Performance Expectation *and Louisiana Connectors*
HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. **LC-HS-ESS1-1a Describe components of a model illustrating that the sun shines because of nuclear fusion reactions which release light and heat energy which make life on Earth possible.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. **Develop multiple types of models to provide mechanistic accounts and move flexibly between model types based on merits and limitations.** **Use multiple types of models to provide mechanistic accounts and move flexibly between model types based on merits and limitations.** **Develop multiple types of models**	**THE UNIVERSE AND ITS STARS** All stars, such as our sun, are evolving. The star called Sol, our sun, will burn out over a lifespan of approximately 10 billion years. (HS.ESS1A.a) **The sun is but one of a vast number of stars in the Milky Way galaxy.** **Stars go through a sequence of developmental stages—they are formed; evolve in size, mass, and brightness; and eventually burn out.** **The sun is a medium-sized star.** **The sun's lifespan is about 10 billion years.** **The sun is about halfway through its predicted life span.** The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS.ESS1A.c) **The Big Bang theory is a core scientific theory that is supported by a large body of evidence.** **According to this theory, the universe began with a period of extreme and rapid expansion known as the Big Bang, which occurred about 13.7 billion years ago.** **It states that the universe began in a hot dense state of energy and matter, and the universe has been expanding ever since.** **Spectroscopes are used to analyze starlight to reveal information about the composition and evolution of stars.** **The sun and our Solar System are part of the Milky Way galaxy consisting of billions of other stars that appear to be made of the same elements found on Earth.** **Stars' radiation of visible light and other forms of energy can be measured and studied to develop explanations about the formation, age, and composition of the universe.**	**SCALE, PROPORTION, AND QUANTITY** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. **The size and time scales relevant to various objects, systems, and processes determine the significance of a phenomena.** **Specific phenomena correspond to a specific scale (e.g., the size of the nucleus of an atom to the size of the galaxy and beyond).**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
to predict phenomena and move flexibly between model types based on merits and limitations. **Use multiple types of models to predict phenomena and move flexibly between model types based on merits and limitations.**	**ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS.PS3D.c) **The sun is a star that gives off radiant energy that drives Earth systems.** **The source of the sun's energy is the fusion of hydrogen atoms into helium.** **The sun's energy reaches Earth as solar radiation.**	

Clarification Statement
Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.

Performance Expectation *and Louisiana Connectors*
HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. **LC-HS-ESS1-1a Describe components of a model illustrating that the sun shines because of nuclear fusion reactions which release light and heat energy which make life on Earth possible.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. **Develop multiple types of models to provide mechanistic accounts and move flexibly between model types based on merits and limitations.** **Use multiple types of models to provide mechanistic accounts and move flexibly between model types based on merits and limitations.** **Develop multiple types of models to predict phenomena and move**	**THE UNIVERSE AND ITS STARS** All stars, such as our sun, are evolving. The star called Sol, our sun, will burn out over a lifespan of approximately 10 billion years. (HS.ESS1A.a) **The sun is but one of a vast number of stars in the Milky Way galaxy.** **Stars go through a sequence of developmental stages—they are formed; evolve in size, mass, and brightness; and eventually burn out.** **The sun is a medium-sized star.** **The sun's lifespan is about 10 billion years.** **The sun is about halfway through its predicted life span.** The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS.ESS1A.c) **The Big Bang theory is a core scientific theory that is supported by a large body of evidence.** **According to this theory, the universe began with a period of extreme and rapid expansion known as the Big Bang, which occurred about 13.7 billion years ago.** **It states that the universe began in a hot dense state of energy and matter, and the universe has been expanding ever since.** **Spectroscopes are used to analyze starlight to reveal information about the composition and evolution of stars.** **The sun and our Solar System are part of the Milky Way galaxy consisting of billions of other stars that appear to be made of the same elements found on Earth.** **Stars' radiation of visible light and other forms of energy can be measured and studied to develop explanations about the formation, age, and composition of the universe.** **ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE**	**SCALE, PROPORTION, AND QUANTITY** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. **The size and time scales relevant to various objects, systems, and processes determine the significance of a phenomena.** **Specific phenomena correspond to a specific scale (e.g., the size of the nucleus of an atom to the size of the galaxy and beyond).**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
flexibly between model types based on merits and limitations. **Use multiple types of models to predict phenomena and move flexibly between model types based on merits and limitations.**	Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS.PS3D.c) **The sun is a star that gives off radiant energy that drives Earth systems.** **The source of the sun's energy is the fusion of hydrogen atoms into helium.** **The sun's energy reaches Earth as solar radiation.**	

Clarification Statement
Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.

