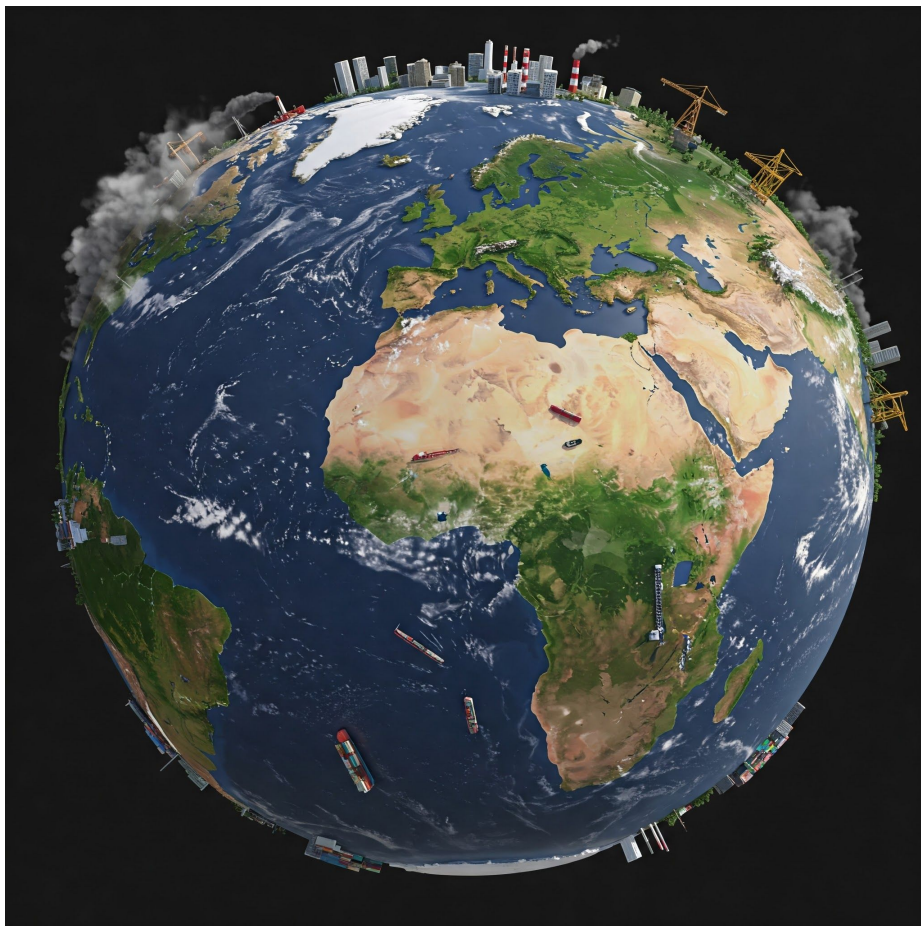


Solutions for a Sustainable Future - Teacher Materials

Unit 6

Earth and Space Science



The Curriculum and Instruction Department at New Visions for Public Schools develops free, full-course materials for all areas of high school science, math, ELA, and social studies, for use across our network of 80 New York City schools and beyond.



Materials created by New Visions are shareable under a [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International \(CC BY-NC-SA 4.0\)](#) license; materials created by our partners and others are governed by other license agreements. For more details, please see [this page](#).

Unit 6 Solutions for a Sustainable Future Table of Contents

Unit 6 Solutions for a Sustainable Future	2
Unit Introduction	3
Storyline and Pacing Guide	5
Unit Standards	10
Implementing Unit 6	16
Unit Opening	23
Burning Fossil Fuels 5E	33
Land Use and Biodiversity 5E	75
Mining 5E	110
Unit Closing	138

Unit 6 Solutions for a Sustainable Future

Human Sustainability

Performance Expectations

HS-ESS3-4, HS-ESS3-6, HS-ETS1-3, HS-ESS3-3, HS-ETS1-4, HS-ESS3-2, HS-ETS1-2

Time

25-31 days

How can we model and evaluate solutions for a sustainable future to mitigate the environmental problems caused by humans?

As the human population continues to grow so does our need for food, materials, and transportation. As humans mine for materials, use, and transport these materials, the impact can often be seen with an increase in air pollution which can impact those with health problems disproportionately. While these human endeavors often have a negative impact on the environment, as technology and innovation improve, so do the solutions to these issues. Students will explore how human activity has changed the environment and ecosystem around us using data to create arguments for potential solutions. Students will create computational models to show how human activity impacts Earth's systems as well as design solution models to improve the stability of the Earth's ecosystems. They will continue to evaluate the possible solutions to this multisystem problem using system and system models showing how solutions can mitigate human impacts on multiple Earth systems.

Unit Opening

Burning Fossil Fuels 5E

Land Use and Biodiversity 5E

Mining 5E

Unit Closing

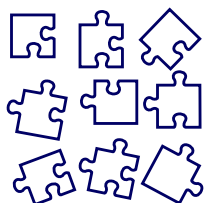
Anchor Phenomenon

→

5E Lessons connect learning to the performance task

→

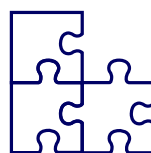
Performance Task



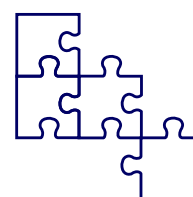
How is human activity harming the health of humans and the natural environment? How is the health of humans and the natural environment intertwined? What solutions adequately address these problems and can be implemented in the real world?



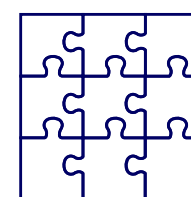
Why is burning fossil fuels causing those negative outcomes, and how can we evaluate and refine solutions to reduce them?



How do the ways humans change land affect the health of people and biodiversity? How can we stabilize systems that have been destabilized by these changes?



How can we evaluate and compare solutions that try to mitigate negative health outcomes for people and organisms that result from mining coal?



How is human activity harming the health of humans and the natural environment? How is the health of humans and the natural environment intertwined? What solutions adequately address these problems and can be implemented in the real world?

Unit Introduction

How do we make science education meaningful and relevant to our students? High school earth and space science courses are traditionally filled with lectures and cookbook labs, memorizing vocabulary, and an occasional research report. New science education standards (NGSS/NYSSLS) require a more engaging, accessible vision of science teaching and learning to help *all* students learn about the natural world and become scientifically literate citizens.

The three-dimensional, phenomenon-driven materials in this unit support students in engaging in the authentic practices of science. Students construct meaning about the natural world through modeling, investigations, labs and experiments. As students have opportunities to manipulate the physical tools of science, they also engage in productive struggle that can be resolved through creating models from evidence and engaging in consensus building discussions. The materials support teachers in becoming skillful facilitators of student sense-making and deepen teachers' understanding of how to teach science in an interactive way that is driven by students' questions and ideas.

This unit was intentionally designed to build on the fifth unit of this course, *More Hurricanes and Blizzards in NYC?*, in which students investigate how human activities will impact future storms. In *Solutions for a Sustainable Future*, students argue in favor of solutions to reduce the impacts they have been learning about over the past two units. The common embedded group learning routines and curriculum structures introduced in the first unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to argue in favor of sustainable solutions to weigh their costs and benefits in service of a better future.

The embedded group learning routines and formative assessments found in each of the Earth and Space Science units support teachers in learning about their students, both academically and personally. Whether students had strong science programs prior in prior courses, or if three-dimensional teaching and learning is brand new to them (or the teacher!), this unit is designed to reinforce and further build on students' earlier experiences with three-dimensional learning.

Unit Coherence

In Unit 6, the overall question about how we can improve human and organismal health through sustainability is intended to motivate student engagement across the unit. From the students' perspective, there should be a clear and explicit unit storyline that guides the sequence of activities. Rather than one long continuous unit, we have chosen to use an instructional model to develop three coherent sequences of lessons within Unit 6. Each sequence is based on students' questions and builds towards figuring out something that contributes to the overall unit-level question about how to analyze sustainable solutions. This in turn allows students to argue in favor of one or more solutions that will best improve global health. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 5.

Phenomenon-Driven Instruction

Phenomena are a key part of instruction in A Framework for K-12 Science Education and the NGSS. As in the work of scientists, students should be encouraged to move from observable phenomena to generalizable explanations of the natural world. Too often, traditional science instruction has started with generalizable principles, sidelining the lived experience and intuitions that all young people bring to school. In this unit (and all New Visions units) there are two kinds of phenomena: anchor phenomena and investigative phenomena.

Anchor Phenomenon	Investigative Phenomena
• One per unit; drives the learning of the unit • Attention-grabbing and relevant • Does not have to be phenomenal	• One per 5E sequence (three in this unit) • Presented in the Engage phase of each 5E

Anchor Phenomenon

To support coherence, students are prompted to figure out one overarching, real-world question over the course of the unit. The anchor phenomenon question is revisited across the unit, and this question motivates the investigations conducted in each of the 5E instructional sequences. A good anchor phenomenon should be attention-grabbing and relevant to students but also thought-provoking, comprehensible, and connected to the science learning goals. It needs to be observable to students through firsthand experiences or through someone else's experiences, such as through a video or secondary data. If a teacher feels the anchor phenomenon will not be familiar or accessible to all students, we suggest relating it to similar, more familiar phenomena. It is important to notice that the phenomenon question anchoring the unit is different from the more generalized and abstracted science question for the unit. This difference is part of what helps make the unit more student-centered, rather than teacher-centered.

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon, typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized, rather than the traditional content questions teachers use as their lesson aims. They present what is being figured out; therefore, the scientific concepts that are in the learning goal cannot be part of the wording of the question!

Storyline and Pacing Guide

Unit Opening

How is human activity harming the health of humans and the natural environment? How is the health of humans and the natural environment intertwined? What solutions adequately address these problems and can be implemented in the real world?

Performance Expectations

Anchor Phenomenon

Around the world, the health of humans and the natural environment is suffering negative consequences of human activity.

Time
2 days

Student Questions

These questions motivate the unit storyline.

- What human actions are causing these problems?
- What environmental conditions are causing health problems?
- Are some places that are near each other hotter than others because of differences in the land?
- Are some places more polluted than others?
- How do environmental conditions cause respiratory diseases, cardiovascular diseases, cancer, and other diseases?
- What is the connection between biodiversity and human health?
- Why do some countries have more deaths from environmental causes than others?
- Why do some countries have more biodiversity loss than others?
- Why do some areas that are side-by-side have such different health outcomes?
- How are these factors linked to climate change?
- How are these factors linked to burning fossil fuels?
- Are “greener” or “natural” places healthier than other places?

What Students Do

Students have discussions and watch videos about the ways that the environment can cause health problems for people and result in the current biodiversity crisis. Students observe maps showing the distribution of biodiversity loss, deaths from environmental causes, and heat deaths globally.

Students are then introduced to the unit performance task which is focused on using computational models related to human impacts on the environment in order to analyze the effects of the human actions and then evaluating, refining, and arguing for solutions to minimize these negative effects.

Finally, students surface their initial ideas about the types of solutions that might reduce negative impacts on the environment and generate questions that they want to investigate in order to make further sense of how and why human activities are causing negative health outcomes for humans and other organisms.

The text entered here will be used on the Storyline and Pacing Guide. Write this in third person. This should be around 10 sentences or 150 words.

Student Ideas

These ideas are revisited throughout the unit storyline.

- Some areas might be more polluted than others, which could cause negative health impacts
- Some places might have more green space than others, which might have positive health impacts
- Maybe areas where there is more biodiversity loss are also areas where humans have affected the environment most
- Maybe climate change is causing global warming which is increasing heat deaths

During the Driving Question Board routine, students ask questions about what types of human actions are causing damage to the environment, how pollution and the relationship of these actions to climate change and burning fossil fuels. Once a category related to these questions has been articulated, let students know that over the next few class periods, they will begin investigating this question to figure out how burning fossil fuels may relate to some of these negative outcomes.

The text entered here will be used on the Storyline and Pacing Guide. If left blank, “Fitting it all together” will not be included for this lesson on the Storyline and Pacing Guide.

Burning Fossil Fuels 5E

Why is burning fossil fuels causing those negative outcomes, and how can we evaluate and refine solutions to reduce them?

Performance Expectations
HS-ESS3-4, HS-ESS3-6, HS-ETS1-3

Investigative Phenomenon
Around the world, millions of people and organisms are dying as a result of burning fossil fuels, but the damage is not equally distributed.

Time
7-9 days

Student Questions	What Students Do	Student Ideas
<i>These questions motivate this 5E sequence and the unit storyline.</i> - How does burning fossil fuels relate to human health or loss of biodiversity? - Do areas that are more polluted have more deaths from environmental causes? - What is the connection between biodiversity and human health? - How can we reduce deaths from environmental causes? - How can we reduce biodiversity loss?	In this 5E instructional sequence, students investigate the questions surfaced during the Driving Question Board launch. First, students observe data showing global deaths from air pollution resulting from burning fossil fuels and the pollutants that are emitted when fossil fuels are burned. Then, they analyze the difference in air pollution and fossil fuel use between different countries, focusing on India, France, and the United States. Students will determine that France has lower pollution because it utilizes nuclear energy, and will refine France's nuclear energy solution to apply to the United States. After that, students will focus on the carbon dioxide emissions of burning fossil fuels and investigate its impact on ocean acidification, as well as how coastal restoration can offset that negative outcome. Students will construct a model showing how these emissions affect different systems and use that model to demonstrate how utilizing zones of limited car emissions would impact multiple systems.	<i>Students figure out these ideas in this 5E sequence.</i> - Burning fossil fuels releases different types of emissions including: carbon dioxide, particulate matter (including black carbon), nitrous oxides, sulfur dioxide, and carbon monoxide - Carbon dioxide is a greenhouse gas, but doesn't directly impact human health. - Other fossil fuel emissions cause air pollution, which can cause diseases like respiratory and cardiovascular disease. - Although carbon dioxide doesn't directly impact human health, it does cause ocean acidification, which puts ocean ecosystems at risk, which can have impacts on the health of humans - Reducing the use of fossil fuels will help: 1) reduce air pollution; 2) reduce ocean acidification; and 3) reduce climate change. - One option to reduce fossil fuel use is to switch to nuclear energy - Another option to reduce fossil fuel use is to create zones of limited emissions - Ocean coastal restoration can absorb carbon dioxide and offset the impacts of ocean acidification

After explaining how burning fossil fuels contributes to air pollution, students are able to determine that reducing the use of fossil fuels will benefit human health and biodiversity by reducing air pollution and reducing ocean acidification. Students will be able to evaluate three solutions: using nuclear energy, performing coastal restoration, and implementing zones of limited emissions. They will be able to explain how using these solutions together can help approach the larger problem of deaths from environmental causes by modeling the impacts of these actions on air pollution and ocean acidification.

Land Use and Biodiversity 5E

How do the ways humans change land affect the health of people and biodiversity?
How can we stabilize systems that have been destabilized by these changes?

Performance Expectations
HS-ESS3-3, HS-ETS1-4

Investigative Phenomenon
350 New Yorkers die every year from the urban heat island effect, which affects people differently according to the heat vulnerability index of different neighborhoods.

Time
6-8 days

Student Questions	What Students Do	Student Ideas
<i>These questions motivate this 5E sequence and the unit storyline.</i> From the Unit Launch - Why do some areas that are side-by-side have such different health outcomes? - Are “greener” or “wilder” places healthier than other places? From the Fossil Fuels 5E - What role does the heat component of carbon dioxide emissions play in human and biodiversity health? - Does burning fossil fuels contribute to the heat deaths around the world?	In this 5E instructional sequence, students investigate the questions surfaced during the Driving Question Board launch and which were raised in the last 5E. First, students observe the heat island effect in New York City. Then they analyze variables relating to land use which might contribute to the heat island effect and to the sustainability of neighborhoods. Using that information, students construct and use a computational model to demonstrate the relationships between the variables and how altering one impacts the others. Next, students read about a solution implemented in another city and use their models to evaluate how that solution would impact heat and sustainability in New York City. After that, students analyze the parallel phenomenon of deforestation in the Amazon, which also causes localized heat islands and related effects on human health and biodiversity. Finally, students will use a computational model to analyze how utilizing green roof space would reduce the heat island effect and improve health outcomes.	<i>Students figure out these ideas in this 5E sequence.</i> - The urban heat island effect is a result of human society and urbanization, which has reduced green space and replaced it with surfaces that absorb and reradiate heat like asphalt - Increasing trees creates positive feedback loops that also increase biodiversity and decrease heat and energy use - Changes to land use over human history are likely irreversible, but changes can be made to stabilize the systems - Deforestation is also happening in other areas, like the Amazon rainforest, which is causing localized heating and other negative impacts on health and biodiversity - There might be other ways that we are using land that also is contributing to deaths from environmental causes

After explaining how reducing green space for urbanization and agriculture impacts ecosystems, students will model the impacts of increasing green space on these systems. Then they will explore how solutions designed to increase green space can cause positive feedback loops that increase sustainability. Students should end wondering if there are other ways that people modify land and the impacts of those changes. Use these questions to transition to the mining 5E.

Mining 5E

How can we evaluate and compare solutions that try to mitigate negative health outcomes for people and organisms that result from mining coal?

Performance Expectations
HS-ESS3-2

Investigative Phenomenon
Within the United States, areas around coal mines in Appalachia have higher rates

Time
7-9 days

Student Questions	What Students Do	Student Ideas
<i>These questions motivate this 5E sequence and the unit storyline.</i> From the Unit Launch - How do environmental conditions cause cancer? - How are these factors linked to fossil fuels? From the Land Use and Biodiversity 5E - Are there other ways we use land that cause damage to human and ecosystem health?	In this 5E instructional sequence, students investigate the questions surfaced during the Driving Question Board launch and which were raised in the last 5E. First, students observe maps showing an area of high rates of lung cancer and biodiversity loss. Then they model the effects of mining using a hands-on simulation and quantify the costs and benefits of coal mining. After that, they fully define the problem of mountaintop removal coal mining by reading about its impacts on biodiversity and human health. Next, students evaluate the differences between coal mining in Appalachia and mining practices in New York City, and then evaluate pairs of solutions to better understand their costs, benefits, and tradeoffs. Finally, students will argue in favor of one solution to reduce the negative impacts of mining on human and ecosystem health	<i>Students figure out these ideas in this 5E sequence.</i> - We extract resources from the Earth through mining - Mining for coal, a major fossil fuel, especially using mountaintop removal coal mining technology, causes huge amounts of environmental destruction and results in high rates of cancer - The negative impacts of mining can be reduced through mine reclamation, regulation of sustainable practices, reusing mining waste, and reducing reliance on fossil fuels - All solutions have costs, benefits, and tradeoffs

After students have reviewed the impacts of mining and solutions to reduce its negative effects, students will have many ways they can approach the problem of deaths from environmental causes and negative impacts on biodiversity. At this point, students should understand that environmental causes of disease also often cause reductions in biodiversity, and that solutions that help one of those categories also help the other.

Unit Closing

How is human activity harming the health of humans and the natural environment? How is the health of humans and the natural environment intertwined? What solutions adequately address these problems and can be implemented in the real world?

Performance Expectations
HS-ESS3.2, HS-ETS1-2

Anchor Phenomenon
Around the world, the health of humans and the natural environment is suffering negative consequences of human activity.

Time
3 days

Student Questions

These questions are addressed in the performance task.

What Students Do

Students draw connections between all of the problems they identified and the use of fossil fuels. Students use a computational model to simulate the combined effects of the different solutions they evaluated on projected greenhouse gas emissions and argue for the components of the problems they can solve.

Student Ideas

These ideas were developed throughout the unit storyline.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Performance Expectations

- HS-ESS3-4 *** **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).
Assessment Boundary: None
- In NYS, the phrase "could range from local efforts" has been replaced with the phrase "could include practices ranging from local efforts."
- 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.**
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-ETS1-3 *** **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.**
Clarification Statement: None
Assessment Boundary: None
- HS-ESS3-3** **Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.**
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.
Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.
- In NYS both occurrences of the word "include," has been modified to say "could include."
- HS-ETS1-4 *** **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**
Clarification Statement: None
Assessment Boundary: None

HS-ESS3-2 *	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. 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, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen. Assessment Boundary: None
HS-ETS1-2 *	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Clarification Statement: None Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school Earth and Space Science, Unit 6 focuses primarily on ideas related to human impact and sustainability. This unit also engages students' use of the SEP of Thinking Mathematically and has a secondary focus on the SEP of Constructing Explanations and Designing Solutions. That is not to say that students will not engage in other SEPs throughout the lessons; however, it is important to foreground and be explicit about a limited number of practices with enough duration to see how students develop their understanding and ability to use this practice. This is important for both student and teacher learning! Similarly, the foregrounded CCC for this unit is *Patterns*, which fits well with our selected SEP and the understanding that patterns in Earth's processes and systems allows scientists to determine the structure and composition of Earth. Two secondary CCCs for the unit, Energy and Matter and Stability and Change are also useful to students as they use these ideas in two ways: (1) examining the changes to Earth's surface as a result of tectonic activity and; (2) developing explanations for how energy and matter move together during tectonic activity. The design of instruction across the unit supports students' three-dimensional learning and shifts classrooms to become more NGSS-aligned spaces.

Three Dimensions Foregrounded in Unit 6

This chart is a high-level summary of the foregrounded standards. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems	ESS2.B Plate Tectonics and Large-Scale System Interactions	Systems and Systems Models
Using Mathematics and Computational Thinking	ESS2.D Weather and Climate	Stability and Change
Constructing Explanations and Designing Solutions	ESS3.A Natural Resources	Influence of Science, Engineering, and Technology on Society and the Natural World
Engaging in Argument from Evidence	ESS3.C Human Impacts on Earth Systems	Science is a Human Endeavor
	ESS3.D Global Climate Change	Science Addresses Questions About the Natural and Material World
	ETS1.A Defining and Delimiting an Engineering Problem	
	ETS1.B Developing Possible Solutions	
	ETS1.C Optimizing the Design Solution	

Building on Middle School

High school science teaching necessarily builds on student learning from middle school. It is helpful to consider the middle school standards in order to enact a unit that builds on students' prior experiences. As we are in the middle of a multi-year transition, however, it is also critical to keep in mind that not all students will have experienced an NGSS-designed unit when they come to high school, so the process of building on middle school learning may be particularly complex for years to come. The following sections detail the ways in which this unit builds on middle school standards across the three dimensions.

Disciplinary Core Ideas from Middle School

ESS2.A Earth Materials and Systems

- In middle school, students learn that all Earth's processes are a result of energy flowing and matter cycling within and between Earth's systems over different scales. In this unit, students build upon that understanding by considering how energy drives the motion of matter during tectonic activity.

ESS2.B Plate Tectonics and Large-Scale System Interactions

- Students in middle school learn that Earth's plates have moved. This unit builds on that basic idea by adding complexity to the mechanisms of that motion, including how Earth's structure contributes to that motion and how energy from radioactive decay in Earth's mantle drives the movement.

ESS1.C The History of Planet Earth

- In middle school, students learn foundational concepts about tectonic activity slowly generating the seafloor and ocean ridges. In this unit, students expand upon that understanding by relating it to the rates of change that construct Earth's surface features and connect it to plate tectonic theory.

Crosscutting Concepts from Middle School

Stability and Change

This unit builds on the following aspects of Stability and Change in middle school:

- Middle school students learn that changes in one part of a system can impact other parts, and that change can happen quickly or over a long period of time. This unit builds on that background as students examine changes that happened gradually over Earth's history and disruptions that caused more rapid changes over shorter scales.

Patterns

This unit builds on the following aspects of Patterns in middle school:

- Middle school students learn that patterns in rates of change can provide information about natural systems. This unit builds on that background by using patterns at different scales to gain information about Earth's structure and plate tectonic theory.

