Unit Summary
How do humans depend on Earth's resources?   ***How and why do humans interact with their environment and what are the effects of these interactions?***   In this unit of study, students examine factors that have influenced the distribution and development of human society; these factors include climate, natural resource availability, and natural disasters. Students use *computational representations* to analyze how earth systems and their relationships are being modified by human activity. Students also develop an understanding of how human activities affect natural resources and of the interdependence between humans and Earth's systems, which affect the availability of natural resources. Students will apply their engineering capabilities to reduce human impacts on earth systems and improve social and environmental cost–benefit ratios. The crosscutting concepts of *cause and effect*, *systems and systems models*, *stability and change*, and *the influence of engineering, technology, and science on society and the natural world* are called out as organizing concepts for the disciplinary core ideas. Students will analyze and interpret data, use mathematical and computational thinking, and construct explanations as they demonstrate understanding of the disciplinary core ideas.
Student Learning Objectives
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. *[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). 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-ESS3-1)**
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. *[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.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]* **(HS-ESS3-6)**
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. *[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).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]* **(HS-ESS3-5)**
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* *[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).]* **(HS-ESS3-4)**
Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety,

reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)

Quick Links		

Unit Sequence	
Part A: *How are human activities influence the global ecosystem?*	
Concepts	**Formative Assessment**
• Resource vitality has guided the development of human society. • Natural hazards and other geologic events have shaped the course of human history. • Natural hazards and other geologic events have significantly altered the sizes of human populations and have driven human migration. • Empirical evidence is required to differentiate between cause and correlation and make claims about how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activities. • Modern civilization depends on major technological systems. • Changes in climate can affect population or drive mass migration.	*Students who understand the concepts are able to:* • Construct an explanation based on valid and reliable evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. • Use empirical evidence to differentiate between how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Unit Sequence	
Part B: *What are the relationships among earth's systems and how are those relationships being modified due to human activity?*	
Concepts	**Formative Assessment**
• Current models predict that, although future regional climate changes will be complex and will vary, average global temperatures will continue to rise. • The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases are added to the atmosphere each year and by the ways in which these gases are absorbed by	*Students who understand the concepts are able to:* • Use a computational representation to illustrate the relationships among Earth systems and how these relationships are being modified due to human activity.

the ocean and biosphere. • 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. • 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. • Criteria may need to be broken down into similar ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. • Human activities can modify the relationships among Earth systems.	• Describe the boundaries of Earth systems. • Analyze and describe the inputs and outputs of Earth systems.

Unit Sequence	
Part C: *What is the current rate of global or regional climate change and what are the associated future impacts to Earth's systems?*	
Concepts	**Formative Assessment**
• Although the magnitude of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. • Change in rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • Science knowledge is based on empirical evidence.	*Students who understand the concepts are able to:* • Analyze geosciences 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. • Quantify and model change and rates of change in geosciences data and rates of global or regional climate change and associated impacts to Earth systems.

Unit Sequence	
Part D: *How can the impacts of human activities on natural systems be reduced?*	
Concepts	**Formative Assessment**
• Scientist and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. • Engineers continuously modify these systems to increase benefits while	*Students who understand the concepts are able to:* • Evaluate or refine a technological solution that reduces impacts of human activities on natural systems based on scientific knowledge and student-generated sources of evidence; prioritize criteria and tradeoff considerations.

decreasing costs and risks. • Feedback (negative or positive) can stabilize or destabilize natural systems. • When evaluating solutions, it is important to take into account a range of constraints, including costs, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. • New technologies can have deep impacts on society and the environment, including some that are not anticipated. • Analysis of costs and benefits is a critical aspect of decisions about technology.	

What It Looks Like in the Classroom

Students will use their understanding of photosynthesis, cellular respiration, and the carbon cycle from prior units and examine their relationship to climate change and human impact on climate. They will develop an understanding of how human activity can influence the complex set of interactions within an ecosystem, causing changes in the number of different types of species.

Students will also build on the idea that 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. All of these concepts support students' understanding of human dependence on Earth's resources, human interactions with the environment, and human impacts on Earth's systems.

Environmental factors have affected human populations over the course of history. Resource availability, natural disasters, and other geologic events have driven global development of societies, sizes of human populations, and human migrations. Student understanding of these relationships could be enhanced by examining and citing evidence from text or other investigations that show correlations between human population distribution and regional availability of resources such as fresh water, fertile soils, and fossils fuels.

Students should look for cause-and-effect relationships between human population distribution and resource availability and distinguish between causality and correlation. In developing an explanation for how the availability of natural resources has influenced human activity, students might consider, for example, the dependence of large urban populations on the technology required to deliver potable water. An example of the role that technology plays could include the impounding of the Colorado River by the Hoover Dam and the formation of Lake Mead, which provides the water required to support large human populations in an otherwise arid and desert habitat.

