1 Storing Nuclear Waste

TALKING IT OVER

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students are introduced to the compelling issue of determining a central location to store nuclear waste in the United States. They learn about nuclear waste and begin to consider the challenges associated with storing radioactive material. The activity elicits students' initial ideas about natural hazards that could have an impact on the safety of a nuclear waste storage site. The crosscutting concept of *patterns* helps students make sense of the data presented in this activity.

Prepare to teach the unit by reviewing the *Quick Start to Issues and Science*, found at the front of this Teacher Edition. This guide breaks down the resources and equipment needed to teach the unit. It calls out critical planning tools including the *NGSS Overview*, the *Phenomena, Driving Questions, and SEPUP Storyline* overview, and the *SEPUP Scoring Guides*. For more detailed information on the program as a whole, see the "*Issues and Science* Program Overview" section of the *Teacher Resources*.

If this is your **first** SEPUP unit, read through "Planning for First-Time Users," found on the last page of the *Quick Start*.

NGSS CORRELATIONS

Performance Expectations

Working toward MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Disciplinary Core Ideas

MS-ESS3.B Natural Hazards: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.

Science and Engineering Practices

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Asking Questions and Defining Problems: Ask questions to identify and clarify evidence of an argument.

Obtaining, Evaluating, and Communicating Information: Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.

Crosscutting Concepts

Patterns: Graphs, charts, and images can be used to identify patterns.

Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World: All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.

Connections to Nature of Science: Science Addresses Questions about the Natural and Material World: Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Common Core State Standards—Mathematics

MP.2: Reason abstractly and quantitatively.

Common Core State Standards—ELA/Literacy

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

INVESTIGATIVE PHENOMENA AND SENSEMAKING

Teacher Resources

Investigative Phenomena, Sensemaking

Nuclear waste must be protected from natural hazards.

Students begin the unit by examining the issue of safe storage of nuclear waste. They begin using Student Sheet 1.1, "Considering Where to Store Nuclear Waste," a sensemaking tool they will revisit and add to in multiple activities. Students further engage in sensemaking by identifying gaps in their knowledge related to natural hazards and the storage of nuclear waste.

WHAT STUDENTS DO

Students read about nuclear waste: what it is, how it affects people, and how it should be stored safely. They review maps that show population density by county and the locations of operating nuclear reactors in the contiguous United States, and consider the social concerns related to choosing a central location to store the country's nuclear waste. Students use what they learn from the reading and their map analysis to identify the risks and challenges in selecting a long-term storage site for nuclear waste.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Scoring Guide: EVIDENCE AND TRADE-OFFS (E&T)
  - Driving Questions Board cards and instructions
  - * chart paper and markers
- *For each student*
  - 1 Student Sheet 1.1, "Considering Where to Store Nuclear Waste"
  - 1 Scoring Guide: EVIDENCE AND TRADE-OFFS (E&T) (optional)

** not included in kit*

The EVIDENCE AND TRADE-OFFS (E&T) Scoring Guide can be found in the Assessment tab in the back of this Teacher Edition.

The Driving Questions Board cards and instructions can be found in the front pouch of your printed Teacher Edition or as a download on the "Tools and Resources" page in your online Teacher Portal.

In this activity, you will want to start an ongoing class chart of Student Sheet 1.1, "Considerations for Nuclear Waste Storage," that you revisit from time to time throughout the unit.

TEACHING SUMMARY

GET STARTED

1. Engage students' interest by introducing the issue used to drive their learning in this unit.
   a. Have students read the vignette that opens the unit.
   b. Identify the societal issue that students will explore in the unit.
   c. (SENSEMAKING) Begin a Driving Questions Board.
2. Initiate students' sensemaking by eliciting and building on their ideas about nuclear waste storage.
   a. Turn the lights on and off, and ask, "Where does the electricity that runs these lights come from?"
   b. Direct students' attention to the introduction and first guiding question: What factors must be considered when deciding where to store nuclear waste?

DO THE ACTIVITY

3. Students learn more about the issue of nuclear waste storage by completing Part A of the Procedure.
   a. Have students work on Part A in groups of four.

  b. Continue to foster sensemaking by having students generate questions about nuclear waste.

