AN OUTLINE FOR A GREEN SCHOOLS ENERGY CURRICULUM

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The course outlined here targets middle school ideas about energy resources and the responsible use of energy in a "Green Schools" context, that is, a context that focuses on reducing the environmental impact of energy use in schools and improving sustainable practices, with applications to students' homes as well. The ideas and activities are organized into five units, and we recommend that a minimum of two weeks be spent on each unit. If the instructional time is available, an entire course could be devoted to the ideas presented in this outline.

The five units in the course are:

1. Energy and Energy Resources: Why We Need Energy, How Much We Use, and How We Get It
2. From Energy Resources to Energy Use: Transfer and Transformation
3. Natural and Artificial Light
4. Staying Warm and Staying Cool
5. Putting It All Together: Designing and Maintaining Greener School Buildings

The first two units focus on what energy is, why we need it, how much we use, where it comes from, how the energy in energy resources is converted into a useable form, and the costs and consequences associated with those energy conversions. The third and fourth units look more closely at two examples of how energy is used in schools. Students examine the use of energy resources to generate artificial light and to heat and cool their school buildings. The focus in these two units is on the nature of light and heat and the comparative efficiency of different ways of lighting, heating, and cooling a school building as well as ways to use less energy. In the final unit, students explore ways to re-engineer their school building so that it uses less energy and uses energy resources that minimize negative impacts on the environment. Students think about changes that could be implemented immediately as well as those that could apply if a new building were being designed.

Alignment to standards. The course is aligned to the performance expectations from *Next Generation Science Standards* (NGSS) and the disciplinary core ideas, crosscutting concepts, and science and engineering practices that are embedded within those performance expectations. It also draws from statements in *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education* prepared by the U.S. Department of Energy (DOE). The *Energy Literacy Framework* is a major policy document developed by several governmental agencies with the help of professional organizations interested in the application of energy concepts to the everyday lives of American citizens. Because of the applied focus of the DOE statements, they add another important dimension to students' learning experience.

We use the NGSS **performance expectations** to model the deliberate integration of science and engineering practices, disciplinary core ideas, and crosscutting concepts that is the focus of NGSS. A number of these crosscutting concepts and science and engineering practices recur throughout the course: The flow of energy through designed and natural systems, the use of graphs and charts to identify patterns in data, and the use of models to represent systems and interactions are just some of the crosscutting themes that are addressed repeatedly across the five units. Science and engineering practices include gathering, evaluating, and using information from multiple sources to answer scientific and engineering questions; analyzing and interpreting data; constructing and interpreting graphical displays of data; using basic mathematical concepts to help answer scientific and engineering questions; and engaging in argument from evidence. The full list of NGSS crosscutting concepts and science and engineering practices addressed in the course includes:

NGSS Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

NGSS Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and defining solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Targeted grade level. The primary intended audience for the course is middle school students between grades six and eight, although many high school students will find these activities useful as well. It is assumed that students will already have had an introduction to energy and energy resources to the extent recommended for the elementary grades in NGSS and other national standards documents. To ensure a smooth progression to the ideas covered in this course, most of the units are introduced with one or more of these elementary level ideas. Some Grade 9-12 ideas are also included in the course outline because they are important for creating a coherent storyline, and we think the ones we have chosen can be taught at a level appropriate for middle school students.

Supplementary ideas. A few ideas and activities are labeled "supplementary." These ideas and activities fit well into the storyline but addressing them may have to wait until students are ready for their higher level of sophistication. We assume that most middle school students will not be introduced to these ideas during this course.

Unit organization. This course outline includes the following information about each unit: (1) a narrative description that introduces the unit's key learning goals and the general nature and purpose of the activities that students will engage in, (2) a list of the specific performance expectations from NGSS (including the NGSS clarification statements when available) and statements from the Department of Energy's *Energy Literacy Framework* targeted in the unit, and (3) bulleted lists of suggestions for activities designed to help students gain the required knowledge and skills.

In the description of each unit, the targeted DOE statements and NGSS performance expectations have been sequenced into a coherent storyline. In some cases, the text for a particular part of an NGSS or DOE statement has been grayed out to indicate that it is not relevant to the theme of the course and is not included as a learning goal for students. Because the DOE statements are not grade-range specific, the suggestions for instructional activities have been designed to be appropriate for the middle grades.