Historical accounts of natural disasters (e.g., Krakatoa eruption, American Dust Bowl, 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. Previous climate change events (sea level fall and rise, desertification of the Sahara) could be studied as examples of natural events that can drive human migrations. Students should use evidence from data analysis to make inferences and predictions about the impacts of future climate change and global warming on displacement or migration of humans.

When examining and reporting data, students should represent resource availability, natural disasters, and human activity symbolically and determine what quantitative relationships exist. Students might map these relationships in graphs, charts, or other descriptive models, while considering any limitations on measurement when reporting quantities.

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. Students should describe the boundaries of Earth's systems by looking at models, data sets, or graphics showing temperatures and currents of the ocean and atmosphere. They should identify evidence to support the claim that human activity can modify Earth's systems. When students are 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. Students might also analyze and describe the inputs and outputs of Earth's systems by researching and investigating the amount of carbon dioxide produced by human activities. In their research, students should integrate and evaluate multiple sources of information and verify data when possible. Students could then design a solution to decrease the amount of carbon dioxide added by human activity. The design process may need to be broken down into logical steps that can be approached systematically, and decisions about the priority of certain criteria over others should be considered throughout the process.

Current global 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 depend on the amount of human-generated greenhouse gases added to the atmosphere each year and on the ways in which these gases are absorbed by the ocean and biosphere. Students can use computational representations of geoscience data to illustrate these relationships and make forecasts about Earth's systems. Students might illustrate how relationships are being modified due to human activity by graphing temperature changes over a period of time. Rates of change should be quantified and modeled at different time scales. In symbolic representations of relationships between Earth's systems and human activity, students should consider appropriate quantities and limitations on measurement when reporting data.

When evaluating or refining a technological solution that reduces impacts of human activities on natural systems, such as use of alternative energy sources, students should read and integrate multiple sources of information to create a coherent understanding of the problem. In their evaluation, they should consider costs, benefits, and risks of systems created by engineers. When evaluating solutions, students should take into account a range of constraints, including costs, safety, and reliability, as well as any social, cultural, and environmental impacts. Models created by students should be used to illustrate and analyze positive and negative feedback within natural systems that may lead to stabilization or destabilization.

Examples of technologies that might limit future impacts of human activity could be small-scale local efforts or large-scale geoengineering solutions for more global issues. Students might research and analyze data regarding the use of fossil fuels to power machines and the quantities and types of pollutants produced. The analysis of data could be used to investigate how alternative energy machines, such as electric- or hydrogen powered cars, could be used to reduce carbon emissions. Students should consider the availability of infrastructure, trained technicians, economic constraints, reliability, and other trade-offs, like personal aesthetic preference, in their evaluations or design decisions.

Integration of engineering-

Performance expectation HS-ESS3-4 specifically identifies a connection to HS-ETS1-3. This requires students to evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. To meet this requirement, students will evaluate technological solutions that limit human impacts on natural systems. In their evaluations, students should consider how new technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Connecting with English language arts/literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence of the availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Use empirical evidence to write an explanation for how the availability of natural resources, occurrence of natural hazards, and changes in climate have

influenced human activity.

- Cite specific textual evidence supporting forecasts of the current rate of global or regional climate change and associated future impacts to Earth systems, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Determine and clearly state results from data on global climate models and associated impacts to Earth systems by paraphrasing them in simpler but still accurate terms.
- Integrate and evaluate global climate change data from multiple sources to reveal patterns and relationships and forecast current rate of global or regional climate change and associated future impacts.
- Cite specific textual evidence to support a technological solution that reduces the impacts of human activities on natural systems, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Evaluate the validity of hypotheses, data, analysis, and conclusions in a science or technical text about the impact of human activities on natural systems, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order to evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- Read multiple sources in order to refine design solutions to reduce impacts of human activities on natural systems and create a coherent understanding of the problem.

Mathematics

- Represent how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity symbolically and manipulate the representing symbols. Make sense of quantities and relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Use units as a way to understand the relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity. Choose and interpret units consistently in formulas to determine relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Choose and interpret the scale and the origin in graphs and data displays representing relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Define appropriate quantities for the purpose of descriptive modeling of relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Represent symbolically the relationships among Earth systems and how these relationships are being modified due to human activity, and manipulate the representing symbols. Make sense of quantities and relationships between Earth systems and human activity.
- Use a mathematical model to describe the relationships among Earth systems and how those relationships are being modified due to human activity. Identify important quantities in human activities and their effects on Earth systems and map their relationships using tools. Analyze these relationships mathematically

