparities.

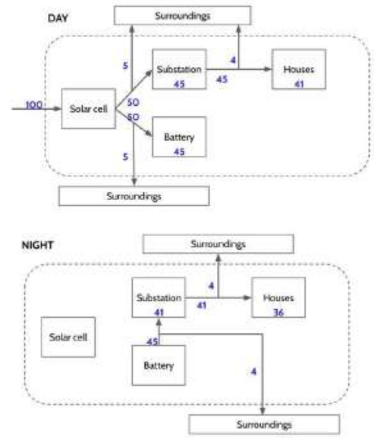



*Zeal Shah, Feng Chi Hsu, Jay Taneja, JP Carvallo*

| | | | |
|---|---|---|---|
| | *patterns in the Texas power outages that we could not discern at a county-level scale.* | ● Throughout Texas, power companies made decisions to keep the power on in neighborhoods with “essential” buildings. | |

⇓ **Navigation to Next Lesson:** We figure out tradeoffs, related to generating power, around which sources we use. We leave with a home learning about tradeoffs associated with various energy sources.

## Lesson Set 2: What design solutions could improve the electricity systems in our communities?

| Lesson Question | Phenomena or Design Problem | What we do and figure out | How we represent it |
|---|---|---|---|
| **LESSON 9**<br>Lesson Set 2<br><br>2 days<br><br>**How can energy storage make our systems more reliable during an energy crisis?**<br><br>Investigation | <br>*Batteries are not currently widely used in power grids.* | We develop and revise energy transfer models to represent how batteries can make electric grid systems more reliable. We quantify how much energy was needed to prevent the energy crisis in Texas 2021. We use data from energy storage solutions to calculate the number of batteries needed and the costs associated with adding these batteries to the system. We wonder about the costs from design solutions that are not financial. We figure out:<br>● All forms of energy production and other resource extraction have economic, social, environmental, and geopolitical costs and risks as well as benefits that we will need to consider when making decisions about our own communities.<br>● Design solutions that store excess energy can prevent an energy crisis by bridging the gap between energy demand and supply.<br>● Energy storage systems can make an electric grid more reliable by providing power when the energy supply drops. |  |

⇓ **Navigation to Next Lesson:** We wonder what additional, non-financial costs might be associated with design solutions.

## LESSON 10
Lesson Set 2

3 days

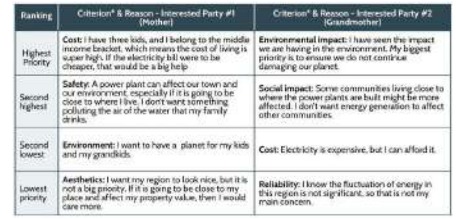
**What decisions do we need to make to design more reliable systems to meet our community's energy needs?**

Investigation

*There are multiple criteria, constraints, and tradeoffs to consider in making engineering decisions, and the interested parties in our communities don't always agree.*

We read about tradeoffs associated with various energy sources. We create a class Consensus Decisions Matrix that represents the criteria we agree are important when making decisions. We read quotes from interested parties, and develop and carry out an interview protocol to capture the values of people in our community. We begin developing a plan for improving electricity infrastructure in our community. We figure out:

- When developing design 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.
- Input from interested parties can be a great tool for determining the values that should guide how we address tradeoffs.



| Ranking | Criterion* & Reason - Interested Party #1 (Mother) | Criterion* & Reason - Interested Party #2 (Grandmother) |
|---|---|---|
| Highest Priority | **Cost:** I have three kids, and I belong to the middle income bracket, which means the cost of living is super high. If the electricity bill were to be cheaper, that would be a big help | **Environmental impact:** I have seen the impact we are having in the environment. My biggest priority is to ensure we do not continue damaging our planet. |
| Second highest | **Safety:** A power plant can affect our town and our environment, especially if it is going to be close to where I live. I don't want something polluting the air of the water that my family drinks. | **Social impact:** Some communities living close to where the power plants are built might be more affected. I don't want energy generation to affect other communities. |
| Second lowest | **Environment:** I want to have a planet for my kids and my grandkids. | **Cost:** Electricity is expensive, but I can afford it. |
| Lowest priority | **Aesthetics:** I want my region to look nice, but it is not a big priority. If it is going to be close to my place and affect my property value, then I would care more. | **Reliability:** I know the fluctuation of energy in this region is not significant, so that is not my main concern. |

⇓ **Navigation to Next Lesson:** While we have identified tradeoffs associated with various energy sources, and criteria from various interested parties, we haven not yet produced designs for improving the electricity infrastructure in our community that responds to interested parties' opinions that address these tradeoffs.

## LESSON 11
Lesson Set 2

3 days

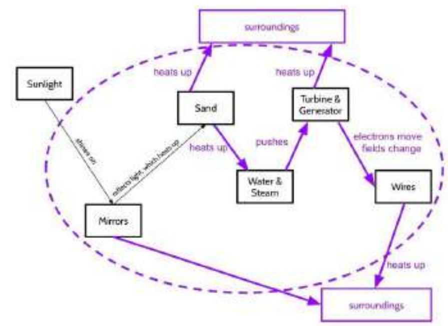
**What have we figured out, and what can we carry forward?**

Putting Pieces Together

*Complex global challenges manifest in our communities. Developing solutions will require science practices and creative design thinking.*

We learn about the Energy Grid Calculator, a computational model that we use to measure the success of our solutions against a variety of criteria. We describe our design solution to our classmates, and we give each other feedback that we use to refine our designs. We return to the DQB and celebrate our progress in light of all the questions we can answer. We work through an assessment task in which we explain energy transfer in a solar sand power plant and use data to evaluate the feasibility of using this technology to provide reliable power to a community. We figure out:

- Science learning is about asking questions, defining problems, and gathering evidence to answer those questions and address those problems.



⇓ **Navigation to Next Lesson:** This is the last lesson in the unit.

## LESSONS 1-11

28 days total

# TEACHER BACKGROUND KNOWLEDGE

## Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices when conducting hands-on science investigations and demonstrations, whether in a traditional laboratory or in the field. To this end, teachers must be aware of any school or district safety policies, legal safety standards, and professional best practices that are applicable to the activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., safety goggles, non-latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). **Science investigations should always be directly supervised by qualified adults, who should review safety procedures annually, before initiating any hands-on activities or demonstrations.** Prior to each investigation, students should be reminded of the specific safety procedures they must follow. Each lesson within the OpenSciEd units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as disassembling, disposing of, and storing materials.

Prior to the first investigation of the year, a safety acknowledgement form for students and parents/guardians should be provided and signed. You can access a model safety acknowledgement form for high school activities here: https://static.nsta.org/pdfs/SafetyAcknowledgmentForm-HighSchool.pdf

*Disclaimer*: The safety precautions provided for each activity are based in part on use of the specifically recommended materials and instructions, as well as legal safety standards and professional best practices. Be aware that selecting alternative materials or procedures for these activities may affect the activity's level of safety, and is therefore at the user's own risk.

**Please follow these lab safety recommendations for any science investigation:**

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take-down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip-and-fall hazard.
3. Follow your *Teacher Guide* for instructions on disassembling and storing materials and disposing of waste materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing the activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a call-out box.

## Where does this unit fall within the OpenSciEd Scope and Sequence?

This unit, *OpenSciEd Unit P.1: How can we design more reliable systems to meet our communities' energy needs? (Electricity Unit)*, is the first in the OpenSciEd High School Physics course sequence. It is designed to transition students into high school level physics ideas and practices in a relevant context grounded in real-world decision-making. Although students have been asking questions, modeling systems, designing solutions, and engaging in argument from evidence throughout K-12, this may be their first time using these practices the way physicists do: to figure out how and why matter moves and changes, using the lens of energy transfer. Students develop ideas around energy transfer and conservation in the context of charged particles (electrons) colliding with other electrons (electricity) to transfer energy across great distances. This unit builds a foundation for understanding energy transfer and conservation in a physics context that students will carry forward into the rest of the course; however, it does not yet focus on forces as a way to model interactions.

In the second unit of the physics course, *OpenSciEd Unit P.2: How forces in Earth's interior determine what will happen to its surface? (Earth's Interior Unit)*, a sudden rip in Earth's crust motivates the need to consider forces to explain our observations. In the third unit, *OpenSciEd Unit P.3: What can we do to make driving safer for everyone? (Vehicle Collisions Unit)*, students develop a more robust understanding of forces as vectors and use conservation of momentum to make predictions about the outcomes of collisions. In the fourth unit, *OpenSciEd Unit P.4: Meteors, Orbits, and Gravity (Meteors Unit)*, students expand their model of forces to include the force of gravity at great distances, using ideas about fields developed in the first unit to understand the relationships between gravity and energy transfer. In the fifth unit, *OpenSciEd Unit P.5: How do we use radiation in our lives and is it safe for humans? (Microwave Unit)*, students use energy transfer, electromagnetism, wave mechanics, and forces at a distance to explain how food heats up in a microwave and how this technology might be dangerous for humans. In the final unit, *OpenSciEd Unit P.6: Earth's History and the Big Bang (Cosmology Unit)*, students explore cosmology and the Big Bang, applying ideas about forces and energy from all five previous units on the largest scale.

This unit intentionally incorporates, in the moment, a number of activities that would typically take place in a "Unit 0." These include co-construction of Community Agreements, use of a Progress Tracker, and development of energy transfer diagram conventions. We recommend that you begin this unit at the start of the school year, following any requirements in your school or district.

## What is the anchoring phenomenon, and why was it chosen?

**This unit is anchored by the story of the 2021 power crisis in Texas and the accompanying design problem of improving the reliability of our own electric infrastructure.** This event provides a rich context in which to investigate the nature of electrical energy transfer, the stability and change of energy inputs and outputs, the impact of energy transfer on our everyday lives, and the social/environmental trade-offs inherent in sourcing energy from Earth's systems. Over the course of the unit, students read about what happened in Texas and analyze multiple types of real data from the event. They investigate each part of the electrical system at various scales, from designing investigations using a simulation of the inside of a wire, to building their own working generators. They also model an electric grid in the classroom using power strips, alligator clips, LED bulbs, and cardboard buildings.

