HS.PS-E Energy

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Students who demonstrate understanding can:

a. Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system. [Assessment Boundary: Computational accounting for energy in a system limited to systems of two or three components.]

b. Identify problems and suggest design solutions to optimize the energy transfer into and out of a system. [Clarification Statement: Design solution examples can include insulation, microchip temperature control, cooking electronics, and roller coaster design.] [Assessment Boundary: Limited to mechanical and thermal systems.]

c. Analyze data to support claims that closed systems move toward more uniform energy distribution.

d. Design a solution to minimize or slow a system's inclination to degrade to identify the effects on the flow of the energy in the system. [Clarification Statement: Examples of system degradation can include wearing down due to friction, increase in disorder, and radioactive decay.]

e. Construct models to show that energy is transformed and transferred within and between living organisms. [Assessment Boundary: Does not mean particular biological processes such as Krebs cycle.]

f. Construct models to represent and explain that all forms of energy can be viewed as either the movement of particles or energy stored in fields. [Assessment Boundary: Models representing field energies need not be mathematical.]

g. Construct representations that show that some forms of energy may be best understood at the molecular or atomic scale. [Clarification Statement: Forms of energy represented can include thermal, electromagnetic, and sound.] Assessment Boundary: Limited to conceptual understanding; quantitative representations are not required.]

h. Design, build, and evaluate devices that convert one form of energy into another form of energy. [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, and generators.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (b)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a),(f)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (e),(g)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to create explanation, computational models, or simulations. (a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (b),(d),(h)

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. (a)
- 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. (a),(e),(h)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. (h)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (f),(g)

PS3.B: Conservation of Energy and Energy Transfer

- 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. (a),(h)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (b),(c),(e),(h)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (a),(c)
- The availability of energy limits what can occur in any system. (d)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (c),(d),(e)
- Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (d)

PS3.D: Energy in Chemical Processes

- The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (e)
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (h)
- A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions. (e)
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (b),(h)

Crosscutting Concepts

Systems and System Models

Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (a),(c),(d),(e),(f),(g),(h)

- [Clarification Statement for all PEs: Energy transfer cannot be directly studied- a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined]

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems 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. (b)

HS.PS-ECT Energy *(continued)*
Connections to other DCIs in this grade-level: **HS.LS-SFIP, HS.LS-MEOE, HS.ESS-CC, HS.ESS-HS, HS.ESS-ES, HS.ESS-SS, HS.ETS-ED, HS.ETS-ETSS**
Articulation to DCIs across grade-levels: **MS.PS-E, MS.PS-CR**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **SL.1.c** Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives. **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others **MP.4** Model with Mathematics **MP.6** Attend to precision **A-REI.10** Represent and solve equations and inequalities graphically. **A.SSE** Interpret the structure of expressions. **A.CED** Create equations that describe numbers or relationships.