This proposed Green Schools Energy Curriculum is meant to move us closer to a vision of science education in which understanding science concepts is connected to how science is done. This outline provides an introduction to what a Green Schools course might look like along with suggestions for activities that can be used to address the target learning goals. The next step will be to identify relevant and engaging data sets and readings that can become the focus of the activities of an actual curriculum.

UNIT 1

ENERGY AND ENERGY RESOURCES: WHY WE NEED ENERGY, HOW MUCH WE USE, AND HOW WE GET IT

The focus of this unit is on humans' need for energy to do the things they want to do and the environmental consequences of that energy use, whether the energy resources are used directly or converted to other forms before they are used. Many energy resources are limited, and even when they are not, there are costs associated with converting the energy in those energy resources into a form of energy that can be used. Students explore how energy is used by humans and how much is used, and they design ways to minimize the negative consequences of energy use and how to be responsible stewards of environmental resources. They examine a variety of energy resources such as fossil fuels, wind, biofuels, geothermal resources, and the sun, as well as the environmental consequences and economic impact of obtaining energy from those resources. And they examine the effect that changes to the environment have on populations of organisms in that environment.

Two elementary school ideas lay the foundation for this unit: The NGSS Disciplinary Core Idea for Grade 4 under Natural Resources says: "Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not." The Grade 3 Disciplinary Core Idea under Ecosystem Dynamics, Functioning, and Resilience also helps focus the unit: "When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die." The important idea in this second statement is that when environments change, the populations of organisms that can survive in those environments may change as well. In addition, the NGSS middle school Disciplinary Core Idea for Global Climate Change contains another concept that is central to this unit: "Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming)." Although there are other causes of ecosystem disruption, global warming is now generally considered to be the main intermediary step between the use of natural resources (especially the burning of fossil fuels and agricultural practices) and habitat disruption.

Expected Learning Outcomes and Suggestions for Instructional Activities for Unit 1

1. NGSS 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile[1] materials. Examples of

[1] Fissile materials are materials whose atoms can be easily split at the nuclear level.

environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

- Explain different ways that energy can be generated from energy resources. Use models to support your explanations. Models can be graphical or conceptual.
- For a variety of energy resources (e.g., sun, wind, fossil fuels, etc.) describe how each can be used directly and how the energy in these resources can be converted into other forms of energy or into other energy resources such as electricity before being used.
- Describe various energy resources (wind, water behind dams, sunlight, fossil fuels) and how the use of each of them affects the environment (e.g., birds killed by the rotating blades of windmills, loss of habitat due to the creation of dams, oil spills, mountain top removal, or air pollution from burning fossil fuels).

2. NGSS MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

    - Examine reports that include data on changes in resource availability (food, water, nesting sites, shelter, etc.) and changes in the numbers and health of organisms in ecosystems in relation to those environmental changes.
    - Choose a population of organisms living in a particular region whose ecosystem has been recently disrupted. Analyze and interpret data on changes in the numbers of organisms in that region (either increased or decreased) and the environmental changes that have taken place. Make an argument that the changes in the number of organisms are due to changes in resource availability. (Resources can include food, water, nesting sites, shelter, etc.)
    - Compare results of the population study with other members of the class and use the combined data to construct a general argument about the effect of resource availability on numbers of organisms in ecosystems. Present your argument to another team for rebuttal, and then refine your claim using additional evidence and sound logic.
    - Interview long-term community members who have witnessed changes to the environment in that community. Ask them to describe the environmental changes in their community and changes in the number and type of organisms in that environment.

3. NGSS MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience[2] processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), [and] metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).

    - Describe how many of earth's energy resources (e.g., coal, fuel oil, natural gas) result from past and current geoscience processes such as the burial of organic sediments.

[2] geological

- Examine data on where energy resources are located around the world and how the availability of each energy resource has changed over time as it has been removed and used by humans. Create charts and tables to summarize the findings.
- Examine data that show the increasing difficulty and cost of extracting and transporting energy resources as they are used up. Create charts and tables to summarize the findings.
- Discuss additional costs (such as social or environmental costs) that go beyond the direct economic costs of using certain energy resources (e.g., health care costs or costs associated with the loss of species diversity). Discuss possible ways to measure and quantify those costs.