The Texas blackouts anchoring phenomenon was chosen from a group of phenomena aligned with the target performance expectations, based on the results of a survey administered to almost 1,000 students across the country and in consultation with external advisory panels that included teachers, subject matter experts, and state science administrators. This phenomenon includes a strong engineering component linked to a complex global problem, and includes humans and human activity in the systems under study. The full physics course is designed to purposefully highlight various types of phenomena. Although we design to privilege the interests of students to whom we owe an educational debt, we must not essentialize minoritized groups by assuming that a trend in the data equates to homogenous interests and experiences. Providing a diverse suite of entry points into content and practices creates more opportunities for every student to connect with the content.

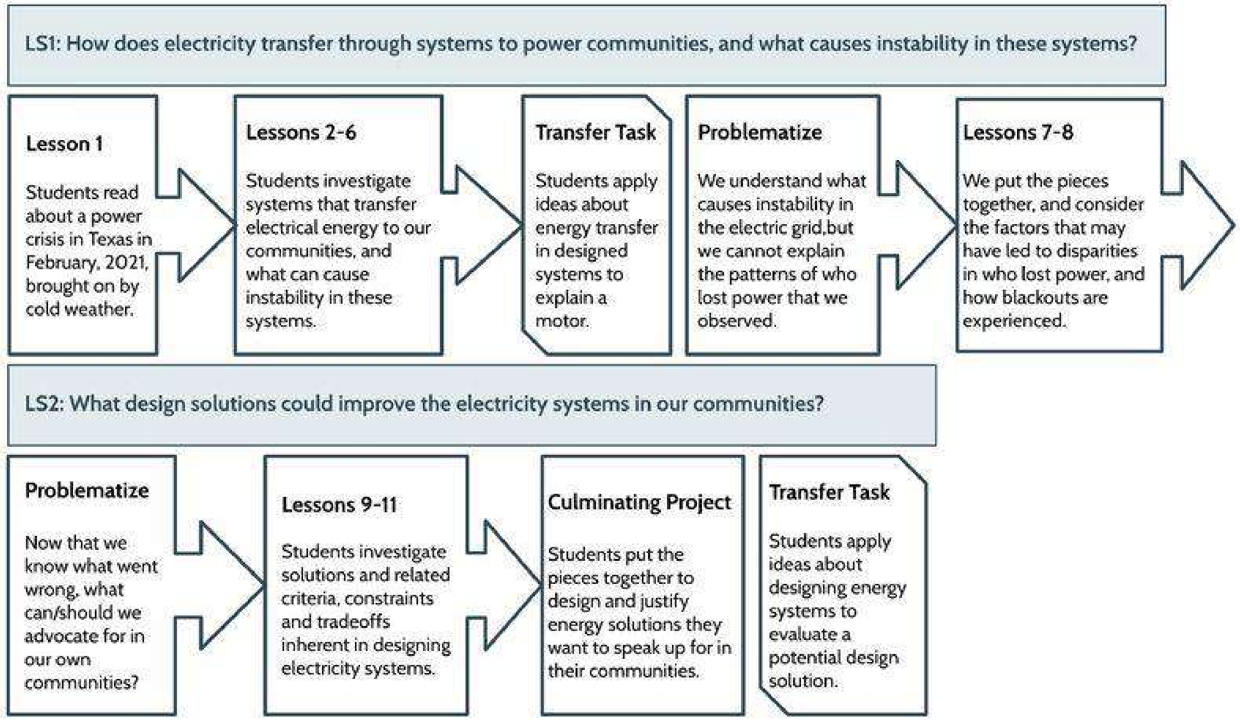
The blackouts phenomenon was chosen for the following reasons:

- Students showed high interest in explaining electricity-related phenomena.
- To provide a diverse suite of entry points across the course, we sought an event that allowed students to consider a relevant societal problem.
- Teachers and administrators saw the phenomenon as interesting and on grade band.
- Explaining the mechanisms that bring electricity to communities grounds abstract ideas about energy transfer in a real-world context.
- Explaining the phenomenon addresses all the DCIs in the bundle at a high school level.
- Explaining the phenomenon requires the use of mathematical thinking at a middle school level, helping students transition into high school physics.

## How is the unit structured?

The unit is organized into two lesson sets. In the **first lesson set (Lessons 1-8)**, students read articles about an energy crisis in Texas that left much of the state in the dark. They develop models for how energy transfers through systems when the electricity grid is stable and when conditions change. They document the energy infrastructure in their school, homes, and community, and look for patterns that can provide clues as to how energy transfers. They follow these clues to an electrical outlet, dissect a power strip to investigate circuits, then wire several power strips together inside cardboard boxes to simulate the wiring of a small model community complete with substations and a battery "power plant." They investigate various sources of power and determine that supply (energy input) and demand (energy output) must be equal to keep the system stable. They begin to keep track of engineering solutions and constraints, and trace the energy back to a generator in the power plant, build generators, and model energy flow through electric and magnetic fields to explain how those work. They "zoom in" on the wires to understand the particle nature of electrical energy transfer, and then "zoom back out" to put the pieces together and explain how an imbalance of inputs and outputs caused the energy crisis they read about. In Lessons 7-8, they problematize the explanation for what happened in Texas, motivating them to investigate the cause of disparities in the pattern of power outages on state, county, and municipal scales, using data and computational models, and talk about how outages have an inequitable impact on people in low-income neighborhoods due to existing disparities.

In the **second lesson set (Lessons 9-11)**, students turn their attention to their own community and consider what decisions they need to make to design more reliable power systems that meet their specific needs. They investigate considerations and trade-offs associated with using battery storage to improve reliability of renewable and low-carbon energy sources, including chemical, mechanical, and thermal solutions. Finally, they put the pieces together to design energy solutions they want to advocate for in their communities. Students apply these ideas in a culminating project that begins in Lesson 10, and a transfer task in Lesson 11.


LS1: How does electricity transfer through systems to power communities, and what causes instability in these systems?
Lesson 1
Students read about a power crisis in Texas in February, 2021, brought on by cold weather.
Lessons 2-6
Students investigate systems that transfer electrical energy to our communities, and what can cause instability in these systems.
Transfer Task
Students apply ideas about energy transfer in designed systems to explain a motor.
Problematize
We understand what causes instability in the electric grid,but we cannot explain the patterns of who lost power that we observed.
Lessons 7-8
We put the pieces together, and consider the factors that may have led to disparities in who lost power, and how blackouts are experienced.
LS2: What design solutions could improve the electricity systems in our communities?
Problematize
Now that we know what went wrong, what can/should we advocate for in our own communities?
Lessons 9-11
Students investigate solutions and related criteria, constraints and tradeoffs inherent in designing electricity systems.
Culminating Project
Students put the pieces together to design and justify energy solutions they want to speak up for in their communities.
Transfer Task
Students apply ideas about designing energy systems to evaluate a potential design solution.

## What elements of the NGSS three dimensions are developed in this unit?

As noted above, this unit is designed to introduce students to the concept of energy transfer in a relevant and grounded context. Asking questions and defining problems **is intentionally developed** across this unit, beginning in Lesson 1 when students start to define the design problem that will drive the second half of the unit: how to address global challenges such as severe weather events, a growing population, climate change, and accelerating land use by making and advocating for informed energy design decisions that align to community values. In the first lesson set, students look closely at an energy crisis in Texas in 2021 to understand and model the conditions under which energy systems are stable, and when those change. Stability and change **is intentionally developed** as students return to the idea of reliability throughout the unit, using it to drive their design thinking. In the second lesson set, as students apply their ideas about energy transfer through electrical systems to design a plan for their own community, constructing explanations and designing solutions **is intentionally developed** in the context of engineering.

Analyzing and interpreting data **is intentionally developed** over the entire unit, as students look at and analyze various types of data to understand energy systems, and evaluate design solutions, including graphs of energy supply and demand from Texas, data generated by a simulation of electrons in a wire, interview responses collected from friends and family, and data generated by a computational model to describe their design solutions (the *Energy Grid Calculator*).

Developing and using models **is intentionally developed** in this unit, as students model energy inputs, outputs, and transfer through systems at various scales to understand how our energy grid works. Students model the transfer of energy through electric and magnetic fields in a generator, the transfer of energy through wires, including energy loss to the surroundings, and the transfer of energy into storage solutions like batteries. To support using these energy models to make sense of the electrical systems, energy and matter and systems and system models are both **intentionally developed** throughout the unit.

Although not intentionally developed, planning and carrying out investigations is **key to the sensemaking** in this unit, as students use a simulation to produce data to answer questions about electricity in wires. Also **key to the sensemaking** is mathematics and computational thinking, as students use middle school mathematics to understand phenomena such as energy loss, and to inform evaluation of the scalability of various design solutions. Also **key to the sensemaking** is obtaining, evaluating, and communicating information, which students engage in throughout the unit. Scale, proportion and quantity, cause and effect, structure and function, and patterns are also **key to the sensemaking** in several lessons.

| This unit builds toward these performance expectations: |
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| **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.<br>**HS-PS3-5†** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the changes in energy of the objects due to the interaction.<br>**HS-PS3-2†** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).<br>**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.<br>**HS-PS3-1†** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.<br>**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. |

**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.
**HS-ESS3-2†** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

*This performance expectation is developed across multiple units. This unit reinforces these NGSS PEs in a physics context.
†This performance expectation is developed across multiple courses. This unit reinforces or works toward these NGSS PEs that students will have previously developed in the OpenSciEd chemistry and/or biology courses.

