How Learning About Climate Change Progresses in Next Generation Science Standards (K-12)

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Introduction

Few issues facing society are more urgent than reducing our vulnerability to climate impacts, preparing for the staggering transition to a low-carbon economy, and building resilient communities. Yet K-12 schools, higher education, and free-choice learning institutions are not fully prepared or focused on building awareness and inspiring action to care for our communities and our planet. Through activation of extensive education systems with comprehensive climate change education, communities can more quickly embrace a low-carbon future, inspire future leaders, showcase their communities' adaptability, and create stronger communities. The need for comprehensive, interdisciplinary climate change education is more important now than ever before.

The Climate Science and Education stated in the 2009 "Climate Literacy: The Essential Principles of Climate Science guide for Individuals and Communities" (USGCRP, 2009) why climate is key scientific issue that students need to address in their learning;

> "To protect fragile ecosystems and to build sustainable communities that are resilient to climate change— including extreme weather and climate events—a climate-literate citizenry is essential. This climate science literacy guide identifies the essential principles and fundamental concepts that individuals and communities should understand about Earth's climate system. Such understanding improves our ability to make decisions about activities that increase vulnerability to the impacts of climate change and to take precautionary steps in our lives and livelihoods that would reduce those vulnerabilities."

Climate change involves complex, dynamic systems that demand a systems thinking approach when it comes to developing possible solutions. A systems thinking approach is increasingly recognized as a critical approach for education to address climate change (Barth, 2016; Claesson and Svanström, 2015; Hämäläinen et al., 2013; Iwaniec et al., 2014; Liu et al., 2015; Marcus et al., 2015; Pruneau et al., 2016). Climate change epitomizes a problem that demands a systems thinking and system dynamics approach: it is dynamic, complex, and crosses disciplines and societal sectors. Addressing the impacts and societal problems resulting from climate change requires an unprecedented level of integration and education across scientific, social science, civic/government, and humanities fields. Systems thinking offers an opportunity to integrate knowledge across disciplines and move society's capabilities to rapidly transition to a low-carbon economy and address the impacts of climate change.

Leaders in the field of climate change education argue based on extensive experience and carefully developed evidence that the emissions gap cannot be closed without also closing the education gap – that is, the gap between the science and society's understanding of climate change, the threats it poses, and the transition to sustainable systems it demands. It is recognized that education for action requires more than scientific literacy; it must integrate concepts and dynamics across disciplines and in ways that address affective, social, and cultural forces – a challenge that can be met through effective and evidence-based climate change education.

The 2018 National Science Teachers Association (NSTA) released a **position statement** on climate change calling for a suite of recommendations to ensure evidence-based science is taught at all levels. "While the details of scientific understandings about the Earth's climate will undoubtedly evolve in the future, a large body of foundational knowledge exists regarding climate science that is agreed upon by the scientific community and should be included in science education at all levels. These understandings include the increase in global temperatures and the significant impact of human activities on these increases (U.S. Global Change Research Program, 2009), as well as mitigation and resilience strategies that human societies may choose to adopt. Students in today's classrooms will be the ones accelerating these decisions well underway in communities across the world" (NSTA, 2018).

Americans recognize that educators should teach climate change, with 78% supporting teaching climate change in school (Cheskis et al., 2018). In spite of this support, an education gap exists, akin to the formidable 'emissions gap' between the aspirational goals of communities, states, nations, businesses and what climate science calls for to avoid dangerous climate change. This 'education gap' represents a gap between scientific and societal understanding; that is, addressing climate change effectively will require transfer and use of knowledge (i.e., education) to enable informed decision-making at all levels in society.

Teachers across the country are preparing to teach students the science and engineering called for in the new science standards. These new concepts address global challenges and opportunities posed by climate change, such as generating sufficient clean energy, building climate resilience for businesses and communities, maintaining safe supplies of food and clean water, and solving the problems of global environmental change. Consequently, the amount of time teachers spend on these issues is going up significantly. As a result, new interdisciplinary models of education support learners of all levels and foster climate and energy literacy and action. Armed with newfound knowledge and skills, students are increasingly able to contribute to and accelerate climate actions in their communities.