to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Use units as a way to understand how relationships among Earth systems are being modified by human activity. Choose and interpret units consistently in formulas to determine relationships among
- Earth systems and how they are being modified by human activity. Choose and interpret the scale and origin in graphs and data displays representing how human activity modifies relationships among Earth systems.
- Define appropriate quantities for the purpose of descriptive modeling of how the relationships among Earth systems are being modified due to human activity.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing relationships among Earth systems and how they are being modified due to human activity.
- Represent forecasts of the current rate of global or regional climate change and associated future impacts to Earth systems symbolically, and manipulate the representing symbols. Make sense of quantities and relationships between geoscience data and results from global climate models to forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- Define appropriate quantities for the purpose of descriptive modeling of forecasts of the current rate of global or regional climate change and associated future impacts to Earth systems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing forecasts of the current rate of global or regional climate change and associated future impacts to Earth systems.
- Represent impacts of human activities on natural systems symbolically and manipulate the representing symbols. Make sense of quantities and relationships between human activities and natural systems.
- Use units as a way to understand the impacts of human activities on natural systems. Choose and interpret units consistently in formulas to determine the impacts of human activities on natural systems. Choose and interpret the scale and origin in graphs and data displays representing the impacts of human activities on natural systems.
- Define appropriate quantities for the purpose of descriptive modeling of the impacts of human activities on natural systems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of human activities and their impacts on natural systems.
- Use a mathematical model to describe human activities and their effects on natural systems. Identify important quantities in human activities and their effects on natural systems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations,

graphs, charts, data tables, multimedia, modeling).

- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning

Most high school students seem to know that some kind of cyclical process takes place in ecosystems. Some students see only chains of events and pay little attention to the matter involved in processes such as plant growth or animals eating plants. They think the processes involve creating and destroying matter rather than transforming it from one substance to another. Other students recognize one form of recycling through soil minerals but fail to incorporate water, oxygen, and carbon dioxide into matter cycles. Even after specially designed instruction, students cling to their misinterpretations. Instruction that traces matter through the ecosystem as a basic pattern of thinking may help correct these difficulties (NSDL, 2015).

Prior Learning

By the end of Grade 8, students understand that:

Physical science

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- 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.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Life science

- Organisms, and populations of organisms, are dependent on their environmental interactions with other living things and with nonliving factors.
- 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.

- Growth of organisms and population increases are limited by access to resources.
- 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.
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on, such as water purification and recycling.
- 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.
- 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.
- 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.
- 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.

Earth and space science

- 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 the matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- 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.
- 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.
- 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.
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- 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.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.
- Water's movements, both on the land and underground, cause weathering and erosion, which change the land's surface features and create underground formations.
- 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.
- 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.
- 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.
- 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.
- Because these patterns are so complex, weather can only be predicted probabilistically.
- 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.

Connections to Other Courses

Physical science

- 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.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

Life science

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- 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.
- 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.
- 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, the ecosystem 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.
- 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.
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- 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.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- 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.

Earth and space sciences

- Humans depend on the living world for 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.
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- 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.
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Sample of Open Education Resources
Climate Change Impacts: NOAA Education Resources that can be used to teach climate science.
Digital Library for Earth System Education: DLESE is the Digital Library for Earth System Education, a free resource that supports teaching and learning about the Earth system. DLESE's development was funded by the National Science Foundation and continues to be built by a distributed community of educators, students, and scientists to support Earth system education at all levels. DLESE is operated by the National Center for Atmospheric Research (NCAR) Computational and Information Systems Laboratory and the NCAR Library on behalf of the education community.

Appendix A: NGSS and Foundations for the Unit
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. *[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). 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-ESS3-1)**
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. *[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.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]* **(HS-ESS3-6)**
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. *[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).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]* **(HS-ESS3-5)**
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. *[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).]* **(HS-ESS3-4)**
Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions • 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. (HS-ESS3-1) • 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. (HS-ESS3-4) **Analyzing and Interpreting Data** • Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5) **Using Mathematics and Computational Thinking** • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)	**ESS3.A: Natural Resources** • Resource availability has guided the development of human society. (HS-ESS3-1) **ESS3.B: 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-ESS3-1) **ESS2.D: 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. (secondary to HS-ESS3-6) **ESS3.D: Global Climate Change** • 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. (HS-ESS3-6) **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1) **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. (HS-ESS3-6) **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. (HSESS3-4) - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.1** (HS-ETS1-3) Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.7** (HS-ETS1-3) Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-ETS1-3) Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. **RST.11-12.9** (HS-ETS1-3).	Reason abstractly and quantitatively. **MP.2** (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7) Model with mathematics. **MP.4** (HS-ETS1-3) Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays**. HSN.Q.A.1** (HS-ETS1-3). Define appropriate quantities for the purpose of descriptive modeling. **HSN.Q.A.2** (HS-ETS1-3). Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSN.Q.A.3** (HS-ETS1-3).