4. Introduce crosscutting concepts.
   a. Explain that crosscutting concepts bridge disciplines.
   b. Introduce the crosscutting concept of *patterns*, and give an example that makes sense to students.
   c. Relate *patterns* to this activity.
5. Students complete Part B of the Procedure.
   a. Introduce the data presented on the maps in the Student Book.
   b. Introduce Student Sheet 1.1, "Considerations for Nuclear Waste Storage."
   c. Enhance students' sensemaking by discussing their analysis of the maps as a class.
6. Discuss the concept of risk analysis.

BUILD UNDERSTANDING

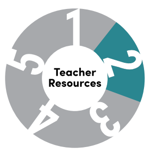
7. If you have not previously done so, introduce scientific evidence in science.
   a. Explain how scientists define and use evidence.
   b. Distinguish evidence from opinion.
   c. Discuss the sources, quality, and quantity of evidence.
   d. Support students' understanding of key scientific vocabulary.
8. If you have not previously done so, introduce the concept of trade-offs.
   a. Introduce the idea that decisions about solutions to scientific and engineering problems often involve trade-offs.
   b. Provide an example of trade-offs.
   c. Develop some examples of trade-offs in students' lives.
9. If you have not previously done so, introduce the SEPUP Assessment System.
   a. Provide an overview of the Scoring Guides.
   b. Explain the expectations for student growth over time.
10. Use the Analysis items to summarize the key ideas.
    a. (E&T ASSESSMENT) Have students complete Analysis item 1.
    b. Use Analysis item 2 to identify students' prior knowledge about the scientific concerns regarding natural hazards that they will need to consider when deciding where to store nuclear waste.

TEACHING STEPS

GET STARTED

1. Engage students' interest by introducing the issue used to drive their learning in this unit.

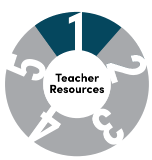
   a. Have students read the vignette that opens the unit.

   Anchoring Phenomenon

   The vignette of Nayeli describing the 1980 eruption of Mt. St. Helens relates to the front cover photo of this book, which shows a more recent explosive eruption of an active volcano, this one in Kamchatka, Russia. Both Mt. St. Helens and the volcano in the photo are located on the "Ring of Fire." After reading the text, have students examine the photo closely and/or read the description of the photo on the back cover. Ask them to generate some questions about the physical phenomenon presented in the vignette. If students are not familiar with the term *phenomenon* (or its plural form, *phenomena*), explain that a *phenomenon* is an observable fact or event. In this unit, the phenomenon of volcanic eruptions is one aspect students will study under the anchoring phenomenon of Earth's surface changing over time.

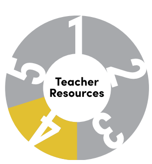
   b. Identify the societal issue that students will explore in the unit.

   Defining Issues

   Remind students of Izaiah's comments in the vignette, and then have them read the description of what they will investigate in this unit on the bottom of the same page. Allow time for discussion before identifying that students will investigate the issue of storing nuclear waste and how this might be affected by natural hazards associated with changes in Earth's surface, such as (but not limited to) volcanic eruptions.

   c. (SENSEMAKING) Begin a Driving Questions Board.

   Driving Questions Board

   If you have not already done so, introduce the Driving Questions Board and explain to students how the Driving Questions Board cards will be used throughout the unit.

   In SEPUP, the Driving Questions Board elicits students' initial wonderings about the unit issue and the investigative phenomena; the class is then prompted to revisit the Driving Questions Board throughout the unit. Ideally, student questions generated at the start of each learning sequence can be condensed through class discussion into a unified driving question. As a scaffold to teachers who are new to this teaching strategy, Driving Questions Board cards are provided for each learning sequence and can be displayed as the unified driving question. The driving questions are also identified on the Phenomena, Driving Questions, and SEPUP Storyline overview found in the NGSS and Common Core tab in the back of this Teacher Edition.

2. Initiate students' sensemaking by eliciting and building on their ideas about nuclear waste storage.

   a. Turn the lights on and off, and ask, "Where does the electricity that runs these lights come from?"

      Elicit students' ideas about where their electricity comes from. Prompt students to share if they've noticed any power plants near their community, what these power plants look like, and if these plants are different from power plants they have seen in other places. Explain that most electricity is generated in power plants. Power plants need energy to produce electricity, and energy can be transformed in different ways, such as from burning fossil fuels like coal or from the heat released during nuclear reactions. Point out that one advantage of using nuclear reactions to produce electricity is that this process does not release carbon dioxide into the atmosphere, like various other energy sources do. Use this point to emphasize that most methods of generating electricity have advantages and disadvantages. In the case of nuclear reactors, one of the disadvantages is the production of nuclear waste.