4. DOE 4.4. Humans transport energy from place to place. Fuels are often not used at their source but are transported, sometimes over long distances. Fuels are transported primarily by pipelines, trucks, ships, and trains. Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy to distant locations. Electricity is not a primary source of energy, but an energy carrier.[3]

5. Describe how primary energy resources such as biofuels and fossil fuels are obtained and transported from their source to where they are used (by pipelines, trucks ships, etc.), often to different parts of the world.

    - Examine data on how much energy is needed to extract and transport various resources. Create charts and tables to summarize the findings. (This activity should include the transport of fuels to the site of electricity generation but not the actual generation and transmission of electricity, which is covered in a later activity.) Compare the amount of energy needed to extract and transport different fuels.
    - Examine data comparing the cost of electrical generation to what is charged to the consumer for electricity. Discuss why consumers pay more for electricity than it costs to generate the electricity. Include electricity generated by wind, hydropower, and the burning of fuels.
    - Students find online maps of the electrical grid in the U.S. and share them with the rest of the class. Discuss costs associated with moving electricity between locations.

6. DOE 6.4. Earth has limited energy resources. Increasing human energy consumption places stress on the natural processes that renew some energy resources and it depletes those that cannot be renewed.

    - Examine data on the use of energy resources locally, nationally, and globally over time (e.g., month-to-month or year-to-year). Compare trends in overall usage over these time periods. Use scientific notation (powers of ten) to describe the energy usage. Create charts and tables to summarize the findings.
    - Examine data on how energy is used in school buildings, including the percentage of the total that is used for heating, cooling, water heating, cooking, refrigeration, office equipment and how much the energy for each of these functions costs. Track trends in usage by year and by month. Create charts and tables to report the findings. Compare local averages to national averages in each category.

[3] The grayed out section is an important idea that is covered in the next unit.

- Examine the overall energy usage in a particular school building in all relevant categories (electrical, natural gas, heating oil, etc.). Plot usage trends by month and by year. Compare the school's energy usage to that of other schools. Share data online with other students at other schools and identify possible causes of large differences between schools.
- Discuss with classmates and with students at other schools how increasing human energy consumption depletes non-renewable energy resources and makes it more difficult to obtain them. Begin to generate ideas within the local school and between schools about how energy usage could be reduced by changing human behavior, such as how people use lights, fans, thermostats, etc.
- Apply what is learned from the examination of the school's energy use and cost to the use and cost of energy at home. Consider ways to use less energy at home and between home and school.

7. NGSS MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

   - Examine evidence that human activities such as the burning of fossil fuels have caused the rise in global temperatures over the past century. Evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the change in the rate of human activities.
   - Teams of students generate arguments that human activities have caused an increase in global temperatures over the past century. Present the argument to other teams for rebuttal. Refine the arguments using additional evidence and sound logic. Identify questions that still need to be answered to clarify the evidence.
   - Compare data estimating the impact that major human activities (transportation, heating and cooling, agriculture, cement production) have on increasing the level of atmospheric gases.

UNIT 2

FROM ENERGY RESOURCES TO ENERGY USE: TRANSFORMATION, TRANSFER, AND LOSS OF ENERGY TO THE ENVIRONMENT

In the second unit, students focus on the transformation and transfer of energy, tracing pathways that begin with primary resources and that end with energy in a form that can be used by humans. Pathways include the path that the generation of electricity takes from wind and moving water that turn turbines, and the use of fossil fuels to generate steam or hot water that can be used to warm the air in buildings. Attention is paid to the energy efficiency of the transfers and transformations as well as the monetary and environmental costs of each. Students conduct cost-benefit analyses to compare the cost and efficiency of retrieval, transformation, and transfer of energy for different energy resources. Costs also include the cost of manufacturing devices to capture energy (e.g., solar panels). Students explore the environmental costs of transfers and transformations on habitat disruption, air and water pollution, and the production of greenhouse gases.