Energy and Matter

This unit builds on the following aspects of Energy and Matter in middle school:

- Middle school students learn that matter is conserved and that the transfer of energy drives the movement of matter. This unit builds on that background as students examine the sources and movement of energy driving the movement of matter during tectonic activity.

Science and Engineering Practices from Middle School

Constructing Explanations and Designing Solutions

- Students in middle school have experience constructing explanations using multiple lines of evidence. In this unit, students build upon that practice by adding student-generated sources of evidence from investigations in order to make a claim about the relationship between different variables.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 6 targets a bundle of four PEs taken from core idea 3 high school Earth and Space Science (ESS3); those standards are HS-ESS3-2, HS-ESS3-3, HS-ESS3-4, and HS-ESS3-6. This PE bundle informs the types of three-dimensional tasks in which students engage across the unit. Each sequence of lessons within the unit targets elements from one or more of the performance expectations for the unit, and the teacher has opportunities to collect evidence of student learning around these elements within that learning sequence. The unit-level Performance Task only targets a subset of three-dimensional learning goals informed by the bundled PEs for the unit. All other evidence of learning related the other dimensions/elements in the PEs can be found within the instructional sequences. The **Teacher Materials** for each sequence of lessons includes a matrix that lists which student artifacts can provide evidence of student learning for each of three-dimensional learning goals from that sequence.

This unit was designed to support teachers in tracking student progress across the three dimensions, not for mastery within individual lessons. The targeted disciplinary core ideas (DCIs) listed below will be developed throughout the unit. While all of the science and engineering practices (SEPs) may be utilized across the unit, the three target SEPs for the unit are listed below. Similarly, many crosscutting concepts (CCCs) may be useful in making sense of the phenomena in this unit, however the foregrounded, targeted CCCs are listed below.

The following **Science and Engineering Practices**, **Disciplinary Core Ideas**, and **Crosscutting Concepts** are assessed throughout the unit:

	Burning Fossil Fuels 5E	Land Use and Biodiversity 5E	Mining 5E
Asking Questions and Defining Problems	✓		
Using Mathematics and Computational Thinking	✓	✓	✓
Constructing Explanations and Designing Solutions	✓	✓	
Engaging in Argument from Evidence			✓
ESS2.B Plate Tectonics and Large-Scale System Interactions			✓
ESS2.D Weather and Climate	✓		

	Burning Fossil Fuels 5E	Land Use and Biodiversity 5E	Mining 5E
ESS3.A Natural Resources			✓
ESS3.C Human Impacts on Earth Systems	✓	✓	✓
ESS3.D Global Climate Change	✓		
ETS1.A Defining and Delimiting an Engineering Problem	✓		
ETS1.B Developing Possible Solutions	✓	✓	✓
ETS1.C Optimizing the Design Solution		✓	
Systems and Systems Models	✓	✓	
Stability and Change	✓	✓	
Influence of Science, Engineering, and Technology on Society and the Natural World	✓	✓	✓
Science is a Human Endeavor		✓	
Science Addresses Questions About the Natural and Material World			✓

At the end of Unit 6, teachers will have evidence in student work (tasks) related to the elements listed in this table and can therefore make claims at the end of this unit related to student proficiency for all three performance expectations.

To support assessment throughout the unit, rubrics have been included in the **Student Materials** to support the Evaluate phase in every 5E instructional sequence. Teachers should customize these rubrics to support their schools' grading systems. Rubrics address both individual reflection, peer review, and the teacher's feedback. The Unit 6 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit - we have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (ELA/Literacy)

Speaking and Listening Standards

SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Reading Standards for Literacy in Science and Technical Subjects

- RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects

- WHST.9-10.1 Write arguments focused on discipline-specific content.
- WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- WHST.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research.

Implementing Unit 6

This unit is designed to be the sixth unit of the Earth and Space Science course. We do not recommend spending more than two months on this unit, as our field testing showed that six to eight weeks is the maximum amount of time students can stay engaged with the unit-level anchor phenomenon.

Within the unit, we also suggest spending no more than two weeks on each 5E instructional sequence. It is important to trust that ideas will build over time. Part of learning to teach NGSS-designed curriculum is getting comfortable with moving on, even if not every student “gets it,” with the knowledge that there are additional opportunities to revisit particular standards. See the Assessment section below for guidance on providing multiple opportunities for assessment throughout the unit.

The first time enacting any unit with students may take longer than anticipated, particularly if the pedagogical approach is significantly different from what a teacher is used to. A teacher may want to skip entire lessons or activities, or revert to more traditional approaches when it seems like time is running out. We often ask teachers to think about the best way to modify recipes. Just like when using a recipe for the first time, it’s a good idea to stay as true to the materials as possible before making modifications or substitutions! As teachers become more familiar and comfortable with the instructional model, the embedded routines, and three-dimensional teaching overall, the desire to skip things will dissipate. Teachers using our curriculum over time have noticed that they are able to move a bit quicker through this and other NGSS-designed units each year.

Routines

The table below summarizes the routines embedded in this unit. The number indicates the number of times a given routine appears in a lesson.

	Unit Opening	Burning Fossil Fuels 5E	Land Use and Biodiversity 5E	Mining 5E	Unit Closing
Class Consensus Discussion		2	1	2	
Domino Discover	2	4	4	3	
Driving Question Board		1			
Idea Carousel	1	1			
Read-Generate-Sort-Solve		1		1	
Rumore	1				
Tell the Story	1				
Think-Talk-Open Exchange		1	1	1	

Literacy Strategies

The table below summarizes the literacy strategies embedded in this unit. The number indicates the number of times a given strategy appears in a lesson.

	Unit Opening	Burning Fossil Fuels 5E	Land Use and Biodiversity 5E	Mining 5E	Unit Closing
Chunking Text		1			
Concept Mapping		1			
Text Annotation		2		4	
Text Chunking			1		
Text annotation	1				

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Burning Fossil Fuels 5E	Carbon Dioxide and the Carbon Cycle Simulation	https://contrib.pbslearningmedia.org/WGBH/pcep14/pcep14_int_co2cycle/index.html#chart_illustration	NA	NA
Burning Fossil Fuels 5E	En-ROADS Simulation	https://en-roads.climateinteractive.org/scenario.html?v=24.11.0	NA	NA
Land Use and Biodiversity 5E	The Welikia Project	https://www.welikia.org/map-explorer#9.22/40.7372/-74.0178	NA	NA
Land Use and Biodiversity 5E	Amazon Deforestation	https://earthobservatory.nasa.gov/world-of-change/Deforestation	NA	NA
Land Use and Biodiversity 5E	En-ROADS Simulation	https://en-roads.climateinteractive.org/scenario.html?v=24.11.0	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	WHO: Preventing Disease Through Healthy Environments	https://www.youtube.com/watch?v=tupJDf13jBo	NA	NA
Unit Opening	The Biodiversity Crisis	https://www.pbs.org/video/biodiversity-crisis-brbvuuq/	NA	NA
Burning Fossil Fuels 5E	Fossil fuel emission may spur 20% of early deaths	https://www.youtube.com/watch?v=ca3K7jHUGLg	NA	NA
Burning Fossil Fuels 5E	India Pushes for Nuclear Power	https://www.youtube.com/watch?v=YVMBa09kru8	NA	NA
Burning Fossil Fuels 5E	Optional Ocean Acidification	https://www.dfo-mpo.gc.ca/videos/acidic-acides-eng.html	NA	NA
Burning Fossil Fuels 5E	Citizen Science	https://www.youtube.com/watch?v=0La7Dwi771M	NA	NA
Burning Fossil Fuels 5E	Saving turtles in Nicaragua by working with communities	https://www.youtube.com/watch?v=vnc4IbHUMRI	NA	NA
Land Use and Biodiversity 5E	Global Urban Heat Islands	https://www.nsf.gov/news/solutions-urban-heat-differences-between-tropical-drier	NA	NA
Land Use and Biodiversity 5E	New Yorkers stay cool on day 6 of heat wave	https://www.youtube.com/watch?v=Oguz1tgoX6Y	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Land Use and Biodiversity 5E	Poor neighborhoods are hotter than rich ones - especially during heat waves	https://www.cnn.com/2021/12/10/urban-heat-mapping-project-in-nyc-finds-poor-neighborhoods-hotter.html	NA	NA
Land Use and Biodiversity 5E	Medellin's Green Corridors	https://www.weforum.org/videos/medellin-green-corridors/	NA	NA
Mining 5E	The Land of Mountaintop Removal	https://www.youtube.com/watch?v=p5RcbPZXUzo	NA	NA
Mining 5E	The shocking danger of mountaintop removal - and why it must end	https://www.ted.com/talks/michael_hendryx_the_shocking_danger_of_mountaintop_removal_and_why_it_must_end/transcript?subtitle=en	NA	NA
Mining 5E	Rock Cleavage	https://www.youtube.com/watch?v=w0OknTVG1Kw	NA	NA
Mining 5E	Mineral Hardness Test	https://www.youtube.com/watch?v=R-bw7_u3gSQ	NA	NA
Mining 5E	2 Minute Video on Rock Mineral Cleavage	https://www.youtube.com/watch?v=w0OknTVG1Kw	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
--------	-----	------------------------------

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	☐ Printed Labeled world map ☐ Sticky notes ☐ Chart paper
Burning Fossil Fuels 5E	☐ Environmental Causes of Death from the Unit Launch ☐ <i>Labeled World Map</i> ☐ Computer access ☐ Carbon Calculator ☐ Chart paper titled: Concepts for Designing Solutions ☐ Chart paper ☐ Computer access ☐ Data-collection graphs ☐ <i>Fossil Fuels Card Sort</i> ☐ Chart paper ☐ Markers ☐ Group concept maps from Explain 2 ☐ <i>Return to the Performance Task: Burning Fossil Fuels</i>
Land Use and Biodiversity 5E	☐ <i>New York City Land Use Maps</i> ☐ New York City Neighborhoods ☐ Chart Paper ☐ Markers ☐ Calculators ☐ <i>New York City Land Use Maps</i> from Explore ☐ <i>Sustainability and Heat Index Variable Descriptors</i> ☐ Land Use Computational Model ☐ Computational models from Explain 1 ☐ Scenario 4 charts from Explain1 ☐ Chart Paper ☐ Markers ☐ <i>Modeling Sustainability</i> ☐ Calculators ☐ Dataset: Amazon Deforestation Data ☐ Calculator ☐ <i>Unknown material with identifier: ess.u6.l2.evaluate.sw</i>
Mining 5E	☐ Optional Scaffold: <i>Labeled Map of the United States</i> ☐ Lung Cancer Interactive Atlas ☐ Teacher Guide for Mining Lab ☐ Calculators ☐ World of Change: Mountaintop Mining ☐ Picture: how mountaintop removal works ☐ Poster paper and markers

Lesson	Materials needed
Unit Closing	☐ Driving Question Board ☐ En-ROADS Simulation

Teacher Materials for Unit 6

Unit Opening

How is human activity harming the health of humans and the natural environment? How is the health of humans and the natural environment intertwined? What solutions adequately address these problems and can be implemented in the real world?

Performance Expectations

Anchor Phenomenon
Around the world, the health of humans and the natural environment is suffering negative consequences of human activity.

Time
2 days

Human health and the natural environment are increasingly suffering from the impacts of pollution and environmental degradation. Air pollution, driven by industrial emissions, vehicle exhaust, and deforestation, is linked to a range of health problems, from respiratory and cardiovascular diseases to cancer and premature death. Poor air quality affects vulnerable groups like children, the elderly, and those with pre-existing health conditions. Meanwhile, human activity isn't just harming humans—it's also disrupting the delicate balance of ecosystems. Forests, wetlands, and oceans play a crucial role in absorbing carbon dioxide, filtering pollutants, and stabilizing climate patterns. But as these natural systems are degraded through deforestation, overdevelopment, and climate change, their ability to mitigate pollution and regulate the climate is severely diminished. This creates a vicious cycle: as degradation of the environment due to human activity worsens, it reduces the environment's capacity to combat it, further endangering both human health and the health of the planet.

ANCHORING PHENOMENON

What are the current challenges to human and environmental health?

Students surface ideas related to the negative effects of human activity on human health and the natural environment by noting details from videos, data maps, and infographics in order to tell the story of the unit phenomenon.

PERFORMANCE TASK

Students review the Performance Task.

Review the Performance Task with students.

DRIVING QUESTION BOARD

What questions do we have? What data do we need to figure out the answers to these questions?

Based on ideas that have surfaced through student discussion, students create a driving question board and develop ideas for investigations that will drive the unit.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Anchoring Phenomenon

What are the current challenges to human and environmental health?

Students surface ideas related to the negative effects of human activity on human health and the natural environment by noting details from videos, data maps, and infographics in order to tell the story of the unit phenomenon.

Preparation

Student Grouping

- ☐ Pairs
- ☐ Table groups

Routines

- ☐ Domino Discover
- ☐ Tell the Story

Literacy Strategies

- ☐ Text annotation

Materials

Handouts

- ☐ Tell the Story

Lab Supplies

None

Other Resources

- ☐ Printed Labeled world map
- ☐ [WHO: Preventing Disease Through Healthy Environments](#)
- ☐ [The Biodiversity Crisis](#)

Launch

1. Remind students that throughout the course so far they have learned about challenges humans face from natural tectonic hazards and extreme weather which has been exacerbated by climate change. Let them know that in this unit they will have an opportunity to investigate how heat waves exacerbated by climate change and other unhealthy environments affect human health, so that as citizens they can come to their own conclusions about what solutions to support through voting, activism, conversations with family and friends, or other forms of civic engagement. .
2. Have students discuss and share what they know about the negative impact heat waves and other unhealthy environments can have on human health.
 - How can a heat wave negatively impact human health?
 - What other kinds of unhealthy environments can cause or contribute to health problems? What health problems do they each cause?
3. Ask groups to decide on one health problem and the unhealthy environment (including heat waves) that causes it to share about with the rest of the class. Use the **Domino Discover** group learning routine, to surface student ideas. Document these ideas for the class on chart paper or the board.

Routine



This is the first time the routine **Domino Discover** appears in this unit! Please read the Earth and Space Science Course Guide for detailed steps about this routine.

Look & Listen For



Possible student ideas:

- Heat waves can cause people to pass out.
- Heat waves can cause a stroke.
- Environments with a lot of air pollution can cause problems with breathing.
- Places with contaminated water can cause many different health problems.
- Places with certain chemicals in the air can cause cancer.

4. Acknowledge and honor all student ideas. Tell them that they will now have an opportunity to add or refine their initial thinking by watching a video and looking at some data from around the world.

Telling the Story

1. Tell students that they will now have a chance to better understand the impact heat waves and other unhealthy environments have on human health by observing and noting details from a video, data maps, and an infographic.
2. Provide students with the *Tell the Story* handout. Share with students that you are going to show a short video from the World Health Organization, made by leading experts on human health and that they can note 3 or more details in the first section of their Tell the Story organizer. Show the video, *WHO: Preventing disease through healthy environments*.
3. Have students read and annotate the texts 2 and 3, circling or highlighting three details from each that are the most important to the phenomenon being described.
4. Students share their ideas in their group, with every individual identifying the details that they thought were important.

Conferring Prompts



Confer with students as they tell the story.

- Why do you think this detail is important?
- Did your group members and you circle or highlight the same details?
- How did you agree, as a group, about the most important details?

5. Use the **Domino Discover** group learning routine, to surface student ideas. Document these ideas for the class.

Routine



Domino Discover routine is used to surface student ideas and look for patterns in student answers. Use the look and listen for, to guide students during the discussion.

Look & Listen For



- Around the world about 50 million people die from disease and nearly one quarter of those deaths are caused by environmental factors.
- There are 1,400 deaths every hour of every day caused by an unhealthy environment.
- The people most impacted are in low and middle income countries, especially in Africa and SouthEast Asia, and the young and old are most severely affected.
- More than half the world lives in urban areas with heavy traffic and air pollution.
- We all face the impact of these unsafe environments.
- Climate change makes things even more uncertain.
- Human activities can either make the environment worse or or better.

6. If students do not mention that these unsafe environments are caused by human activity, ask them what causes these environments to be unsafe to surface the idea of human activity.
7. Ask students if they think humans are the only species that are negatively impacted by human activity. Listen for students to say that animals and plants are also being harmed as a result of human activity.
8. Tell students that you are going to show a video and share a map that will help them better understand how animals and plants are being impacted by humans.
9. Let students know that the video is going to focus on biodiversity. Ask students what they remember from middle school about what biodiversity means. Listen for them to say it means the variety of life. Review the definition of biodiversity to ensure students have access to the video that follows.
10. Show the video, The Biodiversity Crisis. Have students record 1-3 details from the video in their Tell the Story organizer.
11. Have students read and annotate the text 5, circling or highlighting three details from each that are the most important to the phenomenon being described.
12. Students share their ideas in their group, with every individual identifying the details that they thought were important.
13. Use the **Domino Discover** group learning routine, to surface student ideas. Document these ideas for the class in the same place that details from texts 1-3 were documented.

Look & Listen For



- Biodiversity loss threatens our ability to feed ourselves and to control our climate.
- It increases the chances of pandemics.
- We're losing biodiversity at a rate that is unprecedented in human history.
- All groups of species are in decline, getting smaller and smaller.
- Since 1970 vertebrates have declined by 60%.
- Large mammals have dispersed from $\frac{3}{4}$ of the range where they were found before.
- Biodiversity is happening with all organisms everywhere on the planet.
- Less than 60% biodiversity remains in large regions all around the world.
- The central part of North America, the southern tips of South America and Africa, Australia, and the central and northern parts of Asia have experienced the most biodiversity loss.
- The northern hemisphere has experienced the least biodiversity loss.

Performance Task

Students review the Performance Task.

Review the Performance Task with students.

Preparation

Student Grouping

None

Routines

- ☐ Domino Discover
- ☐ Rumore
- ☐ Idea Carousel

Literacy Strategies

None

Materials

Handouts

- ☐ Introducing the Performance Task
- ☐ Developing Initial Solutions

Lab Supplies

None

Other Resources

Reviewing the Performance Task

1. Tell students that for this unit they will focus on a performance task that relates to the problems and solutions related to human health and biodiversity loss caused by human activity.
2. Introduce the performance task found in the handout, *Introducing the Performance Task*. Allow students to ask clarifying questions about the performance task prompt.
3. Share with students that they will now have a chance to share their initial ideas related to the unit.

Surfacing Student ideas

1. Ask students to individually brainstorm initial solution ideas for addressing the problems related to the details of the phenomenon surfaced during Tell the Story.
2. Tell students to identify the idea they feel most confident about, and write it on a post-it note.
3. Using the **Rumors** routine, students share out ideas with the class.
4. Classify student ideas on the board to surface patterns.

Look & Listen For



Possible student ideas:

- Stop burning fossil fuels.
- Take care of or protect the environment.
- Stop climate change.
- Reduce pollution.

5. Have table groups decide on one solution idea to focus on as a group.
6. Provide students with the material *Developing Initial Solutions*. Ask students to then individually develop an initial model for how this solution idea will address one or more of the problems related to the details of the phenomenon surfaced during Tell the Story.

Implementation Tip



Domino Discover routine is used to surface student ideas and look for patterns in student answers. Use the look and listen for, to guide students during the discussion.

7. After students have independently developed an initial model, have them share their initial models with their table group and work together to develop a group model on poster paper.
8. Use the **Idea Carousel** group learning routine, to facilitate a sharing of ideas across groups.
9. Let students know that it's ok if there is some disagreement across groups, as they will have an opportunity to investigate climate factors and confirm, refine, or change their initial ideas.

Routine



This is the first time the routine **Idea Carousel** appears in this unit! This routine supports groups of students in thinking through a set of related problems, tasks, or visuals, in order to develop a larger insight or discovery. Therefore, it's great for developing complex understandings of a phenomenon in science. For the first implementation, focus on having students learn the steps. Please read the Earth & Space Science Course Guide for detailed steps about this routine.

Driving Question Board

What questions do we have? What data do we need to figure out the answers to these questions?

Based on ideas that have surfaced through student discussion, students create a driving question board and develop ideas for investigations that will drive the unit.

Preparation

Student Grouping

☐ Table groups

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

- ☐ Sticky notes
- ☐ Chart paper

Generating Questions

1. At this point, students should have a lot of questions! Let them know that they will be investigating environmental and health problems throughout this unit, and how to evaluate and refine solutions to problems.
2. Individually, students come up with questions they would need to answer in order to figure out which solutions best address the interconnected health of humans and nature, while considering practical limitations and trade-offs in the real world.. Each question goes on a separate sticky note.

- **What do we need to investigate in order to answer the question:**

What solutions adequately address problems related to environmental impact on human health and biodiversity and can be implemented in the real world?

3. As a whole class or in small groups, students share and categorize their questions, as they organize the questions on chart paper.

Integrating Three Dimensions



Students have been engaging in **SEP#1 Asking Questions** during the Unit Openings from Units 1 and 2 when Driving Question Boards are launched, however as this element is part of the PE bundle, it is included in Unit 3 in the assessment matrix.

Conferring Prompts



Confer with students as they create and categorize questions

- Why do these questions belong together?
- What is the category that connects these?
- Are there other questions within this category?
- Now that you see all of your questions grouped together, do other questions come up?
- For each category, is it possible to develop an umbrella question that encompasses all of the other sub-questions in that category?

Differentiation Point



Students have had multiple opportunities to develop a DQB at the beginning of previous units.

Ideally students should be able to generate relevant questions about the phenomenon, but if students are struggling, encourage students to ask “how” or “why” questions, or provide them with a few sentence stems to get them started.

For more guidance on using the DQB throughout the unit, see the Earth and Space Science Course Guide.

4. Ask students to think about investigations they could do or data they would need to answer their questions. Have them turn and talk to a partner before asking them to share out with the class. As they share, record their ideas on a piece of chart paper titled, “Ideas for Investigations.” If students struggle to come up with ideas, have them focus on just one cluster of questions or even one question to share ideas about.

Standards in Unit Opening

Performance Expectations

Aspects of Three-Dimensional Learning

Science and Engineering Practices

- Constructing Explanations and Designing Solutions
- 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. SEP6(5)

Disciplinary Core Ideas

- ETS1.A Defining and Delimiting an Engineering Problem
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. ETS1.A(1)
 - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. ETS1.A(2)

Crosscutting Concepts

- 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. INFLU-H3
-

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task
Constructing Explanations and Designing Solutions		Initial Solutions	
ETS1.A Defining and Delimiting an Engineering Problem		Initial Solutions	
Influence of Science, Engineering, and Technology on Society and the Natural World	Tell the Story		Driving Question Board

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task
Mathematics	MP.2		
ELA/Literacy	RST.9-10.1 RST.9-10.7 WHST.9-10.2 SL.9-10.1 SL 9-10.4		

Burning Fossil Fuels 5E

Why is burning fossil fuels causing those negative outcomes, and how can we evaluate and refine solutions to reduce them?

Performance Expectations
HS-ESS3-4, HS-ESS3-6, HS-ETS1-3

Investigative Phenomenon
Around the world, millions of people and organisms are dying as a result of burning fossil fuels, but the damage is not equally distributed.

Time
7-9 days

Students have already learned that burning fossil fuels is causing global temperatures to rise; now students investigate how emissions from the burning of fossil fuels themselves are impacting human and ecosystem health and evaluate and refine solutions to reduce those impacts.