| Focal Science and Engineering Practices | Focal Disciplinary Core Ideas* | Focal Crosscutting Concepts |
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| This unit **intentionally develops** students' engagement in these practice elements:<br><br>**Asking questions and defining problems** in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. The following elements of this practice are intentionally developed across this unit:<br>● Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.<br>● Ask questions to clarify and refine a model, an explanation, or an engineering problem.<br>● Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.<br>● Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.<br><br>**Developing and using models** in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. The following elements of this practice are intentionally developed across this unit:<br>● Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. | **ETS1.A: Defining and Delimiting Engineering Problems**<br>● Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. (HS-ETS1-1)<br><br>**ETS1.B: Developing Possible Solutions**<br>● 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. (HS-ETS1-3)<br>● Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet their needs. (HS-ETS1-4)<br><br>**PS2.B: Types of Interactions**<br>● 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)<br><br>**PS3.A: Definitions of Energy**<br>● *Electrical energy* may mean energy stored in a battery or energy transmitted by electric currents. (secondary | This unit **intentionally develops** students' engagement in these crosscutting concept elements:<br><br>**Systems and System Models.** A *system* is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. The following elements of this crosscutting concept are intentionally developed across this unit:<br>● Systems can be designed to do specific tasks.<br>● Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.<br><br>**Energy and Matter.** Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. The following elements of this crosscutting concept are intentionally developed across this unit:<br>● The total amount of energy and matter in closed systems is conserved.<br>● Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.<br>● Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. |

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| • Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. | to HS-PS2-5)<br>• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3) | |

| Focal Science and Engineering Practices | Focal Disciplinary Core Ideas* | Focal Crosscutting Concepts |
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| **Analyzing and interpreting data** in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. The following elements of this practice are intentionally developed across this unit:<br>● Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.<br>● Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.<br>● Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.<br>Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.<br><br>**Constructing explanations and designing solutions** in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. The following element of this practice is intentionally developed across this unit:<br>● Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. | **PS3.A: Definitions of Energy (cont.)**<br>● *Energy* is a quantitative property of a system that depends on the motion and interactions of matter and radiation within the system. That there is a single quantity called *energy* is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1) (HS-PS3-2)<br>● These relationships are better understood at the microscopic scale, at which all the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position) of the particles. In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes *radiation*, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)<br><br>**PS3.B: Conservation of Energy and Energy Transfer**<br>● The availability of energy limits what can occur in any system. (HS-PS3-1)<br>● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1) (HS-PS3-4)<br>● Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)<br><br>**PS3.C: Relationship Between Energy and Forces** | **Stability and Change.** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.<br>● Much of science deals with constructing explanations of how things change and how they remain stable.<br>Systems can be designed for greater or lesser stability.<br><br>Elements from the following crosscutting concepts are also **key to the sensemaking** in this unit:<br>● Patterns<br>● Structure and Function<br>● Cause and Effect |

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| Elements from the following practices are also **key to the sensemaking** in this unit:<br>● Using Mathematics and Computational Thinking.<br>● Planning and Carrying Out Investigations<br>● Obtaining, Evaluating, and Communicating Information | ● Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3) (HS-PS3-4)<br><br>**ESS3.A Natural Resources**<br>● 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. (HS-ESS3-2) | |

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## Connections to the Nature of Science (NOS) and Engineering, Technology, and Applications of Science (ETS)

| Connections to the Nature of Science (NOS) | |
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| Which elements of NOS are developed in the unit? | How are they developed? |
| **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. | These ideas are woven throughout the unit, but appear at the forefront of Lessons 7 and 8, when students learn about disparities in who lost power in Texas. Students reflect on how human decision-making interacted with natural systems to cause these disparities. and consider whether decisions made by the power company were fair. |
| **Science Addresses Questions About the Natural and Material World.** 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. | In Lesson 10, students figure out that the way we extract energy sources from Earth's systems can have a profound impact on those systems. They read about how, if we want to prevent further damage, we need to make decisions that reflect what we value. They go on to interview their friends and families to learn about what criteria they value most, and reflect on how values impact engineering decision-making. |
| **Science Addresses Questions About the Natural and Material World.** Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. | In Lesson 8, students listen to a podcast in which a researcher explains that even if harmful decisions were unintentional, that doesn't mean we shouldn't strive to do better. |
| **Science Is a Human Endeavor.** Science and engineering are influenced by society, and society is influenced by science and engineering. | In Lesson 2, students learn about the human-made structures we see every day in and around our homes and school, and how science ideas shape these structures, which have in turn changed the way we live. |

| Connections to Engineering, Technology, and Applications of Science (ETS) | |
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| Which elements of ETS are developed in the unit? | How are they developed? |
| **Influence of Science, Engineering, and Technology on Society and the Natural World.** New technologies can have deep impacts on society and the environment, including some that were not anticipated. | In Lesson 2, students create a poster to remind themselves of our responsibility for considering our own safety and the safety of others whenever we are doing investigations. In Lessons 3 and 10, students learn about how extracting energy sources from Earth's systems can have a profound impact on those systems. In Lesson 8, students listen to a podcast in which a researcher explains that even if harmful decisions were unintentional, that doesn't mean we shouldn't strive to do better. |
| **Influence of Science, Engineering, and Technology on Society and the Natural World.** Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3) | In Lesson 10, students identify costs and benefits associated with various energy sources in a jigsaw, and use these to articulate trade-offs. At the end of the lesson, in an Electronic Exit Ticket aligned to this engineering connection, students reflect explicitly on why costs and benefits are so important. |

## How does the unit build three-dimensional progressions across the course and the program?

OpenSciEd units support students in integrated development and use of the three dimensions. No one dimension can be developed in isolation from the others, as reflected in three-dimensional Lesson-Level Performance Expectations (LLPEs) which detail the specific dimensions and elements used and assessed in each lesson. However, some practices and crosscutting concepts are more productive for investigating particular anchoring phenomena, so focal practices and crosscutting concepts are articulated in each unit. All 46 SEP and 29 CCC elements are developed at some point in the high school OpenSciEd program, so all elements of a given SEP or CCC may not be present even in a unit that emphasizes developing that SEP or CCC.

This unit uses and builds upon the following **Disciplinary Core Ideas (DCIs)** and other science ideas that students should have previously developed in the **OpenSciEd High School Biology and Chemistry courses**:

- We can trace energy flow in systems using computational models because energy is conserved. (*OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*, *OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)*, *OpenSciEd Unit C.5: Which fuels should we design our next generation vehicles to use? (Fuels Unit)*)
- Electrons move toward different charges and away from like charges, transferring electrical energy, and move particularly easily through metals. (*OpenSciEd Unit C.2: What causes lightning and why are some places safer than others when it strikes? (Electrostatics Unit)*)
- Energy flows through Earth's systems, including the atmosphere, hydrosphere, geosphere, and biosphere. (*OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)*)
- Energy can be transferred into and out of, and be stored in, magnetic and electric fields. (*OpenSciEd Unit C.2: What causes lightning and why are some places safer than others when it strikes? (Electrostatics Unit)*, *OpenSciEd Unit C.5: Which fuels should we design our next generation vehicles to use? (Fuels Unit)*)

This unit also reinforces and builds from the following **DCI elements** from the **OpenSciEd Middle School sequence**:

- Energy flows through Earth's systems. (*OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*)
- Magnets have invisible fields through which objects can interact and energy can transfer without contact. (*OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*)

This unit uses and builds upon high school level **Science and Engineering Practices (SEPs)** and **Crosscutting Concepts (CCCs)** that students should have previously developed in **OpenSciEd High School Biology and Chemistry**, and will continue to build in future units. The progressions of these practices and concepts across the program are as follows:

| | Questions | Models | Investigations | Data | Math | Explanation | Argument | Obtaining |
|---|---|---|---|---|---|---|---|---|
| **Biology** | *Genetics Unit* | *Serengeti Unit, Fires Unit* | *Fires Unit, Natural Selection Unit* | *Natural Selection Unit, Genetics Unit* | *Serengeti Unit* | *Fires Unit, Genetics Unit, Natural Selection Unit* | *Speciation Unit* | *Genetics Unit, Speciation Unit* |
| **Chemistry** | *Polar Ice Unit, Oysters Unit* | *Electrostatics Unit, Space Survival Unit* | *Polar Ice Unit* | *Fuels Unit* | *Polar Ice Unit, Oysters Unit* | *Fuels Unit* | *Fuels Unit* | *Electrostatics Unit, Space Survival Unit* |
| **Physics** | *Electricity Unit, Cosmology Unit* | *Electricity Unit, Microwave Unit* | *Microwave Unit* | *Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit, Meteors Unit* | *Vehicle Collisions Unit, Meteors Unit* | *Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit* | *Vehicle Collisions Unit* | *Cosmology Unit, Microwave Unit* |

| | Patterns | Cause/Effect | Scale | Systems/Models | Energy/Matter | Structure/Function | Stability/Change |
|---|---|---|---|---|---|---|---|
| **Biology** | *Natural Selection Unit, Speciation Unit* | *Genetics Unit, Natural Selection Unit, Speciation Unit, Serengeti Unit* | *Serengeti Unit* | *Fires Unit, Genetics Unit, Serengeti Unit* | *Fires Unit, Serengeti Unit* | *Genetics Unit* | *Speciation Unit, Serengeti Unit* |
| **Chemistry** | *Electrostatics Unit, Space Survival Unit* | *Oysters Unit, Fuels Unit* | *Electrostatics Unit, Oysters Unit* | *Polar Ice Unit* | *Polar Ice Unit, Fuels Unit* | *Space Survival Unit* | *Oysters Unit* |

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| **Physics** | *Cosmology Unit, Vehicle Collisions Unit, Earth's Interior Unit* | *Vehicle Collisions Unit, Earth's Interior Unit* | *Meteors Unit, Earth's Interior Unit* | *Electricity Unit, Vehicle Collisions Unit, Microwave Unit* | *Electricity Unit, Earth's Interior Unit* | *Earth's Interior Unit, Vehicle Collisions Unit* | *Electricity Unit, Cosmology Unit* |

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## What are some common ideas that students might have?

Students will come into the unit with many ideas about energy derived from previous classroom experiences, intuitive understandings of the way the world works, everyday experiences with movement, and conversations with parents, friends, and family members. Some of these relevant ideas are:

1. Energy has distinct forms that are fundamentally different from each other (i.e., electrical, thermal, kinetic, chemical, and sound energy).
2. Energy is only a property of living things (i.e., a rock has no energy).
3. Energy is a force--these two words are interchangeable (note that students will explicitly unpack the distinction between energy and forces in Unit 2).
4. Energy is only associated with motion, so a rock being held at height "has no energy."
5. Energy of motion (kinetic energy) is only associated with macroscopic motion (i.e., pressing hard on a wall does not transfer energy because we do not see the wall move; in fact, the matter is compressed on a particle scale).
6. Energy causes things to happen (in fact, it is a force that is causal).
7. Energy is fuel (we often use *energy* as a shorthand to describe a fuel like coal or petroleum--this is an everyday use for the term).
8. Energy is something we can will to move around our bodies or the world.
9. Energy is a thing, or "stuff."
10. Energy is light waves.