There are two central ideas that are explored in this unit. The first is that energy can be converted from one form to another and transferred from place to place; the second is that these conversions and transfers are not completely efficient because some energy is always lost to the surrounding environment. Again, an elementary school idea sets the stage for this unit: The Grade 4 NGSS Disciplinary Core Idea from PS3.A: Definitions of Energy captures the first idea: **"**Energy can be moved from place to place by moving objects or through sound, light, or electrical currents." The second idea is captured in the Grades 9-12 idea from PS3.D: Energy in Chemical Processes and Everyday Life: "Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment." It is also captured by the DOE *Energy Literacy Framework* statement 1.4: "Energy available to do useful work decreases as it is transferred from system to system. During all transfers of energy between two systems, some energy is lost to the surroundings. In a practical sense, this lost energy has been 'used up[4],' even though it is still around somewhere. A more efficient system will lose less energy, up to a theoretical limit." Unit 2 focuses on the conversion of energy from the sun to energy stored chemically in the biomass[5], the conversion of energy in moving air and moving water to generate electrical energy by way of turbines and electrical generators, and the spontaneous transfer of energy from hotter to colder regions. Additional conversions involving the generation of electricity by way of solar cells are considered supplementary ideas for more advanced students.

Expected Learning Outcomes and Suggestions for Instructional Activities for Unit 2

1. NGSS 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

    - Provide examples from personal experience of energy being transferred from one place to another by light, heat, and electric currents (e.g., light bulbs, electric fans). Identify the energy source and the observable action or outcome that provides evidence that energy is being transferred. Create charts, tables, and video presentations to summarize the findings. Combine data from other students in the class to create a master list of energy transfers.

2. DOE 4.1. Humans transfer and transform energy from the environment into forms useful for human endeavors. The primary sources of energy in the environment include fuels like coal, oil, natural gas, uranium, and biomass. All primary source fuels except biomass are non-renewable. Primary sources also include renewable sources such as sunlight, wind, moving water, and geothermal energy.

    - For a variety of energy resources (e.g., sun, wind, fossil fuels, etc.) describe how the energy in each can be converted into forms of energy that can be used by humans.
    - Choose one of these energy resource and construct a conceptual model (diagram, flow chart) that shows how the energy from that resource can be converted into a form of energy that can be used by humans
    - Create a diagram to show how the kinetic and potential energy of water changes as dammed water goes over a waterfall and the kinetic energy is used to do useful work.

3. DOE 4.3. Fossil and biofuels are organic matter that contains energy captured from sunlight. The energy in fossil fuels such as oil, natural gas, and coal comes from energy that producers such as

[4] Teachers should make sure that students do not think that energy is "used up," but rather converted to other forms or transferred from one place to another.

[5] The biomass is the organic (biological) material derived from living or recently living organisms. For our purposes it refers exclusively to plant material.

plants, algae, and cyanobacteria captured from sunlight long ago. The energy in biofuels such as food, wood, and ethanol comes from energy that producers captured from sunlight very recently. Energy stored in these fuels is released during chemical reactions, such as combustion and respiration, which also release carbon dioxide into the atmosphere.

- Use a model (e.g., diagram, chemical equation) to illustrate how photosynthesis transforms light energy into stored chemical energy. Include each type of molecule that reacts during photosynthesis and each type of molecule that results. Indicate where the chemical energy is stored and how it is released.

4. DOE 4.4. Humans transport energy from place to place. Fuels are often not used at their source but are transported, sometimes over long distances. Fuels are transported primarily by pipelines, trucks, ships, and trains.[6] Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy to distant locations. Electricity is not a primary source of energy, but an energy carrier.

    - Examine data showing the efficiency of retrieving, converting, and transporting different energy resources to produce electricity. For example, note that energy generated by solar panels on a school or home roof does not have to travel very far to be used. Create charts and graphs to summarize the findings.

5. NGSS 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.

    - Using basic materials including magnets, wire, and ammeter (or, instead of an ammeter, other electrical devices that can be used to show a flow of electricity such a light bulb or small motor), demonstrate that a changing magnetic field can cause an electric current to flow in a wire. Describe how this basic phenomenon is related to the generation of electricity using an electric generator.