ENGAGE	How does burning fossil fuel contribute to environmental causes of death around the world?	Students analyze evidence of a real-world problem by observing costs to human safety of fossil fuel burning technology .
EXPLORE 1	Why does air pollution from fossil fuels cause more deaths in the United States than in France?	Students compare health outcome costs and benefits in the United States and France in order to generate evidence about how a green energy solution functions to produce less pollution .
EXPLAIN 1	How can we apply solutions used in France to the United States in order to reduce deaths?	Students refine a green energy technological solution that produces less pollution and waste used in France to apply it to the United States, taking into account the unique constraints of each population to increase health benefits while decreasing costs and risks .
EXPLORE 2	How does carbon mediate interactions between different global systems, and how do human activities modify those interactions?	Students use a computational representation of the carbon cycle to identify and describe how the inputs and outputs of affected systems have been modified in response to human activities .
EXPLAIN 2	How do the ways that burning fossil fuels impacts natural systems combine to impact human health?	Students use evidence from the previous computational representation and data about health outcomes to illustrate the way in which relationships among Earth's systems have been destabilized due to the amounts of human-generated greenhouse gases added to the atmosphere .
ELABORATE	How can we design and refine solutions to reduce the impacts of human activities on natural systems?	Students evaluate a technological solution designed to stabilize Earth's systems by modifying the ways in which gases are absorbed in the ocean and biosphere .
EVALUATE	How can we reduce the number of deaths from pollution generated by burning fossil fuels?	Students refine a solution designed to reduce car emissions and then evaluate the combined impacts of the solutions they evaluated on reducing global deaths from environmental causes .

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

How does burning fossil fuel contribute to environmental causes of death around the world?

Students **analyze evidence of a real-world problem** by observing **costs to human safety** of **fossil fuel burning technology**.

Preparation

Student Grouping

None

Routines

☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

☐ Death from Fossil Fuels

Lab Supplies

☐ Petri dishes or small containers
☐ Petroleum jelly or clear packing tape

Other Resources

☐ Environmental Causes of Death from the Unit Launch
☐ [Fossil fuel emission may spur 20% of early deaths](#)

Launch and Surfacing Student Ideas

Implementation Tip



Before starting this lesson, you need to set up the air quality testers by following the steps below. These should be **set up several days before** you begin this lesson to collect visible amounts of particulate matter.

- Decide on two to three locations to place the test containers and how many you will need for your course(s). Place at least one container outside or near a location exposed to outside air. Near a parking lot is an ideal spot. High foot traffic locations are also good places.
- Place a thin layer of petroleum jelly on the bottom of each Petri dish or deli container as evenly as possible.
- Place the containers open to the air (no lids) in your chosen locations. You may want to place a sign that says “Experiment in Process, Do Not Move”.
- Collect containers the day you plan to use them. They can then be covered if you choose.
- Another option, if you have more time, is to place clear packing tape sticky side up in the bottom of the container or on the back of a notecard with holes punched into it. These can be placed in locations the same as described above. The sticky tape can be observed under a stereoscope or on the low power of a compound light microscope to see even smaller particulate matter collected.
- After 24 - 48 hours there should be small particles of dust, debris, thread, hair, etc on the tape or petroleum jelly. The one outside should have more than the one inside and higher foot traffic than lower foot traffic areas. The longer you let the air quality testers sit the more particulate matter you will collect.

1. Remind students that, during the Driving Question Board launch, one category of questions that emerged was related to what environmental causes of death are, and where they come from.
2. Show students the air quality collectors that were set up ahead of time to collect particulate matter from around the school. Have them turn to their tablemates and discuss what they notice and wonder and wonder and have a few students share out.
3. Highlight students’ connections between the pollutants on the petri dishes and connections to car exhaust. If students haven’t already specifically surfaced the idea that fossil fuel burning leads to emissions of exhaust, remind students that car exhaust comes from burning gasoline, which is a fossil fuel.
4. Ask students to recall what they learned from Unit 3 about what is emitted when we burn fossil fuels. If students have forgotten, remind students that they learned about burning fossil fuels emitting carbon dioxide, which we know is a greenhouse gas that causes climate change. Ask students if they think carbon dioxide is the only thing that is emitted in car exhaust from burning fossil fuels. Students are likely to say things like smog, smoke, air pollution, or other gases.
5. Tell students that we will now look at some information that helps them understand the types of pollutants released by burning fossil fuels and some connections to the environmental deaths they observe during the unit launch.
6. Provide students with the handout *Death from Fossil Fuels*.

Access for All Learners



If students are having trouble relating to the phenomenon, show them the video [Fossil fuel emission may spur 20% of early deaths](#). Ask students if they have ever experienced pollution like the video shows, and how they think that might make people sick.

Integrating Three Dimensions



In this unit students are focused on developing and evaluating solutions to real-world problems caused by human activities. In this 5E, they focus on **SEP#6, Constructing Explanations and Designing Solutions**. Their work during this phase is designed to help them clearly define a real-world problem in need of solving and gather evidence that will inform their criteria for successful solutions in future phases.

Routine



The **Domino Discover** is an opportunity to surface students’ thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

7. Ask students to work independently to complete the See-Think-Wonder based on their observations, then use their See-Think-Wonders to discuss them.
8. While students are working, help them make connections between the diseases listed in this phase and the environmental causes of death and maps of environmental deaths from the Unit Launch.

Conferring Prompts



Confer with students during the investigation. Suggested conferring questions:

- Where have we seen cardiovascular disease, respiratory disease, or cancers before?
- How do these relate to the environmental causes of death from the Unit Launch?
- How do you think air pollution might be contributing to these environmental causes of death?
- How does the map of air pollution deaths from burning fossil fuels compare to the map of environmental deaths from the Unit Launch?

9. Ask groups to come up with one important idea and / or question to share with the whole class, from their See-Think-Wonder.
10. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from the texts.

Look & Listen For



- Cars and power plants emit pollution
- That pollution includes particulate matter, nitrous oxides, carbon monoxide, sulfur dioxide, and ozone
- These pollutants are known to cause health problems, including similar types of diseases to those seen in the Unit Launch

11. If students don't surface that CO₂ is not listed as a pollutant, highlight that it was not present in these diagrams. Tell students that, although CO₂ is a greenhouse gas, which causes climate change as we've already seen, it actually isn't a pollutant that directly interferes with human health.

Explore 1

Why does air pollution from fossil fuels cause more deaths in the United States than in France?

Students compare health outcome **costs and benefits** in the United States and France in order to **generate evidence** about how a **green energy solution functions to produce less pollution**.

Preparation

Student Grouping

- ☐ Pair
- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Fossil Fuel Air Pollution

Lab Supplies

None

Other Resources

- ☐ *Labeled World Map*
- ☐ Computer access
- ☐ [Carbon Calculator](#)

Launch

1. Tell students that they will now have the opportunity to investigate why some areas have higher rates of death from air pollution from burning fossil fuels than others.
2. Ask students to brainstorm what factors might contribute to these different levels, and how they might impact natural systems as well as health outcomes.

Look & Listen For



Possible student ideas and questions:

- Some places burn more fossil fuels/electricity/cars
- Some places might have less healthy populations or less good access to health care
- Some places might have other factors that make it worse, like heat

3. Ask students which of the factors they named most directly ties to deaths from burning fossil fuels. Listen for students to say the amount of fossil fuels that different countries / regions burn. Let them know that they will have an opportunity to start their investigation by analyzing data related to that.

Investigation

1. Provide students with the handout *Fossil Fuel Air Pollution*. Have students work in pairs to complete Part 1. Students will work in pairs except when they calculate their carbon footprints, which will be completed individually.

Implementation Tip



In this part of the activity, students are making connections between burning fossil fuels, air pollution, and CO₂ emissions. Students should end this phase with an understanding that CO₂ is not considered air pollution, but that it is generated at the same time as air pollution when fossil fuels are burned. Help students distinguish between these different types of emissions: CO₂, a greenhouse gas that is not directly dangerous to human health, and other gases and particulate air pollution, which directly impact human health through respiratory and cardiovascular diseases.

2. Students should complete this part by answering the questions interspersed with the data as well as by recording their observations and questions in the See-Think-Wonder chart.
3. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts



Confer with students during the investigation. Suggested during-lab conferring questions:

- How are carbon footprints related to air pollution?
- If you reduce your carbon footprint, how do you think that would influence air pollution?
- How could you as a person or we as a country reduce our carbon footprints?
- How do the carbon footprints of France, India, and the United States differ?
- How do you think air pollution deaths in France, India, and the United States differ?

4. Pause students after Part 1 to help the class surface the relationship between carbon footprints and air pollution from burning fossil fuels. Students should see that carbon footprints are correlated to levels of pollution because they both come from burning fossil fuels; and students should be able to interpret that people or areas with higher carbon footprints likely are also contributing more pollution to the air.
5. Ask students what categories of activities contribute to carbon footprints as shown by the carbon footprint calculator. Guide students to cluster the activities they share into groups, such as these
 - Transportation
 - Electricity
 - Food habits
 - Consumerism
6. Tell students they will look at data about electricity use in France, India, and the United States to try to uncover one source of different pollution levels between the two countries.
7. Have students work in table groups to complete Part 2 of the investigation, answering the analysis questions and recording their observations and questions in the See-Think-Wonder chart.

Integrating Three Dimensions



In order to properly evaluate and refine solutions, students are working on understanding costs and benefits of technology aligned to **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World**. In this phase, emphasis is placed on the health implications of our use of energy as a cost, but help students emphasize the benefits of energy use in the aspects of life shown in the carbon footprint calculator.

8. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts



Confer with students during the investigation. Suggested during-lab conferring questions:

- How are emissions different between the United States, India, and France
- How is energy use in France, India and the United States different?
- Why would that contribute to different levels of pollution in the three countries?

Whole-Class Investigation Summary

1. Ask students to work in table groups to discuss the prompt “how are energy use and pollution different between the United States, India, and France?”
2. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' discussions. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Look & Listen For



Possible student ideas and questions:

- Places that use more fossil fuels have higher carbon footprints and higher polluting emissions
- Emissions, like NO₂, SO₂, O₃, CO, O₃, and PM are all dangerous to human health and also come from burning fossil fuels
- France has a smaller carbon footprint in the United States and uses less fossil fuel per capita
- India has a smaller carbon footprint compared to the United States but a larger one compared to France, and emits less CO₂ per capita
- France has less air pollution than the United States
- India has more air pollution than the United States or France
- France uses a lot more nuclear energy for electricity than the United States does
- The United States uses a lot more coal, oil, and gas for electricity than France
- India uses almost exclusively coal

3. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Biology Course Guide for support with this routine.

Access for Multilingual Learners



Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine.

Explain 1

How can we apply solutions used in France to the United States in order to reduce deaths?

Students **refine a green energy technological solution** that **produces less pollution and waste** used in France to apply it to the United States, taking into account the **unique constraints** of each population to **increase health benefits while decreasing costs and risks**.

Preparation

Student Grouping

- ☐ Groups of 3

Routines

- ☐ Read-Generate-Sort-Solve
- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Chunking Text

Materials

Handouts

- ☐ Refining Solutions for Fossil Fuel Air Pollution
- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ Chart paper titled: Concepts for Designing Solutions
- ☐ Chart paper
- ☐ [India Pushes for Nuclear Power](#)

Steps for Evaluating and Refining Solutions

1. In the Explore phase, students observed differences in CO₂ and deaths from air pollution emissions from burning fossil fuels between different countries. Tell students that we are now going to think about components of that problem, and think about solutions that might help reduce these negative health outcomes.
2. Prepare to facilitate a discussion with students about how to think about solutions to problems. Hang a piece of a chart paper to record student responses that align to each part of the solution design process that follows.
3. Ask students to brainstorm factors that might contribute to high rates of death from air pollution from burning fossil fuels. Students should list things like high levels of electricity use, high use of cars and planes, and high levels of consumerism. They may also list things like pre-existing health conditions, access to health care, confounding factors like heat, and generally poor health. All of these are different components that contribute to deaths from fossil fuel pollution.
4. Tell students that it is likely impossible to solve all aspects of this larger problem (all deaths from air pollution resulting from burning fossil fuels), but we may be able to tackle one of the components we listed above.

Integrating Three Dimensions



In this unit, students are developing proficiency with the **SEP#6, Constructing Explanations and Designing Solutions**, refining solutions according to criteria and within realistic constraints. This is the first opportunity students have to experience and discuss these concepts, which will be further explored in future phases. Use this opportunity to clarify the meaning of each concept and begin reinforcing their use.

5. As a class, choose one element of the problem, which you already listed, to practice discussing solutions for. Be sure not to choose electricity use, because students will evaluate a solution around electricity use in the next part.

Implementation Tip



For this section, we will be giving an example of possible ideas about defining a problem and refining a solution that students might generate if the class chooses to discuss the component of the problem related to unequal access to healthcare.

If it works for your classroom, you can encourage students to explore that option. If the class focuses on a different component, you can use the example ideas about access to healthcare to think about what responses could look like for your class discussion.

6. Help students practice defining the part of the problem they are trying to solve.
7. Explain that all solutions must be evaluated using criteria (requirements for success). Brainstorm criteria for a successful solution as a class.
8. Define constraints, and brainstorm a few that might apply to solutions around this topic
9. Brainstorm solutions that take into account these factors. These solutions do not have to be well-researched or detailed at this point; the goal in this conversation is to practice with each concept before students work independently.
10. Introduce costs, benefits, and tradeoffs. Choose a potential solution that students have brainstormed, and discuss the costs, benefits, and tradeoffs that might result from it.

Access for All Learners



Students may struggle with the complexities of defining a problem and the many steps required to evaluate and refine a solution for it. Using a concrete example during whole-class discussion will help students apply these concepts to a real-world model before working in groups to practice these skills. It is recommended that you create a poster with each of these concepts and the examples from class for students to reference while they work.

Implementation Tip



Your answers from students will be very different depending on the aspect of this problem they choose to discuss as a class. Here is one example set of responses for the component “access to healthcare.” This example is intended to help you get a sense of how students should be thinking about these concepts.

Defining the problem: around the world, people die from pollution resulting from burning fossil fuels. If people have less access to healthcare, then they are more likely to die from pollution-caused illnesses.

Criteria:

- For a solution to be successful, it should result in at least a 10% reduction in deaths from pollution caused by burning fossil fuels.
- It should also reduce differences in deaths between people in the population currently with and without good access to healthcare.

Constraints:

- In some parts of the world, there simply may not be enough doctors for everyone who needs to see one quickly, so not everyone waiting for a doctor can see one at the same time.
- In societies without centralized medical services, access to pay for medical care may impede the ability of certain citizens to get help, even if enough doctors exist.
- Transportation limitations and large distances may prevent people from being able to reach medical care.
- Some people may have other disease conditions that are challenging to treat and make air pollution more dangerous.

Potential Solutions:

- Create a set of ads that tell people: air pollution is particularly dangerous if you have any of these other conditions, so go to your doctor to manage those conditions
- Set up small clinics of specially trained nurses or other medical professionals who only treat issues relating to air pollution
- Provide free or low cost air filters or masks to reduce the air pollution that people are breathing in, so that they require less medical care

Costs/Benefits of one solution, providing air filters:

- Cost: The actual filters will cost money for whoever is providing them
- Cost: filters do not address the actual healthcare disparities between people; they only try to reduce the need for healthcare so that the disparities affect people less
- Benefit: if filters reduce exposure to the air pollutants, having less access to care will matter less
- Benefit: providing filters doesn't require systemic changes in the way medical care is handled in the country
- Tradeoff: this solution is low-cost and simple to implement, but doesn't address the underlying inequalities of access to care

Refining a Solution for New Context

In the Explore phase, students observed differences in fossil fuel use in France, India, and the United States. Now, they will consider how to apply the solution of nuclear energy used in France to the United States context. Be clear with students that we are thinking specifically about air pollution that results from burning fossil fuels, not carbon dioxide emissions. The next explore/explain will discuss carbon dioxide specifically.

1. Provide students with the handout *Refining Solutions for Fossil Fuel Air Pollution*. Explain to them that this Read-Generate-Sort-Solve will work a little differently than others that we've done. For this one, the Read part includes prompts to break down solution evaluation in order to help students define the problem, evaluate the solution of nuclear energy in France, and figure out what the different constraints and limitations are in the United States. After that, they will generate ideas around refining this solution in order to work for the United States, and then continue with the sort and solve parts of the routine.
2. Confer with students as they individually work through the reading sections and then work in triads on the RGSS routine.

Differentiation Point



This is a text-heavy Explain phase, which may be challenging for some students. The text is already chunked so that students pause to analyze text in smaller pieces, but for some students, it may still be challenging. One option is to pause between sections to discuss what they've read; this pause could happen before students answer the analysis prompts for that section in order to ensure that all students have a good understanding of the text before responding, or this pause could happen after students have answered the questions in order to review their responses. Another option is to jigsaw the texts, and have some students read about how nuclear energy is used in France and other students read about the specific context of the United States, and then teach each other.

3. Provide each group with chart paper and tell them to represent their solution refinements in words, images, or diagrams. They should include all the key components of criteria, tradeoffs, and constraints addressed by their solution.

Integrating Three Dimensions



In this unit, students are engaging with **CCC#7, Stability and Change**. Here, they are prompted to consider how the solution they are exploring stabilizes or destabilizes the systems it is interacting with. This is one of the first times in this unit that students are thinking about systems in this way. Support students as they make connections between Earth's systems and how human interactions can interrupt or assist them.

Routine



The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. This is the first time this routine appears in this routine. Be sure to refer to the Biology Course Guide for planning support.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
 - “We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how the United States could implement changes that shift us towards using more nuclear energy in hopes of reducing pollution from fossil-fuel generated electricity.”

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of refining solutions to work in a new context. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.
5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions



The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** explicit for students by elevating and probing for ideas related to the concept that engineering solutions should increase benefits and decrease risks.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- Nuclear energy is as safe or safer than fossil fuel energy
- The United States does not currently use as much nuclear energy as France because of fear, existing infrastructure, and a good supply of oil, gas, and coal
- To implement France's nuclear solution, we would have to refine it to apply to the United States' needs
- Refinements could include public education around safety of nuclear energy; repurposing fossil fuel burning electricity plans to use for nuclear power; disincentivizing fossil fuel use to change the cost-benefit ratios of nuclear power

6. Return to student questions that bring up lingering issues not yet resolved, such as:
 - What about other uses of fossil fuels, like in cars and transportation?

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about fossil fuel reduction and solution refinement.

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions, including the concept of evaluating and refining solutions** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Explore 2

How does carbon mediate interactions between different global systems, and how do human activities modify those interactions?

Students use a **computational representation** of the carbon cycle to identify and describe how the **inputs and outputs of affected systems** have been **modified in response to human activities**.

Preparation

Student Grouping

- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Fossil Fuel Emissions in Global Systems

Lab Supplies

- ☐ 2 Beakers or cups to hold 100 ml of seawater per group (if you don't have access to seawater you can use any water that is pH 8)
- ☐ Straw
- ☐ Blue and red sticky dots (or colored pencils)
- ☐ Timer
- ☐ pH meters or pH paper
- ☐ Distilled or tap water for rinsing off pH meters

Other Resources

- ☐ Computer access
- ☐ Data-collection graphs
- ☐ [Carbon Dioxide and the Carbon Cycle Simulation](#)

Launch

1. So far in this 5E, students have been looking at the direct effects of air pollution from burning fossil fuels on human health. Tell students that now we will look at CO₂ emissions, which indirectly impact human population health.
2. Ask students to brainstorm ways in which they think CO₂ might indirectly affect human health.

Look & Listen For



Possible student ideas and questions:

- CO₂ is a greenhouse gas, which is causing temperatures to rise globally, and could cause heat stroke
- Heat from climate change might make other diseases worse
- Maybe breathing in too much CO₂ is bad for us

3. Let students know that they will now have an opportunity to explore how CO₂ moves between global systems using a computer model, and then consider how changes in that movement impact human health indirectly.

Investigation Part 1: How does Carbon Move between Reservoirs?

1. Provide each student with the handout *Fossil Fuel Emissions in Global Systems*.
2. Support students as they work through Part 1 of the handout, using the [Carbon Dioxide and the Carbon Cycle Simulation](#) to observe how carbon flow has changed since the industrial revolution.

Differentiation Point



Some students may find the idea that systems (the hydrosphere and atmosphere, for example) within a larger system (the carbon cycle) challenging. You can help students process that idea using examples of other things that are made of smaller, similar parts. For example, a stress ball is a ball made of lots of smaller balls inside, and the squishy texture of the stress ball is determined by how the smaller balls inside interact and move around each other.

3. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts



Confer with students during the investigation. Suggested during-lab conferring questions:

- What do you think "carbon reservoirs" means?
- Where is carbon held, and what systems hold it?
- How did carbon move between reservoirs before humans?
- 300 years ago, was carbon moving evenly between reservoirs? Did additional carbon end up in any specific reservoir(s)?
- Now, is carbon moving evenly between reservoirs? Does additional carbon end up in any specific reservoir(s)?

4. Have students work in table groups to complete the illustrations and analysis questions in Part 1 of the lab.

Access for Multilingual Learners



Visual instructions for simulations, showing students how and where to click, can assist entering and emerging language learners. It is also helpful to pre-teach vocabulary that appears in the simulation for all levels of language learners.

Integrating Three Dimensions



In this explore/explain, students are engaging with **CCC#4, Systems and Systems models**, to support their analysis of solutions in future phases. In this activity, students must define the system boundaries and inputs and outputs to understand the model they are engaging with.

Investigation Part 2: How does Excess Carbon Affect Oceans?

1. Transition to the hands-on part of the activity, where students will investigate how additional carbon moving into the oceans impacts the hydrosphere.
2. Have students turn to Part 2 of the handout. Tell students that we will be modeling how carbon dioxide changes the ocean by blowing into water and measuring the pH of the water. Remind students that we breathe out carbon dioxide, so our blowing into the cup is similar to carbon dioxide from the atmosphere moving into the hydrosphere.
3. Assist students in following the instructions to investigate how pH changes when carbon dioxide is added
4. Have students work in table groups to complete the illustrations and analysis questions in Part 2 of the lab and fill in the See-Think-Wonder chart.

Investigation: Whole-Class Investigation Summary

1. Ask groups to come up with one important idea to share with the whole class, from their Summary notes.
2. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Look & Listen For



Possible student ideas and questions:

- 300 years ago, carbon movement was in equilibrium: the total amount of carbon moving between reservoirs was the same going in and out
- In the present day, more carbon is leaving the fossil fuels reservoir because of human activities
- More carbon is going into the atmosphere, which causes more carbon to go into the hydrosphere and the biosphere
- The hydrosphere and biosphere cannot absorb all of the excess carbon, so carbon is still increasing in the atmosphere
- Increasing carbon in the hydrosphere is causing the oceans to become acidic
- What impacts does that have on the systems that have more carbon dioxide?

3. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Biology Course Guide for support with this routine.

Access for Multilingual Learners



Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine.

Explain 2

How do the ways that burning fossil fuels impacts natural systems combine to impact human health?

Students use **evidence from the previous computational representation** and data about health outcomes to **illustrate** the way in which **relationships among Earth's systems** have been **destabilized** due to the amounts of **human-generated greenhouse gases added to the atmosphere**.

Preparation

Student Grouping

- ☐ Table Groups

Routines

- ☐ Think-Talk-Open Exchange
- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation
- ☐ Concept Mapping

Materials

Handouts

- ☐ Diagramming the Impacts of CO2
- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ *Fossil Fuels Card Sort*
- ☐ Chart paper
- ☐ Markers
- ☐ Optional [Ocean Acidification](#)

Diagramming the Impacts of CO2

1. In the Explore phase, students investigated how carbon dioxide emitted from burning fossil fuels can destabilize natural systems. Now, they will have the opportunity to learn about how those disruptions impact organisms in the ocean, and the effect on human health.
2. Ask students what they think might happen to ocean organisms as the ocean gets more acidic. Give them an opportunity to share if they have heard of ocean acidification or any of its impacts before.
3. Ask students what benefits humans derive from oceans. Ask them if they can think of any negative impacts that ocean acidification might have on humans.
4. Provide students with the handout *Diagramming the Impacts of CO2*. Have students work independently to read the text in Part 1.
5. Ask students to discuss the prompt: how does ocean acidification negatively impact human health? using the routine Think-Talk-Open-Exchange

Access for All Learners



Students may struggle to connect with the topic of ocean acidification. The text will connect it to human health, but for some students it may be helpful to provide a little more background on the severity and ecosystem impacts of ocean acidification by showing a video like [Ocean Acidification](#).