      If needed, distinguish between the hazards related to nuclear reactors and nuclear waste. In the event of a meltdown of core fuel, a nuclear reactor can explode, rapidly releasing radioactive materials. Nuclear waste does not present a risk of explosion but does pose a risk of release of radioactive material if the containers of nuclear waste were to leak. Stress that the risk from nuclear waste is not an explosion but rather the health effects of radioactive materials should they get into the environment and be inhaled or ingested in food or drinking water.

   b. Direct students' attention to the introduction and the guiding question: What factors must be considered when deciding where to store nuclear waste?

      Read aloud, or have students read, the introduction to the activity. Introduce the term *nuclear waste*. Have students share what they would look for in a location to store nuclear waste, based on what they learned.

      Point out to students that this activity starts a sequence of learning around the first driving question: Where should deep underground sites for storing nuclear waste be developed in the United States? This question is identified on the Phenomena, Driving Questions, and SEPUP Storyline overview found in the NGSS and Common Core tab at the back of your Teacher Edition. Pose the question, and have students share their ideas.

DO THE ACTIVITY

3. Students learn more about the issue of nuclear waste storage by completing Part A of the Procedure.

   a. Have students work on Part A in groups of four.

      Students should begin by reading the background information on nuclear waste found in the Student Book. The Procedure asks students to read the background information out loud to one another in groups of four. You may wish to select an additional literacy strategy to support students' reading comprehension as appropriate for your class.

   b. Continue to foster sensemaking by having students generate questions about nuclear waste.

      As you respond to students' questions, keep the focus on storing the nuclear waste that already exists. The activity is not about the trade-offs of nuclear power plants as an energy source, the dangers of radiation, etc. This activity is intended to initiate students' thinking about Earth and to introduce them to the social and scientific considerations that must be addressed when deciding where to store nuclear waste.

4. Introduce crosscutting concepts.

   a. Explain that crosscutting concepts bridge disciplines.

      Teacher Resources
      Crosscutting Concepts

      They can be a lens or touchstone through which students make sense of phenomena and deepen their understanding of disciplinary core ideas. Refer students to Appendix G: Crosscutting Concepts in the Student Book, and point out the symbols and definitions provided.

   b. Introduce the crosscutting concept of *patterns*, and give an example that makes sense to students.

      Display the definition and symbol used for *patterns* in Appendix G, and give students a simple example. Patterns that students have almost certainly noticed include the predictable pattern of the seasons every year. Earth scientists might study patterns in rock layers, physical scientists might study patterns in the behavior of chemicals, and life scientists might study patterns in the kinds of trees in different climates. Observing, questioning, and trying to explain patterns are things that all scientists do. This is why *patterns* are considered a crosscutting concept.

      Note that a pattern can be structural, as shown in the diagram, or it can be a pattern in events, such as the phases of the Moon. Point out to students that seeing patterns in nature can lead scientists to organize and classify their observations. It can also lead them to ask questions about relationships and the causes of patterns. Students will look for patterns when they analyze and interpret data, ask questions about the patterns they observe, and suggest cause-and-effect relationships to explain patterns.

c. Relate *patterns* to this activity.

Tell students that in Part B of this activity, they will analyze and interpret the data presented on two maps to identify any patterns. The patterns they identify in the data may help them think more deeply about what must be considered when deciding where to store nuclear waste.

5. Students complete Part B of the Procedure.

a. Introduce the data presented on the maps in the Student Book.

Direct students' attention to the two maps in the Student Book. Point out that the maps are of the contiguous United States—the 48 adjoining U.S. states plus Washington, D.C., but not Alaska, Hawaii, and the U.S. territories. Explain that one map shows the human population density by county, which is the average number of people per square mile. The data on this map came from the 2010 U.S. Census, which is an official count of every resident and a record of where they live in the United States. The second map shows the locations of operating nuclear reactors in the contiguous United States. This is where nuclear waste is produced as a result of using nuclear reactions to generate electricity.

b. Introduce Student Sheet 1.1, "Considerations for Nuclear Waste Storage."