New Science Education Standards Address Global Challenges and Opportunities Posed by Climate Change

In 2013, the Next Generation Science Standards (NGSS) were released as the most current, research-based way of educating students in STEM and preparing them for STEM careers. The NGSS establish high standards for delivering effective STEM education. They challenge curriculum providers and professional developers to provide the instructional support necessary to make the NGSS accessible to educators. Hands-on learning, effective communication, making connections across all domains of science and other disciplines, an emphasis on including "all voices," and the importance of developing a learning progression are all integral to effective NGSS implementation.

NGSS performance expectations represent the final assessment of learning and therefore one lesson, or even a few, cannot fully develop a student's full mastery. Additionally, true NGSS related instruction and learning is three-dimensional, including not only disciplinary core ideas (DCI), but cross cutting concepts (CCC) and scientific and engineering practices (SEP) as well.

After the release of the Next Generation Science Standards (NGSS) there have been several teams who conducted analysis of performance standards related to the topic of climate change. Science teachers have stated that standards, like the NGSS, are one of the main reasons for teaching climate change (Wise, 2010). Thus, these detailed analyses can provide insights into where climate change is likely to be taught from grades K-12.

In this document, three different analyses are explored on how learning progresses in the NGSS related to climate change. All show the significant increase in climate change content across all years of science education and in all disciplines.

Section 1: Climate Change in the Next Generation Science Standards (K-12)

In 2012 the National Science Foundation awarded six grants as part of the Climate Change Education Partnership (CCEP) grant program. The University of Maryland, College Park, along with partners, was among those selected. The project, Maryland and Delaware Climate Change Education, Assessment and Research (MADE CLEAR) brought together science educators, learning scientists, schools, climate scientists, and the broader community to address comprehensive climate change education in Delaware and Maryland.

The Climate Change Learning Science Research at University of Maryland program completed detailed analysis of Climate Change in the Next Generation Science Standards (NGSS). The resulting work is available in the Climate Change in the Next Generation Science Standards (K-12) (PDF).

Standards *explicitly* addressing climate change are present at the middle and high school levels. These standards use the terms "global temperatures," "changes in climate," or "climate change." One middle school standard addresses the cause of rising global temperatures (MS-ESS3-5). At the high school level, standards introduce the constructs of evidence for climate change (HS-ESS3-1), climate modeling (HS-ESS2-4, HS-ESS3- 5), and geoengineering (HS-ESS3-4). A noteworthy observation is that the topic is not explicitly stated at the elementary level, with the exception of standards 3-ESS2-1 and 3- LS4-4. These performance standards explicitly state that climate change is *not* assessed in grade 3.

Also of importance are standards that are *proximally* related to climate change. Proximal standards are those that are considered "close" to the climate change topic, but are not explicitly related to climate change. These proximal standards are present at all grade levels from K-12. For example, kindergarten standard K-PS3-1 states, "Make observations to determine the effect of sunlight on Earth's surface," which is related to the imbalance between incoming and outgoing radiation—the reason that average global temperatures are rising. Similarly, high school standard HS-ESS2-6 states, "Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere." Anthropogenic climate change is occurring because humans are altering the natural balance of Earth's carbon cycle.

Climate Change Learning Science Research at University of Maryland program acknowledge that it is possible that others may identify in the NGSS additional standards that are *distally* related to the climate change topic (i.e., the relationship with climate change is not as close as those that are proximally related). However, in this document, they only present those standards that are explicitly or proximally related to climate change.

Table 1*: Middle School Performance Standard*

Code	Standard	Clarification Statement & Assessment Boundary
MS-ESS3-5	Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	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.

Table 2*: High School Performance Standards*

HS-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.	Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.
HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition. Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.
HS-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).
HS-ESS3-5	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition). Assessment is limited to one example of a climate change and its associated impacts.

Supporting Information for Table 1: The primary source for the Climate Change Learning Science Research at University of Maryland program's analysis was a document labeled DCI View and downloaded directly from the NGSS website.

Performance Standards with *Explicit* Mention of Climate Change
The first column identifies the code of each performance standard. For example, the code MS-ESS3-5 indicates that the standard is for middle school (MS) Earth and Space Science (ESS). Additionally, the #3 indicates that it belongs to the third set of ESS standards included in the NGSS. Finally, the #5 indicates that this is the fifth standard under the ESS3 sublevel.