In fact, energy is not stuff; it is a quantitative property of stuff, often described as "the ability to do work." But "doing work" doesn't mean much in everyday language beyond homework, yardwork, and jobs, and can in fact be more confusing to students. In physics, *work* is when something moves because it has been pushed or pulled. *Energy* is the ability of something to make something move through a push or a pull, with or without contact. And when the work is done to impart that motion through a push or a pull, energy is *transferred.*

It is valuable to think of such ideas not as misconceptions that need to be erased but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. For example, in this unit, students begin to use the term *electrical energy* as a distinct energy "form" (see relevant idea 1 above). They figure out over the course of the lesson that electrical energy on a particle scale looks very familiar: electrons (stuff) pushing on each other and making each other move, thus transferring energy along a wire. They know from chemistry that *thermal energy transfer* is simply atoms and molecules pushing each other. *Potential energy, such as* that stored in a rock that has been lifted off the ground, is the ability of that rock to move if someone lets go, pulled this time by a gravitational field. *Fields* are simply a way to apply these energy-transferring pushes without physical contact. So even though energy forms are not real in a scientific sense, building explicitly from these ideas about distinct forms to draw connections is a productive pedagogical tool that helps students construct a new, more accurate conceptual model for energy transfer.

## How will I need to modify the unit if taught out of sequence?

This is the first unit of the High School Physics Course in the OpenSciEd Scope and Sequence. Given this placement, several modifications need to be made if physics is taught first, or if this unit is taught later in the Physics course. These include the following adjustments:

- If this unit is taught before OpenSciEd High School Chemistry, supplemental teaching of the particle model of matter will be required, including conceptual understanding of the nature of electrons, nuclei, and atoms.
- If it is taught later in the school year, additional supplementary materials related to forces should be incorporated into class discussions to help students integrate a “forces and energy” perspective.
- If it is taught as part of an AP Physics course, be prepared to provide students with additional support around equations that are not treated in depth. Extension opportunities to support students who want to go on to AP Physics are provided.

## How do I shorten or condense the unit if needed? How can I extend the unit if needed?

**The following are example options to shorten or condense parts of the unit without eliminating important sensemaking:**

- Lessons 2, 5, 6, and 7: You can film demonstrations in Electric City ahead of time and cut these investigations from the unit. This reduces the number of hands-on activities available to students, but cuts time significantly.
- Lessons 9-11: The second lesson set addresses engineering performance expectations. If these are not a priority for your school or district, you can end the unit after putting the pieces together in Lesson 8. Students will not have the opportunity to design their community solutions.

**To extend or enhance the unit, consider the following:**

- Lesson 2: Give students the opportunity to design and build Electric City, rather than having the buildings and structures pre-assembled. Students can model the city after their own community, and spend time experimenting with various configurations to see how that affects the reliability of the system.
- Lesson 6: This lesson includes guidance on how to provide a coherent enrichment experience for students who are interested in learning more about circuits, or who have met and exceeded the performance expectations. These might also be helpful if your state has standards related to electricity and circuits in addition to those laid out in the NGSS. Look in the *Teacher Guide* for the heading “Extension opportunity” to find optional enrichment support.
- Lesson 11: Give students additional time and resources to complete the culminating task. Consider planning an assembly, or inviting friends, family, and community members into the classroom to see the presentations.
- All lessons: Remove scaffolds provided with Science and Engineering Practices (SEPs) as a way to give students more independent work with the elements of these practices.

## What mathematics concepts will students engage with in the unit?

During the **first lesson set**, students are introduced to a tool, the Energy Transfer Model, for representing how energy flows in a system and the types of matter interactions associated with it. This model uses a simple quantitative approach to make sense of energy transfer and to determine whether the amount of energy increases or decreases as the energy flows. Quantifying energy supports students in thinking about conservation of energy while helping them draw connections between the system’s stability and reliability. Students use a data visualization and analysis tool (CODAP) to identify the correlation coefficient of a linear fit between various demographic variables and the percentage of people who lost power in a given Texas county in February 2021. They explore issues with the scale of the data used to explain the lack of correlation, and reasons why causal relationships cannot be determined from a correlation in this context. In *OpenSciEd Unit P.4: Meteors, Orbits, and Gravity (Meteors Unit)*, students will use their ideas about correlation between two variables to investigate linear and nonlinear relationships.

In the **second lesson set**, students continue using quantitative reasoning to consider how to model the role of a battery in the flow of energy in a system. This supports students in making connections between energy storage and reliability. Students also apply ratios and unit conversions to calculate the costs and land use area of various energy storage systems.

This unit does not assume fluency with the mathematical practices listed below; rather, students develop these practices as part of the sensemaking. Thus, these standards are not so much prerequisites as co-requisites. If students are simultaneously developing the skills and vocabulary in math class, you can help by making explicit connections to the mathematical standards listed below:

| Category | Code | Domain and Heading | Standard | Relevant Lessons |
|---|---|---|---|---|
| Number and Quantity | CCSS.MATH.CONTENT.HS.N-Q.2 | **Quantities:** Reason quantitatively and use units to solve problems. | Define appropriate quantities for the purpose of descriptive modeling. | 3, 9 |
| Functions | CCSS.MATH.CONTENT.HS.N-Q.1 | **Interpreting Functions:** Interpret functions that arise in applications in terms of the context. | Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. | 9, 11 |
| Statistics and Probability | CCSS.MATH.CONTENT.HS.S-ID.8 | **Interpreting Categorical and Quantitative data:** Interpret linear models. | Compute (using technology) and interpret the correlation coefficient of a linear fit. | 7 |
| | CCSS.MATH.CONTENT.HS.S-ID.9 | **Interpreting Categorical and Quantitative data:** Interpret linear models. | Distinguish between correlation and causation. | 8 |

*See individual lessons referenced above for details.*

## What strategies are available to support equitable science learning in this unit?

OpenSciEd units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies that are integrated throughout the OpenSciEd routines and are intended to increase relevance and provide access to science learning for all students. These equity goals are supported through several specific strategies, such as: (1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and increase accessibility for students to engage in learning experiences; (2) developing and supporting classroom agreements that encourage a safe learning culture; (3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and (4) offering specific strategies for supporting emerging multilingual students in science classrooms.

Many of these strategies are highlighted in the *Teacher Guides* in sidebar callout boxes with these headings:

- Attending to Equity
- Supporting Emerging Multilingual Learners
- Supporting Universal Design for Learning
- Additional Guidance
- Alternate Activity
- Key Ideas
- Discussion

## What are recommended adult-level learning resources for the science concepts in this unit?

The OpenSciEd instructional model casts the teacher as a member of the classroom community, supporting students motivated by their own questions about phenomena to figure out scientific ideas. Students iteratively build their understanding of phenomena as the unit unfolds. To match the incremental build of a full scientific explanation across the unit, the science content background necessary for you to teach the lessons also builds incrementally. Throughout the unit, we provide just-in-time science content background for you that is specific to the Disciplinary Core Ideas (DCIs) figured out in each lesson. Places to find this guidance include the “Where we are going” and “Where we are not going” sections of the lesson’s *Teacher Guide*. The expected student responses, keys, and rubrics also illustrate important science ideas that should be developed. The K-12 Science Framework is another great resource for learning more about the DCIs in this unit (**ETS1.A: Defining and Delimiting Engineering Problems**, **ETS1.B: Developing Possible Solutions**, **PS2.B: Types of Interactions**, **PS3.A: Definitions of Energy**, **PS3.B: Conservation of Energy and Energy Transfer**, **PS3.C: Relationship Between Energy and Forces**, **ESS3.A Natural Resources**), including what students have learned previously and where they are headed in high school.

In addition to the science content background information embedded in the lesson resources, below we provide recommended resources that can help build your understanding of this unit’s phenomena and Performance Expectations bundle.

- To learn more about the crisis in Texas in February 2021:
  - **The Disconnect: Power, Politics and the Texas Blackout (podcast):** https://www.npr.org/podcasts/1004840920/the-disconnect-power-politics-and-the-texas-blackout
  - **The Timeline and Events of the February 2021 Texas Electric Grid Blackouts (report from the UT Austin Energy Institute):** https://energy.utexas.edu/sites/default/files/UTAustin%20%282021%29%20EventsFebruary2021TexasBlackout%2020210714.pdf

    - **Frozen Out in Texas: Blackouts and Inequity (Case Study from the Rockefeller Foundation):** https://www.rockefellerfoundation.org/case-study/frozen-out-in-texas-blackouts-and-inequity/
- To obtain statistics related to various energy sources and storage solutions:
    - **The United States Department of Energy:** https://www.energy.gov/energy-sources
    - **The U.S. Energy Information Administration:** https://www.eia.gov/
- To learn more about some of the difficult trade-offs associated with choosing energy sources and solutions:
    - **WA NI SKA TAN Alliance of Hydro-Impacted Communities:** https://hydroimpacted.ca/
    - **United Nations Climate Action:** https://www.un.org/en/climatechange/science/causes-effects-climate-change
    - **Wind Energy Technologies Office:** https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy

## How do I support students' emotional needs?

The Texas power crisis of February 2021 anchoring this unit is a phenomenon that straddles the traditional divide between science and culture. Students read articles featuring interviews with real people who have experienced trauma. The Texas power outages resulted in hundreds of lives lost, and some students' lives and families may have been (or may still be) greatly affected. Before beginning this unit, **reach out to the counselor at your school** for student-specific support and strategies that might be needed in regard to the students in your class, and consider asking the counselor to join you on the first day of instruction. Also consider planning follow-up check-ins with the counselor in regard to any students who may need additional emotional support.