Look & Listen For



- Some species that humans eat will experience higher rates of death, causing potential food reduction for humans
- Some species humans eat may become less nutritious
- Acidification can intensify contaminating pollutants in some fish species
- Acidification can increase algal blooms, which can release toxins that cause respiratory irritation

Explaining Relationships between Systems

1. Remind students of their earlier questions about how carbon dioxide and polluting emissions were related, and how they connect to impact human health. Tell students that they will now connect all of the different elements they have investigated so far to demonstrate how burning fossil fuels destabilize relationships between natural systems.
2. Provide students with chart paper, markers, and the *Fossil Fuels Card Sort*.
3. Instruct students to arrange the cards on the chart paper and draw arrows between the different pieces of the system, showing how they are impacted as a result of changes to another component. Have students annotate their arrows to show the impact each connected piece has on the other.

There are several ways students could construct their concept map, but a finished product may look like this:

Integrating Three Dimensions

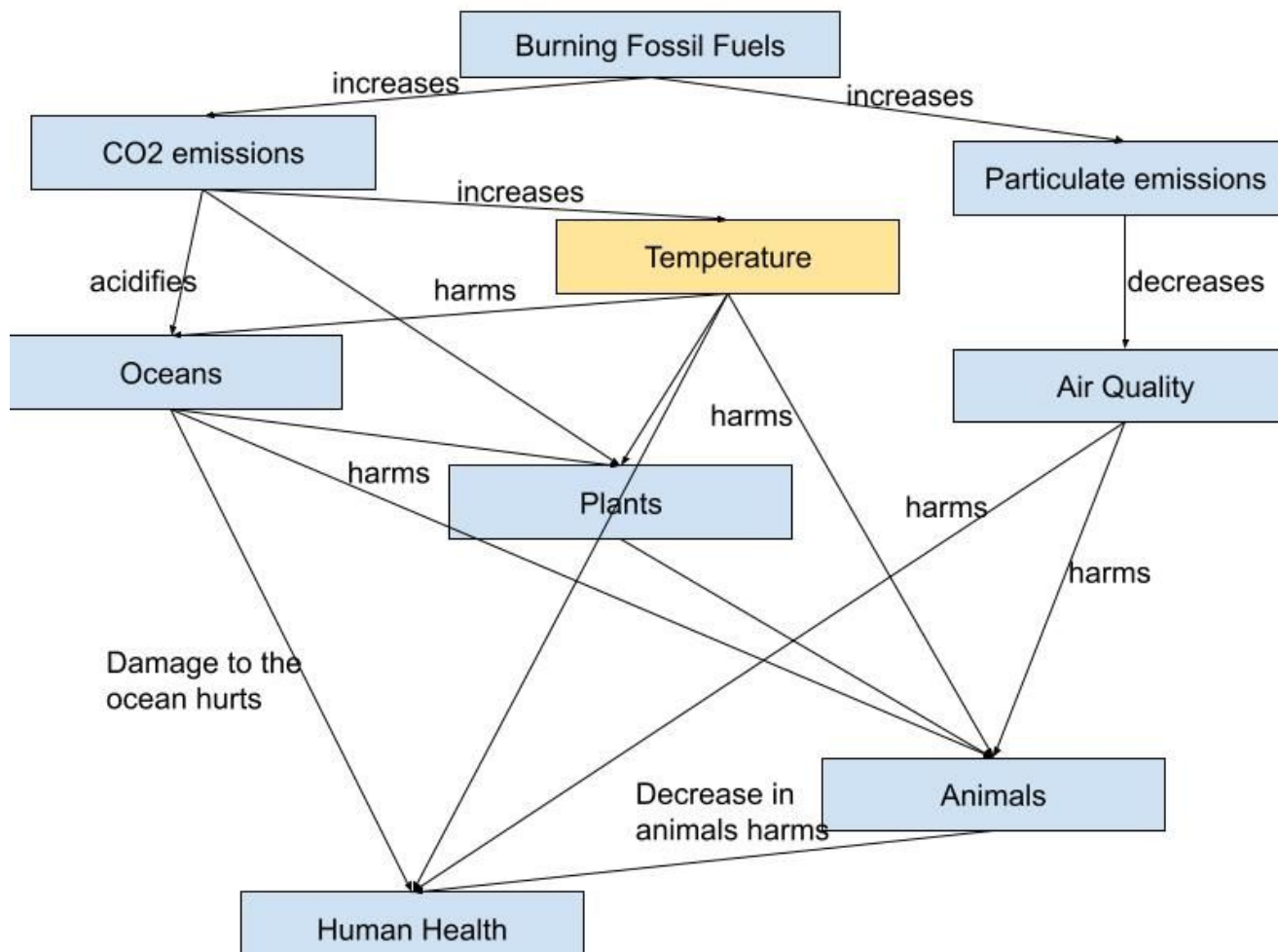


In this explore/explain, students are engaging with **SEP#5, Using Mathematical and Computational Thinking**, to support their analysis of solutions in future phases.

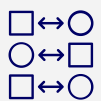
Routine



This is the first time the routine **Think-Talk-Open Exchange** appears in this unit! During this routine, students share with others and gain feedback on their ideas by finding similarities and differences, piecing together disparate bits of information, or reconciling different interpretations. Overall, the routine allows students to clarify or generate ideas collaboratively. Please consult the Biology Course Guide for detailed steps about this routine.



Differentiation Point



Students may need support in constructing this concept map. To scaffold it for students, you may choose to give students only some cards to begin with, and add more as their web grows. It can also be helpful to model constructing the first few arrows and use a think-aloud to demonstrate how to think about connections between these items.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
 - “We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how burning fossil fuels impacts human health both directly and indirectly.”

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how fossil fuels destabilize various systems and impact their interactions in such a way that causes negative impacts on humans. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.
5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions



The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #4 - Systems and System models** explicit for students by elevating and probing for ideas related to the concept that parts of the system are interdependent, and that changing inputs and outputs of one part of the system can cause effects in others, an important element of systems modeling at the high school level. The prompts about patterns in the Class Consensus Discussion are in support of students' consideration of **CCC #4 - Systems and System Models**.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- Burning fossil fuels emits both carbon dioxide and polluting emissions
- Polluting emissions cause health problems for humans, which can even cause death
- Carbon dioxide emissions do not directly harm humans, but disrupt natural systems
- Carbon dioxide has been increasing in the atmosphere, biosphere, and hydrosphere
- In the atmosphere, carbon dioxide causes temperatures to rise
- In the hydrosphere, carbon dioxide causes acidification
- Ocean acidification disrupts ocean ecosystems, which can cause nutrition deficiencies and respiratory problems

6. Return to student questions that bring up lingering issues not yet resolved, such as:

- How does carbon dioxide interact with the biosphere?
- How can we solve these problems?

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about how antibiotic resistance develops.

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions, including the concept of system relationships and stability, to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How can we design and refine solutions to reduce the impacts of human activities on natural systems?

Students **evaluate a technological solution** designed to **stabilize Earth's systems** by modifying the ways in which **gases are absorbed in the ocean and biosphere**.

Preparation

Student Grouping

- ☐ Table Groups

Routines

- ☐ Idea Carousel

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Using Oceans to Capture Carbon

Lab Supplies

None

Other Resources

- ☐ Citizen Science
- ☐ Saving turtles in Nicaragua by working with communities

Text-Based Task

1. Tell students that they will now read about and refine a solution to help reduce ocean acidification. Provide students with the handout *Using Oceans to Capture Carbon*.
2. Students read the text using text annotation and then respond to the solution refinement prompts.

Implementation Tip



If students are struggling to think of refinements, show them examples of other environmentally focused initiatives that have solved some of the problems in coastal restoration. One option is to show them the video [Citizen Science](#), which helps conservation efforts monitor ecosystems. Another option is to show them the video [Saving turtles in Nicaragua by working with communities](#), which harnesses the power of local communities to perform conservation work.

3. In groups, students discuss their answers and represent their ideas on chart paper.
4. Facilitate the group learning routine **Idea Carousel**, as a way for students to synthesize and extend their thinking.

Routine



This is the first time the routine **Idea Carousel** appears in this unit! This routine supports groups of students in thinking through a set of related problems, tasks, or visuals, in order to develop a larger insight or discovery. Therefore, it's great for developing complex understandings of a phenomenon in science. For the first implementation, focus on having students learn the steps. Please read the Biology Course Guide for detailed steps about this routine.

Evaluate

How can we reduce the number of deaths from pollution generated by burning fossil fuels?

Students **refine a solution designed to reduce car emissions** and then **evaluate** the **combined impacts** of the **solutions** they evaluated on reducing **global deaths from environmental causes**.

Preparation

Student Grouping

None

Routines

- ☐ Domino Discover
- ☐ Driving Question Board

Literacy Strategies

None

Materials

Handouts

- ☐ Limited Emissions Zones
- ☐ Return to the Performance Task: Burning Fossil Fuels

Lab Supplies

None

Other Resources

- ☐ Group concept maps from Explain 2
- ☐ *Return to the Performance Task: Burning Fossil Fuels*
- ☐ [En-ROADS Simulation](#)

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence. This will be something like: How does burning fossil fuels relate to environmental causes of death? Why does this source of illness affect people unequally? What types of solutions might reduce environmentally caused deaths from burning fossil fuels?

Implementation Tip



When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class' actual questions!

2. Provide students with the handout *Limited Emissions Zones*.
3. Students will read about limited emissions zones in France and refine the solution to apply to New York City.
4. Confer with students while they are working.

Conferring Prompts



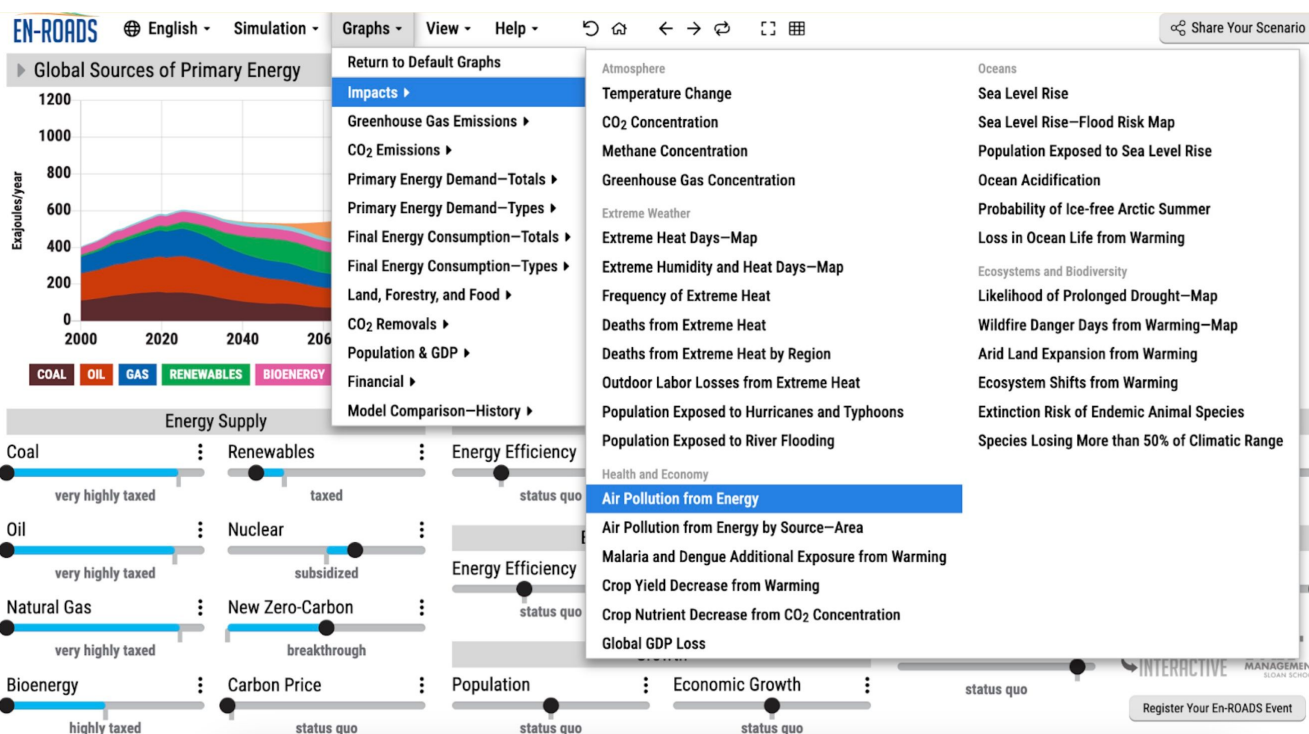
Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room.

Suggested conferring questions:

- What evidence did you generate in this 5E sequence?
- Where did the evidence come from?
- How well does that evidence support the claim?
- What ideas or contradictory evidence weaken the claim?

5. As a class, open the [En-ROADS Simulation](#), which shows how different changes to fossil fuel use could impact greenhouse gas emissions in the next 75 years.

6. Toggle to the view “Air Pollution from Energy” Under the “graphs” tab and “impacts” arrow, as shown below.



7. As a class, discuss which variables shown in the simulation would be affected by the solutions they have read about

8. Show students the impact on air pollution that those solutions would have on decreasing air pollution.
9. Reset the model by clicking on the “simulation” tab and clicking “reset policies.”
10. Toggle to view “Ocean Acidification” and observe the impact that these solutions would have on reducing ocean acidification.
11. Allow the class to explore other impact graphs related to these phenomena in order to understand the widespread influences of their solutions on the many interlinked problems to human health.
12. Have students turn to the *Return to the Performance Task: Burning Fossil Fuels* and complete the task.

Document Class Thinking

1. Prompt students to discuss with their groups their solution refinements and evaluations. Students can use the notes in their performance task organizers in these discussions.
3. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point.

Revisit the Driving Question Board

1. Use the **Driving Question Board Routine** to discuss which of the class’s questions have been answered.
2. Have students identify which categories or questions they have not figured out yet. Prompt students to share out these questions, and document new questions that arise based on what they have been learning.
3. Add new questions to the Driving Question Board.
4. One question category still unanswered relates to questions about how heat and temperature changes impact human health. Tell students that, in the next sequence of lessons, they will investigate how human use of land has impacted local and global temperatures and their impact on human health.

Standards in Burning Fossil Fuels 5E

Performance Expectations

- HS-ESS3-4 *** **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).
Assessment Boundary: None
- In NYS, the phrase "could range from local efforts" has been replaced with the phrase "could include practices ranging from local efforts."
- 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.**
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-ETS1-3 *** **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.**
Clarification Statement: None
Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems - Analyze complex real-world problems by specifying criteria and constraints for successful solutions. SEP1(9) Using Mathematics and Computational Thinking - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(2) Constructing Explanations and Designing Solutions - 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. SEP6(5)	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. ESS2.D(4) ESS3.C 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. ESS3.C(2) 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. ESS3.D(2) ETS1.A Defining and Delimiting an Engineering Problem - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. ETS1.A(1) - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. ETS1.A(2) ETS1.B Developing Possible Solutions	Systems and Systems 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. CCC4(2) Stability and Change - Feedback (negative or positive) can stabilize or destabilize a system. CCC7(3) 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. INFLU-H3 - Engineers continuously modify these systems to increase benefits while decreasing costs and risks. INFLU-H2

Science and Engineering Practices

Disciplinary Core Ideas**Crosscutting Concepts**

- 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. ETS1.B(1)
-

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Asking Questions and Defining Problems	✓	✓		✓	✓
Using Mathematics and Computational Thinking			✓		✓
Constructing Explanations and Designing Solutions		✓		✓	✓
ESS2.D Weather and Climate			✓	✓	✓
ESS3.C Human Impacts on Earth Systems		✓			✓
ESS3.D Global Climate Change			✓		✓
ETS1.A Defining and Delimiting an Engineering Problem	✓		✓	✓	✓
ETS1.B Developing Possible Solutions		✓		✓	✓
Systems and Systems Models			✓		✓
Stability and Change			✓	✓	✓
Influence of Science, Engineering, and Technology on Society and the Natural World		✓		✓	✓

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics					
ELA/Literacy					

Student Work for Burning Fossil Fuels 5E

Return to the Performance Task: Burning Fossil Fuels

Reducing the Impacts of Burning Fossil Fuels

Restate how the emissions from burning fossil fuels are causing problems:

Burning fossil fuels releases emissions including CO₂ and air pollution like particulate matter, ozone, carbon monoxide, sulfur dioxide, and nitrous oxides.

Explain how these problems relate to the overall problem of global death from environmental causes:

Globally, millions of people die every year from diseases resulting from air pollution from burning fossil fuels. Burning fossil fuels releases carbon dioxide and other pollution. Carbon dioxide is a greenhouse gas that contributes to climate change and ocean acidification. The other pollutants cause health problems like headaches, inflammation, asthma, cancer, pulmonary disease, and cardiovascular diseases. These diseases like asthma, cardiovascular disease, pulmonary disease, and cancer are all related to the top 3 causes of death from the environment, which include heart disease, respiratory diseases, and cancer. Additionally, carbon dioxide causes ocean acidification, which can deplete food fish stocks and make food less nutritious. Specifically, fish have high levels of omega-3 fatty acids, which reduce inflammation and heart disease; ocean acidification

reduces omega-3 fatty acid levels in fish, and the people who consume those fish have increased risk of stroke, cardiovascular disease, and cancer.

Analyze the Possible Solutions

Solutions the Class has Evaluated	What parts of the problem does it address?	What parts of the problem does it not address?	What are some constraints / tradeoffs?
Nuclear Energy	- prevents burning fossil fuels for electricity production - reduces CO₂ emissions and air pollution that would be released by energy production - when France switched to nuclear energy, its levels of nitrous oxides,	- only reduces emissions caused by energy production - other sources of air pollution from burning fossil fuels, like transport and industry, still produce those emissions	- nuclear waste needs to be stored - building nuclear power plants is expensive - The United States has a fear of nuclear power

	sulphur dioxide, carbon monoxide, and black carbon particulate matter all decreased		
Restoration of Coastal Ecosystems	- absorbs CO₂ from the oceans, decreasing its acidity - carbon that is captured by coastal restoration is trapped for over 1,000 years - supports fish habitats which stabilizes their populations, biodiversity, and increases nutritional content of seafood, which helps reduce cardiovascular disease and cancer risk in populations that eat fish	- does not prevent carbon dioxide emissions from occurring to begin with - does not target the causes of air pollution, and does not address air pollution directly	- can be expensive to implement and maintain - is not always successful, or success is difficult to measure - requires local community buy-in
Zones of Limited Emissions	- reduces polluting emissions from car	- only addresses fossil fuel use in cars, not	- not all people may be able to get new cars,

traffic in city centers

- when Paris began its zones of limited emissions, nitrous oxide levels dropped, and particulate matter pollution nearly disappeared
- pushes consumers towards using electric vehicles, which would reduce fossil fuel use and reduce carbon dioxide emissions

other sectors

- only addresses car use locally in certain zones; may not impact larger areas

which would negatively impact those unable to drive in the city

- some people may not want to buy new vehicles or to be forced to buy new vehicles
- car restriction plans are not popular in the United States

Based on everything we learned, I recommend using a combination of all three solutions. Combining nuclear energy with zones of limited emissions would reduce CO₂ and polluting emissions from both electrical energy use and transportation, which are large sources of fossil fuel use. In France, when nuclear energy and zones of limited emissions were implemented, nitrous oxides, carbon monoxide, sulphur dioxide, and particulate matter levels decreased.

These policies would not be immediately popular with people living in the United States. Therefore, education initiatives would need to be implemented in order to make citizens less concerned about the safety of nuclear energy and the benefits of electric vehicles. Additionally, these may be expensive solutions at the beginning. Costs can be saved by retrofitting coal burning power plants into nuclear power plants, and tax incentives could help people buy new cars, which would be paid for later by a reduction in health costs.

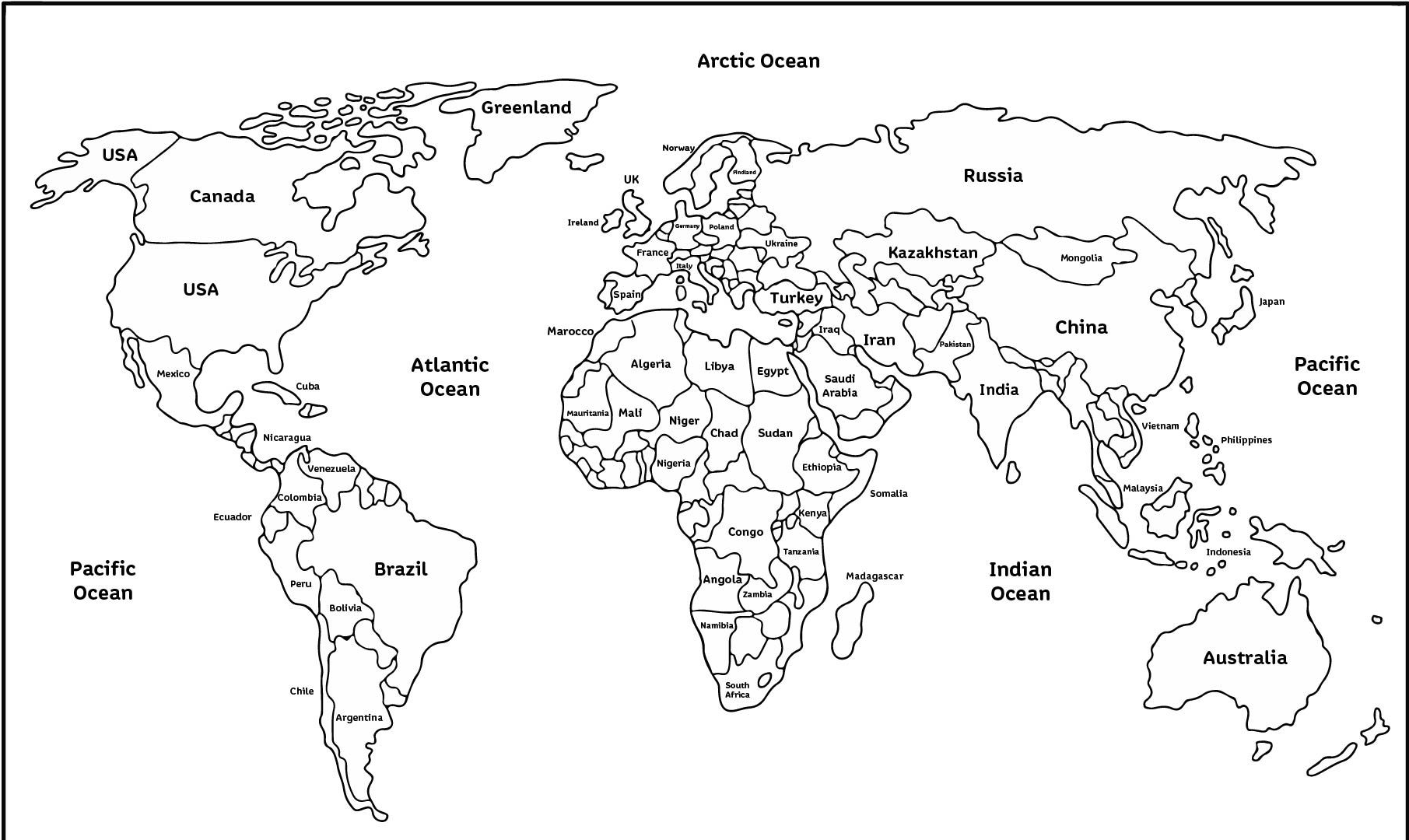
However, these solutions cannot reduce damage already done, so they need to be used in conjunction with coastal restoration. Coastal restoration can be accomplished more efficiently by involving local communities and turning restored areas into ecotourism sites, which generate income.