Performance Expectation *and Louisiana Connectors*
HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements. **LC-HS-ESS1-3a Communicate by using models that solar activity creates elements through nuclear fusion.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Obtaining, evaluating, and communicating information: Obtaining, evaluating, and communicating information in 9-12 builds on K-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). **Communicate scientific information in multiple formats (i.e., orally, graphically, textually, mathematically).** **Communicate technical information in multiple formats (i.e., orally, graphically, textually, mathematically).** **Communicate scientific ideas in multiple formats (i.e., orally,**	**THE UNIVERSE AND ITS STARS** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS.ESS1A.b) **The composition of stars can be determined by analysis of their spectra.** **Stars range greatly in their size and distance from Earth.** **Stars' light spectra and brightness are used to identify their distances from Earth.** **Our knowledge of the history of the Universe is based on electromagnetic energy that has traveled vast distances and takes a long period of time to reach us.** Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS.ESS1A.d) **Most elements are formed as a result of natural astronomical processes, either in the Big Bang itself or in the natural evolution of stars.** **Nuclear fusion within stars produces all atomic nuclei lighter than and including iron.** **A supernova is the explosion of a dying giant or supergiant star.** **After a supernova, some of the material (e.g., heavier elements) from the star expands into space.** **ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS.PS3D.c) **The sun is a star that gives off radiant energy that drives Earth systems.**	**ENERGY AND MATTER** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **The total number of nuclear particles are the same both before and after the nuclear process, although the total number of protons and the total number of neutrons may be different before and after.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
graphically, textually, mathematically).	**The source of the sun's energy is the fusion of hydrogen atoms into helium.** **The sun's energy reaches Earth as solar radiation.**	

Clarification Statement
Emphasis is on the way nucleosynthesis, and therefore the different elements created, depends on the mass of a star and the stage of its lifetime.

Performance Expectation ***and Louisiana Connectors***
HS-ESS1-4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. **LC-HS-ESS1-4a Recognize that objects in the solar system orbit the sun and have an orderly motion (e.g., elliptical paths around the sun).** **LC-HS-ESS1-4b Relate Earth's orbital characteristics to other bodies in the solar system.** **LC-HS-ESS1-4c Use a mathematical or computational representation to predict the motion of orbiting objects in the solar system.**

Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concept**
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential, and logarithmic) 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, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. **Use mathematical or algorithmic forms for scientific modeling of phenomena and/or design solutions to describe claims.**	**EARTH AND THE SOLAR SYSTEM** 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. (HS.ESS1B.a) **Kepler discovered that the orbit of each planet is an ellipse.** **Kepler's laws describe the elliptical paths around the sun in which objects in the solar system move.** **Objects' orbits may change due to the gravitational interactions of other objects in the solar system.** **Objects' orbits may change due to collisions with other objects in the solar system.**	**SCALE, PROPORTIONS, AND QUANTITY** Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Examine scientific data to predict the effect of a change in one variable on another. Algebraic thinking can be used to explore complex mathematical relationships in science (e.g., the difference between linear growth and exponential growth).**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Use mathematical or algorithmic forms for scientific modeling of phenomena and/or design solutions to support claims. Use mathematical or algorithmic forms for scientific modeling of phenomena and/or design solutions to describe explanations. Use mathematical or algorithmic forms for scientific modeling of phenomena and/or design solutions to support explanations.		

Clarification Statement
Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as other celestial bodies (e.g., graphical representations of orbits).

Performance Expectation *and Louisiana Connectors*
HS-ESS1-5 Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. **LC-HS-ESS1-5a Explain the relationship between the motion of continental plates and how materials of different ages are arranged on Earth's surface.** **LC-HS-ESS1-5b Relate/evaluate evidence of past and/or current movements in Earth's crust (plate tectonics) with the ages of crustal rocks.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Engaging in argument from evidence: Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. **Evaluate the claims behind currently accepted explanations to determine the merits of arguments.** **Evaluate the claims behind currently accepted solutions to determine the merits of arguments.** **Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.**	**THE HISTORY OF PLANET EARTH** Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS.ESS1C.b) **According to theory of plate tectonics, evidence of the past and current movements of continental and oceanic crust can be used to explain the ages of crustal rocks.** **Sea floor spreading adds new crust to the ocean floor.** **Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** **Continental rocks can be older than 4 billion years.** **Rocks of the ocean floor are less than 200 million years old.** Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS.ESS1C.c) **Active geologic processes have destroyed or altered most of the very early rock record on Earth.** **Some objects in the solar system have changed little over billions of years.** **Scientists study objects in the solar system (i.e., lunar rocks, asteroids, meteorites) to search for clues about Earth's history.** **Studying these objects can help scientists deduce the solar system's age and history, including the formation of planet Earth.** **PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.	**PATTERNS** Empirical evidence is needed to identify patterns. **Evidence is required when identifying a pattern in an observed phenomenon.** **Evidence is required to explain the pattern in a system under study.** **Evidence is required to support a claim about the pattern in a system under study.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Evaluate the evidence behind currently accepted solutions to determine the merits of arguments. **Evaluate the reasoning behind currently accepted explanations to determine the merits of arguments.** **Evaluate the reasoning behind currently accepted solutions to determine the merits of arguments.**	(HS.ESS2B.a) **Plate tectonics is the theory that explains the past and current movement of Earth's plates.** **Plate tectonics also provides a framework for understanding Earth's geologic history.** **NUCLEAR PROCESSES** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (HS.PS1C.b) **Radioactive elements found in rocks decay at a constant rate.** **The half-life of a radioactive element is the time it takes for half of the radioactive atoms to decay.** **Scientists compare the amount of a radioactive element in a rock with the amount of stable element into which the radioactive element decays.** **Thus, scientists use radioactive dating to determine the absolute ages of rocks and other materials.**	

Clarification Statement
Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient continental center (a result of past plate interactions).