Often in science classrooms, we are focused on evidence and data. When addressing a phenomenon or design solution that straddles the nature-culture divide, like this one, supporting students in using a social and emotional lens rooted in empathy is also important. According to the CDC, "Adopting a trauma-informed approach is not accomplished through any single particular technique or checklist. It requires constant attention, caring awareness, [and] sensitivity." Make space for students to process information, and validate their feelings and reactions. Be aware that students who are struggling may demonstrate a variety of behaviors, including but not limited to: fidgeting, withdrawal, disruption or distraction, rapid breathing, holding their breath, change in body language or tonation. If you notice a student might be struggling, share what you are observing and ask whether they need some help.

**Social awareness.** In Lesson 1, giving students space to consider what these power outages were like can help support the development of their social awareness, one of the Collaborative for Academic, Social, and Emotional Learning (CASEL) five core competencies. *Social awareness* describes the abilities to understand the perspectives of and empathize with others, including those from diverse backgrounds, cultures, and contexts. Students have another opportunity in Lesson 11 to develop social awareness by thoughtfully taking the perspective of multiple stakeholders. It is important to help students imagine these roles, but also to support them in not essentializing the people in these groups. Point out that these categories are not monoliths, and that many of them interact with one another and with other social and professional identities.

**Self-awareness.** In Lesson 8, students learn about existing and inextricable economic, racial, and health disparities that impacted the way people experienced the power outages. Again, make space for them to process, and validate their feelings and reactions. Giving students a chance to think about how they feel in relation to the content of the podcast and the reading can help support the development of their self-awareness, another one of the CASEL five core competencies. *Self-awareness* describes the abilities to understand one's own emotions, thoughts, and values and how they influence behavior across contexts.

**Responsible decision-making.** In addition to developing self-awareness, students are given several opportunities to consider what choices they would make after considering their own emotions, which supports the development of another core competency that is highlighted over the second lesson set of this unit: responsible decision-making. *Responsible decision-making* describes the abilities to make caring and constructive choices about personal behavior and social interactions across diverse situations. This includes the capacity to consider ethical standards and safety concerns, and to evaluate the benefits and consequences of various actions for personal, social, and collective well-being.

**Transformative SEL.** The culminating task in Lesson 11 was designed to give students and educators an opportunity to engage in "transformative social and emotional learning." *Transformative SEL* describes a process "whereby young people and adults build strong, respectful, and lasting relationships that facilitate co-learning to critically examine root causes of inequity, and to develop collaborative solutions that lead to personal, community, and societal well-being." Rather than provide a fictional scenario, the task is designed to support students in taking agency, and to give them the tools to speak up in their local and global community for a better energy future that aligns with their values.

For more support around Social and Emotional Learning, visit https://casel.org.

For more trauma-informed strategies to support your students' emotional needs, visit https://transformingeducation.org.

## What is the Learning in Places socio-ecological deliberation and decision-making framework?

This unit is informed by the Learning in Places socio-ecological deliberation and decision-making framework. This framework involves sensemaking across seven dimensions, which include making sense of both human and other-than-human values, needs, and behaviors across multiple temporal and spatial scales. The framework guides learners toward designing actions or making decisions for making change in adaptive and resilient ways.


Socio-ecological decisions are those made by individuals, communities, organizations, and institutions that are informed by and impact the natural world. These decisions are affected by relationships between humans and the natural world, called *nature-culture relations*. Nature-culture relations often vary by culture, context, and society, and affect which socio-ecological decisions are made and enacted. Understanding the connections between humans and the natural world is imperative for creating and sustaining socially and environmentally just decisions.

Some examples of this framework in action in this unit are:

- Students consider how disparities in access to resources makes the experience of decisions made by those in power very different in Lesson 8.
- Students are faced with decisions around designing and maintaining electrical infrastructure. In thinking about these decisions, they are asked to consider the needs of humans, and also of animals and the environment, when considering trade-offs in Lesson 10.
- Students consider the values that guide decision-making by considering the perspectives of interested parties in Lesson 10, interviewing their friends and families, and discussing the importance of values in energy decision-making.
- Students think about the geographies of their own region and how those will inform their design thinking in Lesson 11.

For more about socio-ecological deliberation and decision-making, visit http://learninginplaces.org.

Text and image courtesy of Learning in Places Collaborative (2021). Ethical Deliberation and Decision-Making in Socio-Ecological Systems Framework. Learning in Places website. http://learninginplaces.org/frameworks/ethical-deliberation-and-decision-making-in-socio-ecological-systems-framework/.

## Guidance for Developing Your Personal Glossaries

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students experience and discuss science ideas before they know the specific vocabulary words that name those ideas. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have co-developed that definition and can add the specific term to a Personal Glossary at the back of their science notebooks. These “definitions we co-develop” should be recorded using students’ own words whenever possible. On the other hand, “definitions we encounter” are “given” in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, definitions we encounter are helpful only in that lesson and need not be recorded in students’ glossaries. However, if a “word we encounter” will be frequently referred to throughout the unit, it should be added.

It is best for students if you create consensus definitions in the moment, using phrases and pictorial representations that the class develops together as they discuss their experiences in the lesson. When students co-create the meaning of a word, they “own” the word--it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support. Sometimes defining a word is a challenge. The *Teacher Guide* provides a suggested definition for each term to support you in helping your class develop student-friendly definitions that are also scientifically accurate.

The definitions we co-develop and encounter in this unit are listed in this document and in each lesson’s guide to help you prepare and to avoid introducing a word before students have earned it. They are *not* intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when allowed to experience them first as ideas they’re trying to figure out. Some lessons include built-in opportunities for students to add to their glossaries, but some do not. Offer this opportunity whenever students feel they have co-constructed a definition and it would be helpful to keep track of it, and encourage them to keep track of words from previous lessons that have become useful, in addition to new words.

| Lesson | Words and Equations with Meanings We Co-Construct | Words and Equations with Meanings We Encounter |
|---|---|---|
| L1 | electricity, energy, infrastructure, grid | electricity, energy, infrastructure, grid, reliable |
| L2 | circuit, switch, ground, substation | incandescent, insulator, short circuit, broken circuit |
| L3 | | criteria, constraint, supply, demand |
| L4 | reliability, efficiency, power | dispatchability |
| L5 | generator, power plant, wind turbine, magnetic field | field |
| L6 | electron, current | |
| L7 | hypothesis, correlation, $r^2$ | |

| | | |
|---|---|---|
| L8 | | trade-off |
| L9 | storage solution | pumped hydropower, flywheel |
| L10 | costs, benefits | interested party, life-cycle analysis, dispatchability |
| L11 | | |

# ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

## Overall Unit Assessment

| When | Assessment and Scoring Guidance | Purpose of Assessment |
|---|---|---|
| Lesson 1 | Initial models<br><br>Driving Question Board | **Pre-Assessment**<br>The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit.<br><br>The initial model developed on day 2 of Lesson 1 is a good opportunity to pre-assess student understanding of which parts of the system are important for explaining what happened in Texas.<br><br>The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions and to post to the board. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions when they relate to the investigations underway. |
| Lesson 6 | *Wire Simulation Investigation, Simulation Investigation Key*<br><br>*Motors Transfer Task, Motors Transfer Task Key* | **Formative**<br>In lesson 5, students get a chance to make a claim about the relationship between two variables in a simulation of electricity moving through a wire, and then plan and conduct an investigation, and analyze the data to use as evidence to either support or refute their claim.<br><br>**Summative** |

| | | |
|---|---|---|
| | Optional: *Transformer Transfer Task* | In this assessment, students get a chance to use what they have figured out about generators to model and explain energy transfer in a motor. An additional parallel task is included (*Transformer Transfer Task*) as an option for students who might benefit from another opportunity to take a similar assessment after receiving feedback.<br><br>We strongly recommend that you encourage students to use their notebooks as a resource for completing all assessments. |
| Lesson 8 | L8 Electronic Exit Ticket, *L8 Electronic Exit Ticket Key* | **Summative**<br>This electronic Exit Ticket addresses 3-D elements associated with the lesson-level performance expectations from Lessons 7 and 8, which function together as a problematize/putting the pieces together routine for the first lesson set of the unit. This assessment is designed to be easy to gather information about where your students are still struggling to put the pieces together. |
| Lesson 9 | *Modeling Reliability*, *Modeling Reliability Key*<br><br>*Peer Modeling Rubric*, *Peer Feedback Self-Assessment*<br><br>*Testing Battery Storage Solutions*, *Testing Battery Storage Solutions Key* | **Formative**<br>Students make a complex energy transfer model to show how adding a battery could improve the reliability of the electric grid. They incorporate many of the conventions and ideas we have developed across the unit.<br><br>**Self-Assessment**<br>Students are asked to complete a self-assessment where they reflect on how well they gave and received feedback on the modeling task.<br><br>**Formative**<br>Students get the opportunity to practice computations coherently (in the context of figuring out the phenomenon), before being expected to use those same computations in the Lesson 10 electronic Exit Ticket and the final Transfer Task. |
| Lesson 10 | L10 Electronic Exit Ticket, *L10 Electronic Exit Ticket Key* | **Formative**<br>This electronic Exit Ticket addresses 3-D elements associated with the lesson-level performance expectations from Lessons 9 and 10. This assessment is designed to be easy to gather information about where your students are still struggling to apply certain practices in the context of engineering. |
| Lesson 11 | *Design Challenge*, *Design Challenge Key*<br><br>*Peer Interactions Support*, *Peer Feedback Self-Assessment* | **Summative**<br>In this lesson students put all the pieces together to design a plan for their community. The task requires them to poll stakeholders, consider how values impact tradeoff decision making in engineering, and choose criteria and constraints. They will need to apply what they have learned about electrical energy sources and systems to complete the assignment, including energy loss and efficiency. |

