"Solutions-Oriented Learning" Storyline

HS-Renewable Energy: Solar

Storyline introduction and overview:

Solar energy in the form of light is available to organisms on Earth in abundance. Natural systems and other organisms have structures that function in ways to manage the interaction with and use of this energy. Using these natural examples, humans have (in the past) and continue to design and construct homes which manage solar energy in passive and active ways to reduce the need for energy from other sources. In this storyline, students will explore passive and active solar energy management through examples in the natural world. Students will use knowledge gained to design a building that maximizes the free and abundant energy gifts of the sun.

Renewable Energy: Solar NGSS Learning Progression: The high school storyline is part of a larger learning progression that includes students mastering standards pre-K to 12th grade. Look at how the high school performance expectations fit in a continuum of learning for your students.

Placemaking:	**Anchoring phenomena:**	**Drawdown:**
Students take temperature and sunlight meter* readings at several places throughout a building (home or school) and note different materials at each location. *Apps available for free on smartphones.	Materials absorb, reflect and transform different amounts of solar energy. Phenomena: Explore a variety of materials (cotton balls, wool cloth, polyester cloth, wood, soil, plant material) in direct sunlight (preferably outside). Students notice the varying relative temperatures given the same amount of solar radiation.	Insulation Solar Water Distributed Solar Panels
Indigenous and other relevant cultural connections: Since time immemorial Indigenous peoples used the sun and materials in their environment to heat their homes, mark the passage of time and grow and harvest food.	**NGSS PEs (progress towards):** **HS-ETS1-2**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. **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-PS3-3**: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	

Estimated time required to implement this storyline: 3 - 5 weeks

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NGSS PEs:

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
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-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Science & Engineering Practice (SEP)	Disciplinary Core Idea (DCI)	Cross Cutting Concept (CCC)
Constructing Explanations and Designing Solutions 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. • 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** • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary) **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.	**Energy and Matter** • 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. - **Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering and Technology on Society and the Natural World** • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Materials:

Learning Session	Materials
2. Phenomena	insulation materials (i.e., cotton balls, cloth, wood, soil, plant material, foam, ceramic, air) thermometers sunlight (preferred) or incandescent light
4b.	small glass laboratory beakers (1 or 5 or more, depending on the chosen set-up)

	ice cubes stopwatch or a similar timing device low-temperature hot plate Insulation Materials Investigation Worksheet blank paper and pencils
5.	Print resources embedded in Guiding Question
6.	Flashlight Circular piece of cardboard with a 1.25 cm (.5 in.) square opening cut into the center to cover lens (or cover lens with masking tape leaving a 1.25 centimeter (0.5 in.) square opening) Flashlight holder that permits the flashlight to be rotated through different angles (See Appendix VI for instructions for constructing the flashlight holder.) Protractor Ruler

Learning Sessions

1.	**Grounding Native Ways of Knowing:**	Estimated time: **At least 30** intentional minutes, and time devoted throughout the storyline

To connect to native ways of knowing consider exploring the following ideas in connection with your local tribal nation:

- Sun as part of life
- Sun in relation to dwelling design
- Sun used to produce and preserve food
- Sun as an indicator of time
- Gift of the Sun’s energy in abundance

In addition to stories of the past, research and connect with tribal nations close to your community and their actions to mitigate and adapt to climate change. To access information on how to reach out and build relationships with local tribes, visit the OSPI Office of Native Education: Partnering with Tribes webpage. Use this opportunity to discuss expectations of students during story time and address cultural ethics.

Reading of “How Raven Stole the Sun” (western WA), “Origin of the Sun and Moon” (Eastern WA). This is a way we open the storyline, to begin thinking about how the sun is part of our lives here on earth, and the abundant gift of energy the sun provides.

> Teacher Reflection: In the story of “How Raven Stole the Sun,” Raven transformed to bring social justice. Often, we as educators, transform our thinking, our practices, and our approach to do the same.

2.	**Examine phenomena:**	Estimated time: **60 - 120 minutes** (depending on depth of exploration)

Display different materials (i.e. cotton balls, cloth, wood, soil, plant material, foam, ceramic, air) within containers, place thermometers into those containers, and place the containers into the sunlight (preferred), or incandescent light.

Use an "Anchoring Phenomena Routine" to explore the phenomena. Students record their findings and observations throughout the routine in a "Science Notebook" or journal.