Performance Standards with *Proximal* Connections to Climate Change

The Climate Change Learning Science Research team's analysis of the performance standards in the document reflects proximal connections to climate change. For example, standard MS-ESS3-4 concerns the construction of an argument about how human population growth and consumption of natural resources impact Earth's systems. A close connection to climate change of this standard is that human population growth has been fueled by the burning of fossil fuel resources, including coal, oil, and natural gas. The consumption of these natural resources has resulted in the release of greenhouse gases (e.g. carbon dioxide), altering Earth's atmosphere. The changing composition of the atmosphere, in turn, has altered Earth's other systems (e.g. the hydrosphere), resulting in global climate change.

The Climate Change in the Next Generation Science Standards (K-12) document further develops proximal connections to climate change in detail for another 47 NGSS Performance expectations.

Section 2: NGSS Appendix E on Progressions Within the Next Generation Science Standards that Relate to Climate Change

In the NGSS Appendix E on Progressions Within the Next Generation Science Standards they describe the **Disciplinary Core Idea Progression** for all ideas. The National Research Council's Framework describes the progression of disciplinary core ideas in the grade band endpoints. The progressions are summarized this NGSS appendix, which describe the content that occurs at each grade band.

The purpose of these tables is to briefly describe the content at each grade band for each disciplinary core idea across K-12. This progression is for reference only. The full progressions can be seen in the Framework. In addition, the NGSS show the integration of the three dimensions. This document in no way endorses separating the disciplinary core ideas from the other two dimensions.

→ Earth Space Science Progression →

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
ESS1.B Earth and the solar system	Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.	The Earth's orbit and rotation, and the orbit of the moon around the Earth cause observable patterns.	The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons.	Kepler's laws describe common features of the motions of orbiting objects. Observations from astronomy and space probes provide evidence for explanations of solar system formation. Changes in Earth's tilt and orbit cause climate changes such as Ice Ages.
ESS2.A Earth materials and systems	Wind and water change the shape of the land.	Four major Earth systems interact. Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, organisms, and gravity break rocks, soils, and sediments into smaller pieces and move them around.	Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources. Plate tectonics is one result of these processes.	Feedback effects exist within and among Earth's systems.

	K-2	3-5	6-8	9-12
ESS2.C The roles of water in Earth's surface processes	Water is found in many types of places and in different forms on Earth.	Most of Earth's water is in the ocean and much of the Earth's fresh water is in glaciers or underground.	Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of sea water drive interconnected ocean currents. Water movement causes weathering and erosion, changing landscape features. ————————	The planet's dynamics are greatly influenced by water's unique chemical and physical properties.
ESS2.D Weather and climate		Climate describes patterns of typical weather conditions over different scales and variations. Historical weather patterns can be analyzed.	Complex interactions determine local weather patterns and influence climate, including the role of the ocean.	The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural factors.
ESS2.E Biogeology	Plants and animals can change their local environment. ————————	Living things can affect the physical characteristics of their environment	[Content found in LS4.A and LS4.D]	The biosphere and Earth's other systems have many interconnections that cause a continual coevolution of Earth's surface and life on it.
ESS3.A Natural resources	Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.	Energy and fuels humans use are derived from natural sources and their use affects the environment. Some resources are renewable over time, others are not.	Humans depend on Earth's land, ocean, atmosphere, and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.	Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.

	K-2	3-5	6-8	9-12
ESS3.B Natural hazards	In a region, some kinds of severe weather are more likely than others. Forecasts allow communities to prepare for severe weather.	A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts.	Mapping the history of natural hazards in a region and understanding related geological forces	Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales.
ESS3.C Human impacts on Earth systems	Things people do can affect the environment but they can make choices to reduce their impacts	Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth's resources and environments.	Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. Activities and technologies can be engineered to reduce people's impacts on Earth.	Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies.
ESS3.D Global climate change	N/A	N/A	Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.	Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

Life Science Progression
INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
LS1.C Organization for matter and energy flow in organisms	Animals obtain food they need from plants or other animals. Plants need water and light.	Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.	Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.	The hydrocarbon backbones of sugars produced through photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism as elements are recombined to form different products and transfer energy.
LS2.A Interdependent relationships in ecosystems	Plants depend on water and light to grow, and also depend on animals for pollination or to move their seeds around.	The food of almost any animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants, while decomposers restore some materials back to the soil.	Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth. Competitive, predatory, and mutually beneficial interactions vary across ecosystems but the patterns are shared.	Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects the abundance of species in any given ecosystem.