Hand out Student Sheet 1.1. Explain that students will use this Student Sheet throughout the unit to keep track of their ideas about storing nuclear waste. Consider how to best store the sheets so that students can easily return to them throughout the unit.

Have students begin completing Student Sheet 1.1. You may wish to model how to complete the first row of the chart.

Teacher Resources

Science and Engineering Practices

This is the first opportunity in the unit for students to engage in the science and engineering practice of *analyzing and interpreting data*. This practice is first assessed in the activity "Mapping Locations of Earthquakes and Volcanoes." Students are likely to have different ideas based on their interpretations of the data presented in the maps and the patterns they identify as relevant to the issue. Encourage students to discuss their ideas with their group members as they record their explanations of the actions they recommended for each consideration. Tell students that their explanations will be strengthened if they refer to observations they made and patterns they identified in the data.

c. Enhance students' sensemaking by discussing their analysis of the maps as a class.

   Ask students what they think about the considerations of human population density and the locations of nuclear reactors. Use students' responses to create a class version of Student Sheet 1.1 on chart paper.

   Teacher's Note: Throughout the unit, you can return to this chart as students build deeper understanding of the scientific and social concerns related to the issue and how these considerations might inform decision-making.

6. Discuss the concept of risk analysis.

   Use the ideas shared from the Student Sheet as an opportunity to discuss the concept of risk analysis. While storing nuclear waste near people increases the risk of radiation exposure, it does not mean that radiation exposure is certain to happen.

   Determining the level of risk involves identifying how likely an event is to happen. For example, the Consumer Product Safety Commission collected data about the causes of injuries to patients under age 14 at 101 selected hospital emergency rooms in the United States. They found that there were 3.2 million reports of injuries related to sports and recreation and 282,000 reports of injuries from being a passenger in a motor vehicle. These data show that each year more children under the age of 14 are injured from playing sports than from being a passenger in a motor vehicle. Using these data, you could conclude that the risk of injury from sports and recreation is greater than the risk associated with being a passenger in a car. You may want to use this example to discuss how people's perception of risk influences their decision-making (perception of risk vs. probability).

   When making a decision, people often evaluate the likelihood that something will happen and the trade-offs involved. For example, even though participating in sports increases the risk of injury, most people determine that the level of risk is worth the pleasure of participating. Most people prefer to have low levels of risk for actions in which they may have little control or perceive little benefit. The storage of nuclear waste is such an issue. A low-probability event with high-stakes consequences (e.g., an earthquake, a tsunami, or accidental exposure to high levels of radiation) may be perceived to carry more risk than a higher-probability event with high-stakes consequences (e.g., a severe car accident), even if there are data to the contrary.

   Ask, "Imagine that a site near our city or town is being considered for long-term storage of nuclear waste. Would you agree to have nuclear waste stored where we live? Why or why not?" Encourage students to consider how evaluating risk may not only depend on relevant evidence but also on how much emphasis is placed on pieces of evidence and on each individual's perspective.

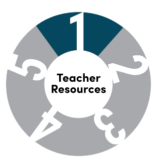
BUILD UNDERSTANDING

7. If you have not previously done so, introduce scientific evidence in science.

   a. Explain how scientists define and use evidence.

   Analysis item 1 provides an opportunity to introduce the definition of *evidence* provided in the Student Book. Explain that scientists collect information (data) with various tools and strategies, including observation and experimentation. Like scientists, students will use evidence to develop explanations, construct scientific arguments, and recommend solutions to problems. In this instance, after reading scientific text about nuclear waste and analyzing maps related to population density and locations of nuclear reactors, students are asked to make an initial evaluation of whether deep underground storage of nuclear waste at a central site is better than current nuclear waste storage at nuclear power plants. They are asked to cite evidence to support their position and discuss trade-offs.

   b. Distinguish evidence from opinion.



Evidence and Trade-Offs

   Explain that *evidence* is information that supports a claim. In contrast, an *opinion* is the view someone takes about a certain issue based on their own judgment. An opinion might not be based on evidence. An informed opinion might be based on evidence; however, another person may have a different opinion based on the same evidence. To distinguish evidence from opinion in science, it is helpful to determine if a statement describes information gathered through reliable and appropriate procedures and is likely to be reproducible. The question is: Could someone else gather similar information under similar circumstances? If the answer is yes, the statement is not opinion and is likely to be evidence.

   c. Discuss the sources, quality, and quantity of evidence.

