GRADES 6–8

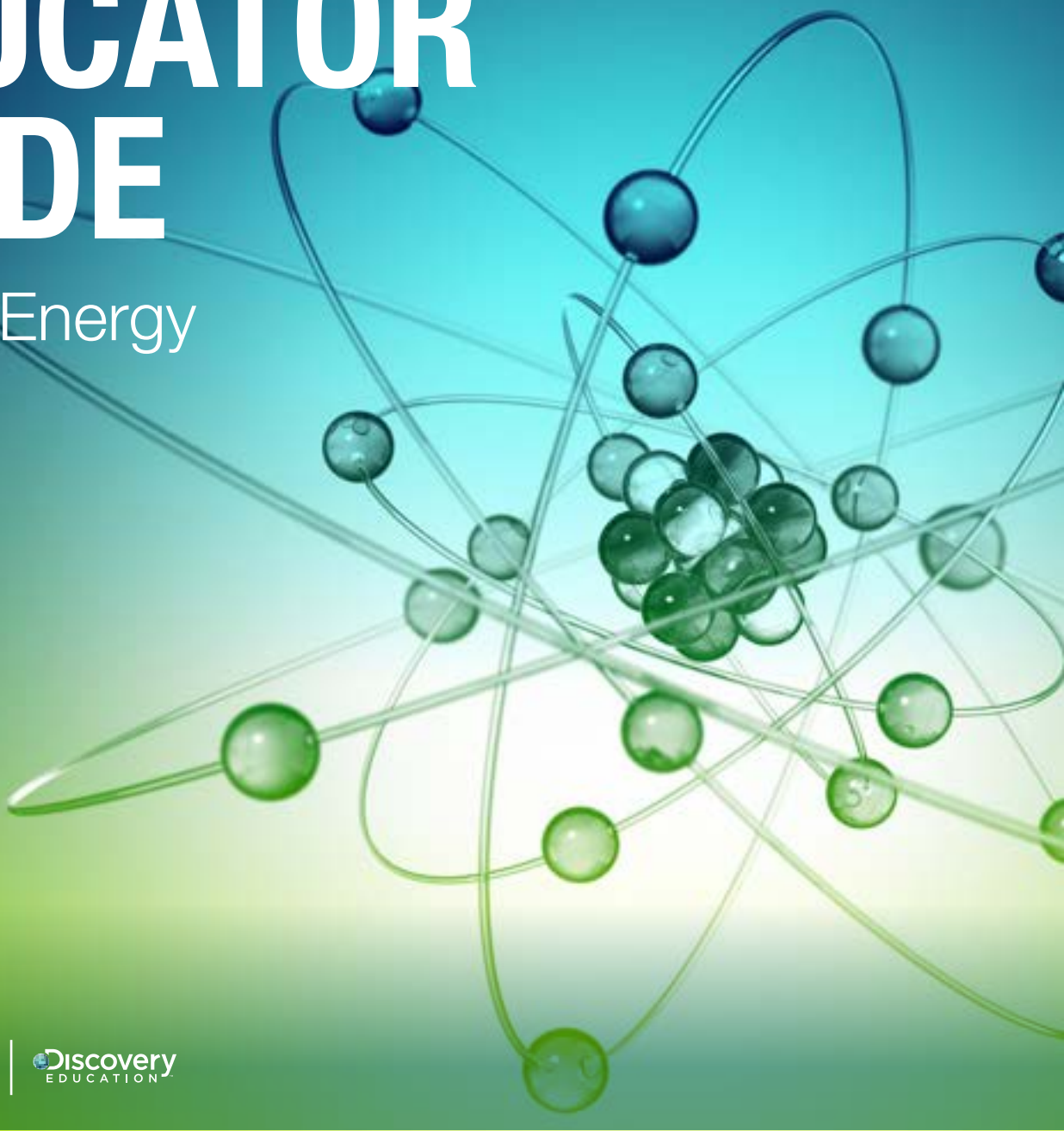
NAVIGATING™ NUCLEAR

Energizing Our World

Middle School Digital Lesson

EDUCATOR GUIDE

Nuclear Energy



ANS Center for Nuclear Science and Technology Information | Discovery EDUCATION

Lesson Overview

As the negative effects of burning fossil fuels become more apparent, low-carbon power sources will be increasingly essential. Because nuclear power is the most widely used low-carbon energy source, it will play a large part in our power generation plan over time. However, there are many misconceptions about the risk of nuclear power. At the beginning of this lesson, students will examine misconceptions and facts about nuclear power. Through a series of investigations, they will explore the science behind nuclear power and analyze its benefits and relative risks, as well as the long-term issues associated with it. Students will discover that nuclear power is safe, especially given the risks of carbon emissions and pollution from burning fossil fuels. They will apply what they learn to explain and communicate the science behind actual examples of the uses of nuclear power in electricity generation, space probes, and nuclear submarines.

Duration

135–180 minutes

Content Areas

Earth Science/Environmental Science, Physics

Grade Level:

Grades 6–8

Essential Questions

1. What are the benefits and relative risks of nuclear power?
2. How does nuclear power work?
3. How does nuclear power compare to other sources of power?