Anchoring Phenomena Routine include:

1. Exploration of the anchoring phenomenon through observation and interaction with the phenomenon,
2. Attempt to make sense of the phenomenon by constructing an initial explanation based on their observations,
3. Identify related phenomena by connecting the activity to other examples or outside-of-school experiences, and
4. Developing questions and next steps related to the target science concepts.

Big Idea: Materials absorb, reflect and transform different amounts of solar energy.

Use this visual diagram to stem a discussion about how our atmosphere is an insulating blanket to Earth. Gasses emitted into our atmosphere add to this insulation, including CO_2.
Climate Kids: Greenhouse Gasses

Placemaking: Students explore this phenomenon further by exploring building and construction materials. Students take temperature and sunlight meter* readings at several places throughout a building (home or school) and make note of different materials at each location.
**Light meter apps are available for free for Android and Apple smartphones.*

3.	**Pre-Assessment**	Estimated time: **30 minutes**

HS-RE Solar Pre-Assessment

TASK: Design a solution that manages solar energy in a building to maintain human optimal temperature at your location, year-round. Address both passive and active energy management in your solution. Incorporate into your design labels illustrating energy transfers and transformations, descriptions, and relevant materials that will aid in the solution to the problem. Describe the scientific rationale for choices of materials and structure of the solution, and how this solution will reduce the need for energy from other sources.

	Students will draw/sketch their design on a piece of paper, whiteboard, or an application that can be edited over time, and after new knowledge is gained during the following learning sessions. Use a strategy to track student revisions to their design (such as color-coding, sticky notes, or timestamps). This will allow you to see progression and growth. For the final assessment, students should construct a physical model of their design. HS -Renewable Energy: Solar Assessment Rubric

4a.	**Guiding question: How (at the macro level) do different materials and structures convert light energy into different forms of usable energy?***	Estimated time: **45 minutes**
	Cat Eye Exploration: Watch How do animals see in the dark? (YouTube) This video is about the management of light. While at first it may seem unrelated, watch with an open mind. Evaluate the adaptations and synthesize applications to building design. After watching the video, begin discussion about the adaptations presented in the video by asking students to collaborate around the various adaptations about the management of light. List the adaptations. Once students have a list of 3 or 4 different adaptations / light management strategies, ask them to think about how we could apply these light management strategies to passive solar building design. Example adaptations / light management strategies: - Structure allows more sunlight in, or less sunlight - Structure slows the transfer of light energy - Structure removes the details, perhaps only allowing certain wavelengths through - Structure allows light energy to be “used again” Finish with students revisiting their model OR move to 4b, which is an investigation. *This question does NOT apply to the sub-atomic level of energy transformation.	

4b.	**Guiding question: How (at the macro level) do different materials and structures convert light energy into different forms of usable energy? (Investigation)**	Estimated time: **100 - 120 minutes** (two 50-minute class periods)
	Exploring Heat Management: ● Lab: Teach Engineering: Insulation Lab ● Adaptation to be used in conjunction to the above lab: Perform the adaptation outdoors	

	if possible. Use the classic can calorimeter. Add 200ml of water into the can and allow it to equilibrate to the can and outdoor temperature. Place the thermometer into the water and record the initial temperature. Wrap the can in the insulating material you want to test and place the can in direct sunlight. After 30 minutes, record the temperature. Noting the change in temperature, and knowing the volume of water, calculate the energy gain of the water and infer the insulation’s effect. • Class discussion: Management can also be holding warm or cool air in addition to trying to keep it out. Discussion: How is Earth’s atmosphere like an insulator? How is it changing? Finish with students revisiting their model to make modifications.

5.	**Guiding question: How does the conversion of light to other forms of energy relate to passive and/or active solar energy management?**	Estimated time: **100 - 120 minutes** (for individual completion of task) **60 - 90 minutes** (for “Jigsaw” completion of task)
	Teachers may choose to have each student participate in this exploration individually or may want to “Jigsaw” the activity. What is Solar Energy? (“Student Informational Text” on page 41) We will be looking at different kinds of energy use; both are important and they’re not mutually exclusive. You should use both to maximize the potential of solar energy. ACTIVE: Use the anatomy of a solar panel (light-->electricity-->heat) & the analogy of a plant (photosynthesis). Photosynthesis to plants is what solar panels are to humans - actively transforming light to another form of energy. Look at this diagram, Solar energy is an infinite source of energy which can be harvested. Which is better at capturing solar energy? Plants vs Solar Panels PASSIVE: Using abundant energy patterns to transfer light energy to other forms. How can we use **biomimicry,** *noun; the design and production of materials, structures, and systems that are modeled on biological entities and processes,* to guide habitat designs that manage and utilize the abundance of solar energy. *Biomimicry has been utilized in the use of materials and design of tools and structures by indigenous peoples*	

throughout time.