	K-2	3-5	6-8	9-12
LS2.B Cycles of matter and energy transfer in ecosystems	[Content found in LS1.C and ESS3.A]	LS1.C and ESS3.A] Matter cycles between the air and soil and among organisms as they live and die.	The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem	Photosynthesis and cellular respiration provide most of the energy for life processes. Only a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels. At each link in an ecosystem elements are combined in different ways and matter and energy are conserved. Photosynthesis and cellular respiration are key components of the global carbon cycle.
LS2.C Ecosystem dynamics, functioning, and resilience	N/A	Climate describes patterns of typical weather conditions over different scales and variations. Historical weather patterns can be analyzed.	Ecosystem characteristics vary over time. Disruptions to any part of an ecosystem can lead to shifts in all of its populations. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex set of interactions within the ecosystem.
LS2.D Social interactions and group behavior	N/A	Being part of a group helps animals obtain food, defend themselves, and cope with changes.	N/A	Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

<table>
<tr><th></th><th>K-2</th><th>3-5</th><th>6-8</th><th>9-12</th></tr>
<tr><td>LS4.C Adaptation</td><td>N/A</td><td rowspan="2">Particular organisms can only survive in particular environments.
——————————
Populations of organisms live in a variety of habitats. Change in those habitats affects the organisms living there.</td><td>Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common.</td><td>Evolution results primarily from genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce. Adaptation means that the distribution of traits in a population, as well as species expansion, emergence or extinction, can change when conditions change.</td></tr>
<tr><td>LS4.D Biodiversity and humans</td><td>A range of different organisms lives in different places.</td><td>Changes in biodiversity can influence humans' resources and ecosystem services they rely on.</td><td>Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth.</td></tr>
</table>

Physical Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
PS3.A Definitions of energy	N/A	Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.	Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.	The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects). —————————- Systems move toward stable states.
PS3.B Conservation of energy and energy transfer	[Content found in PS3.D]			
PS3.D Energy in chemical processes and everyday life	Sunlight warms Earth's surface	Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food.	Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.	Photosynthesis is the primary biological means of capturing radiation from the sun; energy cannot be destroyed, it can be converted to less useful forms.
PS4.B Electro-magnetic radiation	Objects can be seen only when light is available to illuminate them	Object can be seen when light reflected from their surface enters our eyes.	The construct of a wave is used to model how light interacts with objects.	Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

Section 3: CLEAN Network Analysis of NGSS and Climate Change related Ideas

Climate science and energy technology are some of the most rapidly changing science and engineering fields. It is a challenge to have the time and knowledge to find credible and up-to-date climate science and energy educational resources. The Climate Literacy and Energy Awareness Network (CLEAN) develops and promotes a comprehensive source of high-quality, NGSS-aligned resources for grades K-16. To complete the NGSS alignment, a comprehensive and robust analysis of the NGSS was completed to explore how and where the NGSS directly or supports the Climate and Energy literacy frameworks.

In this document, only the climate and energy literacy related NGSS ideas are shown. The CLEAN Network and the CLEAN Collection team completed a full analysis of all related and supporting NGSS standards to support their collection building and alignment process. As a result, the tables below show how climate and energy topics are a natural fit for NGSS. These subjects weave together science and engineering design concepts with analyzing evidence, examining relationships between different parts of the Earth system, designing and evaluating solutions, and communicating findings.

As education systems and teachers retool their curriculum with the Next Generation Science Standards and related standards the CLEAN Portal can provide support related to climate and energy topic. CLEAN provides several tools to ease the transition and help curriculum specialists and teachers find useful materials and assemble them into complete curricular plans.