Classroom Resources for Burning Fossil Fuels 5E

Labeled World Map
Fossil Fuels Card Sort

Labeled World Map

World Map





Fossil Fuels Card Sort

Burning Fossil Fuels	Carbon Dioxide Emissions	Particulate Emissions
Plants	Air Quality	Human Health
Animals	Oceans	Temperature

Land Use and Biodiversity 5E

How do the ways humans change land affect the health of people and biodiversity? How can we stabilize systems that have been destabilized by these changes?

Performance Expectations
HS-ESS3-3, HS-ETS1-4

Investigative Phenomenon
350 New Yorkers die every year from the urban heat island effect, which affects people differently according to the heat vulnerability index of different neighborhoods.

Time
6-8 days

Students layer complexity onto the stories of how humans are impacting biodiversity and human health by analyzing how land use choices impact ecosystems, including urban heat islands and deforested areas of the rainforest. In this sequence, students will determine the impacts of urbanization on ecosystem sustainability, biodiversity, and human health outcomes and consider solutions to minimize those negative impacts. Then students apply what they learned about the effects of land use to the example of the Amazon rainforest, where deforestation is creating similar outcomes to urban heat islands. Finally, students evaluate solutions to reduce the negative effects of land use globally.

ENGAGE	How is the heat impacting the health of New Yorkers?	Students analyze data showing the impacts of urbanization on humans in order to begin considering the sustainability of human society .
EXPLORE	How has the change in land use in New York City over the past 400 years contributed to the heat island effect?	Students analyze maps demonstrating how modern urbanization has impacted the use of land as a natural resource and introduced variables that contribute to the phenomenon of the urban heat island effect .
EXPLAIN 1	How does land use in New York City contribute to heat-related deaths?	Students create a computational model representing the sustainability of human populations given the use of land as a resource in the change from forested wetland to urbanization in New York City.
EXPLAIN 2	How can we intervene to increase the sustainability of cities?	Students compare a real-world solution to their computational models in order to simulate the effects of this solution and analyze its effects on biodiversity and sustainability of the land.
ELABORATE	How are humans changing land in other areas in unsustainable ways with negative impacts to human and ecosystem health?	Students compute the rate of change of and feedback loops that occur during deforestation of the land in the Amazon rainforest in order to calculate how long it will take for the changes in the Amazon to be irreversible .
EVALUATE	How can green roofs contribute to sustainability, and how do these solutions combine to heat deaths globally?	Students calculate the sustainability of neighborhoods given a technological solution of green roofs, then evaluate the combined impacts of the solutions they evaluated on reducing global deaths from environmental causes.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

How is the heat impacting the health of New Yorkers?

Students analyze data showing the **impacts of urbanization on humans** in order to begin considering the **sustainability of human society**.

Preparation

Student Grouping

☐ Table Groups

Routines

☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

☐ Heat in NYC

Lab Supplies

None

Other Resources

- ☐ Global Urban Heat Islands
- ☐ New Yorkers stay cool on day 6 of heat wave

Launch and Surfacing Student Ideas

1. Remind students that, during the Driving Question Board launch, one category of questions that emerged was related to how green or natural space related to environmental causes of death, especially heat deaths, or why some places that are next to each other have very different levels of death from environmental causes and whether some places that are near each other are hotter than others because of differences in the land?
2. Use these or related questions to introduce the question: *How do the ways humans change land affect the health of people and biodiversity?*
3. Tell students that to investigate this question they will have an opportunity to look at an extreme example of an area that has been very changed from its natural state, New York City. And instead of looking at air pollution like they did in the Fossil Fuels 5E, this time we will look at how these changes to the natural state impacts the amount of heat, and in turn, the health of humans and other organisms.
4. Ask students to think about how their bodies feel when it gets too hot. Ask what types of health impacts they think happen to their bodies when they feel too hot. Also ask them what types of behaviors they engage in to cool down. Have students turn and talk to each other, then have a few students share out what they discussed.

Access for All Learners



It is possible that not all students will identify with the phenomenon happening in New York City. Many cities around the world experience the heat island effect, and even non-urban settings can have situations where some areas feel hotter than others. This conversation can be widened to discuss other cities by showing heat island maps from those places as well, or simply by asking students if they have felt similar heat differences in other places.

Differentiation Point



During this phase, students will be observing that different areas of New York City have different vulnerabilities to negative health effects from heat. Asking students to think about how they cool down from the heat helps students think about the types of infrastructure and resources that protect people from high temperatures, which will be part of the conversation moving through this 5E.

5. Provide students with the handout *Heat in NYC*. Show students the video, [New Yorkers stay cool on day 6 of heat wave](#) and have students write down the key information that describes some effects of a heat wave in NYC.
6. Tell students that although we are talking about New York City as an example, this heat island effect phenomenon happens all around the world. Show students the [Global Urban Heat Islands](#). Tell students that the local phenomenon we are observing can be applied to understand some of the causes of heat related deaths globally.

Implementation Tip



Be sure to stop the video around 2:23 or it will give away part of the story that students are investigating in this sequence.

7. Have students work in table groups to view the diagram and map in their handout. Encourage students to look back at the texts from the Unit Launch to make connections between the impacts heat has on the body and the Top 10 causes of Death from the Environment. Support students as they work in groups to analyze the data and complete the See-Think-Wonder.

Implementation Tip



The description for the Heat Vulnerability Index is intentionally vague. This index is based on various factors within each neighborhood, including: how much hotter the area gets, its level of vegetative cover, the socioeconomic vulnerability of people living in that neighborhood, and access to air conditioning. These factors all surface throughout the unit, so at this point, students should simply note that vulnerability varies, and ask about why.

8. Ask groups to come up with one important idea and / or question to share with the whole class, from their See-Think-Wonder.
9. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from the texts.

Integrating Three Dimensions



In this phase, students consider the **Influence of Science, Engineering, and Technology on Society and the Natural World**, thinking about the ways in which the requirements of modern cities have impacted the environment.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Look & Listen For



- In NYC, people die every year from heat-related causes
- Heat can cause other conditions to worsen other conditions, like respiratory diseases, heart disease, and stroke
- These deaths are not evenly distributed around the city
- Why are some areas more vulnerable to heat than others?
- What goes into the heat vulnerability index?
- How can we reduce those numbers?

Explore

How has the change in land use in New York City over the past 400 years contributed to the heat island effect?

Students analyze maps demonstrating how **modern urbanization** has impacted the **use of land as a natural resource** and introduced **variables that contribute to the phenomenon of the urban heat island effect**.

Preparation

Student Grouping

- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Land Use in New York City
- ☐ Making Sense of the Land Use in New York City Investigation

Lab Supplies

- ☐ Computers

Other Resources

- ☐ *New York City Land Use Maps*
- ☐ [New York City Neighborhoods](#)
- ☐ [Poor neighborhoods are hotter than rich ones - especially during heat waves](#)
- ☐ [The Welikia Project](#)

Launch

1. Remind students that the map seen in the Engage phase showed that heat vulnerability is not evenly distributed around the city.
2. Let students know that they are going to watch a video that highlights one reason that this uneven distribution exists. Show the video, [Poor neighborhoods are hotter than rich ones - especially during heat waves](#).
3. Tell students that they will now have the opportunity to investigate what differences exist within the city that contribute to those differences.
4. Ask students to brainstorm some things that might be contributing to heat deaths.

Investigation

1. Provide students with the handout Explore: Land Use in New York City. Each group should have a copy of *New York City Land Use Maps*.

Differentiation Point



There is a lot of visual data to review in this phase, and it is helpful if students can directly compare different neighborhoods. Map 5 shows the neighborhoods of New York City and their names, as does the interactive [New York City Neighborhoods](#). Encourage students to use those resources to consistently look across the other maps they are viewing. It may also be helpful to pause the class after they have had time to review each map to ensure that students are interpreting the maps correctly and making connections between each one.

2. Support groups as they observe each map in order, respond to the prompts, and complete the See-Think-Wonder chart.
3. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts



Confer with students during the investigation. Suggested during-lab conferring questions:

- Which areas of the city are hotter? Which are less hot? How big a difference is there between the hottest and coolest parts of the city?
- How has the land changed in Manhattan over the past 400 years? What do you think that has done to the organisms living in it?
- What do you think the different zones in New York are like? What features do you think are common in manufacturing zones? What about commercial or residential zones? What do you think those zones might look like?
- Why do you think some zones might be hotter than others?
- Why do you think trees are important to biodiversity? What types of organisms might rely on trees?
- Have you ever interacted with trees when it is hot? How have trees helped you on hot days?
- Which zones do you think are most likely to have the most or fewest trees? What makes you think that?
- How do you think energy use might relate to heat?
- What factors do you think contribute to the amount of energy used in an area?

Integrating Three Dimensions



In this unit students are developing proficiency with **CCC#7, stability and change**. In this 5E, students are exploring differences between Manhattan 400 years ago and the city now in order to analyze the irreversible change of land use as a natural resource due to human intervention.

Investigation: Whole-Class Investigation Summary

1. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' See-Think-Wonder charts.

Look & Listen For



Possible student ideas and questions:

- New York City has changed from being a natural, tree-covered landscape to a dense city with lots of buildings and paved streets
- There are big differences in the level of additional heat caused by heat islands
- Overall, commercial and manufacturing districts tend to be hotter than residence districts, but some residence districts are very hot
- Overall, areas with less green space are hotter
- Overall, areas with higher energy use are hotter
- Does green space cause cooling, or does it mean there is less pavement which causes heating?
- Is there one variable that contributes more to the heat island effect than others?
- What causes some residential neighborhoods to be hotter than others?
- How does energy use relate to the other maps?
- Are there other factors that contribute to the heat vulnerability index?

2. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
3. Provide students with the handout Making Sense of the Land Use in NYC Investigation
4. Have students work in pairs to answer the summary questions
5. Have a few students in the class share out their responses to the summary questions.

Look & Listen For



Possible student ideas and questions:

- Land is a natural resource
- The way humans have used land has changed it from its natural tree covered landscape to a city
- It is likely not possible to reverse this change
- This change has caused the heat island effect, which negatively impacts human health
- New York City could be a more sustainable habitat for humans and other organisms

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Access for Multilingual Learners



Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine.

Explain 1

How does land use in New York City contribute to heat-related deaths?

Students **create a computational model** representing the **sustainability of human populations** given the use of **land as a resource** in the **change from forested wetland to urbanization** in New York City.

Preparation

Student Grouping

- ☐ Pairs
- ☐ Table Groups

Routines

- ☐ Class Consensus Discussion

Literacy Strategies

None

Materials

Handouts

- ☐ Modeling Sustainability

Lab Supplies

- ☐ Computers

Other Resources

- ☐ Chart Paper
- ☐ Markers
- ☐ Calculators
- ☐ *New York City Land Use Maps* from Explore
- ☐ *Sustainability and Heat Index Variable Descriptors*
- ☐ [Land Use Computational Model](#)

Creating and Using Computational Models

1. Ask students if, based on the factors they observed in the Explore phase, they can explain the amount of urban heat island effect in specific places on the map. At this point, students may have a sense that zone type, energy use, and tree cover matter to the heating of neighborhoods, but they won't have a clear understanding of exactly how those factors interact and explain the extent of urban heat island effect in specific places.
2. Remind students that they have interacted with complex, multivariable situations before. For example, in the previous 5E, they observed how the geosphere, hydrosphere, atmosphere, and biosphere interact to changing levels of carbon dioxide, and quantified the impacts on each. In Unit 1, they used data to complete computations that calculated distances of exoplanets. In each of these cases, students used computational modeling practices to take into account multiple variables to come up with an answer about how variables affect each other.
3. Tell students that they will be using a similar practice here. In this activity, they will be using the data from the maps in the explore phase to construct a computational model showing how each affects heat in different neighborhoods.
4. Prompt students to consider how they could go about creating this computational model of the heat island effect. Ask students to turn and talk to discuss: what variables were in the explore phase that we should be including in these models? Students should state: zone type, energy use, and tree cover.
5. Ask students how they would quantify each variable. Students might raise that it is hard to quantify the zone types. Give students the resource *Sustainability and Heat Index Variable Descriptors*. Ask students what types of characteristics you find in different zones and how those could contribute to heating. This is a good opportunity to do a spiral review of the concept of albedo, which they learned about in Unit 3.

Integrating Three Dimensions



In this unit students are developing proficiency with the **SEP#5 Using Mathematics and Computational Thinking**, both constructing and using computational models. In the last 5E, students worked with a computational model to understand relationships between systems; in this 5E, students are using this practice in more depth to construct and manipulate mathematical models in order to represent relationships between variables and model how changing the system would affect these variables.

Look & Listen For



- We can use the percent tree cover given by the map
- We can use the energy levels given by the map
- Zones are more challenging to assign numbers to
- Manufacturing zones should have higher scores because high levels of dark surfaces mean they likely absorb and reradiate higher levels of heat
- Commercial zones should probably have a middle-high score because they have less asphalt than manufacturing zones, but more than residential zones, and not much shade
- Residential zones should probably have a middle-low score because there is more shade and less hot surface area
- Parks should have low scores because they have lots of shade and less dark surface area

6. Provide students with the handout *Modeling Sustainability*. Have students work in pairs to complete questions 1 - 4 of Part 1 using information from the class discussion.

7. After students have had time to think, ask students to share out how each variable would impact a relative heat score of neighborhoods and how they could represent that mathematically.

Look & Listen For



- Things that increase the heat scores, like energy use and zone score, could be in the numerator of an equation
- Things that increase the heat scores could be represented using addition
- Things that decrease the heat scores, like tree cover, could be in the denominator of an equation
- Things that decrease the heat scores could be represented using subtraction

8. Once students are feeling comfortable thinking mathematically, tell them that they will be using these variables to construct mathematical models of relative heat score in four key neighborhoods. Have students look at Map 5 from the Explore phase to locate the four neighborhoods of interest:

Mott Haven - Port Morris in the Bronx

Midtown - Midtown South in Manhattan

Prospect Lefferts Garden - Wingate in Brooklyn

Glen Oaks - Floral Park - New Hyde Park in Queens

9. Have students continue working in their pairs on steps 5-7.

Differentiation Point



In this section of the activity, students will be constructing computational models using the variables they described in the Explore phase. This can be a challenging way for students to think. Help students leverage information from the whole class discussion to figure out how to use each variable and the types of mathematical operations that would cause a variable to increase or decrease their overall heat scores. Zoning, in particular, may be hard for students to come up with quantities to input in their models. If they need it, you can help them think about assigning scores to different zones, like there are for energy use. Remind students that there are multiple ways to construct these models; the point is to think about relationships, not to have a “correct” model.

10. When students are finished, discuss their models. Have students share their results. Ask students if they think the scores they constructed are meaningful or representative of the heat island effect.
11. Tell students that there are often many ways to construct computational models that describe real world phenomena, and that different ways of modeling can have different strengths and utilities. Tell them that they will now have the opportunity to use another computational model to compare their work to.
12. Have students work in pairs to complete Parts 2 and 3 of the handout. In this phase, they will be using the spreadsheet [Land Use Computational Model](#).

Implementation Tip



In order to use these spreadsheets, students will have to make copies to edit. Make sure students save their work because they will be returning to it later in the unit to test the effects of changing green space on neighborhood sustainability.

Analyzing Feedback Mechanisms

1. During the conversation about zone scores, it may have come up that different zones often have different levels of tree cover and different levels of energy use, or other ways that the variables being used are partially dependent on each other. Tell students that systems can be very complicated, and that mathematical models can help us see how different variables are related, and how changing one can impact others.
2. Tell students that they will now be working to understand how different pieces of how we use our land influence each other.
3. Have students work in table groups to analyze the feedback loops in Part 4 of the handout. Confer with students as they analyze the relationships between components of the systems.

Implementation Tip



The feedback dynamics increase in complexity as more elements are added to the system. This scaffolded structure is designed to help students practice the skill of identifying how different components interact and analyzing those interactions. Scenario 4 is the most challenging, and requires that students first decide which parts of the system interact, then determine if the relationships operate in one or two directions, and how they influence each other. For scenario 4, there is no one correct way to complete the chart. Encourage students to find as many interactions as possible, but remind them that there may not be feedback loops between all elements.

4. Tell students that they will be presenting Scenario 4 during the class consensus discussion, so all groups should feel confident discussing this work.
5. When students are done with their feedback mechanisms, have them work on Part 5 of the handout to evaluate the accuracy of the models they have been using.

Integrating Three Dimensions



The use of constructing feedback loops in this Explain phase is to support the development of students' understanding of stabilizing and destabilizing interactions, in service of **CCC#7, stability and change**.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
 - “We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how increasing or decreasing green space can create or interrupt feedback loops that stabilize or destabilize the city, and how those relate to sustainability.”

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student Scenario 4 charts to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of feedback loops and the relationships between components in the system. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.
5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions



The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #7 - Stability and Change** explicit for students by elevating and probing for ideas related to the concept that interventions can create feedback loops that stabilize or destabilize systems, an important element of stability and change at the high school level.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

Note: all of these are true in reverse

- If tree cover increases, heat increases
- If heat increases, people will use more air conditioning, meaning there is greater energy use
- If energy use increases, heat will increase even further, due to heat waste from electricity use
- If biodiversity increases, tree cover increases, and vice versa, because different tree species support different organisms, and different organisms support different and healthier trees
- Because of the biodiversity and tree cover feedback loop, if biodiversity increases, heat and energy use decrease
- If urbanization increases, tree cover decreases, setting off the other feedback loops and relationships described before
- Altering one component of the system, the green space, impacts the other components, such as the temperature/sustainability and the energy use
- Though the total land use change in New York is likely irreversible, some levels of green space can be changed

6. Return to student questions that bring up lingering issues not yet resolved, such as:

- Why is there a discrepancy between the heat vulnerability and the models?
- Is cooling from green space because it cools spaces or because it prevents other types of surfaces from existing in that space?
- Is that happening around the world?
- What other ways is land being used?

Explain 2

How can we intervene to increase the sustainability of cities?

Students compare a real-world solution to their **computational models** in order to **simulate the effects** of this solution and analyze its effects on **biodiversity and sustainability** of the land.

Preparation

Student Grouping

- ☐ Triads

Routines

- ☐ Think-Talk-Open Exchange

Literacy Strategies

None

Materials

Handouts

- ☐ Intervening in Systems to Increase Sustainability
- ☐ Summary Task

Lab Supplies

- ☐ Computers

Other Resources

- ☐ Computational models from Explain 1
- ☐ Scenario 4 charts from Explain1
- ☐ Chart Paper
- ☐ Markers
- ☐ *Modeling Sustainability*
- ☐ *Medellin's Green Corridors*

Intervening in Systems

1. In the Explain 1 phase, students constructed computational models to analyze how components of cities are related to each other and how they contribute to the sustainability of the city.
2. Pause to ask students what components of the system they could act upon in order to increase sustainability of the city.

Look & Listen For



- We could reduce energy use, especially in buildings
- We could increase green spaces
- We could increase the albedo of the city/change the surface types being used in manufacturing and commercial zones
- We could increase biodiversity in the city

3. Provide students with the handout, *Intervening in Systems to Increase Sustainability*. Ask students to work individually to read the Introduction.

Integrating Three Dimensions



In this unit students are developing proficiency with the **CCC#7, Stability and Change**. Here they have an opportunity to consider how human actions can increase stability. Help students understand that we may not be able to return land to its original state, but we can stabilize the systems.

4. Tell students that they will now look at an example of a city that acted on one of these ideas. Show students the video [Medellin's Green Corridors](#) . As they watch the video, students should record what actions Medellin has taken, how those actions impacted the city, and how those actions might benefit New York City.
5. Have students work in groups of three to complete the Think-Talk-Open Exchange routine to discuss how altering components of the system results in feedback loops that can stabilize the city and increase its sustainability.

Look & Listen For



- Increasing green space cools the city, which increases the sustainability
- If the city is cooler, people will need less energy for air conditioning, which will cool the city further
- Increasing green space also increases biodiversity
- There is the added benefit that increasing green space decreases air pollution and increases exercise, both of which promote healthy populations
- This feedback stabilizes the city

6. When students have finished their discussions, students go back to their computational models from the Explain 1 activity. Students alter their calculations to model increasing green space and record their observations in the handout.

Constructing a Scientific Explanation

1. Remind students of the feedback charts they completed in the Explain 1 phase. Direct students to turn to Scenario 4
2. Provide students with chart paper and markers. Tell students to recreate Scenario 4 on their chart paper, but change it to reflect what would happen if green corridors were implemented in the system. Encourage students to add additional elements that are impacted by green corridors to the chart, like physical activity levels or air pollution levels.
3. Confer with students as they construct their feedback diagrams.

Differentiation Point



If students are struggling, they can begin by adding notes on top of Scenario 4 using another colored pencil or pen to show what would change if green corridors were implemented. Using this as a draft, students can then construct the larger model and add complexity on chart paper.

Integrating Three Dimensions



The use of returning to these feedback loops is to help students think predict how a design solution would affect interactions between systems, in service of **SEP#5, Using Mathematics and Computational Thinking**.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
 - “We are going to use a **class consensus discussion**, just like we did in the last explain, to learn about all the thinking in the room and come to some decisions about how adding green spaces impacts the sustainability of cities.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how solutions can intervene to make use of feedback loops to support sustainable systems. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.
5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- Increasing green space can stabilize the systems by creating positive feedback loops that support biodiversity and decrease heat and energy use
- Feedback loops can stabilize or destabilize systems

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions



The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #7 - Stability and Change** explicit for students by elevating and probing for ideas related to the concept that interventions can create feedback loops that stabilize systems, helping them return to dynamic equilibrium, an important element of stability and change at the high school level.

6. Return to student questions that bring up lingering issues not yet resolved, such as:
 - Would this solution work in New York City?
 - How much space do you need to implement this solution?
 - Are there other ways to add green space to cities?
 - Are there other places where green space should be added, besides cities?

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about how antibiotic resistance develops.

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions, including the concept of changing systems to impact sustainability and the relationships within systems** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How are humans changing land in other areas in unsustainable ways with negative impacts to human and ecosystem health?

Students **compute** the **rate of change of and feedback loops** that occur during **deforestation of the land in the Amazon rainforest** in order to **calculate** how long it will take for the changes in the Amazon to be **irreversible**.

Preparation

Student Grouping

- ☐ Pairs
- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Deforestation of the Amazon

Lab Supplies

None

Other Resources

- ☐ Calculators
- ☐ Dataset: [Amazon Deforestation Data](#)
- ☐ [Amazon Deforestation](#)

Using Global Computational Models

1. Remind students that we began the unit looking at global environmental causes of death, and that we looked at heat deaths globally. Prompt students to consider how effective they think the solution we investigated would be at a global level.
2. Ask students if they think that all heat deaths around the world are due to urban heat islands. Prompt them to consider other ways that humans might be altering land that causes heat to increase locally.
3. Tell students that although scientists know that green space is protective against climate change and local heat impacts, that deforestation is happening all over the world, impacting global and local temperatures in those areas.
4. Provide students with the handout *Deforestation of the Amazon*.
5. Have students work in pairs to work through the handout.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Differentiation Point



This activity asks students to complete calculations for the rate of change of forest cover occurring in the Amazon rainforest and to calculate how long it will take to reach 25% deforestation at this rate. For students who struggle to think mathematically, break down the formulae that are provided to them and support them in finding the correct values to use in their equations. For advanced students, consider removing the provided equations and having students derive their own; there are several ways to complete these calculations accurately and only one option is provided.