6. DOE 4.5. Humans generate electricity in multiple ways. When a magnet moves or a magnetic field changes relative to a coil of wire, electrons are induced to flow in the wire. Most human generation of electricity happens in this way. Electrons can also be induced to flow through direct interaction with light particles; this is the basis upon which a solar cell operates. Other means of generating electricity include electrochemical, piezoelectric, and thermoelectric. (Supplementary)

    - Create a model to show how a turbine and generator can create electricity from other energy resources. The model should include a schematic illustration of the process along with explanatory text. (Supplementary)
    - Describe how a solar (photovoltaic) cell can generate an electric current when photons of energy remove electrons from the semiconductor, typically made of silicon, to create a voltage differential. Create an illustration to show the critical components, the part that each plays, and the steps of the process. (Supplementary)

7. DOE 1.4. Energy available to do useful work decreases as it is transferred from system to system. During all transfers of energy between two systems, some energy is lost to the surroundings. In

[6] The transport of energy resources is an important idea that is covered in the previous unit.

a practical sense, this lost energy has been “used up[7],” even though it is still around somewhere. A more efficient system will lose less energy, up to a theoretical limit.

- For several energy transfers and conversions, identify places where friction (including air and water resistance) can reduce the efficiency of energy transfers and conversions. (Students are not expected to quantify the reduction in efficiency.) Discuss whether it is possible for a system to be 100% efficient.

8. DOE 4.7. Different sources of energy and the different ways energy can be transformed, transported, and stored each have different benefits and drawbacks. A given energy system, from source to sink[8], will have an inherent level of energy efficiency, monetary cost, and environmental risk. Each system will also have national security, access, and equity implications.

- Examine data showing the efficiency of retrieving, converting, and transporting different energy resources. Create charts and graphs to summarize the findings.
- Compare the economic and other social costs of retrieving, converting, and transporting different energy resources.
- In groups, select an energy resource and describe the advantages and drawbacks of retrieving, converting, and transporting that resource compared to the others. Communicate the results to the rest of the class and then, as a class, discuss what aspect of the process they want to maximize (e.g., sustainability, affordability) to determine which is the best energy resource for their school or home.

UNIT 3

NATURAL AND ARTIFICIAL LIGHT

In Unit 3, students learn about different options that are available for generating light and how to use light and the energy resources that can be used to generate light in the most responsible way. If light meters are available in the school, students can use them to observe changes in the amount of light in their classroom throughout the day as they explore their need for artificial light to supplement the natural light that comes into the classroom. They also create models of the changing angle of the sun on their school throughout the day and from season to season as well as the effect that the changing angle of the sun and cloud cover have on how much natural light is available at different times of the day and year.

The focus of this unit is on the light from artificial and natural sources that we need to be able to see—natural light from the sun and artificial light from devices that convert electrical energy to visible light. Students should already know that objects are visible when light, either from the sun or from a light bulb, is reflected off the objects or reaches a detector, such as an eye. This idea is covered in the Grade 4 NGSS Disciplinary Core Idea PS4.B: Electromagnetic Radiation, “An object can be seen when light reflected from its surface enters the eyes.”

Students also know from Unit 2 that energy from a variety of sources can be converted to electricity, which in turn can produce light, and they know from Unit 2 that energy conversions are not completely efficient. Some energy is always lost to the surrounding environment. In Unit 3, students compare the efficiency of different light bulbs by measuring how much each one raises the air temperature of a

[7] See note 4.
[8] Source to sink: Where energy comes from and where it goes.

confined space. They also explore the daily and seasonal changes in the angle at which light from the sun strikes their school building. This idea is covered in the Grade 5 NGSS Disciplinary Core Idea from ESS1.B: Earth and the Solar System**: "**The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its north and south poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year." Although Unit 3 provides an opportunity to explore the wave nature of light, we consider all but the most elementary descriptions of the wavelength and frequency of light to be supplementary ideas for teachers who want to use this context to present a more detailed description of the light spectrum, the wave nature of light, and how light of varying wavelengths and frequencies is perceived.

Expected Learning Outcomes and Suggestions for Instructional Activities for Unit 3

1. NGSS 4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eyes allows objects to be seen.

    - Develop a model to show that objects are seen when light moving in a straight line and reflecting from the objects enters the eye. Models should include drawings and written descriptions.[9]
    - If light meters are available, use them to measure and record light intensity in different parts of the classroom. Compare results across locations of the room or school, at different times of the day, from day to day, and with and without artificial light. Answer the question: How much light do we need to see clearly and do our work comfortably? How important is it that we have a constant degree of illumination?[10]
    - Build a "dark box" from a copier-paper box (or similar size box). Place a book in the box and ask students to read what it says. Change the intensity of light shining on the book or cover the top of the box with different materials. Create a semi-quantitative scale of 0-9 to indicate the ease of reading under each condition. Compare the results with the results from light meter readings if they are available.