Below are the results of this analysis and can be digitally explored to find rigorously review related resources in the CLEAN Collection on the portal. This collection is a free online searchable database containing over 700 classroom-ready and data-rich lesson plans, activities, labs, demos, videos, and visualizations on climate and energy science. All "Selected by CLEAN" resources come from trusted sources and have been rigorously reviewed by both research scientists and teaching experts to ensure their scientific accuracy and educational value. Some issues like climate change and energy production are rapidly evolving and the CLEAN Collection is supplemented and reviewed regularly.

Additionally, educators can use the Getting Started to Create Your Own Climate and Energy Units to find resources using step-by-step guidance in developing lessons and units.

In the CLEAN NGSS analysis, two levels of alignment were developed. NGSS Disciplinary Core Ideas included in the tables below are either target or supporting concepts. The word *target* is used to denote ideas that directly support climate and energy literacy and the CLEAN collection will curate reviewed recourses and provide supporting materials for these ideas.

- ***SC – supporting concept*** *(here CLEAN noted very important concepts in climate and energy literacy but an educator might not find CLEAN as the best starting place to teach about these ideas)*
- ***T – target*** *(these are the target concepts that CLEAN want to* support *teachers with).*

LIFE SCIENCE: ELEMENTARY

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Elementary School						
	Life Sciences					
		2-LS2 Ecosystems: Interactions, Energy, and Dynamics	LS2.A	LS2.A.1	LS2.A: Interdependent Relationships in Ecosystems • Plants depend on water and light to grow. (2-LS2-1)	SC
		3-LS4 Biological Evolution: Unity and Diversity	LS2.C	LS2.C.1	LS2.C: Ecosystem Dynamics, Functioning, and Resilience • 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. *(secondary to 3-LS4-4)*	T
			LS4.A	LS4.A.1	LS4.A: Evidence of Common Ancestry and Diversity • Some kinds of plants and animals that once lived on Earth are no longer found anywhere. *(Note: moved from K-2)* (3-LS4-1)	SC
				LS4.A.2	• Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. (3-LS4-1)	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
		5-LS1 From Molecules to Organisms: Structures and Processes	LS1.C	LS1.C.1	LS1.C: Organization for Matter and Energy Flow in Organisms • Plants acquire their material for growth chiefly from air and water. (5-LS1-1)	SC
		5-LS2 Ecosystems: Interactions, Energy, and Dynamics	LS2.A	LS2.A.1	LS2.A: Interdependent Relationships in Ecosystems • The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (5-LS2-1)	SC
			LS2.B	LS2.B.1	LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1)	T

PHYSICAL SCIENCE: ELEMENTARY

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Elementary School						
	Physical Sciences					
			ETS1.A	ETS1.A.1	ETS1.A: Defining Engineering Problems • A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. *(secondary to K-PS2-2)*	SC
		K-PS3 Energy	PS3.B	PS3.B.1	PS3.B: Conservation of Energy and Energy Transfer • Sunlight warms Earth's surface. (K-PS3-1),(K-PS3-2)	T
				PS3.B.2	• Light also transfers energy from place to place. (4-PS3-2)	SC
			ETS1.A	ETS1.A.1	ETS1.A: Defining Engineering Problems • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. *(secondary to 4-PS3-4)*	SC
			ETS1.C	ETS1.C.1	ETS1.C: Optimizing The Design Solution • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. *(secondary to 4-PS4-3)*	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
		5-PS3 Energy	PS3.D	PS3.D.1	PS3.D: Energy in Chemical Processes and Everyday Life • The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (5-PS3-1)	T