Performance Expectation *and Louisiana Connectors*
HS-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. **LC-HS-ESS1-6a Identify ancient Earth materials, lunar rocks, asteroids, and meteorites as sources of evidence scientists use to understand Earth's early history.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing explanations and designing solutions: Constructing explanations (science) and designing solutions (engineering) in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. **Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation.** **Apply scientific theory to link evidence to the claims to assess the extent to which the reasoning and**	**THE HISTORY OF PLANET EARTH** Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS.ESS1C.c) **Active geologic processes have destroyed or altered most of the very early rock record on Earth.** **Some objects in the solar system have changed little over billions of years.** **Scientists study objects in the solar system (i.e., lunar rocks, asteroids, meteorites) to search for clues about Earth's history.** **Studying these objects can help scientists deduce the solar system's age and history, including the formation of planet Earth.** **NUCLEAR PROCESSES** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (HS.PS1C.b) **Radioactive elements found in rocks decay at a constant rate.** **The half-life of a radioactive element is the time it takes for half of the radioactive atoms to decay.** **Scientists compare the amount of a radioactive element in a rock with the amount of stable element into which the radioactive element decays.**	**STABILITY AND CHANGE** Much of science deals with constructing explanations of how things change and how they remain stable. **Science deals with constructing explanations of how things change.** **Science deals with constructing explanations of how things remain stable.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
data support the explanation. Apply scientific modeling to link evidence to the claims to assess the extent to which the reasoning and data support the explanation. Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the conclusion. Apply scientific theory to link evidence to the claims to assess the extent to which the reasoning and data support the conclusion. Apply scientific modeling to link evidence to the claims to assess the extent to which the reasoning and data support the conclusion.	Thus, scientists use radioactive dating to determine the absolute ages of rocks and other materials.	

Clarification Statement
Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples include the absolute age of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest materials), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.

Performance Expectation *and Louisiana Connectors*
HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. **LC-HS-ESS2-1a Use a model of Earth to identify that the motion of the mantle and its plates occurs primarily through thermal convection, which is primarily driven by radioactive decay within Earth's interior.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. **Develop or use a model to identify and describe the components of a system.** **Develop or use a model to identify and describe the relationships between the components of a system.** **Develop or use a model to predict relationships between systems or within a system.** **Identify that models can help**	**EARTH MATERIALS AND SYSTEMS** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS.ESS2A.a) **Earth's systems are dynamic and interacting.** **Earth has interconnected spheres: lithosphere or geosphere, hydrosphere, biosphere, atmosphere, and cryosphere.** **Changes in one system can cause changes to other systems.** **Rates of change of Earth's internal and surface processes occur over very short and very long periods of time.** **Many complex linkages and feedbacks among erosional and climatic processes in addition to tectonic ones change Earth's systems.** **Such complexities include feedback and stabilizing or destabilizing links between component processes.** **A change in one sphere can cause changes to other spheres, resulting in positive or negative feedback loops.** **PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS** Plate tectonics is the unifying theory that explains the past and current movements of rocks at Earth's surface and provides a framework for understanding its geologic history. (HS.ESS2B.a) **Plate tectonics is the theory that explains the past and current movement of Earth's plates.** **Plate tectonics also provides a framework for understanding Earth's geologic history.** Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (HS.ESS2B.b)	**STABILITY AND CHANGE** Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. **Change and rates of change can be quantified over very short or very long periods of time.** **Change and rates of change can be modeled over very short or very long periods of time.** **Some system changes are irreversible.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
illustrate relationships between systems or within a system.	**Plate movements are responsible for both continental and ocean-floor features.** **Plate movements are responsible to the distribution of most rocks and minerals on Earth.** **Maps showing the distribution of minerals can be used to draw inferences regarding how plates have moved over time.**	

Clarification Statement
Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples include the absolute age of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest materials), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.