Animal Engineers: After reading the article, “Effects of Solar Radiation on Animal Thermoregulation”, what are some animal adaptations that can inform and be applied to habitat architecture that will assist in Solar energy management?

Example:
Termites (Ants)
Animals manage solar energy in a variety of ways. Termites and ants build very sophisticated structures that are well adapted to manage solar energy. Are there biomimicry opportunities from termites and ants that can be applied to the design of human habitats? Watch Termite Architecture | Trials Of Life | BBC Earth to see how this occurs, or See how termites inspired a building that can cool itself.

Adaptations of organisms using materials and structure; Using Nature's Genius in Architecture

Post the statement: “The energy from the sun is a gift, there is an abundance. If organisms have used this as an abundance to help them, how can we? Does your design utilize the abundance of sunlight?”

> *“Virtually all native cultures that have survived without fouling their nest have acknowledged that nature knows best and have had the humility to ask the bears and wolves and ravens and redwoods for guidance. They can only wonder why we don’t do the same.”*
>
> - *from Biomimicry by Janine M. Benyus*

Energy audit - looking at how much energy home uses and comparing to how many solar panels one would need to power, then make changes such as blinds, insulation, etc. and make another connection to how many solar panels one would need. You can use “Cost of Using Machines Investigation” from the NEED Energy Project “Schools Going Solar” (page 33) as an example of the data needed to conduct an energy audit. This tool is designed for an energy audit of a school.

Finish with students revisiting their model to make modifications.

6.	**Guiding question: How does light intensity affect solar energy management?**	Estimated time: **100 - 120 minutes** (add time for extension if desired)
	Through this series of explorations, students will find the relationship between the angle and the intensity of light. Students will start globally and work toward a more local impact and understanding. For the first exploration, the exercise found at NASA’s “Meteorology: An Educator's Resource	

	for Inquiry-Based Learning for Grades 5-9", guides students through inquiry of the relationship between the geographic location, time of year, and the angle of the sunlight. *There is an introductory activity with a stick in the ground. Instead of this, you may want to:* "Shoot the Sun" (activity outline follows) You will make an apparatus that allows you to measure the angle of the sun and the apparent change in its path over time (daily, weekly…) 1. Pound a nail (16 penny; framing nail) into a board on one of the board's face sides, towards the end of the board. The board needs to be large enough to support the student's lab notebook or a sheet of paper. 2. Go outside and set the board down on a level surface that will not change over time and is in direct sunlight (note the time). Orient the board so the nail end is oriented to the south (use a compass or a phone app compass). You will use the same site for multiple readings over time (daily, weekly …) 3. Notice that the nail creates a shadow. Draw a line in your notebook that represents the length of the shadow and its angle from the nail. Date your line. 4. Repeat steps 2-3 at the same time each day for a period of time. You may choose to do this daily for a week or month. Or, you may choose to do this on a particular day each week at the same time for the entire school year. 5. Have students plot the length of the line as well as the angle change versus date. 6. Have students discuss how this data informs them in their design of their building and be prepared to defend their design using Claim, Evidence, Reasoning. Following the activity, facilitate a discussion about Monthly Average Maps from NREL (scroll about ⅓ of the way down the page) of the US showing the solar radiation averages. Ask students to note and explain any patterns. *For a deeper dive into solar radiation patterns, use the US Solar Radiation Resource Maps site. Students are able to select different data sets, data collection types, and times of year to fully explore the relationship between time of year and solar radiation.* Allow students to explore their home solar exposure by typing their address into, Google: Project Sunroof. Explore how to design with the sun in mind. Take a look at Engineering and Architecture: Passive Solar Design House Orientation & Window Placement After exploring light intensity effects on solar energy management, ask the students to revisit their model. Based on where their home is being built, are they managing the abundance of light? What changes should be made to their design to do this?

7.	**Guiding question: What designs/materials have been used and are in use now that utilize/mitigate the use of passive and active solar energy?**	Estimated time: **100 - 120 minutes** (some research could be homework)

We have used light to understand how it interacts with materials. Now, we need to think about what materials and designs are appropriate for construction, and which materials and designs are best. The end goal is to design a structure that uses the abundant resource of solar energy in both passive and active energy resource management. We would like you to find three resources that inform you in management of solar energy to minimize your use of energy from other sources, thus decreasing your carbon footprint.