EARTH AND SPACE SCIENCE: ELEMENTARY

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Elementary School						
	Earth/Space Sciences					
		K-ESS2 Earth's Systems	ESS2.D	ESS2.D.1	ESS2.D: Weather and Climate • Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-1)	T
			ESS3.C	ESS3.C.1	ESS3.C: Human Impacts on Earth Systems • Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. *(secondary to K-ESS2-2)*	T
		K-ESS3 Earth and Human Activity	ESS3.A	ESS3.A.1	ESS3.A: Natural Resources • Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do. (K-ESS3-1)	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
			ESS3.B	ESS3.B.1	ESS3.B: Natural Hazards • Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. (K-ESS3-2)	T
			ESS3.C	ESS3.C.1 1	ESS3.C: Human Impacts on Earth Systems • Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (K-ESS3-3)	T
			ETS1.A	ETS1.A.1	ETS1.A: Defining and Delimiting an Engineering Problem • Asking questions, making observations, and gathering information are helpful in thinking about problems. *(secondary to K-ESS3-2)*	SC
			ETS1.B	ETS1.B.1	ETS1.B: Developing Possible Solutions • Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. *(secondary to K-ESS3-3)*	SC
		1-ESS1 Earth's Place in the Universe	ESS1.A .	ESS1.A.1	ESS1.A: The Universe and its Stars • Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-1)	
			ESS1.B .	ESS1.B.1	ESS1.B: Earth and the Solar System • Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-2)	T

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
		2-ESS1 Earth's Place in the Universe	ESS1.C	ESS1.C.1	ESS1.C: The History of Planet Earth • Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. (2-ESS1-1)	SC
			ESS2.C	ESS2.C.1	ESS2.C: The Roles of Water in Earth's Surface Processes • Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)	SC
			ETS1.C	ETS1.C.1	ETS1.C: Optimizing the Design Solution • Because there is always more than one possible solution to a problem, it is useful to compare and test designs. *(secondary to 2-ESS2-1)*	SC
		3-ESS2 Earth's Systems	ESS2.D	ESS2.D.1	ESS2.D: Weather and Climate • Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1)	T
				ESS2.D.2	• Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2)	T
		3-ESS3 Earth and Human Activity	ESS3.B	ESS3.B.1	ESS3.B: Natural Hazards • A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (3-ESS3-1) *(Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.)*	T
		4-ESS1 Earths Place in the Universe	ESS1.C	ESS1.C.1	ESS1.C: The History of Planet Earth • Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. (4-ESS1-1)	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
			ESS2.E	ESS2.E.1	ESS2.E: Biogeology • Living things affect the physical characteristics of their regions. (4-ESS2-1)	SC
		4-ESS3 Earth and Human Activity	ESS3.A	ESS3.A.1	ESS3.A: Natural Resources • 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. (4-ESS3-1)	T
			ESS3.B	ESS3.B.1	ESS3.B: Natural Hazards • A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2) *(Note: This Disciplinary Core Idea can also be found in 3.WC.)*	T
			ETS1.B	ETS1.B.1	ETS1.B: Designing Solutions to Engineering Problems • Testing a solution involves investigating how well it performs under a range of likely conditions. *(secondary to 4-ESS3-2)*	SC
		5-ESS1 Earth's Place in the Universe	ESS1.A	ESS1.A.1	ESS1.A: The Universe and its Stars • The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1)	SC
			ESS1.B	ESS1.B.1	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. (5-ESS1-2)	T

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
		5-ESS2 Earth's Systems	ESS2.A	ESS2.A.1	ESS2.A: Earth Materials and Systems • Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)	T
			ESS2.C	ESS2.C.1	ESS2.C: The Roles of Water in Earth's Surface Processes • Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)	SC
		5-ESS3 Earth and Human Activity	ESS3.C	ESS3.C.1	ESS3.C: Human Impacts on Earth Systems • Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)	T

ENGINEERING DESIGN: ELEMENTARY

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Elementary School						
	Engineering Design					

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
		K-2-ETS1 Engineering Design	ETS1.A	ETS1.A.1	ETS1.A: Defining and Delimiting Engineering Problems • A situation that people want to change or create can be approached as a problem to be solved through engineering. (K-2-ETS1-1)	SC
				ETS1.A.2	• Asking questions, making observations, and gathering information are helpful in thinking about problems. (K-2-ETS1-1)	T
				ETS1.A.3	• Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)	SC
			ETS1.B	ETS1.B.1	ETS1.B: Developing Possible Solutions • Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (K-2-ETS1-2)	SC
			ETS1.C	ETS1.C.1	ETS1.C: Optimizing the Design Solution • Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3)	SC
		3-5 ETS1 Engineering Design	ETS1.A	ETS1.A.1	ETS1.A: Defining and Delimiting Engineering Problems • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)	SC
			ETS1.B	ETS1.B.1	ETS1.B: Developing Possible Solutions • Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				ETS1.B.2	• At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)	SC
				ETS1.B.3	• Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)	SC
			ETS1.C	ETS1.C.1	ETS1.C: Optimizing the Design Solution • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)	SC