Performance Expectation *and Louisiana Connectors*
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems. **LC-HS-ESS2-2a Identify relationships, using a model, of how the Earth's surface is a complex and dynamic set of interconnected systems (i.e., geosphere, hydrosphere, atmosphere, and biosphere).**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Analyzing and interpreting data: Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Analyze data using tools in order to make valid and reliable scientific claims.** **Analyze data using tools in order to determine an optimal design solution.** **Analyze data using technology in order to make valid and reliable scientific claims.** **Analyze data using technology in order to determine an optimal design solution.**	**EARTH MATERIALS AND SYSTEMS** Earth's systems, being dynamic and interacting, include feedback effects that can increase or decrease the original changes. (HS.ESS2A.a) **Earth's systems are dynamic and interacting.** **Earth has interconnected spheres: lithosphere or geosphere, hydrosphere, biosphere, atmosphere, and cryosphere.** **Changes in one system can cause changes to other systems.** **Rates of change of Earth's internal and surface processes occur over very short and very long periods of time.** **Many complex linkages and feedbacks among erosional and climatic processes in addition to tectonic ones change Earth's systems.** **Such complexities include feedback, stabilizing or destabilizing links between component processes.** **A change in one sphere can cause changes to other spheres, resulting in positive or negative feedback loops.** **WEATHER AND CLIMATE** 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, hydrosphere, and land systems, and this energy's re-radiation into space. (HS.ESS2D.a) **Sunlight is a portion of the electromagnetic radiation given off by the sun.** **Energy from the sun travels to Earth and heats Earth's surface.** **Some of this energy is radiated back into Earth's atmosphere.** **The sun's energy drives Earth's climate systems.** **Uneven heating of Earth's components (i.e., water, land, air) produce local and global**	**STABILITY AND CHANGE** Feedback (negative or positive) can stabilize or destabilize a system. **Stability denotes a condition in which a system is in balance.** **A feedback loop is any mechanism in which a condition triggers some action that causes a change in that same condition.** **The mechanisms of external controls and internal feedback loops are important elements for a stable system.** **A change in one part of a system can cause changes to other parts of the system, resulting in positive or negative feedback loops.** **The changes (negative**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Analyze data using models in order to make valid and reliable scientific claims. **Analyze data using models in order to determine an optimal design solution.**	**atmospheric and oceanic movement.** **Heat energy stored in the oceans and transferred by currents influences climate.**	**or positive) can stabilize or destabilize a system.**

Clarification Statement
Examples could include climate feedbacks such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice which reduces the amount of sunlight reflected from Earth's surface increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how damned rivers increase ground water recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.

Performance Expectation *and Louisiana Connectors*
HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. **LC-HS-ESS2-3a Use a model of Earth to identify that the motion of the mantle and its plates occurs primarily through thermal convection, which is primarily driven by radioactive decay within Earth's interior.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or components of a system. **Develop a model based on evidence to illustrate the relationships between systems.** **Develop a model based on evidence to illustrate the components of a system.**	**EARTH MATERIALS AND SYSTEMS** Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a viscous mantle and solid crust. (HS.ESS2A.b) **Seismic waves are vibrations that travel through Earth carrying the energy released during an earthquake.** **A seismograph records the ground movements caused by seismic waves as they move through the Earth.** **Scientists monitor seismic activity to better understand Earth's interior and to determine earthquake risk.** **Earth's interior is a hot, but solid, inner core and a liquid outer core surrounded by a solid mantle and crust.** **Earth's geosphere is composed of layers of rocks which have separated due to density and temperature differences and classified chemically into a crust (which includes continental and oceanic rock), a hot, convecting mantle, and a dense metallic core.** Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (HS.ESS2A.c) **Convection is the transfer of heat by movements of a heated fluid.** **The flow of heat and matter from Earth's core and the mantle causes crustal plates to move.** **Heat from Earth's mantle and core causes convection currents to form in the athenosphere.** **Hot, therefore less dense, columns of mantle material rise through the athenosphere.** **At the top of the athenosphere, the hot material spreads out, and the cooler, therefore**	**ENERGY AND MATTER** Energy drives the cycling of matter within and between systems. **In many systems there also are cycles of various types.** **The most readily observable cycling may be of matter.** **Any such cycle of matter also involves associated energy transfers at each stage.** **To fully understand the cycling of matter, how matter moves between each part of the system, one must recognize the energy transfer mechanisms that are critical for that motion.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
	more dense, material sinks back into the athenosphere. **PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS** The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (HS.ESS2B.c) **The transfer of energy through empty space is called radiation.** **Energy released by radioactive decay in the Earth's crust provides energy that drives the flow of matter in the mantle.** **The convection currents in the athenosphere cause the movement of Earth's plates.** **Earth has radial layers determined by density, together with the cycling of matter by thermal convection, results in plate tectonics.** **WAVE PROPERTIES** Geologists use seismic waves and their reflections at interfaces between layers to probe structures deep in the planet. (HS.PS4A.c) **Scientists study how seismic waves travel through Earth to understand how the planet is put together (i.e., Earth is made up of several layers).** **Seismic data is used to determine the age of Earth's crust.** **The interpretation of seismic data is used to model the interior of the Earth.**	

Clarification Statement
Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of the Earth's three-dimensional structure obtained from seismic wave data, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high pressure laboratory experiments.