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| | *Sand and Mirrors Assessment*, *Sand and Mirrors Assessment Key* | This culminating task was designed to give students and educators the chance to engage in “transformative social and emotional learning.” Transformative SEL describes a process “whereby young people and adults build strong, respectful, and lasting, relationships that facilitate co-learning to critically examine root causes of inequity, and to develop collaborative solutions that lead to personal, community, and societal well-being.” Rather than provide students with a fictional scenario, the task is designed to support students in taking agency, and to give students the tools to speak up in their local and global community for a better energy future, one that aligns with their values.<br><br>**Self-Assessment**<br>Students are asked to complete a self-assessment where they reflect on how well they gave and received feedback on the modeling task.<br><br>**Summative**<br>At the end of this final lesson, students will have the opportunity to demonstrate their competence with a transfer task. |
| Occurs in several lessons | Lesson Level Performance Expectation Assessment Guidance | **Formative Assessment**<br>Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments. |
| Occurs in several lessons | *Progress Tracker*<br><br>*Engineering Design Tracker*, *Engineering Design Tracker Examples*<br><br>*Decisions Matrix* | **Formative and Self-Assessment**<br>The Progress Trackers are thinking tools designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Trackers reflects their own thinking at that particular moment in time. In this way, the Progress Trackers can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Trackers are meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative “grade” other than for completion.<br><br>In this unit, students add to their *Progress Tracker* in Lessons 1, 2, 5, 6, and 7. Examples of models and ideas students may include in this tracker are embedded in these lessons.<br><br>This unit also includes a second progress tracker specifically for engineering ideas, called the *Engineering Design Tracker*. Students add to their *Engineering Design Tracker* in Lessons 3, 6, 8, 9. This resource is accompanied by a key in Lesson 9 with examples of what these entries might look like. |

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| | | This unit also includes a *Decisions Matrix*, which students will use alongside the Engineering Design Tracker in Lesson Set 2 to make decisions about what designs they would like to advocate for in their community as the electric grid ages. This resources is introduced in Lesson 4, and revisited in Lessons 10 and 11. |
| Occurs in several lessons | Student Self Assessment Discussion Rubric | **Self-Assessment**<br>This resource is available in the front matter. The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.<br><br>In addition to this flexible resource, self-assessment has been written directly in the unit in Lessons 9 and 11. |
| Occurs in several lessons | Peer Feedback Facilitation: A Guide | **Peer Feedback**<br>This resource is available in the front matter. There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process.<br><br>Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.<br><br>In addition to this flexible resource, peer feedback has been written directly in the unit in Lessons 3, 9, and 11. |

For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.

## Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

| Lesson | Lesson-Level Performance Expectation(s) | Assessment Guidance |
|---|---|---|
| Lesson 1 | **1.A** Develop a model of energy transfer through systems to explain how energy manifests as electricity in our communities, including how changes to an otherwise stable system could cause blackouts. (SEP: 2.3; CCC: 7.1; DCI: PS3.A.2, PS3.B.2, PS3.B.4)<br><br>**1.B** Ask questions to clarify and define the problem of how our community can generate energy by designing systems to address both local and global challenges. (SEP: 1.4; 1.8; CCC: 4.1; DCI: ETS1.A.2) | **1.A When to check for understanding:** On day 2 when students do their initial model gallery walk. In addition, you can collect initial models at the end of day 2 to assess students' ideas more closely after class.<br>**What to look for/listen for in the moment:**<br>● Modeling more than one system; for example, the power plant, the wires, and the houses. (SEP: 2.3)<br>● Indication of energy transfer between systems; for example, arrows connect systems, or the systems are drawn in a line, and/or the student indicates energy transfer in their written responses to questions 3 and/or 4 on *Initial Models*. (SEP: 2.3; DCI: PS3.A.2, PS3.B.4)<br>● Second model indicates a clear change to the system, and the repercussions of that change in terms of energy transfer (a blackout). (CCC: 7.1; DCI: PS3.B.2)<br><br>**1.B When to check for understanding:** During the development of the Driving Question Board (DQB).<br>**What to look for/listen for in the moment:**<br>● Questions about specific systems; for example, the power plant, the wires, and/or the building. (SEP: 1.4)<br>● Questions that go beyond mechanistic explanations (e.g., "How does a generator work?") to explore design challenges and tradeoffs (e.g., "How can we prevent something like the Texas blackouts from happening in our community?" or "How can we make energy production more green?"). (SEP: 1.4; CCC: 4.1)<br>● Questions that define specific local or global challenges that students noticed in the anchor and/or bring from their own experience (e.g., pollution, job creation, disparities in electricity access). (SEP: 1.8; DCI: ETS1.A.2) |
| Lesson 2 | **2.A** Collect data from a designed system (a power strip) and a network of interconnected subsystems (multiple | **2.A When to check for understanding:** When groups dissect power strips and use them to power devices with one battery on day 1.<br>1. Investigation A (Dissection) |

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| | powerstrips) on the interactions needed for and failure points in the transfer of electrical energy. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)<br><br>**2.B** Develop, revise, and use a model to identify analogous structures that affect the electrical energy transfers across and between different (sub)systems at different scales (a powerstrip versus a building). (SEP: 2.3; CCC: 4.1, 6.1; DCI: PS3.B.2) | 2. Investigation B (Powered Circuit)<br>**What to look for/listen across 1-2:**<br>1. Identifying at least two parts and/or interactions they observe inside (CCC: 4.1) the powerstrip.<br>2. Observations and tests that may include<br>● Connecting alligator clips to different metal parts to determine which connections are needed for energy transfer from the battery to each light bulb and recording the results. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)<br>● Testing the effect of the switch and noticing it turns on or off all devices together. When the wire connected to the switch isn't used for any devices, the switch does nothing. (SEP: 3.6; CCC: 4.1)<br>● Connecting additional devices in certain configurations (e.g., parallel versus series) either does or does not appear to affect the amount of energy transferred (brightness) to each light bulb. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)<br><br>**2.B When to check for understanding:**<br>1. When you collect students' models of the power strip system at the end of day 1 after Investigation B (Powered Circuit).<br>2. When you discuss the structures in a building on day 2, using ideas students gathered from *Electricity Related Parts*.<br>**What to look for/listen for across 2.B.1 and 2.B.2:**<br>1. Models of the power strip system are analogous to a circuit diagram, showing which parts in the system need to be connected in order for the system to work as designed for energy to transfer from the source to multiple devices. (SEP: 2.3, CCC 6.1, DCI: PS3.B.2)<br>2. Identification of analogous structures and functions between two designed systems at different scales (a building versus a power strip). (SEP: 2.3, CCC 4.1, 6.1) |
| Lesson 3 | **3.A** Develop and use a model based on evidence from our investigation in Lesson 2 to illustrate the energy flow between components of the electric grid system and energy loss from the system as a possible cause of the crisis in Texas. (SEP: 2.3; CCC: 4.3; DCI: PS3.B.2, PS3.D.1)<br><br>**3.B** Evaluate the impact of empirical data about energy supply and demand from Texas in February 2020 and 2021 to | **3.A When to check for understanding:** On day 1, when students develop energy transfer models for Scenarios A-E on *Energy Transfer Scenarios*.<br><br>**What to look for/listen for in the moment:**<br>● Modeling energy transfer across more than one system (e.g., the power plant, substation, and buildings) and using question marks to indicate areas of uncertainty. (SEP: 2.3)<br>● Using numbers or symbols to quantify energy coming in and out of various parts of the system (e.g., the buildings, power plant, and/or substation). (CCC: 4.3)<br>● Indicating that the energy coming into the substation from the power plant is equal to the total energy leaving the substation to buildings and the surroundings. (DCI: PS3.B.2, PS3.D.1) |

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| | identify patterns, and evaluate how scientific knowledge and constraints impact possible solutions. (SEP: 4.5, 6.5; DCI: PS3.B.4; CCC 1.5, Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World) | ● Models for Scenarios A and B include an arrow to indicate a connection between parts of the electric grid and the surroundings, to account for the energy loss in the system. (CCC: 4.3)<br><br>**3.B.1 When to check for understanding:** On day 1 when students fill in their *Engineering Design Tracker*s.<br><br>**What to look for/listen for in the moment:** Look for students to recognize and write about constraints (e.g., cost, space, etc.) on undergrounding power lines that will make it more difficult for communities to implement that design solution. (SEP: 6.5; Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World)<br><br>**3.B.2 When to check for understanding:** On day 2, when students use the Identify and Interpret (I[2]) Strategy to analyze the electricity demand forecast, electricity demand, and electricity production data from Texas in 2020 and 2021.<br><br>**What to look for/listen for in the moment:**<br>● Concise descriptions of patterns (similarities, trends, or changes) presented in the graphs, such as:<br>    ● the rapid increase in electricity demand from February 14 to February 17 of 2021<br>    ● the almost perfect match of supply and predicted demand in 2020<br>    ● the mismatch between energy demand and supply during the energy crisis in 2021<br>● Reasonable inferences about patterns that emerge from the data, such as:<br>    ● People used more power when it got cold because they needed to heat their homes.<br>    ● Power companies make enough supply to match demand when the system is functioning properly.<br>    ● When supply does not match demand, people will lose power. (SEP: 4.5; DCI: PS3.B.4; CCC 1.5) |
| Lesson 4 | **4.A** Analyze multiple types of data to identify characteristics of energy sources derived from Earth's systems that increase the reliability of the energy grid (a criterion for success), given that for the system to remain stable, it must be designed for energy supply to meet energy demand. (SEP: 4.6; CCC: 7.4; DCI: ESS3.A.2; DCI: PS3.B.4) | **4.A.1 When to check for understanding:** When students first see the *Source Cards Full Page* on day 1 (**slide D**).<br><br>**What to look for/listen for:** As you move around the room, ask students the first question on the slide, and listen for them to make the connection that almost all of these sources come from Earth's systems, except solar. (DCI: ESS3.A.2)<br><br>**4.A.2 When to check for understanding:** When we discuss how we change reliability into a criterion after the ranking gallery walk on day 1 (**slide H**).<br><br>**What to look for/listen for:** Students can explain that in order for the system to remain stable, it must be designed for supply to meet demand. (CCC: 7.4; DCI: PS3.B.4) |