LIFE SCIENCE: MIDDLE SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Middle School						
	Life Sciences					
		MS-LS1				
			MS-LS1.C			
				MS-LS1.C1	Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.	SC
		MS-LS2				

			MS-LS2.A			
				MS-LS2.A1	Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.	SC
Middle School	**Life Sciences**	**MS-LS2**	**MS-LS2.A**	**MS-LS2.A2**	In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.	SC
				MS-LS2.A3	Growth of organisms and population increases are limited by access to resources.	T
				MS-LS2.A4	Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.	SC
			MS-LS2.B			
				MS-LS2.B1	Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.	SC
			MS-LS2.C			
				MS-LS2.C1	Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.	T

				MS-LS2.C2	Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health	T
			MS-LS4.D			
				MS-LS4.D1	Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on for example, water purification and recycling.	T
		MS-LS4				
			MS-LS4.A			
				MS-LS4.A1	The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.	T
			MS-LS4.C			
				MS-LS4.C1	Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.	SC

PHYSICAL SCIENCE: MIDDLE SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Middle School	Physical Sciences					
		MS-PS1				
			MS-PS1.A			
				MS-PS1.A3	Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.	SC
				MS-PS1.A4	In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.	SC
				MS-PS1.A6	The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.	SC
			MS-PS1.B			
				MS-PS1.B3	Some chemical reactions release energy, others store energy.	SC
		MS-PS3				
			MS-PS3.B			
				MS-PS3.B2	The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.	SC
				MS-PS3.B3	Energy is spontaneously transferred out of hotter regions or objects and into colder ones.	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
			MS-PS3.D			
				MS-PS3.D1	The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.	T
				MS-PS3.D2	Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.	T
		MS-PS4				
			MS-PS4.B			
				MS-PS4.B1	When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.	SC

EARTH AND SPACE SCIENCE: MIDDLE SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI	ds	CLEAN
Middle School	Earth and Space Sciences					
		MS-ESS1				
			MS-ESS1.B			

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI	ds	CLEAN
				MS-ESS1.B 2	This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.	T
			MS-ESS1.C			
				MS-ESS1.C1	The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.	SC
		MS-ESS2				
			MS-ESS2.A			
				MS-ESS2.A 1	All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms	T
				MS-ESS2.A 2	The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.	SC
			MS-ESS2.C			
				MS-ESS2.C1	Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI	ds	CLEAN
Middle School	**Earth and Space Sciences**	**MS-ESS2**	**MS-ESS2.C**	**MS-ESS2.C2**	The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.	T
				MS-ESS2.C3	Global movements of water and its changes in form are propelled by sunlight and gravity.	T
				MS-ESS2.C4	Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.	SC
				MS-ESS2.C5	Water's movements both on the land and underground cause weathering and erosion, which change the land's surface features and create underground formations.	SC
			MS-ESS2.D			
				MS-ESS2.D1	Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.	T
				MS-ESS2.D2	Because these patterns are so complex, weather can only be predicted probabilistically.	SC
				MS-ESS2.D3	The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.	T
		MS-ESS3				
			MS-ESS3.A			

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI	ds	CLEAN
				MS-ESS3.A 1	Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes	T
			MS-ESS3.B			
				MS-ESS3.B 1	Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events	SC
			MS-ESS3.C			
				MS-ESS3.C1	Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	T
				MS-ESS3.C2	Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	T
			MS-ESS3.D			
				MS-ESS3.D 1	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). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.	T

ENGINEERING DESIGN: MIDDLE SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
Middle School	Engineering, Technology, and Applications of Science					
		MS-ETS1				
			MS-ETS1.B			
				MS-ETS1.B1	A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.	SC
				MS-ETS1.B2	There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	SC
				MS-ETS1.B3	Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.	SC
				MS-ETS1.B4	Models of all kinds are important for testing solutions.	SC
			MS-ETS1.C			
				MS-ETS1.C2	The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution	SC