2. NGSS MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

    - Use [AAAS's weather and climate simulation activities]() to generate graphs and tables of the sun's angle and energy from the sun at four different times of year (spring, summer, fall, and winter) for your school's location to compare how much natural light is available at different times of the year.
    - Use a physical model of the earth-sun system to explain the cyclic pattern of the seasons and the changing angle at which the sun strikes the earth at different locations.
    - Describe how the changing angle of the sun's rays affects the amount of energy transferred from the sun, which then affects such things as the need for artificial light, the need for artificial heating and cooling, and the growth of plants and trees[11].

[9] Models of the eye should be as simple or complex as the students' knowledge of the structure of the eye allows. It is not intended that this will be a place where details of the anatomy of the eye are introduced.

[10] For a discussion of what is required to perform different kinds of tasks comfortably, see, for example: www.ccohs.ca/oshaanswers/ergonomics/lighting_survey.html

[11] Plant growth is important in a school environment for aesthetic reasons, as a way to maintain comfortable temperatures due to rooftop gardening, and as a potential source of biofuels.

3. DOE 1.4. Energy available to do useful work decreases as it is transferred from system to system. During all transfers of energy between two systems, some energy is lost to the surroundings. In a practical sense, this lost energy has been “used up[12],” even though it is still around somewhere. A more efficient system will lose less energy, up to a theoretical limit.

    - Place different types of light bulbs, each having the same rated lumen output but using different technologies to produce the illumination (LED, CFLs, incandescent bulbs), one at a time in a closed insulated box and measure the increase in temperature in the box after 15 minutes. Use the increase in temperature inside the box as an indicator of energy lost to the environment. Use the results to compare efficiencies of different types of light bulbs.
    - Observe and record the types of light bulbs used at home. Discuss with others in the class the reasons why people buy the kinds of light bulbs they do.

4. DOE 6.2. One way to manage energy resources is through conservation. Conservation includes reducing wasteful energy use, using energy for a given purpose more efficiently, making strategic choices as to sources of energy, and reducing energy use altogether.

    - Based on current usage and cost, quantify the energy cost savings of reducing the amount of artificial light used in your school building (1) if no artificial light were used, (2) if half the amount of artificial light were used. Discuss which amount of energy reduction is most likely to actually be implemented in a school building and how that might be done.

UNIT 4

STAYING WARM AND STAYING COOL

The focus of Unit 4 is on the transfer of thermal energy by convection, conduction, and radiation[13]. As in Unit 3, students create models of the changing angle of the sun on their school throughout the day and from season to season, but in this unit the emphasis is on how those changes affect how much the sun warms the school building at different times. Students also model the transfer of energy between the outside and the interior of the classroom by conduction across the walls and windows of the classroom by observing the rate of transfer across different materials and estimating R-values for those materials. They also observe the effects of convection currents on various suspended objects in the classroom and identify places where energy can move around a door or window if those barriers are not sealed properly. Where available, energy audits should be conducted to help students locate where energy is lost and gained. Even though the focus in this unit is on ways to make the school warmer by heating, not on ways to make it cooler by air conditioning, students will also consider ways to minimize the effect that warm air from outside the building has on air conditioned air inside the building and recognize that energy is needed to counter that effect. Students learn that air in buildings is heated when fossil fuels are burned to heat a liquid, generate steam, or superheat steam, which then flows through pipes to transfer thermal energy from the boiler to other locations, and that air in buildings can also be heated by electric radiant or convection heaters.

The transfer of thermal energy is covered in a Grades 6-8 NGSS Disciplinary Core Idea under PS3.B: Conservation of Energy and Energy Transfer: **“**Energy is spontaneously transferred out of hotter regions

[12] See note 4.

[13] Some teachers may choose to introduce “advection,” as a fourth transfer mechanism, that is, the transfer of energy by a fluid due to the fluid's bulk motion. Unlike convection, advection does not include diffusion.

or objects and into colder ones." That statement covers the transfer of energy by convection and conduction, but energy is also transferred directly from one object to another by radiation. The transfer of energy from the sun is particularly important when it comes to heating and cooling our buildings because the intensity of this energy varies throughout the day and year. That idea can be found in the Grades 6-8 NGSS Disciplinary Core Idea under ESS1.B: Earth and the Solar System**: "**…Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons[14] are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year."