Performance Expectation ***and Louisiana Connectors***
HS-ESS2-4 Analyze and interpret data to explore how variations in the flow of energy into and out of Earth's systems result in changes in atmosphere and climate. **LC-HS-ESS2-4a Identify different causes of climate change and results of those changes with respect to the Earth's surface temperatures, precipitation patterns or sea levels over a wide range of temporal and spatial scales using a model.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Analyzing and interpreting data: Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Analyze data using tools in order to make valid and reliable scientific claims.** **Analyze data using tools in order to determine an optimal design solution.** **Analyze data using technology in order to make valid and reliable scientific claims.** **Analyze data using technology in order to determine an optimal**	**EARTH AND THE SOLAR SYSTEM** 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 Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (HS.ESS1B.b) **Gradual changes in the shape of Earth's orbit around the sun contributes to phenomena causing ice ages and other gradual climate changes.** **Earth's global temperatures can warm up or cool down if the amount of sunlight that enters the atmosphere is significantly altered.** **Cyclic variations of Earth's orbit around the sun impact the amount of sunlight that reaches Earth's surface.** **Gradual changes to the tilt of Earth's axis relative to its orbit around the sun have produced different weather patterns.** **EARTH MATERIALS AND SYSTEMS** 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, hydrosphere 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. (HS.ESS2A.d) **All Earth processes are the result of energy flowing and matter cycling within and among Earth's systems.** **Changes to climate occur over a wide range of temporal and spatial scales.** **The geological record (ice cores, sediment deposits, fossil evidence, and paleovegetation**	**CAUSE AND EFFECT** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Evidence is required when attributing an observed phenomenon to a specific cause.** **Evidence is required to explain the causal mechanisms in a system under study.** **Evidence is required to support a claim about the causal mechanisms in a system under study.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
design solution. **Analyze data using models in order to make valid and reliable scientific claims.** **Analyze data using models in order to determine an optimal design solution.**	**restorations) shows that changes to global and regional climate can be caused by several factors (Earth's orbit, tectonic events, volcanic glaciers, vegetation, etc.).** **Changes to the input, output, storages, or redistribution of energy on Earth can occur over a short or extended time frame and can cause extreme weather conditions.** **WEATHER AND CLIMATE** 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, hydrosphere and land systems, and this energy's re-radiation into space. (HS.ESS2D.a) **Sunlight is a portion of the electromagnetic radiation given off by the sun.** **Energy from the sun travels to Earth and heats Earth's surface.** **Some of this energy is radiated back into Earth's atmosphere.** **The sun's energy drives Earth's climate systems.** **Uneven heating of Earth's components (i.e., water, land, air) produce local and global atmospheric and oceanic movement.** **Heat energy stored in the oceans and transferred by currents influence climate.** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS.ESS2D.b) **Plants contribute to the make-up of Earth's atmosphere by absorbing carbon dioxide and releasing oxygen.** **Carbon continuously cycles from one sphere to another.** **In the past, the relative amount of carbon that cycled through the hydrosphere, atmosphere, lithosphere or geosphere, and biosphere was partially due to the activity of plants and other organisms.** Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS.ESS2D.c) **Human activities that add carbon dioxide to the atmosphere may be warming Earth's**	

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
	atmosphere. **A large amount of carbon dioxide has been released into Earth's atmosphere by human-related fossil fuel combustion.** **An increase in atmospheric carbon can increase the amount of heat energy stored in the system.**	

Clarification Statement
Changes differ by timescale, from sudden (large volcanic eruption, hydrosphere circulation) to intermediate (hydrosphere circulation, solar output, human activity) and long-term (Earth's orbit and the orientation of its axis and changes in atmospheric composition). Examples of human activities could include fossil fuel combustion, cement production, or agricultural activity and natural processes such as changes in incoming solar radiation or volcanic activity. Examples of data can include tables, graphs, maps of global and regional temperatures, and atmospheric levels of gases.

Performance Expectation *and Louisiana Connectors*
HS-ESS2-5 Plan and conduct an investigation on the properties of water and its effects on Earth materials and surface processes. **LC-HS-ESS2-5a Identify a connection between the properties of water and its effects on Earth materials.** **LC-HS-ESS2-5b Investigate the effects of water on Earth materials and/or surface processes.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Planning and carrying out investigations: Planning and carrying out investigations to answer questions (science) or test solutions (engineering) to problems in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan an investigation (science) or test a design (engineering) individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **Plan an investigation (science) individually and collaboratively to produce data to serve as the basis**	**THE ROLE OF WATER IN EARTH'S SURFACE PROCESSES** 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. (HS.ESS2C.a) **Water has many unique properties (e.g., capacity to absorb, store, and release large amounts of energy; to expand upon freezing; to dissolve and transport many materials) that play a role in how it affects Earth systems (e.g., ocean thermal capacity contributes to moderating temperature variations, ice expansion contributes to rock erosion).** **Water exhibits a polar nature due to its molecular structure.** **Patterns of temperature, the movement of air, the movement and availability of water at Earth's surface can be related to the effect of the properties of water on energy transfer.** **Mechanical effects of water (e.g., stream transportation and deposition, erosion using variations in soil moisture content, and expansion of water as it freezes) on Earth's materials can be used to infer the effect of water on Earth's surface properties.** **Chemical effects of water (e.g., properties of solubility, the reaction of water on iron) on Earth materials can be used to infer the effect of water on Earth's surface processes.**	**STRUCTURE AND FUNCTION** The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **There are relationships between structure and function of natural and designed objects.** **There are relationships between structure and function of systems.** **Relationships between structure and function can be inferred from their overall structure.** **Relationships between structure and function**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
for evidence as part of building and revising models. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Test a design (engineering) individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Plan an investigation (science) individually and collaboratively to produce data to serve as the basis for evidence for supporting explanations for phenomena. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Test a design (engineering) individually and collaboratively to produce data to serve as the basis for evidence for supporting explanations for phenomena. Consider possible confounding variables or effects and evaluate the investigation's design to ensure		can be inferred from the way their components are shaped. Relationships between structure and function can be inferred from the molecular substructures of its various materials.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
variables are controlled. Plan an investigation (science) individually and collaboratively to produce data to serve as the basis for evidence for testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Test a design (engineering) individually and collaboratively to produce data to serve as the basis for evidence for testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.		