   When evaluating evidence, scientists consider the source, quality, and quantity of the evidence available. Biased or insufficient evidence compromises the validity of scientific conclusions. Scientific conclusions should logically follow the evidence collected, and should not be overly generalized beyond the context of the investigation.

   The criteria for quality evidence may vary among the scientific disciplines. However, evidence is generally considered of higher quality if it is obtained through systematic investigation and is reproducible, meaning that another investigation under the same set of circumstances would obtain similar data.

   Criteria for quantity also vary but might include the sample size or number of trials in an experiment, the number of observations that support a conclusion, or the availability of multiple studies or multiple lines of evidence that lead to the same conclusion.

d. Support students' understanding of key scientific vocabulary.

Vocabulary Approach

When words are formally defined in an activity, they appear in bold type in the Key Vocabulary list, which can be found in the Activity Resources that follow the Teaching Steps. Encourage students to use these words when talking or writing about science. During discussions, listen for these words to see if students are using them correctly. Decide how you will support students' understanding of the vocabulary—perhaps by setting up a word wall in the classroom.

8. If you have not previously done so, introduce the concept of trade-offs.

a. Introduce the idea that decisions about solutions to scientific and engineering problems often involve trade-offs.

This unit includes issues that relate to science and/or engineering and that may lead to decisions about the best solutions or designs for solving problems. One goal of this curriculum is to teach students that decisions about possible solutions often involve trade-offs and that identifying trade-offs involves analyzing evidence.

Explain to students that in this unit, they will make several decisions about where to store nuclear waste. In this activity, students decide whether the current situation for storing nuclear waste is better than having a central storage facility deep underground. In a decision involving trade-offs, something positive (or desirable) is given up to gain another positive (or desirable) outcome. Since many decisions involve trade-offs, students should understand that a perfect choice is often not possible. It is possible, however, to recognize and analyze the trade-offs associated with each decision.

b. Provide an example of trade-offs.

For example, when asked, "Paper or plastic?" at a store checkout counter, most shoppers make the choice quickly. But there are several trade-offs attached to choosing paper or plastic. A shopper who chooses paper over plastic may do so to avoid generating plastic waste. In requesting the paper bag, though, they are contributing to other environmental problems, such as increased water and energy use, and the higher amounts of solid waste and CO_2 emissions associated with making paper bags. Neither choice is ideal, and both choices have a downside. Identifying the trade-offs helps clarify the reasoning that is being applied to make a decision.

c. Develop some examples of trade-offs in students' lives.

To further explore trade-offs, brainstorm with the class a list of decisions they make every day that involve trade-offs. Choose one, and talk through the associated trade-offs of deciding one way or another. This practice will familiarize students with ways to identify and consider trade-offs in this and subsequent activities.

9. If you have not previously done so, introduce the SEPUP Assessment System.

   a. Provide an overview of the Scoring Guides.

   SEPUP Assessment System

   Explain that Analysis item 1 is the first assessment in this unit, and you will use it to introduce the SEPUP Assessment System to your students.

   Distribute the EVIDENCE AND TRADE-OFFS (E&T) Scoring Guide, and use it to model how the SEPUP Assessment System works. Point out the levels in the first column of the Scoring Guide. Tell students that these levels are the same for all Scoring Guides and range from 0 to 4. Review the descriptions of each level. For example, a Level 4 response is "complete and correct" in all Scoring Guides. Point out that the scores (0–4) are based on the quality of students' responses and do not correspond to letter grades. Allow students to refer to the Scoring Guide as they prepare their answers. Be sure they understand that the Scoring Guides do not include the specific content students must provide in their responses; rather, they explain the overall expectations for responses at various levels of performance on the task.

   b. Explain the expectations for student growth over time.

   Explain to students that they aren't expected to always produce complete and correct work on their first attempts. Instead, they should work toward developing consistent Level 3 and Level 4 answers as they become more proficient with the concepts (both disciplinary core ideas and crosscutting concepts) and the science and engineering practices being assessed. It is not necessary (or even expected) that an "A" student will always write Level 4 responses, especially at the beginning of the course or when they are introduced to a new Scoring Guide.

10. Use the Analysis items to summarize the key ideas.

   a. (E&T ASSESSMENT) Have students complete Analysis item 1.