Expected Learning Outcomes and Suggestions for Instructional Activities for Unit 4

1. DOE 1.2. The energy of a system or object that results in its temperature is called thermal energy. When there is a net transfer of energy from one system to another, due to a difference in temperature, the energy transferred is called heat. Heat transfer happens in three ways: convection, conduction, and radiation[15]. Like all energy transfer, heat transfer involves forces exerted over a distance at some level as systems interact.

    - Examine the heating/cooling system of your school. Describe the fuel source and how energy from the fuel source is distributed as thermal energy throughout the building by radiation, convection, and conduction.
    - Observe unforced air convection in the classroom by watching what happens to the motion of various objects when they are suspended from the ceiling, e.g., paper spirals, balloons, hanging ribbons. Describe any patterns that you observe in how thermal energy is transferred from one part of the classroom to another by convection.
    - Hold tissue paper in front of heating vents in the classroom to observe forced convection. Describe how thermal energy is transferred from one part of the classroom to another by forced convection. Compare natural, unforced convection to forced convection in terms of the relative amount of energy used to move the air.
    - Observe energy transfer by radiation by placing your hand near an incandescent light bulb; then place an object between the light bulb and your hand in order to block the radiation from reaching your hand. Describe how thermal energy is transferred from one part of the classroom to another by radiation.

2. NGSS HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.]

    - Design and conduct a set of investigations to test what happens to the temperature of a quantity of water when water at different temperatures is added. Compare the final temperature when different amounts of colder or warmer water are added, controlling for time, amounts of liquid, and surrounding air temperature. Graph the results and explain your observations in terms of thermal energy transfer.

[14] It should be noted that not all places experience "seasons" to the same extent. In places located within the tropical zone, the amount of energy received from the sun throughout the year does not vary as much when compared to places farther north or south.
[15] See note 13.

3. NGSS MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.]

    - Build a model house out of cardboard, using cellophane for the windows and a light bulb for the heat source, in order to explore the rate of heating and cooling under different conditions of insulation and different window areas. Conduct a controlled experiment of the effect of differing conditions on the rate of cooling/heating.
    - Estimate the average R-value of the outside wall of a school classroom.[16] (The other three walls should be interior walls so that the energy transfer can be considered to be across the outside wall only.)
    - Calculate the R-value of different materials given data on the rate of heating/cooling across the materials.[17] Combine data from the entire class to create a table that shows the insulating value of different thicknesses of different materials.
    - Arrange to have an energy audit conducted to identify where energy is moving between the inside and outside of the school building. Have parents arrange to have an energy audit done at home and compare the results between home and school. Discuss ways to reduce the transfer of energy between the inside and outside of the buildings.

4. NGSS MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

    - Use the AAAS weather and climate simulation activities to generate graphs and tables of air temperature, sun's angle, and energy from the sun at four different times of the year for your school's location (spring, summer, fall, winter) to qualitatively compare how much the sun can be expected to warm the school at different times of the year.
    - Graph monthly (or daily, if available) energy usage for heating or cooling against the angle of the sun, cloud cover, average temperature, etc., to look for patterns between these variables and energy usage. When interpreting the data, consider the impact that the presence of students and teachers in the building might have on energy usage compared to when the building is empty.

    - Use a physical model of the earth-sun system to explain the cyclic patterns of the position of the sun in the sky and how this affects how much the sun warms the earth at different times of the year.

5. DOE 6.2. One way to manage energy resources is through conservation. Conservation includes reducing wasteful energy use, using energy for a given purpose more efficiently, making strategic choices as to sources of energy, and reducing energy use altogether.

    - Find out how the school handles heating and cooling after school hours.

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[16] The average R value of a material separating the inside of a classroom from the outside can be estimated by determining the rate of energy transfer across the insulating material, the temperature difference on the two sides of the insulating material, and the area of the insulating material across which the energy transfer is taking place. The rate of energy transfer can be determined by calculating the volume of the room and how fast the temperature of the room changes when a heating or cooling source is turned off. Examples will be included in a full curriculum guide.

[17] See note 16.

- In groups, discuss various ways that less energy could be used to heat the classroom. Share the results with the other groups and then create posters summarizing the results.