6. Have students discuss their final responses in their table groups. Ask table groups to come up with a response to the prompt: "In one sentence, what would you recommend changing in the Amazon in order to maximize benefits and increase risks for as many people as possible?"
7. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. Ask students to consider how they think these responses would impact global health if implemented on a global scale.

Access for All Learners



Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine

Evaluate

How can green roofs contribute to sustainability, and how do these solutions combine to heat deaths globally?

Students **calculate** the **sustainability of neighborhoods** given a **technological solution** of green roofs, then evaluate the combined impacts of the solutions they evaluated on reducing global deaths from environmental causes.

Preparation

Student Grouping

None

Routines

☐ Domino Discover

Literacy Strategies

☐ Text Chunking

Materials

Handouts

- ☐ Green Roofs
- ☐ Return to the Performance Task: Land Use and Biodiversity 5E

Lab Supplies

None

Other Resources

- ☐ Calculator
- ☐ *Unknown material with identifier: [ess.u6.l2.evaluate.sw](#)*
- ☐ [En-ROADS Simulation](#)

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence. This will be something like: based on what we have learned in this sequence, what do we know about how natural or “green” space relates to environmental causes of death? How does this information help us consider why some areas that are side-by-side experience very different health outcomes?”
2. Tell students that they will consider one last way to approach adding green space in cities.

Implementation Tip



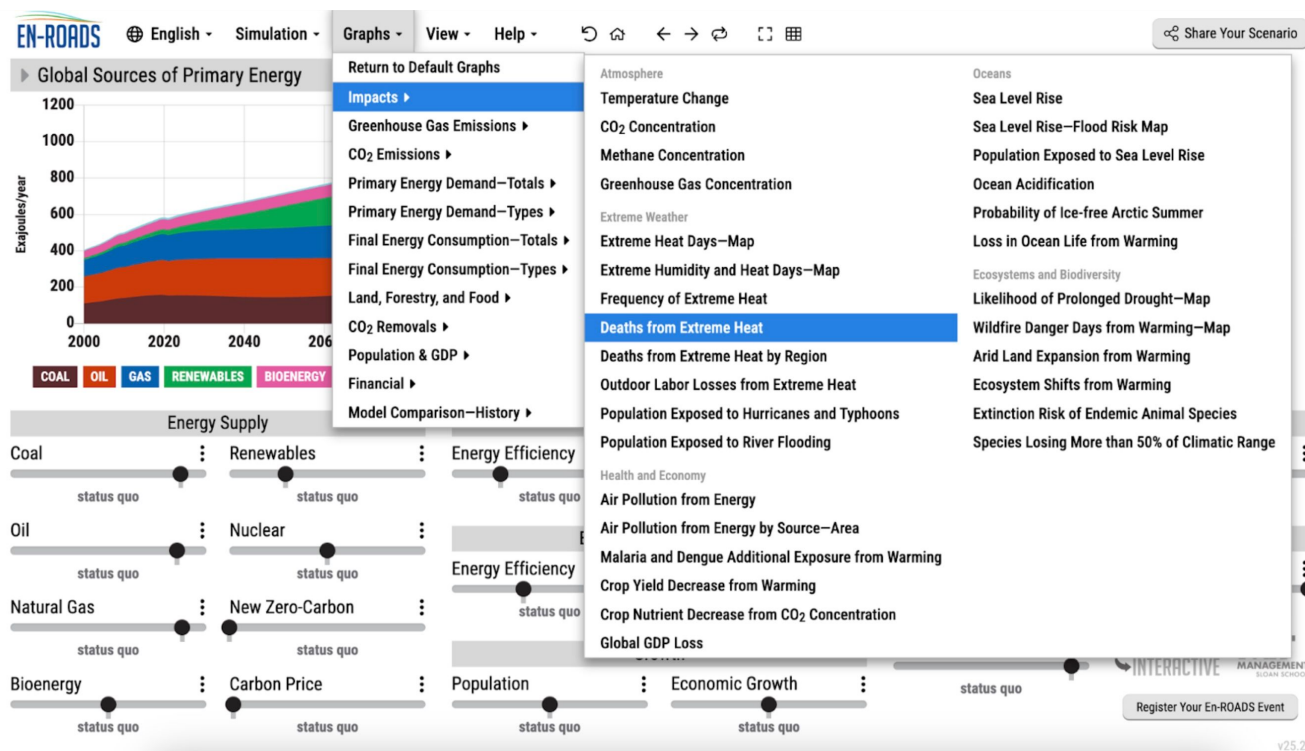
When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class’ actual questions!

3. Provide students with the handout *Evaluate: Green Roofs* and support them as they work independently on the transfer task.

Differentiation Point

- ↔ ○ This task involves using the equation from the computational model they used in the Explain 1 phase. If students need support, have them reopen that spreadsheet to observe how increasing green space affected sustainability to help them predict how green roofs would impact sustainability. Then students can complete the calculations in the evaluate task.

- As a class, open the [En-ROADS Simulation](#), which shows how different changes to fossil fuel use could impact greenhouse gas emissions in the next 75 years.
- Toggle to the view “Deaths from Extreme Heat” Under the “graphs” tab and “impacts” arrow, as shown below.



- As a class, discuss which variables shown in the simulation would be affected by the solutions they have read about
- Show students the impact on heat deaths that those solutions would have on decreasing air pollution.

8. Allow the class to explore other impact graphs (consider land use and deforestation graphs) related to these phenomena in order to understand the widespread influences of their solutions on the many interlinked problems to human health.
9. After completing their work, have students turn to the Performance Task Organizer.
10. Confer with students while they are working.

Conferring Prompts



Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room.

Suggested conferring questions:

- What solutions did you consider in this 5E?
- How did they impact the systems they acted in?
- How did other variables respond to those solutions?
- How did those solutions balance tradeoffs?
- Do you think these solutions would be useful in reducing deaths from environmental causes globally? Would you recommend using them?

Document Class Thinking

1. Prompt students to discuss with their groups their overall takeaways about how solutions discussed in this sequence can help address global deaths from environmental causes. Students can use the notes in their performance task organizers in these discussions.
2. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point.

Revisit the Driving Question Board

1. Use the **Driving Question Board Routine** to discuss which of the class's questions have been answered.
2. Have students identify which categories or questions they have not figured out yet. Prompt students to share out these questions, and document new questions that arise based on what they have been learning.
3. Add new questions to the Driving Question Board.
4. Ask students to reflect on the reasons humans have changed or completely disrupted natural land around the world. Students have seen urbanization and deforestation for agriculture. Ask them what other types of behaviors or phenomena might be impacting natural spaces around the world.
5. Tell students that, in the next sequence of lessons, they will investigate another way that humans are modifying natural land and its impacts on human health and biodiversity.

Standards in Land Use and Biodiversity 5E

Performance Expectations

HS-ESS3-3

Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

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.

Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.

In NYS both occurrences of the word "include," has been modified to say "could include."

HS-ETS1-4 *

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Clarification Statement: None

Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. SEP5(1) - Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. SEP5(6) Constructing Explanations and Designing Solutions - 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. SEP6(5)	ESS3.C Human Impacts on Earth Systems - The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. ESS3.C(1) ETS1.B Developing Possible Solutions - Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. ETS1.B(2) ETS1.C Optimizing the Design Solution - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ETS1.C(1)	Systems and Systems Models - Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. CCC4(3) 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. CCC7(2) 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. INFLU-H3 - Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. INFLU-H1 Science is a Human Endeavor - Scientific knowledge is a result of human endeavor, imagination, and creativity. HE-H1

Assessment Matrix

	Engage	Explore	Explain 1 & 2	Elaborate	Evaluate
Using Mathematics and Computational Thinking	✓	✓	✓		✓
Constructing Explanations and Designing Solutions			✓	✓	✓
ESS3.C Human Impacts on Earth Systems	✓	✓	✓	✓	✓
ETS1.B Developing Possible Solutions			✓	✓	✓
ETS1.C Optimizing the Design Solution			✓	✓	✓
Systems and Systems Models		✓	✓	✓	✓
Stability and Change		✓	✓	✓	✓
Influence of Science, Engineering, and Technology on Society and the Natural World	✓				✓
Science is a Human Endeavor			✓		✓

Common Core State Standards Connections

	Engage	Explore	Explain 1 & 2	Elaborate	Evaluate
Mathematics	MP.2	MP.2 MP.4	MP.2 MP.4 MP.5	MP.2 MP.4 MP.5	MP.2 MP.4 MP.5
ELA/Literacy	RST.9-10.7		WHST.9-10.2 SL.9-10.1 SL.0-10.1	RST.9-10.1 WHST.9-10.9	RST.9-10.1 WHST.9-10.9

Student Work for Land Use and Biodiversity 5E

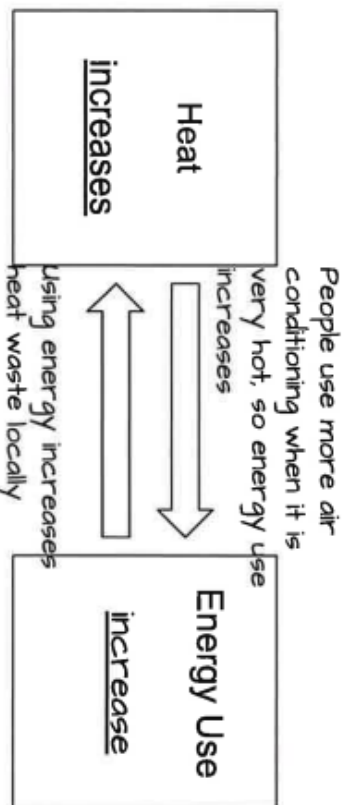
Part 4. Analyzing Feedbacks between Parts of the System

Using the computational model, we saw how tree cover impacts the sustainability of the neighborhood overall. However, there can be additional impacts through feedbacks within the ecosystem. In this part of the activity, you will diagram how different parts of the system you explored are related by explaining how they would react when one part of the system is altered.

Scenario 1. Temperature increases (this one is completed as an example)

Air conditioners create heat waste, and high levels of air conditioner use can increase local temperatures by more than 1 degree C (1.8 F) ([source](#)), further compounding the need for air conditioning.

1. Analyze how a change in heat impacts energy use, and how energy use might impact heat



Scenario 2. Tree cover increases

Tree cover cools areas in several ways. Globally, they absorb carbon dioxide, reducing the greenhouse effect. Locally, they provide shade that cools sidewalk surface, and in ecosystems, they cool the air by releasing water vapor through transpiration.

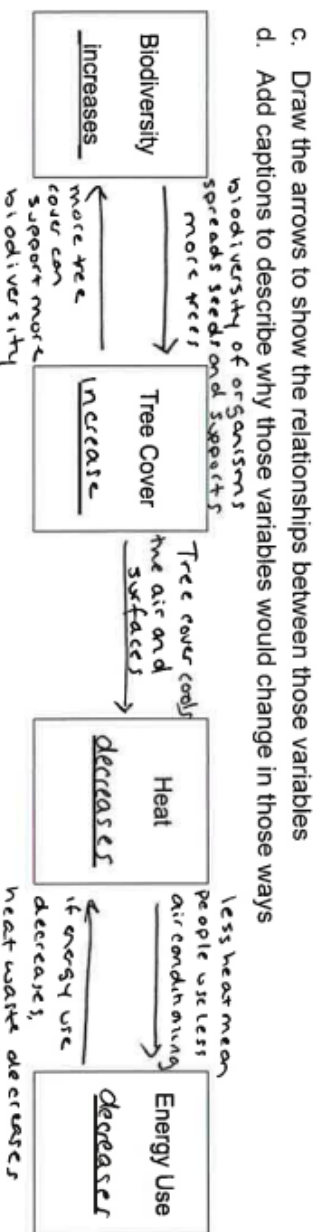
- a. For each arrow, add a description of how the changing variable effects the others



Scenario 3. Biodiversity increases

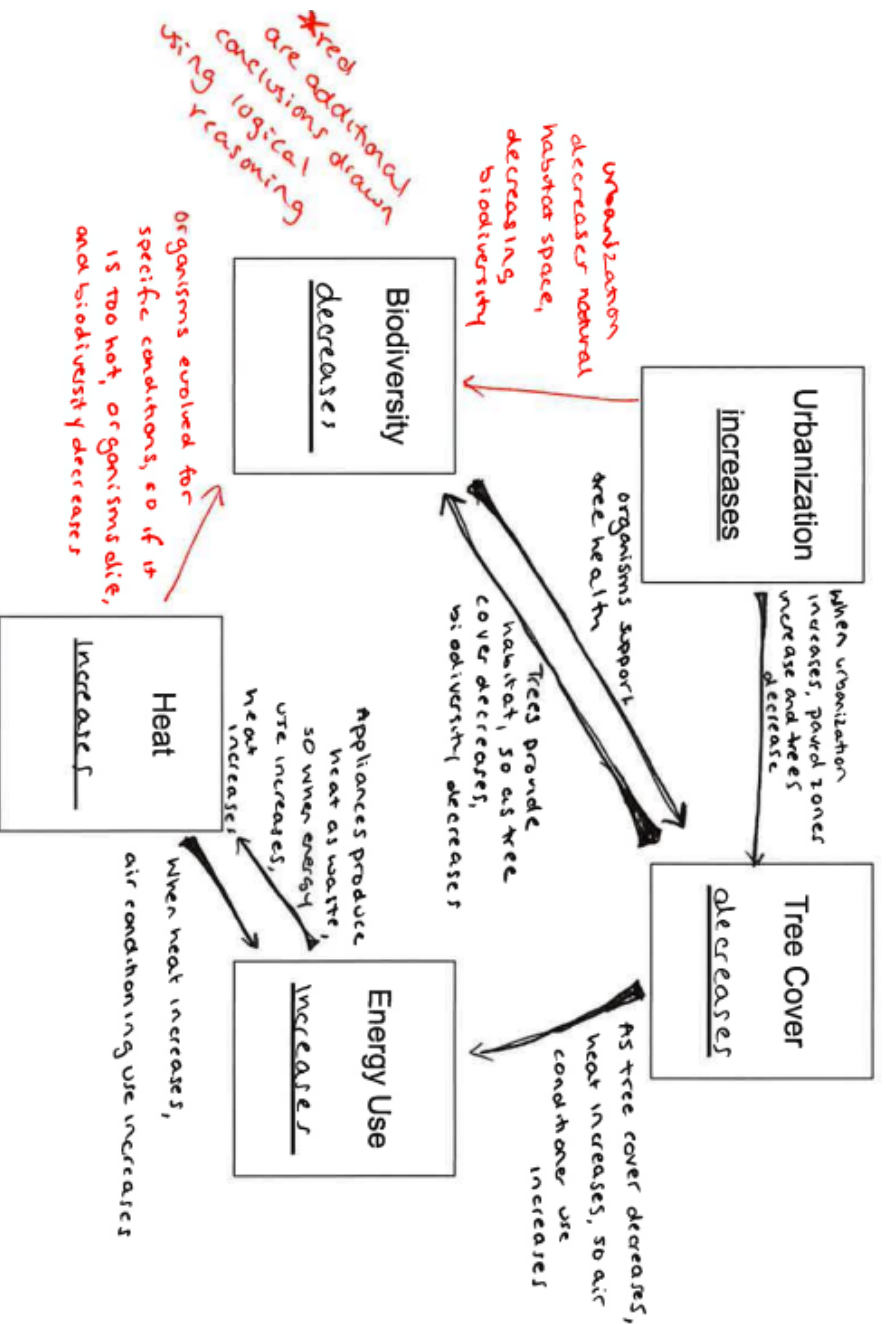
Additionally, as increased tree cover increases biodiversity (both if the trees include more species, and because the trees provide homes for other organisms), increased ecosystem biodiversity also promotes more tree cover by creating healthier soil, distributing more seeds, and increasing pollination of trees and other plants.

- a. Use the the paragraph above to figure out how the other variables would change as a result of increased biodiversity
- b. Decide where feedback loops exist in order to determine if there should be one or two arrows between the variables



Scenario 4. Urbanization/paving increases

- Decide which variables have an impact on each other, and how they impact each other
- Decide where feedback loops exist in order to determine if there should be one or two arrows between the variables
- Draw the arrows to show the relationships between those variables
- Add captions to describe why those variables would change in those ways



Classroom Resources for Land Use and Biodiversity 5E

Sustainability and Heat Index Variable Descriptors
New York City Land Use Maps

Sustainability and Heat Index Variable Descriptors

Sustainability and Heat Index Variable Descriptors

Energy Use

- Using electric appliances creates heat waste. The more electricity used, the hotter the appliance gets. Cooling appliances, like refrigerators and air conditioners, create additional heat waste due to the cooling process.

Zone

- Manufacturing: These areas tend to have large areas of black asphalt, which absorb and reradiate heat, and low amounts of infrastructure that provide shade or reflect sunlight
- Commercial: These areas tend to have medium levels of black asphalt, but also include higher levels of gray cement, which is less heating than black asphalt, plus more infrastructure that provide shade and may reflect sunlight
- Residential: These areas tend to have lower levels of black asphalt, higher levels of gray cement, and a mix of infrastructure types which may provide shade or other cooling features
- Parks: These areas have very low amounts of paving or cement and high levels of shade

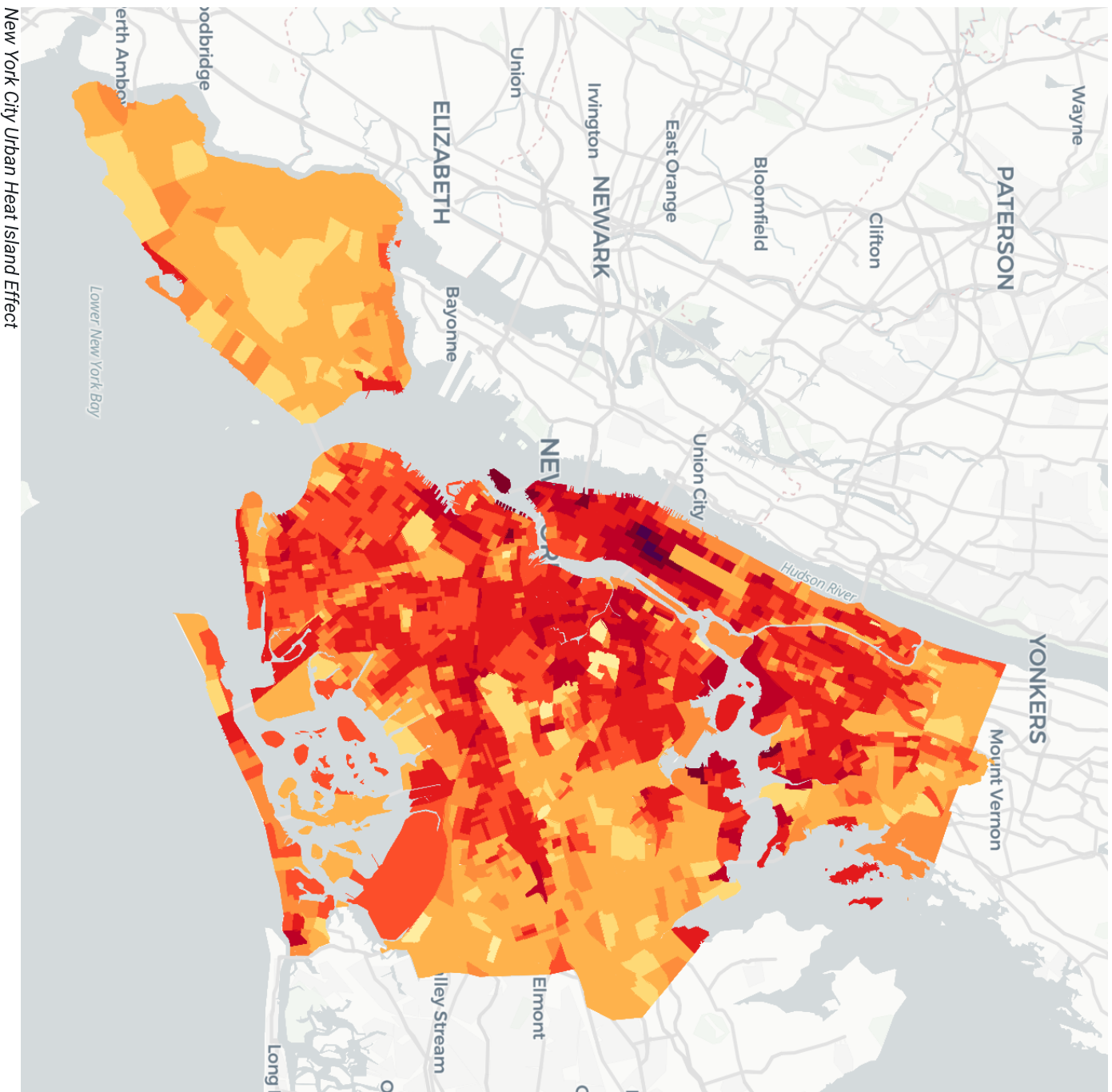
Tree cover

- Trees cool the air by performing a process called evapotranspiration, in which water is pulled out of the ground, up through trees, and then released through their leaves. This process is like sweating: it cools the ground that the water was pulled from.
- Trees also shade the surface, providing local cooling effects.