   You can use the E&T Scoring Guide to assess students' work on Analysis item 1. A sample Level 4 response is provided in the Sample Responses to Analysis.

   Students' responses to Analysis item 1 can also be used to reinforce the idea that nuclear waste is a long-term consequence of using energy from nuclear reactions to generate electricity.

   Use this question to generate a discussion about how science has helped us better understand the risks involved with exposure to radiation from nuclear waste; however, the decisions regarding where and how to store nuclear waste are complex.

   b. Use Analysis item 2 to identify students' prior knowledge about the scientific concerns regarding natural hazards that they will need to consider when deciding where to store nuclear waste.

Point out to the class that in this unit, they will learn about other factors that can influence the decision on where to store nuclear waste, such as natural hazards. You may wish to record students' ideas regarding natural hazards, such as the amount of rainfall at a potential site or the risks associated with volcanoes and earthquakes.

Teacher's Note: Later in this unit, students consider the trade-offs of selecting a site to build a storage facility in proximity to other valuable natural resources. You will refer to these factors in future lessons when students learn about the focal science concepts.

STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

Differentiated Instruction

- Students with learning disabilities: Allow students to complete Student Sheet 1.1 with a partner or to show their understanding by drawing diagrams or pictures rather than constructing verbal responses.
- English learners: Introduce a class word wall for the Geological Processes unit to provide a visual reminder of the new key scientific terms and to make words easily accessible. Begin it for this activity, and continue to add terms throughout the unit. Consider adding an explanatory picture or diagram for some (or all) of the terms.
- Academically gifted students: Challenge students to complete the Extension and to research Yucca Mountain.

SAMPLE RESPONSES TO ANALYSIS

1. (E&T ASSESSMENT) Do you think that storing nuclear waste in one or two sites deep in the ground is better than the current situation: storing nuclear waste at the sites where it is produced?

   a. State your decision.

   b. Support your decision with as many pieces of evidence as you can. **Evidence** is factual information or data that supports or refutes a claim.

   c. Discuss the trade-offs of your decision. A **trade-off** is a desirable outcome given up to gain another desirable outcome.

   Students' responses will likely vary. A sample response appears below.

   SAMPLE LEVEL 4 RESPONSE

   I think that storage deep underground would be better than the current situation where nuclear waste is stored in many different locations all over the country. At each of these sites, there is a risk that the waste might leak radiation that could get into the air or water. If this happened, it could be bad for people's health.

Burying the waste deep underground and in a remote area would keep it away from people, and one or two storage sites would be easier to control. One trade-off is that it is easier to store nuclear waste at the place where it is produced because you do not have to move it long distances, but if it is stored in one or two central locations, more people will be safe.

2. What other information would you like to have before you make a decision about where to store nuclear waste? Be sure to explain how this information would be helpful.

   Students' responses will likely vary. A sample response is shown here:

   I would like to know more information about how earthquakes, volcanic eruptions, and/or landslides could affect the safe storage of nuclear waste. Would the nuclear waste be buried deep enough to avoid being affected by these types of natural hazards? Or could these events create problems for the safe storage of the radioactive material?

3. Choose one of the actions you recommended on Student Sheet 1.1. Are there any disadvantages associated with taking this action? Explain why or why not.

   Students' responses will likely vary. A sample response is shown here:

   There are both advantages and disadvantages to storing nuclear waste in an area where not many people live. One advantage is that if there is an accident with the radioactive material and it leaks into the air or water, then not many people will be affected. One disadvantage is that people who work at the facility may need to drive long distances to get to work.

4. As you learned in this activity, advances in technology often lead to advances in science. Sometimes they also lead to new challenges.

   a. In what ways has the development of nuclear energy led to both advances and challenges for society?

      Students' responses will likely vary. A sample response is shown here:

      Nuclear energy is used to generate electricity, which helps people in their daily lives. One challenge it has presented is figuring out where to store the radioactive waste that is produced in the process.

   b. What other developments in technology have led to both advances and challenges for people?

      Students' responses will likely vary. A sample response is shown here:

      One development in technology that has led to advances is the smartphone. It has allowed people to connect in new ways with one another digitally. But it presents challenges when people use their devices when they are driving or have problems with their eyes or neck because they use their devices too much.