Clarification Statement
Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Performance Expectation *and Louisiana Connectors*
HS-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. **LC-HS-ESS2-6a Use a model of photosynthesis to identify that carbon is exchanged between living and nonliving systems.** **LC-HS-ESS2-6b Use a model of cellular respiration to identify that carbon is exchanged between living and nonliving systems.** **LC-HS-ESS2-6c Develop and/or use a quantitative model to identify relative amount of and/or the rate at which carbon is transferred among hydrosphere, atmosphere, geosphere, and biosphere.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **Develop a model based on evidence to illustrate the relationships between systems.** **Develop a model based on evidence to illustrate the components of a system.**	**WEATHER AND CLIMATE** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS.ESS2D.b) **Plants contribute to the make-up of Earth's atmosphere by absorbing carbon dioxide and releasing oxygen.** **Carbon continuously cycles from one sphere to another.** **In the past, the relative amount of carbon that cycled through the hydrosphere, atmosphere, lithosphere or geosphere, and biosphere was partially due to the activity of plants and other organisms.** Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS.ESS2D.c) **Human activities that add carbon dioxide to the atmosphere may be warming Earth's atmosphere.** **A large amount of carbon dioxide has been released into Earth's atmosphere by human-related fossil fuel combustion.** **An increase in atmospheric carbon can increase the amount of heat energy stored in the system.**	**ENERGY AND MATTER** The total amount of energy and matter in closed systems is conserved. **When materials interact within a closed system, the total mass of the system remains the same.** **Energy may change forms, but the total amount of energy cannot change in physical systems.**

Clarification Statement
Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.

Performance Expectation *and Louisiana Connectors*
HS-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth systems and life on Earth. **LC-HS-ESS2-7a Identify examples of coevolution of Earth's systems and the evolution of life on Earth.** **LC-HS-ESS2-7b Identify evidence (e.g., causal links and/or feedback mechanisms between changes in the biosphere and changes in Earth's other systems) in an argument that there is simultaneous coevolution of Earth's systems and life on Earth.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Engaging in argument from evidence: Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Construct an oral and written argument or counterarguments based on data and evidence. **Construct an oral argument based on data and evidence.** **Construct a written argument based on data and evidence.** **Construct an oral counterargument based on data and evidence.** **Construct a written counterargument based on data and evidence.**	**WEATHER AND CLIMATE** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS.ESS2D.b) **Plants contribute to the make-up of Earth's atmosphere by absorbing carbon dioxide and releasing oxygen.** **Carbon continuously cycles from one sphere to another.** **In the past, the relative amount of carbon that cycled through the hydrosphere, atmosphere, lithosphere or geosphere, and biosphere was partially due to the activity of plants and other organisms.** **BIOGEOLOGY** 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. (HS.ESS2E.a) **Feedback (negative or positive) can stabilize or destabilize a system.** **The feedbacks between life on Earth and the Earth's systems cause life on Earth to evolve and the surface of the Earth to undergo changes at the same time.** **Examples of feedback include how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, thus reducing the amount of sunlight reflected from Earth's surface, which in turn increases surface temperatures and further reduces the amount of ice.**	**STABILITY AND CHANGE** Much of science deals with constructing explanations of how things change and how they remain stable. **Science deals with constructing explanations of how things change.** **Science deals with constructing explanations of how things remain stable.**

Clarification Statement
Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.

Performance Expectation ***and Louisiana Connectors***
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. **LC-HS-ESS3-1a Explain the relationship between human activity (e.g., population size, where humans live, types of crops grown) and changes in the amounts of natural resources using evidence.** **LC-HS-ESS3-1b Explain the relationship between human activity (e.g., population size, where humans live, types of crops grown) and changes in the occurrence of natural hazards using evidence.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing explanations and designing solutions: Constructing explanations (science) and designing solutions (engineering) in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. **Construct an explanation based on valid and reliable evidence from a**	**NATURAL RESOURCES** Resource availability has guided the development of human society. (HS.ESS3A.a) **The availability of natural resources has influenced where humans have populated regions of Earth.** **Environmental factors have affected human populations over the course of history.** **Resource availability has driven global development of societies, sizes of human populations, and human migrations.** **Evidence (e.g., from text or other investigations) show correlations between human population distribution and regional availability of resources such as fresh water, fertile soils, and fossils fuels.** **NATURAL HAZARDS** 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. (HS.ESS3B.a) **Natural hazards, such as earthquakes, tsunamis, volcanic eruptions, severe weather, floods, and coastal erosion, have historically affected the sizes and distributions of human populations.** **Environmental factors have affected human populations over the course of history.** **Natural disasters and other geologic events have driven global development of societies, sizes of human populations, and human migrations.** **Historical accounts of natural disasters (e.g., Krakatoa eruption, American Dust Bowl,**	**CAUSE AND EFFECT** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Evidence is required when attributing an observed phenomenon to a specific cause.** **Evidence is required to explain the causal mechanisms in a system under study.** **Evidence is required to support a claim about the causal mechanisms in a system under study.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
variety of sources. **Construct an explanation based on valid and reliable evidence from the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.** **Revise an explanation based on valid and reliable evidence from a variety of sources.** **Revise an explanation based on valid and reliable evidence from the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.**	**Superstorm Sandy, and Hurricane Katrina) resulting human suffering and loss of life could provide empirical evidence of past impacts on human population size and distribution.**	