Help the students understand good resources by exploring the following with the class, on the overhead or with a list.

- Passive House Northwest Building Directory
    - On this website is a list of different buildings built specifically for passive solar energy management in the Pacific Northwest. It includes images of the homes, designs, and specifications for the materials, ventilation, and performance. It also lists the building team, which would make for good contacts for students to deepen research by talking with experts.
- Native American Homes
    - Explore how indigenous people within our local regions, and throughout North America used natural materials that were in abundance to engineer different styles of homes, with climate zone needs in mind. This website includes photos of each style of home, and descriptions of why specific tribes used that design and materials.
- Insulation Materials from the Department of Energy
  Describes efficiency of different insulation materials used in construction.

Encourage the students to reach out to some of the local businesses that are using these specific techniques and materials.

This would be a good time to include proper research techniques, and citation formats. Writing Videos for Kids: How to Evaluate Sources for Reliability, is a great reminder.

After exploring light intensity and the efficiency of materials as insulation, ask the students to revisit their model. Based on where their home is being built, are they using cost efficient materials to manage the light? What changes should be made to their design and material to do this?

8.	**Guiding question: How would you apply the information about solar energy management, materials, and light intensity to design your "dream" future home? ****	Estimated time: **250 - 300 minutes** (some can be done outside of class)

Identify and categorize costs and benefits by discussing the primary categories that they fall into are direct/indirect, tangible/intangible, and real:

- Direct costs are often associated with production of a cost object (product, service, customer, project, or activity)

	• Indirect costs are usually fixed in nature, and may come from overhead of a department or cost center • Tangible costs are easy to measure and quantify, and are usually related to an identifiable source or asset, like payroll, rent, and purchasing tools • Intangible costs are difficult to identify and measure, like shifts in customer satisfaction, and productivity levels • Real costs are expenses associated with producing an offering, such as labor costs and raw materials Incorporate this editable cost/benefit analysis for students to track the scientific rationale for choices of materials and structure of the solution, and how this solution will reduce the need for energy from other sources. From the NEED Energy Project "Schools Going Solar", activity on page 36 "Can Solar Energy Meet Your Electricity Demands?" Utilize this interactive map, FEMP Screening Map from NREL, to further the discussion around cost/benefit. Reminder: The goal is to build a home that is more energy efficient and therefore less carbon-emitting, and the students will want to choose materials that are safe from the elements. This learning session results in the student's "Post Assessment" artifact - a physical model with annotations and explanations (see the assessment rubric for boundaries). **Option: Instead of a dream home, students work in groups to design a Habitat for Humanity home or a school, etc.

9.	Guiding Question: How does solar energy management draw down carbon from the atmosphere?	Estimated time: **120 minutes**
	1. As a review, students watch Climate Science in a Nutshell #4: Too Much Carbon Dioxide followed by Climate Science in a Nutshell #5: Where Does Carbon Dioxide. Students diagram how: a. the light waves from the sun are absorbed by the surface of Earth and transformed into thermal energy b. the thermal energy is reflected by the atmosphere back to Earth c. increasing the amount of carbon dioxide increases the amount of thermal energy reflected back to Earth thus increasing the temperature of the planet 2. Students use the format CER to respond to the question: "How does solar energy management draw down carbon from the atmosphere?"	

10.	Possible next steps/ extensions:	
	• Explore the subatomic physics of heat transfer and the energy transformation of light to thermal energy. • Connecting with Habitat for Humanity • Connecting with construction teacher or local industry partners	

11	Post Assessment:	Estimated time: **20 minutes**
	HS-Renewable Energy: Solar Post -Assessment Generational Stewardship: Defense of design, overarching idea to work with abundance of energy - SHOUT OUT to community to reduce greenhouse gasses. Reducing energy and greenhouse gasses from other sources, (i.e. refrigerant, heating, cooling). Explain cost-benefit analysis.	

12.	Peer Review:	Estimated time: **Dependent on class**
	Allow students to peer review other students' work. They will need to analyze three other designs. Within their analysis students should address constraints of the job including, but not limited to; report on total cost of the job, safety of the structure, reliability of modifications for active and passive use of sunlight, as well as aesthetics or looks of the final design. This can be done with a 'rotation station' idea - move the classroom around stationary designs at the table, or peer review as each student presents their design to the class. HS- Renewable Energy: Solar Assessment Rubric	

HS-Renewable Energy: Solar OER Tracker

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