EXTENSION

Have students learn more about Yucca Mountain, and prompt them to generate additional questions about the long-term storage of nuclear waste. In 1987, the U.S. government selected Yucca Mountain in southern Nevada as a place to build an underground storage site for the country's nuclear waste. The project was approved in 2002, but in 2011 the government withdrew its funding.

REVISIT THE GUIDING QUESTION

What factors must be considered when deciding where to store nuclear waste?

The radiation from nuclear waste can cause health problems for people if the waste is not stored properly. One thing that must be considered when choosing a place to store nuclear waste is how many people live near the facility. If nuclear waste leaks into the water or air, people in the local area may ingest or breathe in radiation that could be harmful. This is why nuclear waste should be stored away from areas where a lot of people live. Another consideration is how close the location is to the nuclear power plants where the nuclear waste is generated. Nuclear waste needs to be transported to the central storage facility. Transportation and related accidents may increase the risk that the nuclear waste could leak into the water or air and cause harm to people living on the route.

ACTIVITY RESOURCES

KEY VOCABULARY

evidence

nuclear waste

trade-offs

BACKGROUND INFORMATION

RADIOACTIVITY

Radiation is energy released in the form of waves or particles (e.g., alpha, beta, and gamma radiation). Elements that release such energy are described as *radioactive*, and there are over 60 naturally occurring radioactive elements. As a result, there are many natural sources of low-level radiation, including radon gas, and soil.

Exposure to high levels of radiation or exposure to lower levels over long periods of time can increase the risk of cancer. In the United States, most people receive an average annual background radiation dose of about 360 millirem (mrem) from a combination of both natural and manufactured sources. Radon gas is the primary natural source of radiation, and it accounts for about 200 mrem. Medical X-rays, the primary manufactured source, account for another 40 mrem. (A typical chest X-ray results in a 10-mrem dose.)

WASTE FROM NUCLEAR POWER PLANTS

Nuclear energy is the heat energy produced from the splitting of uranium atoms (known as *fission*) in a nuclear reactor. A nuclear power plant uses this heat to produce electricity. Nuclear power plants produce two types of radioactive waste: high-level and low-level. Nearly all high-level waste is from used fuel rods. Low-level waste includes tools and equipment that may contain small amounts of radioactive material. High-level waste is handled remotely and stored in steel-lined concrete pools filled with water or in large steel-lined concrete containers. Low-level waste may be stored or shipped to a disposal facility.

REFERENCES

Blue Ribbon Commission on America's Nuclear Future. (2012, January). *Report to the secretary of energy*. https://energy.gov/sites/prod/files/2013/04/f0/brc_finalreport_jan2012.pdf

U.S. Census Bureau. (2011). *Population distribution and change: 2000 to 2010*. http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf

U.S. Government Accountability Office. (n.d.). *Disposal of high-level nuclear waste*. https://www.gao.gov/key_issues/disposal_of_highlevel_nuclear_waste/issue_summary#t=0

U.S. Nuclear Regulatory Commission. (2017). *U.S. operating commercial nuclear power reactors*. https://www.nrc.gov/reactors/operating/map-power-reactors.html

U.S. Nuclear Regulatory Commission. (2017). *Spent fuel storage in pools and dry casks: Key points and questions & answers*. https://www.nrc.gov/waste/spent-fuel-storage/faqs.html

U.S. Nuclear Regulatory Commission. (2017). *Storage of spent nuclear fuel*. https://www.nrc.gov/waste/spent-fuel-storage.html

Name____ Date__________

STUDENT SHEET 1.1

CONSIDERING WHERE TO STORE NUCLEAR WASTE

Consideration	Recommended action	Explanation

Name *Sample student response* Date

STUDENT SHEET 1.1

CONSIDERING WHERE TO STORE NUCLEAR WASTE

Consideration	Recommended action	Explanation
Human population	*Select a site located in an area with low population density.*	*If the nuclear waste from the facility leaks into the water and air, it could expose a lot of people to radiation in the surrounding area. To lower the risk to humans, the nuclear waste should be stored in an area with low population density.*
Location of operating nuclear reactors	*Select a site located near most operating nuclear reactors.*	*If the storage site is close to the reactors where the waste is produced, it won't need to be transported as far. Transporting nuclear waste involves many risks, which could be reduced if the storage site is as close as possible to many operating nuclear reactors where the waste is generated.*