Clarification Statement
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). Natural hazards and other geologic events exhibit some non-random patterns of occurrence. 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.

Performance Expectation ***and Louisiana Connectors***
HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. **LC-HS-ESS3-2a Identify a solution that demonstrates the most preferred cost-benefit ratios for developing, managing, and utilizing energy and mineral resources (i.e., conservation, recycling, and reuse of resources).** **LC-HS-ESS3-2b Compare design solutions for developing, managing, and/or utilizing energy or mineral resources.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing explanations and designing solutions: Constructing explanations (science) and designing solutions (engineering) in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.** **Evaluate a solution to a complex real-world problem, based on**	**NATURAL RESOURCES** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS.ESS3A.b) **Anything in the environment that is naturally occurring and used by people is a natural resource.** **Demand for energy by society leads to continuous exploration in order to expand supplies of fossil fuels.** **The increase in energy demand and the new technologies being developed to meet these needs and improve the efficiencies of energy systems have social and environmental consequences.** **New technologies of energy production are being developed. For example, the technique of using hydraulic fracturing to extract natural gas from shale deposits is used to acquire energy from natural resources versus other traditional means.** **New technologies could have deep impacts on society and the environment, including some that were not anticipated.** **New technologies are being developed to increase the use of alternate energy sources.** **DESIGNING SOLUTIONS TO ENGINEERING PROBLEMS** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS.ETS1B.a) **It is important to determine the full impact of the advantages and disadvantages when evaluating a solution.**	**SYSTEMS AND SYSTEM MODELS** Systems can be designed to do specific tasks. **Systems can be designed to explain phenomena (scientific).** **Systems can be designed to refine solutions (engineering).** **Systems can be designed for understanding and testing ideas that are applicable throughout science and engineering.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	New technologies offer solutions based on cost benefit ratios, scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, and ethical considerations).	

Clarification Statement
Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural, soil use, forestry, and mining (coal, tar sands, and oil shales), and pumping (ground water, petroleum, and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.

Performance Expectation ***and Louisiana Connectors***
HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. **LC-HS-ESS3-3a Use numerical data to determine the effects of a conservation strategy to manage natural resources and to sustain human society and plant and animal life.**

Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concept**
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential and logarithmic) 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. • Create a computational model or simulation of a phenomenon, designed device, process, or system. **Create/use a computational model of a phenomenon.** **Revise a computational model of a phenomenon.** **Create/use a simulation of a phenomenon.** **Revise a simulation of a**	**HUMAN IMPACTS ON EARTH SYSTEMS** The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS.ESS3C.a) **Responsible use of energy requires consideration of energy availability, efficiency of its use, the environmental impact, and possible alternate sources.** **Poor management of natural resources can have negative impacts on human populations.**	**STABILITY AND CHANGE** Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. **Change and rates of change can be quantified over very short or very long periods of time.** **Change and rates of change can be modeled over very short or very long periods of time.** **Some system changes are irreversible.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
phenomenon. Create/use a computational model of a process. Revise a computational model of a process. Create/use a simulation of a process. Revise a simulation of a process. Create/use a computational model of a system. Revise a computational model of a system. Create/use a simulation of a system. Revise a simulation of a system.		

Clarification Statement
Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.

Performance Expectation *and Louisiana Connectors*
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. **LC-HS-ESS3-4a Connect a technological solution (e.g., wet scrubber; baghouse) to its outcome (e.g., clean air) and its outcome to the human activity impact that it is reducing (e.g., air pollution).**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing explanations and designing solutions: Constructing explanations (science) and designing solutions (engineering) in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations. **Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.** **Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-**	**HUMAN IMPACTS ON EARTH SYSTEMS** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS.ESS3C.b) **Scientists and engineers can develop technological solutions to reduce human impacts on natural systems.** **Societal expectations for a sustainable environment will require new, cleaner technologies for the production and use of energy.** **DESIGNING SOLUTIONS TO ENGINEERING PROBLEMS** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS.ETS1B.a) **It is important to determine the full impact of the advantages and disadvantages when evaluating a solution.** **New technologies offer solutions based on cost benefit ratios, scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, and ethical considerations).** **When scientists and engineers create solutions to problems, they use specific criteria to guide the development of their solutions.** **When scientists and engineers create solutions to problems, they consider the constraints of their design solutions including cost, safety, aesthetics, and reliability.**	**STABILITY AND CHANGE** Feedback (negative or positive) can stabilize or destabilize a system. **Stability denotes a condition in which a system is in balance.** **A feedback loop is any mechanism in which a condition triggers some action that causes a change in that same condition.** **The mechanisms of external controls and internal feedback loops are important elements for a stable system.** **A change in one part of a system can cause changes to other parts of the system, resulting in positive or negative feedback loops.** **The changes (negative**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
generated sources of evidence, prioritized criteria, and tradeoff considerations. **Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.**		**or positive) can stabilize or destabilize a system.**