LIFE SCIENCE: HIGH SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
High School						
	Life Sciences					
		HS-LS1				
			HS-LS1.C			
				HS-LS1.C1	The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	T
				HS-LS1.C2	The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.	SC
				HS-LS1.C3	As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.	T
				HS-LS1.C4	As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.	SC
		HS-LS2				
			HS-LS2.A			

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-LS2.A1	Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	SC
High School	**Life Sciences**	**HS-LS2**	**HS-LS2.B**	**HS-LS2.B2**	Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.	T
				HS-LS2.B3	Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.	T
			HS-LS2.C			

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-LS2.C1	A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	T
				HS-LS2.C2	Moreover, anthropogenic changes (induced by human activity) in the environment including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change can disrupt an ecosystem and threaten the survival of some species.	T
		HS-LS4				
			HS-LS4.C			
				HS-LS4.C3	Adaptation also means that the distribution of traits in a population can change when conditions change.	SC
				HS-LS4.C4	Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline and sometimes the extinction of some species	T
				HS-LS4.C5	Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species evolution is lost.	T
			HS-LS4.D			

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-LS4.D1	Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.	T
				HS-LS4.D2	Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).	T

PHYSICAL SCIENCE: MIDDLE SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
High School	Physical Sciences					
		HS-PS3				
			HS-PS3.A			
				HS-PS3.A2	At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-PS3.A3	These relationships are better understood at the microscopic scale, at which all of 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.	SC
				HS-PS3.A5	Electrical energy may mean energy stored in a battery or energy transmitted by electric currents.	SC
			HS-PS3.B			
				HS-PS3.B1	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.	SC
				HS-PS3.B2	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems	SC
			HS-PS3.D			
				HS-PS3.D1	Although energy cannot be destroyed, it can be converted to less useful forms for example, to thermal energy in the surrounding environment.	SC
				HS-PS3.D2	The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.	T
High School	Physical Sciences	**HS-PS3**	**HS-PS3.D**	**HS-PS3.D3**	Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.	T

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-PS3.D4	Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.	SC
			HS-PS4.B			
				HS-PS4.B2	When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells	SC
				HS-PS4.B3	Photoelectric materials emit electrons when they absorb light of a high-enough frequency	SC

EARTH AND SPACE SCIENCE: HIGH SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
High School	Earth and Space Sciences					
		HS-ESS 1				
			HS-ESS1.B			
				HS-ESS1.B1	Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.	SC

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-ESS1.B2	Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.	SC
		HS-ESS2				
			HS-ESS2.A			
				HS-ESS2.A1	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.	SC
				HS-ESS2.A3	The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.	T
			HS-ESS2.C			
				HS-ESS2.C1	The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.	SC
			HS-ESS2.D			

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
				HS-ESS2.D1	The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.	T
				HS-ESS2.D2	Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.	T
				HS-ESS2.D3	Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	T
				HS-ESS2.D4	Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.	T
			HS-ESS2.E			
				HS-ESS2.E1	The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	SC
		HS-ESS 3				
			HS-ESS3. A			
				HS-ESS3.A1	Resource availability has guided the development of human society.	SC
				HS-ESS3.A2	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.	T

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
			HS-ESS3.B			
				HS-ESS3.B1	Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations	T
			HS-ESS3.C			
				HS-ESS3.C1	The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	T
				HS-ESS3.C2	Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.	T
			HS-ESS3.D			
High School	Earth and Space Sciences	HS-ESS3	HS-ESS3.D	HS-ESS3.D1	Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	T
				HS-ESS3.D2	Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.	SC

ENGINEERING DESIGN: HIGH SCHOOL

Grade Level	Topic	DCI	sub-DCI	sub-sub-DCI		CLEAN
High School	Engineering, Technology, and Applicati					

	ons of Science					
		HS-ETS1				
			HS-ETS1.A			
				HS-ETS1.A1	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.	SC
				HS-ETS1.A2	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 also may have manifestations in local communities	T
			HS-ETS1.B			
				HS-ETS1.B1	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.	T
				HS-ETS1.B2	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 his or her needs.	SC
			HS-ETS1.C			

				HS-ETS1.C1	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	SC

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