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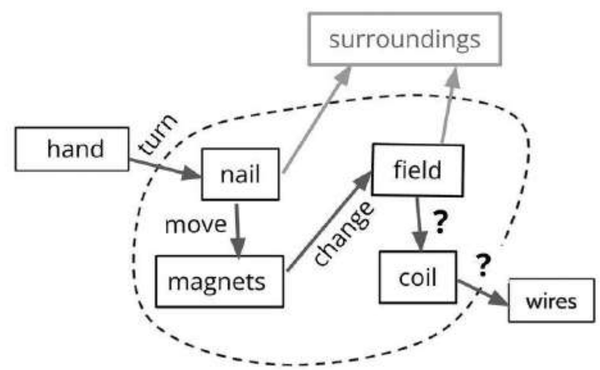
| | | **4.A.3 When to check for understanding:** On day 2, when we build understanding as a class (**slide O**).<br><br>**What to look for/listen for:** Students identify patterns in the data and can explain what they mean, relating their ideas back to reliability. (SEP: 4.6) |
| Lesson 5 | **5.A** Develop a model based on evidence to illustrate the energy and matter changes in a generator, including energy transfer through contact between moving parts and energy transfer at a distance through fields. (SEP: 2.3, CCC: 5.2, DCI: PS3.A.2, PS3.A.3)<br><br>**5.B** Design and build a generator system to transfer motion energy to light that meets agreed-upon criteria, manipulating variables and collecting data to identify failure points and improve performance. (SEP: 3.6, CCC: 4.1, DCI: PS3.A.2) | **5.A.1 When to check for understanding:** On day 1, when students work with a partner to create an energy transfer diagram for the natural gas power plant in *Power Plant Diagrams*.<br><br>**What to look for/listen for in the moment:**<br>● Students should use our box and arrow conventions, and label the arrows with at least one action word to describe energy transfer. (SEP: 2.3)<br>● Energy transfer arrow labels should describe interactions, even partially. These energy transfers will generally manifest as matter changes or motion changes (e.g., fire **heats** emissions, steam **pushes** turbine, turbine **pushes** generator). It is not important that students recognize interactions as forces in this unit. (CCC: 5.2, DCI: PS3.A.2)<br>● Students will likely not yet have a clear idea of how energy transfer manifests in the wires. This uncertainty will motivate the investigations in Lesson 6. Rather than pushing them to figure this out now, encourage them to highlight this limitation of their model by putting a question mark on that arrow. (DCI: PS3.A.2)<br><br>**5.A.2 When to check for understanding:** On day 3, when students complete their class consensus model about their homemade generators.<br><br>**What to look for/listen for in the moment:** As a class, students should model something like this:<br><br><br>● Students should again use our box and arrow conventions, and label the arrows with at least one action word to |

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| | | describe energy transfer. (SEP: 2.3)<br>● The class model should include energy transfer to a field with the arrow labeled as "change" (i.e., magnets **change** the field). (CCC: 5.2, DCI: PS3.A.3)<br>● Students will likely not yet have a clear idea of how energy transfer manifests in the wires. This uncertainty will motivate the investigations in Lesson 6. Rather than pushing them to figure this out now, encourage them to highlight this limitation of their model by putting a question mark on that arrow. (DCI: PS3.A.2)<br><br>**5.A.3 When to check for understanding:** On day 3, when students individually complete their exit tickets.<br><br>**What to look for/listen for in the moment:**<br>● Students should say that the motion of magnets causes field changes, resulting in the transfer of energy. (CCC: 5.2, DCI: PS3.A.3)<br>● Students should identify parts on their model where the magnets move and where the field changes, generating electrical energy. (SEP: 2.3, CCC: 5.2, PS3.A.3)<br>● Students should have questions about what is happening in the wire when energy transfers through it. We haven't yet introduced electrons, but students who have taken chemistry or physics may mention electrons or electric current as a place to go next.<br><br>**5.B When to check for understanding:** On day 2, as students plan, build, test, and improve their homemade generators.<br><br>**What to look for/listen for in the moment:**<br>● Students identify design criteria relevant to the generator's performance, transferring motion energy to light (i.e., lighting multiple bulbs, lighting a bulb for an extended time). (SEP: 3.6, DCI: PS3.A.2)<br>● Students evaluate their own design against the agreed-upon criteria as they build and test their generator design. (SEP: 3.6, CCC: 4.1)<br>● Students use the Design Challenges on the handout to improve their designs in real life. (SEP: 3.6)<br>● Students describe a relationship between a specific design variable (e.g., magnet spinning speed, magnet position, number of wire coils) and the energy output (e.g., "If we spin the nail faster, the light is brighter"). (SEP: 3.6) |
| Lesson 6 | **6.A** Integrate information from a reading alongside student-generated models and a computer simulation to examine smaller-scale mechanisms within the system and develop cause-effect relationships about | **6.A When to check for understanding:** On day 1, when students model passages from *Changing Fields*, and later model the inside of a wire; and on day 2, when students share conclusions from the simulation and connect these conclusions to in-class experiments.<br><br>**What to look for/listen for in the moment:** |

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| | motions of particles or energy stored in fields. (SEP: 8.2; CCC: 2.2; DCI: PS3.A.3)<br><br>**6.B** Use a simulation to model electron flow inside a wire in order to identify patterns, answer questions, and determine relationships between independent and dependent variables involving electrical energy transfer that can be interpreted to reengineer and improve the electric grid. (SEP: 1.3; CCC: 1.3; DCI: PS3.A.4)<br><br>**Transfer Task 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. (SEP: 2.3, 6.5; CCC: 5.2; DCI: PS3.A.2, PS3.A.3, PS3.D.1) | ● Fields store and transfer energy. In energy transfer diagrams, students should label the energy transfer arrow into a field with the word "change" or the like. Energy transfer arrows from a field to a particle, such as an electron, should be labeled "push" or the like. (DCI: PS3.A.3)<br>● Information about fields obtained from a reading is consistent with evidence we have seen in class. We can incorporate both to model energy transfer in wires. (SEP: 8.2; DCI: PS3.A.3)<br>● We can use particle-scale mechanisms for interactions between particles and fields to identify cause-effect relationships for larger systems like a wire, and to explain evidence of energy transfer we have seen in class, such as compasses moving and wires heating up. (CCC: 2.2; DCI: PS3.A.3)<br><br>**6.B When to check for understanding:** On day 2, as students work to fill out *Wire Simulation Investigation*; and on day 3, when students use their conclusions from day 2 to complete their *Engineering Design Tracker*.<br><br>**What to look for/listen for in the moment:**<br>● Use *Simulation Investigation Key* as guidance.<br>● Increasing the wire length and/or decreasing the wire width results in less energy transfer and more energy loss. (SEP: 1.3; DCI: PS3.A.4)<br>● Lower wire temperatures result in slightly more energy transfer and slightly less energy loss, but the effect is small. (SEP: 1.3; DCI: PS3.A.4)<br>● We can use these conclusions to reengineer our electric grid. We will waste less energy if we use thicker wires and minimize wire length by keeping energy sources as close to their destination (buildings) as possible. (CCC: 1.3)<br>● These choices have trade-offs and constraints--energy sources such as coal plants can be unhealthy for residents, and thicker wire costs more money. (CCC: 1.3)<br><br>**Motor Transfer Task:** On day 3 (a half day), administer the *Motors Transfer Task*. This assessment is not building toward a lesson-level performance expectation. It is designed to assess progress toward a performance expectation from the NGSS (HS-PS3-3). See the accompanying *Motors Transfer Task Key* for details. *Transformer Transfer Task* is included as an option for offering parallel tasks, or a retake, and can be assessed using the same key. (SEP: 2.3, 6.5; CCC: 5.2; DCI: PS3.A.2, PS3.A.3, PS3.D.1) |
| Lesson 7 | **7.A** Develop a model showing how insufficient supply entering the system could lead to reduced energy transfer into certain communities in Texas when the temperatures dropped, resulting in | **7.A When to check for understanding:** When students are modeling in groups on day 1, and during the consensus modeling immediately afterward. |

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| | buildings losing power. (SEP: 2.3; CCC: 5.2, 5.3; DCI: PS3.B.4)<br><br>**7.B** Develop and test a correlational hypothesis to investigate tradeoffs inherent in making decisions about energy, and then consider limitations on this analysis to motivate seeking information about patterns at a smaller grain size. (SEP: 1.6, 4.2, 4.3; CCC: 2.1, 3.3; DCI: ETS1.B.1) | **What to look for/listen for:** Note that this task is designed to highlight gaps in our understanding. Do not expect students to accurately model what happens when there is not sufficient energy in the system; they should recognize that when supply does not meet demand, the system will not function, and they should use the appropriate conventions to make this clear.<br>● Students use the energy transfer conventions we developed in Lesson 3 to represent systems and energy transfer between systems.<br>● The subsystems students choose to include may vary, but look for systems to be labeled clearly. At the least, they should include a power plant (or energy source), a transport system (or substation), and at least two communities (or homes/buildings in a community). (SEP: 2.3)<br>● Students use numbers, dots, or some other quantitative representation to show that the amount of energy entering the system is equal to the amount of energy available to homes, minus any energy lost to the surroundings.<br>● Students may choose to reduce supply, increase demand, or both, as long as they show that supply did not meet demand.<br>● If students choose to show energy loss to the surroundings, this loss is reflected in the amount of energy available to homes. (CCC: 5.2, 5.3)<br>● Students indicate that insufficient supply results in power loss, either by labeling the appropriate buildings as blacked out, using an X to indicate no energy transfer, erasing (or not drawing) lines indicating energy transfer, and so forth. (DCI: PS3.B.4)<br><br>**7.B.1 When to check for understanding:** Collect students' *Texas County Data Analysis* handouts at the end of day 2.<br><br>**What to look for/listen for:**<br>● Use *Texas County Data Analysis Key* to look for students to explain why their variable might be related to power loss by making connections to human engineering decision-making or to natural causes (Question 2). (DCI: ETS1.B.1)<br>● Use the key to look at students' hypotheses (Questions 3-4), data analysis (Questions 4-8), and current thinking about limitations (Question 9). (SEP: 1.6, 4.2, 4.3)<br>● Use the key to look at the way students are talking about correlations (Questions 6-8). (CCC: 2.1)<br><br>**7.B.2 When to check for understanding:** Use the conversation about limitations at the end of day 2 as an opportunity to pre-assess how students are understanding the distinction between data sets at various grain sizes.<br><br>**What to look for/listen for:**<br>● Data grouped by counties might not capture the details of how variables are distributed across communities. (CCC: |