Clarification Statement
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).

Performance Expectation *and Louisiana Connectors*
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. **LC-ESS3-5a Use geoscience data to determine the relationship between a change in climate (e.g., precipitation, temperature) and its impact in a region.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Analyzing and interpreting data: Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Analyze data using tools in order to make valid and reliable scientific claims.** **Analyze data using tools in order to determine an optimal design solution.** **Analyze data using technology in order to make valid and reliable scientific claims.** **Analyze data using technology in order to determine an optimal**	**GLOBAL CLIMATE CHANGE** **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. (HS.ESS3D.a)** **Technological advances throughout history have led to the discovery and use of different forms of energy and to more efficient use of all forms of energy.** **The increase in energy demand and the new technologies being developed to meet these needs and improve the efficiencies of energy systems have social and environmental consequences.** **Changes in weather technology have occurred in the areas of gathering weather data and using computers to make forecasts.** **This has allowed scientists to model, predict, and manage current and future impacts using global climate models.** **Geoscience data is used to explain climate change over a wide-range of timescales including:** **• one to ten years: large volcanic eruptions, ocean circulation;** **• ten to hundreds of years: changes in human activity, ocean circulation, solar output;** **• tens of thousands to hundreds of thousands of years: changes to Earth's orbit and the orientation of its axis; and** **• tens of millions to hundreds of millions of years: long-term changes in atmospheric composition.**	**STABILITY AND CHANGE** Change and rates of change can be quantified and modeled over very short or long periods of time. Some system changes are irreversible. **Change and rates of change can be quantified over very short or very long periods of time.** **Change and rates of change can be modeled over very short or very long periods of time.** **Some system changes are irreversible.**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
design solution. **Analyze data using models in order to make valid and reliable scientific claims.** **Analyze data using models in order to determine an optimal design solution.**		

Clarification Statement
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).

Performance Expectation *and Louisiana Connectors*
HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. **LC-HS-ESS3-6a Use representations to describe the relationships among Earth systems and how those relationships are being modified due to human activity (e.g., increase in atmospheric carbon dioxide, increase in ocean acidification, effects on organisms in the ocean (coral reef), carbon cycle of the ocean, possible effects on marine populations).**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential and logarithmic) 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 a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. **Use a computational representation of phenomena to describe claims.** **Use a computational representation of phenomena to**	**WEATHER AND CLIMATE** 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. (HS.ESS2D.d) **Current models of Earth's natural systems include system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric carbon dioxide and production of photosynthetic biomass and ocean acidification).** **Increased carbon dioxide level in the atmosphere traps more heat. This will lead to a gradual increase in the temperature of Earth's atmosphere.** **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.** **Based on current models, Earth's average global temperatures will continue to rise due to an increase in human-generated greenhouse gases (e.g., carbon dioxide and methane) in Earth's atmosphere and associated feedbacks.** **Human impact on climate change must be addressed.** **Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science and engineering capabilities.** **GLOBAL CLIMATE CHANGE** Important discoveries are still being made about how the ocean, the atmosphere, and the	**SYSTEMS AND SYSTEM MODELS** 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. **When investigating a system, the boundaries and initial conditions of the system need to be defined.** **When describing a system, the boundaries and initial conditions of the system need to be defined.** **When investigating a system, the inputs and outputs need to be analyzed and described**

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
describe explanations. **Use a computational representation of phenomena to support claims.** **Use a computational representation of phenomena to support explanations.** **Use a computational representation of a design solution to describe claims.** **Use a computational representation of a design solution to describe explanations.** **Use a computational representation of a design solution to support claims.** **Use a computational representation of a design solution to support explanations.**	biosphere interact and are modified in response to human activities (e.g., through computer simulations and other discoveries satellite imagery). (HS.ESS3D.b) **Scientists continually learn more about how Earth's systems interact and are changed by human activities.** **Modern civilization depends on major technological systems.** **Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities.** **Scientists and engineers use human-generated models including computer simulations, to predict how the amount of greenhouse gases in Earth's atmosphere impacts the biological and physical processes on Earth (e.g., oceanic acidification, coral bleaching, ocean circulation, etc.).**	**using models.** **When describing a system, the inputs and outputs need to be analyzed and described using models.**

Clarification Statement
Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.