UNIT 5

PUTTING IT ALL TOGETHER: DESIGNING AND MAINTAINING GREENER SCHOOL BUILDINGS

In the final unit, students use their knowledge of energy resources, energy conversions, and energy use, coupled with their own creative abilities, to explore ways to make their school buildings more energy efficient and to think about what a green school building could look like if it were being designed and built for energy conservation and sustainability. In addition to sharing the results of these explorations and designs with students in their own class, students also use an online forum to share results with students around the world. In this way, students learn about efforts that are being made to conserve energy and to design more energy-efficient school buildings in other places. They also learn about these conservation efforts by reading about award-winning Green Ribbon Schools recognized by the U.S. Department of Education and schools that have applied for and received LEED certification. Students also share what they have learned by developing presentations for school administrators, school boards, community groups, and community leaders.

When thinking about designs for their own school building, students are expected to use the knowledge they learned in the preceding units as they address the practical problem of choosing devices that use energy more efficiently and designing ways for people to use those devices only when needed. At the same time, students are introduced to several basic design principles that they apply as they attempt to engineer changes to their classroom, the school, and an imagined award-winning green school building. The importance of paying attention to design constraints when making changes is captured in the NGSS Disciplinary Core Idea ETS1.B (Grades 9-12): 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.”

In this unit, students are also asked to think more holistically about the flow of energy in the building and classroom from a systems perspective and to create models that show the ways that energy flows throughout the lighting, heating, and cooling systems and subsystems. The NGSS Crosscutting Concept for Grades 6-8: Systems and System Models is particularly useful here: “Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.”

Expected Learning Outcomes and Suggestions for Instructional Activities for Unit 5

1. NGSS Crosscutting Concept: Systems and System Models (Grades 6-8): (1, 2) Students understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.

    - Students draw a diagram of their classroom showing where energy is transferred in and out, and label all the different types of energy transfers and conversions. Students subdivide the lighting, heating, and cooling systems into subsystems to show how they are interconnected.

2. DOE 6.6. Behavior and design affect the amount of energy used by human society. There are actions individuals and society can take to conserve energy. These actions might come in the form of changes in behavior or in changes to the design of technology and infrastructure. Some of these actions have more impact than others.

    - Conduct online research to determine what Green Schools, Green Ribbon Schools, and LEED certification are. Read about individual Green Ribbon Schools and LEED certified schools to find out what they are doing to use energy responsibly. Describe programs at selected Green Ribbon Schools.
    - Contact administrators at a Green School to find out which behaviors were easy to change and which were difficult to change.
    - Find out what their own school is already doing to achieve Green School status and what could still be done.
    - Take the criteria used in these Green School programs to judge if a school should be considered a Green School, and design a similar “Green Homes” program. Students then use these criteria to assess their own homes and determine what it would take to become certified.
    - Groups of students interview community leaders about ways individual communities use science ideas to protect the earth’s resources and environment. Share information with classmates.

3. NGSS 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

    - Teams of students propose energy saving improvements for their school building. They then make a presentation on how the design will help the school financially, how those energy saving improvements will help (or harm) the environment, and how they will know if they have been successful in their energy saving improvements.
    - Students explain the science principles behind each improvement (e.g. fewer carbon dioxide molecules in the atmosphere, less thermal energy lost to the environment, etc.).
    - Students describe behavioral changes that people have immediate control over that could result in significant energy savings.
    - Students describe the constraints on actually accomplishing the improvements they would like to make, including cost, safety, reliability, and aesthetics. Interview school administrators, teachers, parents, and other community members to find out which designs would be welcomed and which ones would be more difficult to implement and why. Students summarize the lessons learned from their analyses of their school and describe how those lessons could be applied to their homes to improve their energy efficiency.

4. NGSS 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

    - Students compare proposed solutions to their design problems in terms of how well each solution successfully addresses the problem and takes into account the design constraints.
    - Students consider long- and short-term costs of implementing their design solutions and ways to reduce short-term costs.
    - Students share information about their design ideas for conservation with students at other schools by way of a blog post that includes data, discussion of constraints, comparisons of the environmental impacts of their design with those of other possible designs, etc. Students consider ways to combine ideas to optimize their design solutions.

- Students share the results of their research and design solutions with administrators, local school boards, and other community groups.