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| Lesson 8 | **8.A** Integrate quantitative information, visual information, and audio (or text) to define some of the challenges and tradeoffs associated with a drop in energy supply driven by cold weather, and consider additional tradeoffs associated with making energy decisions. (SEP: 8.2; CCC/NOS: 5.2, 5.3; Science Addresses Questions About the Natural and Material World; DCI: ETS1.A.2, ETS1.B.1) | **8.A.1 When to check for understanding:** When students discuss key takeaways from the podcast as a class (**slide C**).<br>**What to look for/listen for in the moment:**<br>● Listen for students to reference ideas they heard in the podcast in conjunction with the graphs they saw projected over the podcast (or in the accompanying handout). (DCI: ETS1.A.2, ETS1.B.1)<br>● Listen for students to identify at least one tradeoff related to decisions made by the power company. The most obvious tradeoff is related to cutting power to protect essential buildings and power plants at the expense of people in certain communities. But listen for more nuanced tradeoffs as well, such as that between weatherizing power plants versus cost, or between reliability in a storm versus using wind/solar power to avoid burning fossil fuels. (SEP: 8.2)<br>● Listen for students to recognize that if energy going into the grid is spread too thin, there will not be sufficient energy in the system to keep electrons in the wires moving fast enough. This could cause the whole grid to shut down, causing weeks of widespread outages. (CCC: 5.2, 5.3)<br><br>**Electronic Exit Ticket:** The Electronic Exit Ticket at the end of this lesson is designed to address the lesson-level performance expectations from Lessons 7 and 8, which function together as a problematizing/putting-the-pieces-together routine for the unit's first lesson set. This assessment is designed to make it easy to gather information about where students are still struggling to put the pieces together. |
| Lesson 9 | **9.A** Develop an energy transfer model to predict the stability in the distribution of electric energy when batteries are present and absent from the system. (SEP: 2.3; CCC: 7.4; DCI: PS3.B.1, PS3.B.4)<br><br>**9.B** Apply ratios, rates, percentages, and unit conversions to calculate the costs and land area of use of a design solution to evaluate its feasibility for preventing an energy crisis like the one in Texas in 2021. (SEP: 5.5; CCC: 3.1; DCI: ETS1.B.1; PS3.D.1) | **9.A When to check for understanding:** On day 1, after students complete *Modeling Reliability*.<br><br>**What to look for/listen for in the moment:** Use *Modeling Reliability Key* to assess the handout. (SEP: 2.3; CCC: 7.4; DCI: PS3.B.1, PS3.B.4)<br><br>**9.B When to check for understanding:** On day 2, after students complete *Testing Battery Storage Solutions*.<br><br>**What to look for/listen for in the moment:** Use *Testing Battery Storage Solutions Key* to score the handout. Look for students to:<br>● Show units in their calculations, and the conversions they make for costs, efficiency, and land area of use. (SEP: 5.5)<br>● Support their claims about feasibility using their calculations. (SEP: 5.5; CCC: 3.1; DCI: ETS1.B.1, PS3.D.1) |

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| Lesson 10 | **10.A** Define the problem, and then interview various interested parties in our community to identify criteria that can help make decisions to improve the electricity infrastructure, including how it is designed for reliability (stability) and its social, cultural, and environmental impacts. (SEP: 1.4, 1.8; CCC: 7.4; DCI: ETS1.B.1)<br><br>**10.B** Analyze data generated by interviews with community members to specify criteria for success related to energy solutions, such as monetary cost, safety, and reliability, and weigh cost/benefit tradeoffs related to social, cultural, and environmental impacts. (SEP: 4.6; CCC: Influence of Science, Engineering, and Technology on Society and the Natural World, Science Is a Human Endeavor; DCI: ETS.1.B.1) | **10.A When to check for understanding:** At the end of day 1, as students complete the *Interview Protocol*.<br><br>**What to look for/listen for in the moment:**<br>● A clear definition of the problem we are trying to solve (designing a more reliable electric grid system that satisfies various criteria for success and the values of various interested parties) that can help interviewees understand the value of their input. (SEP: 1.4, 1.8; CCC: 7.4; DCI: ETS1.B.1)<br>● Questions that look to identify and clarify which criteria are most important to interested parties. (SEP: 1.4; DCI: ETS1.B.1)<br><br>**10.B When to check for understanding:** On day 3, as students complete the Electronic Exit Ticket.<br><br>**What to look for/listen for in the moment:**<br>Use the *L10 Electronic Exit Ticket Key* to assess student work in multiple dimensions. This task is designed to target lesson-level performance expectations from lessons 9 and 10. |
| Lesson 11 | **11.A** Define a problem related to the challenge of improving our electrical grid, and then design, evaluate, and refine a solution, taking into account social, cultural, and environmental impacts (both intentional and unintentional), based on results from a computational model, scientific knowledge we have figured out over the unit, weighted criteria, and tradeoff considerations. (SEP: 1.8, 2.6, 6.5, CCC: 1.3; DCI: ETS1.A.2, ETS1.B.2, ESS3.A.2)<br><br>**11.B** Ask questions to identify and refine criteria for success for our design solutions, | **11.A.1 When to check for understanding:** On day 1, after students complete Question 2 of the *Design Challenge* using the Energy Grid Calculator.<br><br>**What to look for/listen for in the moment:** Use the *Design Challenge Key* for assessment support. (SEP: 1.8, DCI: ESS3.A.2, ETS1.B.1)<br><br>**11.A.2 When to check for understanding:** At the end of day 1, when students complete Part 2 of the *Design Challenge*.<br><br>**What to look for/listen for in the moment:** Use the *Design Challenge Key* for assessment support. (SEP: 1.8, 2.6, 6.5, CCC: 1.3; DCI: ETS1.A.2, ETS1.B.2, ETS1.B.1)<br><br>**11.B When to check for understanding:** At the end of day 2, when students are engaged in the stayer-strayer protocol.<br><br>**What to look for/listen for in the moment:** |

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| | including reliability (stability) and social, cultural, and environmental impacts. (SEP: 1.4, CCC: 7.4; DCI: ETS1.B.1)<br><br>**Transfer Task PE: HS-PS3-2** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). (SEP: 2.3, 4.6, 5.5; CCC: 5.2, 5.3; DCI: PS3.A.1, PS3.A.2, PS3.A.4, PS3.B.1, PS3.B.4, PS3.D.1, ETS1.B.1) | • Look for students to write clear questions regarding the alignment of their peers' proposed design solutions, the reliability of their designed system, and the criteria the class has identified for weighting tradeoffs. (SEP: 1.4, CCC: 7.4; DCI: ETS1.B.1)<br>• Ask clarifying questions about the values and interested parties represented in the design solution. (SEP: 1.4; DCI: ETS1.B.1)<br>• Ask clarifying questions that can help others think about additional changes in the system that can be tried in the grid calculator to improve the reliability of the system and/or its alignment with the criteria for success established by the class. (SEP: 1.4, CCC: 7.4; DCI: ETS1.B.1)<br><br>**Transfer Task:**<br>**When to check for understanding:** On day 3, administer the *Sand and Mirrors Assessment*. This assessment is not building toward a lesson-level performance expectation. It is designed to assess a performance expectation from the NGSS (HS-PS3-2). See the *Sand and Mirrors Assessment Key* for guidance.(SEP: 2.3, 4.6, 5.5; CCC: 5.2, 5.3; DCI: PS3.A.1, PS3.A.2, PS3.A.4, PS3.B.1, PS3.B.4, PS3.D.1, ETS1.B.1) |

# HOME COMMUNICATION

Dear Parents, Guardians, and Caregivers,

Your child's physics class is starting a unit focused on the question *How can we design more reliable systems to meet our communities' energy needs?* as part of the OpenSciEd high school science curriculum. This unit is anchored by the story of a power crisis in Texas, and the accompanying design problem of improving the reliability of our own electric infrastructure. This event provides a rich context in which to investigate the nature of electrical energy transfer, the stability and change of energy inputs and outputs, the impact of energy transfer on our everyday lives, and the social/environmental trade-offs inherent in sourcing energy from Earth's systems.

Over the course of the unit, students will read about what happened in Texas and analyze multiple types of real data from the event. They will investigate each part of the electrical system at various scales, from designing investigations using a simulation of the inside of a wire, to building their own working generators. They will also model an electric grid in the classroom using power strips, alligator clips, LED bulbs, and cardboard buildings.

In the final lessons of the unit, students will consider engineering trade-offs, criteria, and constraints inherent in making decisions about our energy systems, and apply them in a final task: design a reliable energy solution that meets our communities' needs, as articulated by interviews with friends and family members. The task is designed to give students the tools to speak up in their local and global community for a better energy future--one that aligns with their own values and those of their families.

Losing power can be devastating, and recalling past experiences or learning about others' experiences can be triggering. If your child or someone close to your child has had experiences with sustained power outages that might be traumatic, please contact me at ____________________, if you are comfortable doing so. You can also contact the school counselor at ________________. By knowing about these experiences in advance, we can be sensitive to students' needs and provide support if they experience any strong emotions during this unit.

Adolescents sometimes develop difficult behaviors after a traumatic experience. It is important for trusted adults to understand that these behaviors and emotions are common when children experience trauma. Students may be more aggressive or withdrawn, and go through periods of sadness, anger, or emotional "numbing." Contact a counselor if you see any of the following behaviors in your child:

- problems sleeping, nightmares
- changes in school performance
- truancy
- risk-taking behavior
- conflicts with peers
- new or increasing psychosomatic complaints, including stomachaches and headaches
- depression or suicidal thoughts

After a traumatic event, being able to talk to someone who is removed from the situation is often helpful to both adults and children. Children who have experienced trauma are best supported when their parents or trusted caregivers accept their feelings and are open to listen and talk. Let your child come to you. Do not overwhelm them if they are not ready to talk. Respect your child's need to take breaks.

If you have any questions about the content of this unit or would like to discuss anything further, I encourage you to reach out to me at _________________.

Best,