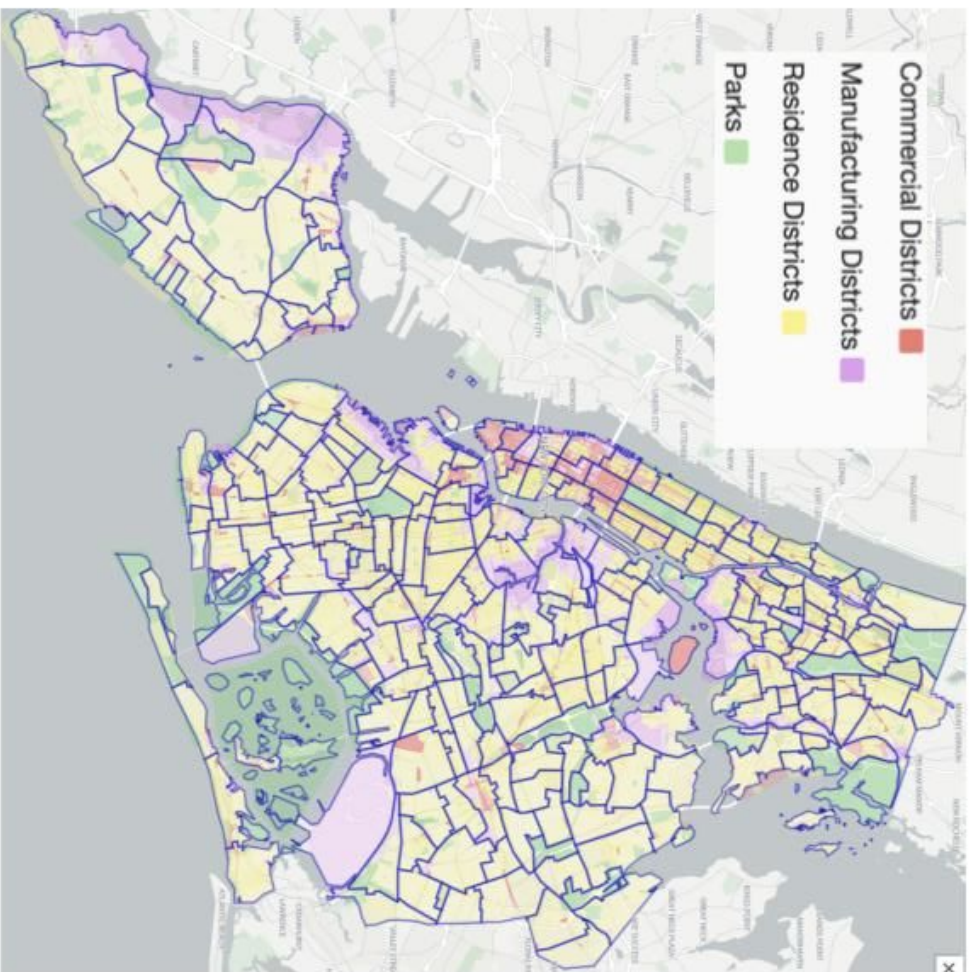
New York City Land Use Maps

Map 1: Increased Heat in New York City

This heat increase is compared to how the city would be if it were the natural landscape



Map 2: Zoning Areas in New York City

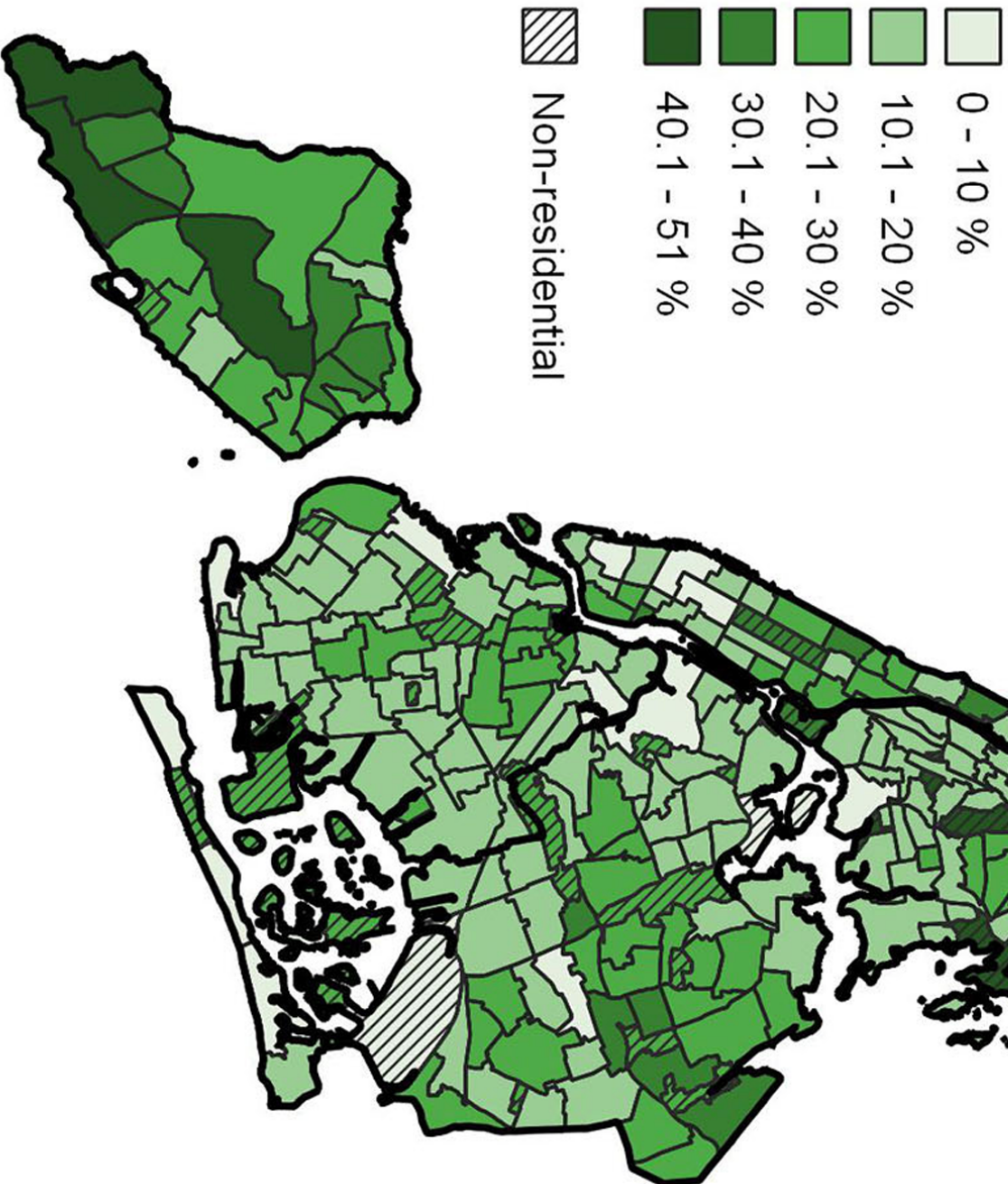


New York City Zones

Map 3: Tree Cover in New York City
 Tree cover includes trees on sidewalks within residential, commercial, and manufacturing zones, not just green space represented by parks. The tree cover within these zones varies.

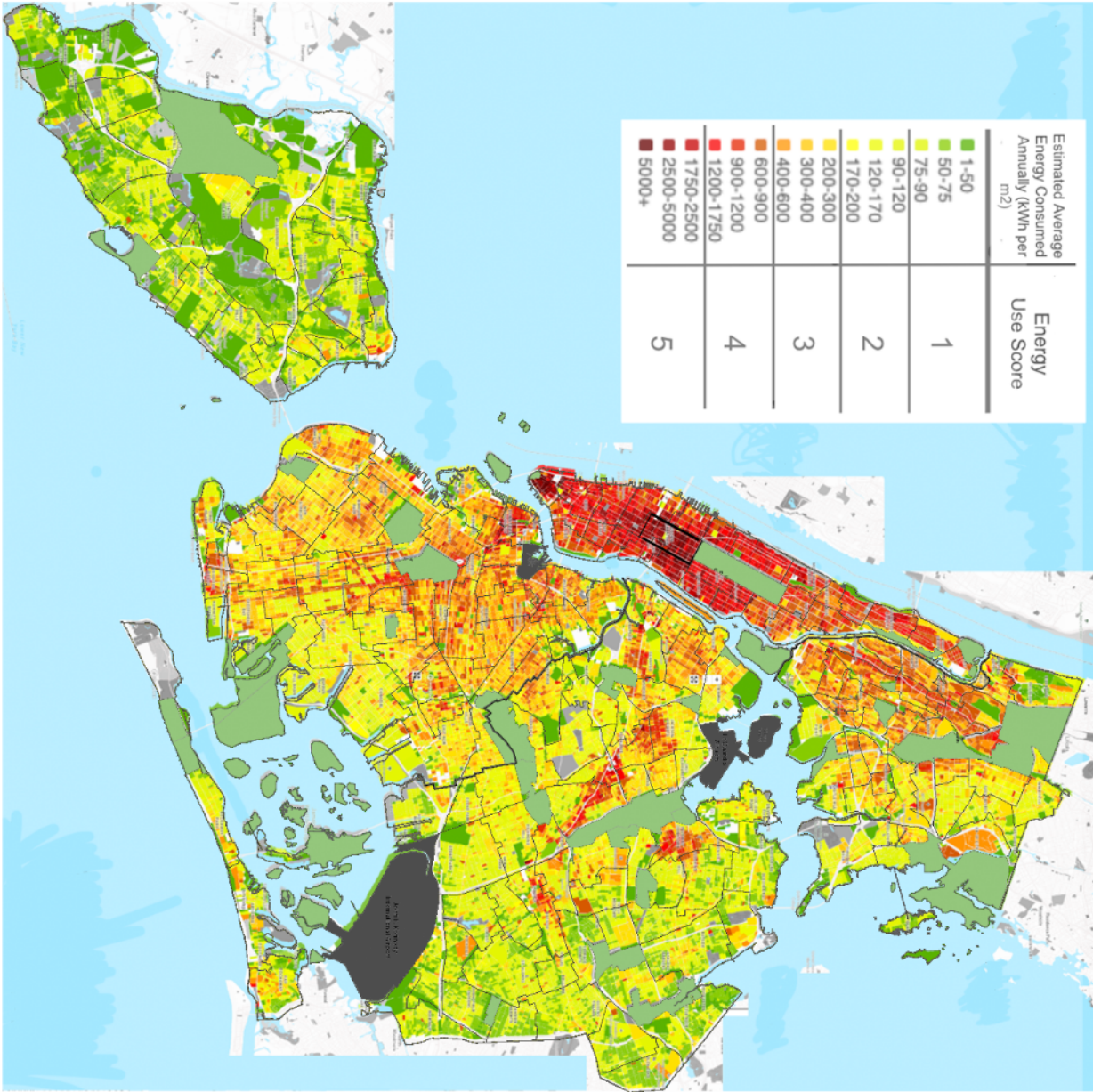
B

Canopy Cover, 2017



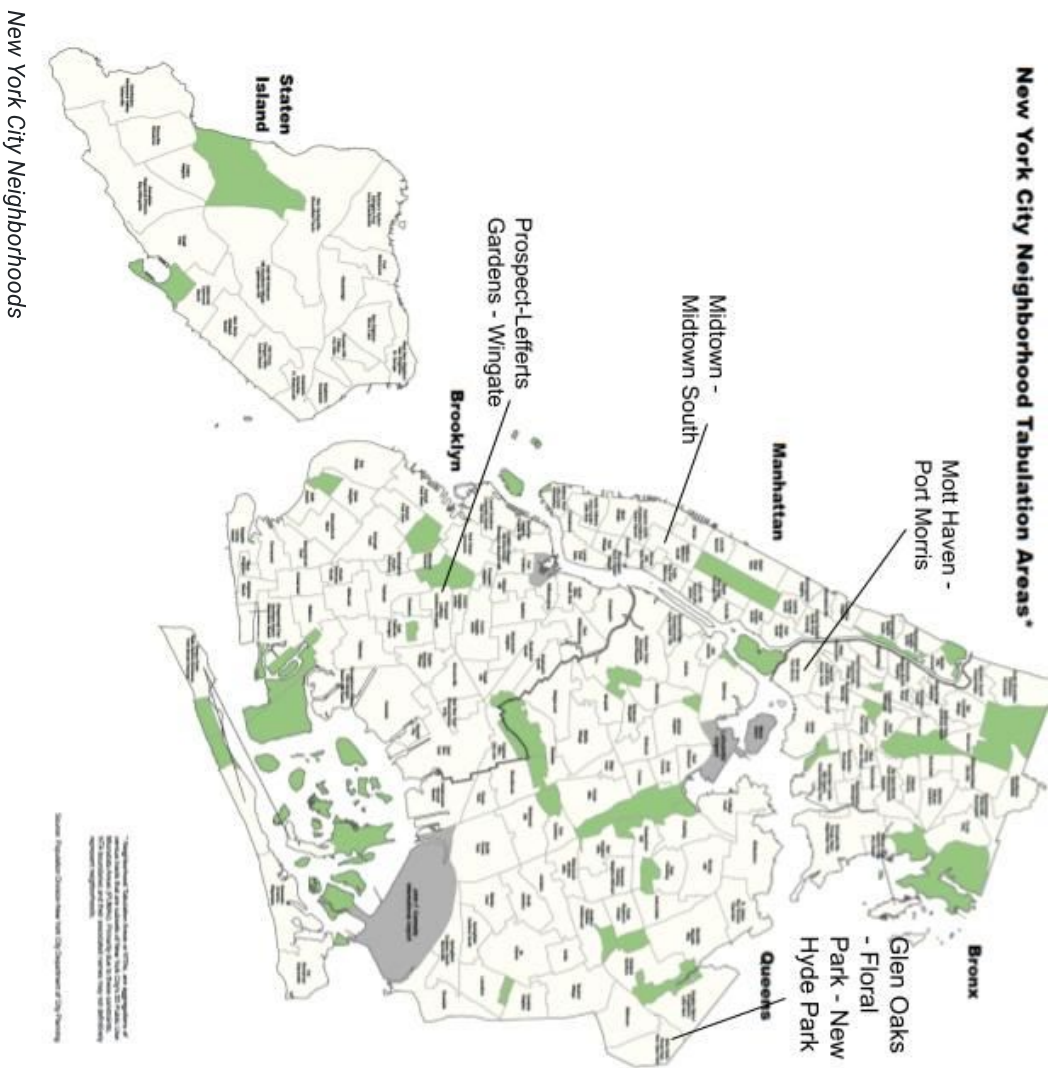
Tree Cover in New York City

Map 4: Energy Use in New York City



Energy Use in New York City

Map 5: New York City Neighborhoods



New York City Neighborhoods



Mining 5E

How can we evaluate and compare solutions that try to mitigate negative health outcomes for people and organisms that result from mining coal?

Performance Expectations
HS-ESS3-2

Investigative Phenomenon
Within the United States, areas around coal mines in Appalachia have higher rates

Time
7-9 days

In this sequence, students look closely at resource extraction in the form of mining. Students draw on what they have already learned about fossil fuel use and human disruption of land to consider the example of coal mining, which is causing negative health outcomes in Appalachia. Then students consider how other resources are mined and how differing mining practices and regulations can reduce negative outcomes. Finally, students compare and contrast solutions designed to minimize these negative outcomes and argue in favor of the solution with the most benefits and least risks.

ENGAGE	Why are lung disease, heart disease, and cancer unequally distributed in the United States?	Students analyze evidence of health safety and environmental costs from maps of the United States to open conversations about costs and benefits of mining technology .
EXPLORE 1	How does coal mining contribute to loss of biodiversity?	Students use a model of coal mining to analyze the costs and benefits of mining technology and the associated economic and environmental risks of extracting coal .
EXPLAIN 1	How does coal mining cause health impacts to nearby communities?	Students consider evidence about the safety and environmental impacts of mountaintop removal coal mining technology to inform constructing logical arguments in favor of design solutions that best weigh the risks and benefits of this technology .
EXPLORE 2	Is mining done in NYS, and how do we know if we have found a valuable mineral?	Students observe and analyze samples using physical and chemical characteristics to collect empirical evidence in support of claims identifying five novel minerals and in preparation to evaluate the costs and benefits of mined resources in New York State. Note: this is an optional Explore/Explain aligned to the New York State Earth and Space Science Reference Tables.
EXPLAIN 2	How does NYS balance costs and benefits to keep mining sustainable?	Students engage in an argument from evidence of the technological systems used in New York State and Appalachia to compare the costs and benefits of mining in these two regions.
ELABORATE	How can we evaluate solutions to minimize environmental causes of death in mining and other communities?	Students evaluate and argue in favor of one of two competing technological solutions designed to reduce negative impacts on Earth's systems by taking into account the constraints of costs, safety, and reliability of each solution.
EVALUATE	How can we argue in favor of solutions that minimize environmental causes of death in mining and other communities?	Students independently evaluate and argue in favor of one of two competing technological solutions designed to reduce negative impacts on Earth's systems by taking into account the constraints of costs, safety, and reliability of each solution.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

Why are lung disease, heart disease, and cancer unequally distributed in the United States?

Students **analyze evidence** of **health safety and environmental costs** from maps of the United States to open conversations about **costs and benefits of mining technology**.

Preparation

Student Grouping

- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Cancer and Biodiversity Loss in the United States

Lab Supplies

None

Other Resources

- ☐ Optional Scaffold: *Labeled Map of the United States*
- ☐ [Lung Cancer Interactive Atlas](#)

Launch and Surfacing Student Ideas

1. Remind students that we are trying to get to the underlying reasons behind environmental causes of disease, and that although we have made progress in understanding factors that contribute to respiratory and cardiovascular diseases, we haven't looked at environmental causes of cancer. We also had unresolved questions at the end of the last 5E about if there are any reasons, other than urbanization and agriculture, that humans are changing land in ways that are causing problems.
2. Prompt students to consider the relationship between areas with high rates of environmental diseases and biodiversity loss. Students should recognize that areas with one of these problems often also have the other, and that solutions that target biodiversity loss also often help human health and vice versa.
3. Tell students that we will look at one area in the United States with high rates of lung cancer and high rates of biodiversity loss.
4. Provide students with the handout *Cancer and Biodiversity Loss in the United States*, and ask students to work independently to complete the See-Think-Wonder based on their observations, then use their See-Think-Wonders to discuss them.
5. Ask groups to come up with one important idea and / or question to share with the whole class, from their See-Think-Wonder.

Integrating Three Dimensions



In this 5E, students will be evaluating design solutions in **SEP#7 - Engaging in Argument from Evidence**. In order to do so, they need to fully define the problem that these solutions are aiming to solve. This detailed discussion is in service of that practice at the high school level.

6. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from the texts.

Look & Listen For



- There is one area with the highest rates of lung cancer
- I notice that there are a lot of areas with biodiversity loss
- One area where there is a lot of biodiversity loss overlaps with the area with high rates of lung cancer
- I think that whatever is causing lung cancer is also causing organisms to die
- I wonder what is happening in that area
- I wonder what is happening in the other areas where there is biodiversity loss
- I wonder what is happening in other areas with lung cancer

7. Let students know that they will now have an opportunity to investigate what coal mining is and how it is done

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Explore 1

How does coal mining contribute to loss of biodiversity?

Students use a **model of coal mining to analyze the costs and benefits of mining technology** and the **associated economic and environmental risks of extracting coal**.

Preparation

Student Grouping

- ☐ Independent
- ☐ Pairs
- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Extracting Materials from the Earth
- ☐ Mining Area Grid

Lab Supplies

- ☐ Chewy chocolate chip cookies - 1 per student
- ☐ Mining tools such as toothpicks or paper clips - 2 per student
- ☐ Scales - 1 per table
- ☐ Small container for cookies (see lab guide for details)
- ☐ Small container for “processing plant” (see lab guide for details)
- ☐ Small container for the “processed coal” (see lab guide for details)

Other Resources

- ☐ [Teacher Guide for Mining Lab](#)
- ☐ Calculators

Launch

1. Remind students that, during the Engage phase, students noticed a correlation between lung cancer and biodiversity loss, but we don’t know what is happening in that area or why it would cause damage to humans or ecosystems
2. Tell students that we will use a physical model to create a computational model of the impacts of mining on ecosystems.

Investigation

1. Provide each student with the handout *Extracting Materials from the Earth*. Introduce the activity to them by reading the introduction as a class and observing the map. Tell students that, in this activity, they will model how coal mining works and what types of effects it has.
2. Provide each student with a copy of the *Mining Area Grid*. Review the procedure and goal of the activity with them.
3. Provide each student with a single chocolate chip cookie. Have students complete the Part 1 of the handout individually and complete the first two rows of the See-Think-Wonder chart.
4. When students are done with Part 1, pause the class to discuss their experiences so far. Ask students to share their initial thinking on how mining has impacted their environment. Connect the look and listen for comments to the real environment. How would those look if they were doing this process outside the school or in an actual mine near a city?

Differentiation Point



- Students may struggle with the lengthy procedure and time management associated with this investigation. You may choose to assist by setting timers for the whole class and prompting them about which steps they will be doing in that time, instead of having individuals time themselves.

5. Have students work in pairs to complete Part 2 of the handout, including finishing the See-Think-Wonder chart. Students should complete Part 2 for each of their cookie mines, but help each other to tally it correctly.
6. When students analyze their data, they will construct a computational model to determine the impact of mining on the environment. This can be a simple equation attempting to quantify the damage.

Implementation Tip



Students will be using computational models of their mining simulation using the data they collected during the analysis section of the mining activity. Be sure that students understand the role that the computational model plays here in quantifying costs and benefits of mining technology.

7. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Access for Multilingual Learners



Using **physical and computational models** at this stage provides support for multilingual learners who are **entering** and **emerging**. Demonstrating the instructions and using symbols to represent natural resources can help these students engage independently with the activity. Providing different types of unique comprehensible input supports students' language development.

Conferring Prompts



Confer with students during the investigation. Suggested during-lab conferring questions:

- How did mining change the landscape?
- What challenges did you face in trying to restore the original landscape?
- How did your mining operation change the natural resources of the area?
- How could you compare the costs and benefits of your mining operation?
- How could you calculate the impact of mining on the environment? What numbers would you want to consider? How can you assign values to your variables?
- Do you think the impact of mining should be positive or negative?

8. Have the students answer the *Summary Questions* in the student packet.
9. In Table groups, ask students to discuss how each individual's choices about location, method of mining, and method of reclamation had different impacts on the ecosystem grid. As a group, they need to surface the costs and benefits of mining for materials.

Look & Listen For



- The cookie/land was never put back to the original state.
- All water downstream from the mine was impacted by acid runoff from the processing plant
- Crumbs/dust was spread over a large area and could not all be reclaimed back into the mine
- Students that put their mines more downstream had a smaller impact on the ecosystem
- Benefits are access to the materials needed for technology
- Students who took their time did not impact the ecosystem as much which is a benefit but also costs more since it takes longer to extract the same amount of ore as those who just dug in and tore the cookie apart.
- Costs include environmental impacts

Investigation: Whole-Class Investigation Summary

1. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' discussions on the cost and benefit of different mining techniques and choices of mine location. Record class thinking on the board for all students to see.

Look & Listen For



Possible student ideas and questions:

- Mining has benefits for the economy, generating money and jobs
- Mining coal provides a key resource for generating electricity
- We can quantify the value of coal mining using the dollar amounts generated by each of these benefits
- Mining has many environmental impacts
- Environmental impacts are harder to quantify because our economy does not assign value to these natural features the same way we do for energy/jobs
- If we had to pay for the negative impacts of mining, it might reduce the incentive to mine
- Reclaiming mined land and restoring it to how it was is very challenging

2. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Access for Multilingual Learners



Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine.

Explain 1

How does coal mining cause health impacts to nearby communities?

Students consider evidence about the **safety and environmental impacts of mountaintop removal coal mining technology** to **inform constructing logical arguments** in favor of **design solutions that best weigh the risks and benefits of this technology**.

Preparation

Student Grouping

- ☐ Groups of 3

Routines

- ☐ Think-Talk-Open Exchange
- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Costs and Benefits of Mountaintop Removal Coal Mining
- ☐ Text 1: Mountaintop Removal Coal Mining and the Ecosystem
- ☐ Text 2: Mountaintop Removal Coal Mining and Human Health
- ☐ Summary Task

Lab Supplies

None

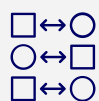
Other Resources

- ☐ [World of Change: Mountaintop Mining](#)
- ☐ [Picture: how mountaintop removal works](#)
- ☐ Poster paper and markers
- ☐ [The Land of Mountaintop Removal](#)
- ☐ [The shocking danger of mountaintop removal - and why it must end](#)

The Costs and Benefits of Mountaintop Removal Coal Mining

1. In the Explore phase, students discovered that mining practices have widespread and cascading effects on the environment, but that mining also has positive economic effects.
2. Provide students with the handout *Costs and Benefits of Mountaintop Removal Coal Mining*, and ask them to create an initial model of the costs and benefits of coal mining on humans.
3. Tell students that they will now have the opportunity to learn more about the impacts of one specific mining technology, called mountaintop removal coal mining. Have students read the Introduction text in their handouts. Give students time to open the website [World of Change: Mountaintop Mining](#) embedded in the text and explore the interactive map showing the growth of the Hobet mine over 20 years.
4. Ensure that students understand what mountaintop removal coal mining means. For additional support, show students the [Picture: how mountaintop removal works](#).
5. Assign students to read either Text 1 or 2. Because students will be in triads, two members of the group will be reading the same text.

Differentiation Point



To support different reading levels, strategically assign texts to match students' needs. Text 1, [Mountaintop Removal Coal Mining and the Ecosystem](#), is a shorter text, but it can be further shortened by only including the sections about Water, Forests, and Biodiversity. Text 2, [Mountaintop Removal Coal Mining and Human Health](#), is longer, but can be divided between two students to reduce the burden on an individual student. Alternatively, two students who need more could be assigned the same text so that they can support each other in identifying all its key details.

6. After students read their assigned texts or portions of text, have the groups of three engage in a think-talk-open exchange to surface key details from the articles.

Look & Listen For



- Mountaintop removal destabilizes ecosystems by destroying forests
- Benefits of mountaintop removal include jobs, coal for energy, and economic gains
- Costs of mountaintop removal include health impacts and environmental destruction
- Coal is a key resource
- Ecosystems have other resources, like clean water and air, that are disrupted by

Integrating Three Dimensions



In this unit students are developing proficiency with the **CCC ETS2.B**, analyzing costs and benefits to increase benefits while reducing costs. This is an opportunity for students to further explore this concept, which was introduced in the last 5E sequence, and which will be used in computational modeling in the next 5E sequence. Use this opportunity to clarify tradeoffs that take place in cost-benefit situations.

Access for All Learners



Students may struggle to connect to this content about coal mining, since it may seem very removed from their lives. In addition to showing the pictures and text, you may choose to show the video [The Land of Mountaintop Removal](#). This video will prime students to consider both the costs and benefits of this type of mining. To further engage students, consider a longer video showing the dangers of mountaintop removal, such as this video [The shocking danger of mountaintop removal - and why it must end](#).

Routine



Tip: This Think-Talk-Open Exchange appears in this unit! During this routine, students share with others and gain feedback on their ideas by finding similarities and differences, piecing together disparate bits of information, or reconciling different interpretations. Overall, the routine allows students to clarify or generate ideas collaboratively. Please read the Biology Course Guide for detailed steps of this routine.

Conducting a Scientific Evaluation of Costs and Benefits

1. Remind students of their earlier questions about how coal and other resource mining is related to environmental causes of death, and why we engage in behaviors known to increase health and environmental costs.
2. Provide each group of 3 with poster paper and markers. Tell students to use the information that surfaced in their discussions to construct a cost-benefit analysis of mountaintop removal coal mining technology. Ask students to include the words: **cost, benefit, stabilize/destabilize, resource, economic, social, and environmental.**
3. Confer with students as they construct their analyses on the poster paper.

Differentiation Point

- ☐ ↔ ☐ At this point, students are practicing with a large amount of vocabulary. It may be helpful to pause the class between the TTOE and cost-benefit analysis to review these words, which they should have gained context about from the texts.
- ☐ ↔ ☐
- ☐ ↔ ☐

Integrating Three Dimensions



The use of evaluating costs and benefits in this Explain phase is to support the development of students' use of weighing different types of evidence while evaluating design solutions, the foregrounded element in **SEP #7 - Engaging in Argument from Evidence**. In later parts of this sequence, students will use cost-benefit analysis to inform their evaluations of competing solutions that minimize costs while maximizing benefits.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
 - “We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how mountaintop removal coal mining impacts natural systems like the biosphere and hydrosphere, and how it results in costs and benefits for our society.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of costs and benefits of mining, and its destabilization of natural systems. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.
5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

Integrating Three Dimensions



The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC ETS2.B**, analyzing costs and benefits, explicit for students by elevating and probing for ideas related to the concept that technologies can be evaluated at different levels, including economic, geopolitical, environmental, and societal

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- Coal is used to generate electricity, which makes it valuable
- Coal produces jobs and money for mining areas, which is an economic advantage
- Coal is needed in some industrial processes, like manufacturing steel
- Mountaintop removal coal mining is safer for miners than going into tunnels
- Mountaintop removal coal mining is less expensive than other coal mining methods
- Mountaintop removal has destroyed 500 mountains so far
- Mountaintop removal disrupts natural systems, including the hydrosphere, by destroying and polluting waterways
- Mountaintop removal disrupts the biosphere by destroying forests and reducing biodiversity
- Birds, fish, and other aquatic species have been negatively impacted by mountaintop removal
- Mountaintop removal coal mining causes air and water pollution
- Areas with mountaintop removal coal mining have been found to have higher rates of lung cancer, respiratory diseases, heart attacks, cardiovascular diseases, and premature death

6. Return to student questions that bring up lingering issues not yet resolved, such as:

- What solutions exist to help balance the costs of coal mining with the benefits of gaining this resource?
- Are there cleaner mining solutions?
- Does society need coal, or can we use something else?
- Why are we still doing mountaintop removal coal mining?

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about the costs, risks, and benefits of mountaintop removal technology for acquiring this energy resource.

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions, including the concept of technology to mine for energy resources, to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Explore 2

Is mining done in NYS, and how do we know if we have found a valuable mineral?

Students observe and analyze samples using **physical and chemical characteristics** to **collect empirical evidence** in support of claims identifying five novel minerals and in preparation to **evaluate the costs and benefits of mined resources** in New York State.

Note: this is an optional Explore/Explain aligned to the New York State Earth and Space Science Reference Tables.

Preparation

Student Grouping

- ☐ Table Groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Mining and Mineral Identification in New York State

Lab Supplies

- ☐ Mineral samples that appear on the NYS mineral identification chart
- ☐ Copper penny
- ☐ Steel nail
- ☐ Glass plate
- ☐ Streak plate
- ☐ Dilute HCl (5-10%)
- ☐ Droppers

Other Resources

- ☐ [Rock Cleavage](#)
- ☐ [Mineral Hardness Test](#)
- ☐ [2 Minute Video on Rock Mineral Cleavage](#)

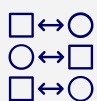
Launch

1. Before you begin, select 5 minerals with different properties. Label each mineral with letters for students to observe and test. Each mineral must be present on the Mineral Identification Flowchart; in an ideal world, at least one would represent a mineral found in New York State as listed in the Energy and Mineral Resources of New York State
2. Prompt students to consider if they have heard of mining any other resources, besides coal. Ask them if they know where valuable metals and stones come from. Tell them to think about if they have heard of any environmental challenges resulting from obtaining those items.
3. Tell students that they will now have the opportunity to investigate mined resources in New York State and how scientists know when they have uncovered a valuable resource.

Investigation

1. Provide students with the handout *Unknown material with identifier: ess.u6.l2.explore2.h* and have them work in their table groups to read the map in Part 1, answer the questions, and fill in the See-Think-Wonder at the end of the investigation. The maps found in Part 1 come from the New York State Earth and Space Science Reference Tables, and can be found on pages 9 and 10.
2. When students are done with Part 1, pause the class to discuss their experiences so far. Prompt students to consider how mining in New York seems different from other types of mining they have seen or may have heard of.
3. Provide students with the mineral samples and testing supplies. Have students work in their table groups to begin Part 2 of the investigation. Students will use four tests (metallic vs. non-metallic; hardness; streak test; and cleavage) and the Mineral Identification Flowchart provided in the investigation to narrow down the potential identities of their minerals. This flowchart comes from the New York State Earth and Space Science Reference Tables, and can be found on pages 16-17.

Differentiation Point



Students may need support reading the Mineral Identification Flowchart. If students are struggling, model how to follow the branches using an example mineral. Students may choose to use colored pencils to trace their choices on the flowchart. It is recommended that the teacher check students' work at this point before they move on.

4. When students have narrowed down the potential options for their minerals, they are asked to use the flowchart to determine what information they need in order to distinguish between minerals. Support students in choosing what tests to complete in order to identify the minerals.

Implementation Tip



- Before beginning the lab and after the samples for the class have been selected, preview the flowchart to determine what information they are given about each mineral and what observations and tests they will need to complete in order to identify the minerals. Plan forward to have key definitions and test items available for students that correspond with their minerals.

For example, if one mineral sample is dolomite, students will have to figure out how to distinguish between dolomite and calcite, which are very similarly described by the flowchart. In that case, be sure to have the acid test ready for students and help them analyze if their sample reacts with acid while in the crystal form or not.

5. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Access for Multilingual Learners



Using **physical samples** at this stage provides support for multilingual learners who are **entering** and **emerging**. Demonstrating the instructions and images to represent mineral identification tests can help these students engage independently with the activity. Providing different types of unique comprehensible input supports students' language development.

Integrating Three Dimensions



In this unit students are developing proficiency with the **Influence of Science, Engineering, and Technology on Society and the Natural World**, considering the costs and benefits of mining in order to inform decisions. In this 5E, students are using information about mineral identification related to the **NYSED DCI, minerals are the building blocks of igneous, metamorphic, and sedimentary rocks and can be identified using physical and chemical characteristics**, and location to determine the challenges of mining in this region, informing students of some of the costs. Later, students will use this information in conjunction with a text about New York State Mining practices to consider benefits as well.

Conferring Prompts



Confer with students during the investigation. Suggested during-lab conferring questions:

- Is the mineral metallic or non-metallic?
- How do you know how hard the mineral is?
- What color streak did it leave?
- How can you identify types of cleavage in the mineral?
- How do you read a flowchart?
- What information are you given that can help you distinguish between these minerals?
- How can you use the information in the flowchart to figure out what observations and tests are needed in order to identify your mineral?

Investigation: Whole-Class Investigation Summary

1. Ask groups to discuss their See-Think-Wonder and come up with one important idea or question to share with the whole class.
2. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' discussions.

Look & Listen For



Possible student ideas and questions:

- New York has oil and gas, but no coal
- New York mines many minerals
- New York also mines other materials like shale, peat, cement, and bluestone
- Identifying minerals can be accomplished using observations and chemical tests

3. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Access for Multilingual Learners



Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Biology Course Guide for more information on this routine.

Explain 2

How does NYS balance costs and benefits to keep mining sustainable?

Students **engage in an argument from evidence** of the **technological systems** used in New York State and Appalachia to compare the **costs and benefits of mining** in these two regions.

Preparation

Student Grouping

- ☐ Pairs

Routines

- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Costs and Benefits of Mining in New York
- ☐ Summary Task

Lab Supplies

None

Other Resources

The Costs and Benefits of New York State Mining Practices

1. In the Explore phase, students discovered that New York has valuable mining resources, and that those resources can be identified by analyzing their chemical and physical properties.
2. Tell students that they will now have the opportunity to learn more about the economic benefits of mining in New York and the specific regulations in place to minimize the health and ecological costs of mining.
3. Provide students with the handout *Costs and Benefits of Mining in New York* and have students work independently to complete Step 1, reading and annotating the text.
4. After students have completed reading and annotating, have them work in pairs to work on Step 2, comparing mining in New York with mining in Appalachia.

Look & Listen For



- New York benefits economically from mining
- There are environmental and health costs to mining
- New York minimizes the costs of mining by enforcing strict regulations on mining reclamation and ecological protections for active mines

Integrating Three Dimensions



In this unit students are developing proficiency with the idea of the **Influence of Science, Engineering, and technology on Society and the Natural World**, considering the costs and benefits of a technology. This is an opportunity students have to solidify their comprehension of this concept, which has been part of previous 5Es.

Engaging in Argument from Evidence

1. Remind students that we began this unit by brainstorming solutions for environmental causes of death, and so far in this unit, we have only seen how mining increases problems. Prompt students to consider how New York's management of mining solves some of the health and ecological problems seen in other mining situations.
2. Have students turn to Step 3 of the handout Explain 2: Costs and Benefits of Mining in New York.
3. Working in pairs, students will use their annotations and mining comparison chart to construct an argument for how New York has been able to reduce its negative impacts from mining. In their argument, students will include the costs and benefits of the solution and an analysis of its efficacy.

Differentiation Point



This is the first time in this unit that students will be using cost-benefit metrics to evaluate and construct an argument regarding the efficacy of solutions to minimize impacts of energy extraction. Support students using the checklist in the handout; some students may need to outline their arguments before writing them in paragraph form.

Integrating Three Dimensions



The use of argument in this Explain phase scaffolds more complex arguments that students will engage with in future phases in this 5E. In this phase, students build off their practice conducting cost-benefit analyses in the previous phases and apply that evidence to arguing about the efficacy of a single solution. In the elaborate and evaluate phases of this 5E sequence, students will evaluate competing solutions in service of the foregrounded element in **SEP #7 - Engaging in Argument from Evidence**.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
 - "We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how New York state regulates mining to minimize costs while maximizing benefits, and if these solutions are effective.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Biology Course Guide for detailed steps of this routine.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of costs and benefits of mining, and the ways in which well-designed solutions can balance tradeoffs. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
3. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
4. Proceed through the steps in the Consensus Discussion Steps.
5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- Regulation in New York State requires full land reclamation
- When mines are opened, the state holds a security deposit that is used to reclaim the land if a mine is abandoned before reclamation is complete
- The types of materials mined in New York State result in less pollution than coal mining
- Some mining has shut down as a result of these regulations
- There are still some ecological and health impacts of mining, despite the regulations

6. Return to student questions that bring up lingering issues not yet resolved, such as:
 - How can these practices be applied to coal mining? Is it even possible?
 - Are there further refinements that could improve the solutions we discussed?
 - Are there other solutions that

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about how solutions can apply scientific knowledge and engineering design to minimize costs and risks while increasing benefits.

Integrating Three Dimensions



The depth of this discussion will really depend on what you've observed in the room and how you respond. Raise the idea that **Science Addresses Questions about the Natural and Material World**, considering that decisions rely on social and cultural contexts in addition to science. This is an opportunity students have to experience and discuss this concept, which has been implicitly part of previous 5Es. Make this idea explicit here so students understand that the social and cultural context of mining in New York State impacts the ways that mining uses technology.

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions, including the concept of costs and benefits, to argue in favor of certain solutions** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How can we evaluate solutions to minimize environmental causes of death in mining and other communities?

Students **evaluate and argue in favor of one of two competing technological solutions** designed to **reduce negative impacts on Earth's systems** by taking into account the **constraints of costs, safety, and reliability** of each solution.

Preparation

Student Grouping

- ☐ Groups of 3 or 4

Routines

- ☐ Read-Generate-Sort-Solve

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Student Texts with Solutions
☐ Reducing the Impacts of Mining

Lab Supplies

None

Other Resources

Evaluating Competing Design Solutions

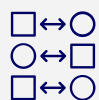
1. Remind students that they started the unit by discussing ways to reduce environmental causes of death. Prompt students to connect the texts they read during Explain 1 to the environmental causes of death from the unit launch; they should observe that mining is linked to cardiovascular disease, chronic respiratory diseases, and cancer, all of which are highlighted in the unit opening. Tell students that we will now have the opportunity to evaluate and compare two solutions to the problems caused by coal mining.
2. Provide students with the handout *Elaborate: Reducing the Impacts of Mining*. Have students work in groups of three to discuss and answer questions 1-4 on the handout.
3. Provide students with the texts *Mining Elaborate Student Texts with Solutions*. Facilitate the group learning routine **Read-Generate-Sort-Solve**, as a way for students to synthesize and extend their thinking.

Routine



The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. Please read the Biology Course Guide for detailed steps of this routine.

Differentiation Point



This elaborate is text heavy; both solutions are one-page texts describing the costs and benefits of a complex solution. To support students, consider using pair reading and/or text chunking strategies to help them dissect the text. Also, consider modeling how to engage with complex texts by engaging in a think-aloud as you read a paragraph to the class.

Access for All Learners



Read-Generate-Sort-Solve is an important routine because it builds in individual think time and opportunities for all students to contribute to the group answer. Students who need additional processing time, or a chance to adjust their thinking after hearing from peers, get that opportunity. This additional time for language input is especially helpful for **emerging language learners**.

Evaluate

How can we argue in favor of solutions that minimize environmental causes of death in mining and other communities?

Students independently **evaluate and argue in favor of one of two competing technological solutions** designed to **reduce negative impacts on Earth's systems** by taking into account the **constraints of costs, safety, and reliability** of each solution.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

☐ Text Annotation

Materials

Handouts

- ☐ Arguing for Solutions
- ☐ Evaluate Mining Student Texts

Lab Supplies

None

Other Resources

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence.

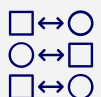
Implementation Tip



When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class' actual questions!

2. Provide students with the handout *Arguing for Solutions* and the *Evaluate Mining Student Texts*.

Differentiation Point



Students are repeating the process they used in the Elaborate phase, but are working independently this time instead of in groups. If students need more support, you can provide opportunities for small group or whole class discussions in order to help students process the key information from the texts before continuing with their comparison and evaluation of the two solutions presented.

3. Confer with students while they are working on *Revisit the Performance Task: Mining*.

Conferring Prompts



Confer with students as they work to evaluate the solutions
Suggested conferring questions:

- What are the costs of the solution?
- What are the benefits?
- How does the solution work within the constraints?
- What tradeoffs are there?

4. As a class, open the [En-ROADS Simulation](#), which shows how different changes to fossil fuel use could impact greenhouse gas emissions in the next 75 years.

5. Discuss with students which maps and tabs might be helpful in understanding the impact of coal mining. Take this opportunity to explore other tabs that might interest students as well.

6. After completing their work, have students turn to the Performance Task Organizer.

7. Confer with students while they are working.

Conferring Prompts



Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room.
Suggested conferring questions:

- What solutions did you consider in this 5E?
- How did they impact the systems they acted in?
- How did other variables respond to those solutions?
- How did those solutions balance tradeoffs?
- Do you think these solutions would be useful in reducing deaths from environmental causes globally? Would you recommend using them?

Document Class Thinking

1. Prompt students to discuss with their groups their overall takeaways about how solutions discussed in this sequence can help address global deaths from environmental causes. Students can use the notes in their performance task organizers in these discussions.

2. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point.

Standards in Mining 5E

Performance Expectations

HS-ESS3-2 *

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

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, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.

Assessment Boundary: None

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. SEP5(1) Engaging in Argument from Evidence - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). SEP7(6)	ESS2.B Plate Tectonics and Large-Scale System Interactions - Minerals are the building blocks of igneous, metamorphic, and sedimentary rocks and can be identified using physical and chemical characteristics. These rock types are evidence of stages of constant recycling of Earth material by surface processes and convection currents in the mantle. ESS2.B(4)NYS ESS3.A 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. ESS3.A(2) ESS3.C 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. ESS3.C(2) ETS1.B Developing Possible Solutions - Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. ETS1.B(2)	Influence of Science, Engineering, and Technology on Society and the Natural World - Engineers continuously modify these systems to increase benefits while decreasing costs and risks. INFLU-H2 - Analysis of costs and benefits is a critical aspect of decisions about technology. INFLU-H4 Science Addresses Questions About the Natural and Material World - Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. AQAW-H2 - Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. AQAW-H3 - Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. AQAW-H4

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Using Mathematics and Computational Thinking		✓			
Engaging in Argument from Evidence			✓	✓	✓
ESS2.B Plate Tectonics and Large-Scale System Interactions			✓		
ESS3.A Natural Resources	✓	✓	✓		
ESS3.C Human Impacts on Earth Systems	✓			✓	✓
ETS1.B Developing Possible Solutions				✓	✓
Influence of Science, Engineering, and Technology on Society and the Natural World		✓	✓	✓	✓
Science Addresses Questions About the Natural and Material World	✓		✓	✓	✓

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP.2 MP.4	MP.1 MP.2		
ELA/Literacy	RST.9-10.7	RST.9-10.8 WHST.9-10.2 SL.9-10.1	RST.9-10.8 WHST.9-10.2 SL.9-10.2 SL.9-10.1	WHST.9-10.2 WHST.9-10.9 SL.9-10.1	WHST.9-10.2 WHST.9-10.9 SL.9-10.1

Classroom Resources for Mining 5E

Labeled Map of the United States

Labeled Map of the United States



Unit Closing

How is human activity harming the health of humans and the natural environment? How is the health of humans and the natural environment intertwined? What solutions adequately address these problems and can be implemented in the real world?

Performance Expectations
HS-ESS3.2, HS-ETS1-2

Anchor Phenomenon
Around the world, the health of humans and the natural environment is suffering negative consequences of human activity.

Time
3 days

Based on the investigations and learning throughout the unit, students.

ANCHOR PHENOMENON	Around the world, the health of humans and the natural environment is suffering negative consequences of human activity.	Students generate more ideas that explain how solutions to environmental causes of diseases are linked.
DRIVING QUESTION BOARD	What questions about global deaths from environmental causes have we not answered yet?	Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.
PERFORMANCE TASK	How do the different solutions students' evaluated contribute to reducing the overall impact of human activities on the environment and environmentally caused diseases?	Based on the investigations and learning throughout the unit, students use a model to analyze the impacts of each solution they evaluated and come to a conclusion about which solutions to prioritize.
UNIT REFLECTION	How can we evaluate our progress on addressing environmental problems related to greenhouse gas emissions?	Students reflect on their learning throughout the unit.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Anchor Phenomenon

Around the world, the health of humans and the natural environment is suffering negative consequences of human activity.

Students generate more ideas that explain how solutions to environmental causes of diseases are linked.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

Generating Ideas about Anchor Phenomenon

1. Students return to the anchor phenomenon of global deaths from environmental causes and loss of biodiversity. They review their ideas about the relationship of these problems with greenhouse gas emissions and how solutions to climate change are intrinsically linked to reducing deaths from pollution, ocean acidification, temperature increases, and mining pollution.

Driving Question Board

What questions about global deaths from environmental causes have we not answered yet?

Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

☐ Driving Question Board

Revisit the Driving Question Board

1. Students return to the questions generated throughout the unit and reflect. What questions have been answered? Are there questions that we still need to investigate?
2. Note that not all of the students' questions will be answered at the end of the unit, and students may have generated entirely new questions. Depending on student interest and instructional time, prompt students to explore some of the unanswered questions independently.

Performance Task

How do the different solutions students' evaluated contribute to reducing the overall impact of human activities on the environment and environmentally caused diseases?

Based on the investigations and learning throughout the unit, students use a model to analyze the impacts of each solution they evaluated and come to a conclusion about which solutions to prioritize.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Unit Closing: Global Impacts of Solutions

Lab Supplies

None

Other Resources

- ☐ [En-ROADS Simulation](#)

Generate a Design Solution

1. Prompt students to review all of the environmental problems they have investigated in this unit and the types of negative consequences that they have.
2. Help students draw connections between all of these environmental problems and greenhouse gas emissions
 - Air pollution is caused by emissions from burning fossil fuels
 - Ocean acidification is caused by emissions from burning fossil fuels
 - Urban heat islands are increasing because of climate change due to burning fossil fuels
 - Deforestation increases the impacts of local and global heat from burning fossil fuels
 - Coal mining is practiced in order to gain fuel to burn
3. Prompt students to review the solutions for environmental problems they have evaluated in this unit, and ask students how they would expect each solution to contribute to greenhouse gas levels.
4. Provide students with the *Final Performance Task*.
5. Students use the En-ROADS simulation to analyze the relative impacts of each solution on global greenhouse gas emissions and come to a conclusion about which solutions should be prioritized given their costs, benefits, and tradeoffs.

Integrating Three Dimensions



Throughout this unit, students have used both **CCC#2 Cause and Effect** and **CCC#6 Structure and Function** to both understand the phenomena and to design solutions to the mismatch problem. In the final design task, students may choose to explain how they use one or both of these cross-cutting concepts in the rationale for their design.

Unit Reflection

How can we evaluate our progress on addressing environmental problems related to greenhouse gas emissions?

Students reflect on their learning throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Standards in Unit Closing

Performance Expectations

HS-ETS1-2 *	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Clarification Statement: None Assessment Boundary: None
-------------	---

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking - Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. SEP5(6) Constructing Explanations and Designing Solutions - 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. SEP6(5) Engaging in Argument from Evidence - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). SEP7(6)	ESS3.A 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. ESS3.A(2) 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. ETS1.B(1) ETS1.C Optimizing the Design Solution - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ETS1.C(1)	Influence of Science, Engineering, and Technology on Society and the Natural World - Engineers continuously modify these systems to increase benefits while decreasing costs and risks. INFLU-H2 - Analysis of costs and benefits is a critical aspect of decisions about technology. INFLU-H4

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Using Mathematics and Computational Thinking			✓	
Constructing Explanations and Designing Solutions			✓	
Engaging in Argument from Evidence	✓	✓	✓	
ESS3.A Natural Resources	✓	✓	✓	
ETS1.B Developing Possible Solutions			✓	
ETS1.C Optimizing the Design Solution			✓	
Influence of Science, Engineering, and Technology on Society and the Natural World	✓	✓	✓	

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics			MP.3 MP.4	
ELA/Literacy			WHST.9-10.1 WHST.9-10.8	