National Standards

Next Generation Science Standards (NGSS)

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Planning and Carrying Out Investigations Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	**PS3.B: Conservation of Energy and Energy Transfer** The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.)	**Scale, Proportion, and Quantity** Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Materials

- Computers connected to the Internet
- Ping pong balls or crumpled up pieces of paper (roughly three per student)
- Evaluating Claims about Nuclear Energy student activity sheet (one per student)
- Exploring Energy student activity sheet (one per student)
- Exploring Energy Gallery Walks student activity sheet (one per student)
- THINK-PAIR-SHARE Summary student activity sheet (one per student)

Objectives

- Model the process of nuclear fission.
- Evaluate the risks and benefits of nuclear power, especially in comparison to other power sources.
- Analyze and communicate the science behind uses of nuclear power.

Background

Prior to this lesson, students should know about atoms and that they are made of smaller particles. Specifically, they should know that neutrons are one of these smaller particles in the atom. They should know the rough structure of the atom, namely, that it has a nucleus.

Procedure

Day 1 (Slides 1–7)

Slide 1

- Before students begin researching, see what they already know about nuclear energy. On the Evaluating Claims about Nuclear Energy student activity sheet, invite students to read each claim and write whether they believe it is a fact or misconception. Invite discussion about student responses.
- Explain to students that they will have an opportunity to prove or refute one of the claims. Assign groups of 4 and ask each group to select a claim they would like to prove or refute. Each student in the group will be responsible for gathering evidence that can help support or refute the claim. Possible websites for research include:
  - https://www.energy.gov/ne/office-nuclear-energy
  - https://www.energy.gov/ne/articles/5-fast-facts-about-nuclear-energy
  - http://needtoknow.nas.edu/energy/energy-sources/nuclear/
- Each group member will share out information about what they learned with their group. Students then will refer back to the claim they selected and support or refute the claim using their research as evidence. Invite groups to share out their claims and evidence to the class. Based on each presentation, challenge students to determine if the evidence supports or refutes the claim. Students should capture their ideas by completing the "What I now know: Fact or Misconception" column of their Evaluating Claims about Nuclear Energy student activity sheet. Review correct responses with students and clarify any questions.
  - **Claim 1:** A nuclear reactor can explode like a nuclear bomb. (Misconception)
    It is impossible for a reactor to explode like a nuclear weapon; these weapons contain very special materials in very particular configurations, neither of which are present in a nuclear reactor.
  - **Claim 2:** Nuclear energy is bad for the environment (Misconception)
    Nuclear reactors emit no greenhouse gasses during operation. Over their full lifetimes, they result in comparable emissions to renewable forms of energy such as wind and solar. Nuclear energy requires less land use than most other forms of energy.
    Meier,P.J., 2002. Life-Cycle Assessment of Electricity Generation Systems and Applications for Climate Change Policy Analysis.
  - **Claim 3:** Nuclear power releases dangerous amounts of radiation into the atmosphere. (Misconception)
    Nuclear power plants do emit some radiation, but the amounts are environmentally insignificant and pose no threat. These emissions fall well below the legal safety limit sanctioned by the Nuclear Reg¬ulatory Commission (NRC).
    U.S. Department of Energy, Oak Ridge Office, "About Radiation," at https://www.energy.gov/em/articles/annual-report-shows-potential-inl-radiation-dose-well-below-safe (October 2018).
  - **Claim 4:** Nuclear power plants are some of the safest and most secure workplace facilities in the U.S. (Fact)
    The U.S. Bureau of Labor reports that it is safer to work at a nuclear power plant than at a fast food restaurant or grocery store! The industry is heavily regulated and safety is regarded highly.

Slide 2

- Review the lesson objectives for the three-day lesson.

Slide 3

- Review the background for the three-day lesson.

Slide 4

- Prompt students to observe the animation of a boiling water reactor. Explain that there are two types of reactors used in the United States, pressurized water reactors and boiling water reactors. Boiling water reactors are a little easier to explain, so that's what they will examine. https://www.nrc.gov/reading-rm/basic-ref/students/animated-bwr.html
- Ask students to consider the following questions:
- What do you think is happening in this animation?
- What do you predict is the purpose of a boiling water reactor?
- Can you explain where you have seen or heard the words turbine or generator before?
- Can you explain where you have seen or hear the words condense or pressure before?
- Give students two to three minutes to think about and record their thoughts.
- Divide the class into two equal groups and create two lines that face each other with students matched up one-to-one. Name the lines: A and B.
- Allow students in line A one minute (30 seconds for younger children) to share their thoughts with their matched partners in line B.
- When the one minute is up, give the matched student in line B one minute to comment or provide feedback on what the first student shared.
- Switch sides: allow students in line B one minute to share their thoughts and the students in line A one minute to respond and provide feedback.
- Ask students in line A to take one step to the right, pairing themselves with the next student in line B. The student at the end of line A should walk quickly to the beginning of the line.
- Repeat this process several more times.
- Explain to students that boiling water reactors are a type of nuclear reactor. They generate electricity and a similar system is used to power submarines and naval vessels. Reactors use water to remove heat produced inside the reactor core. But what exactly is going on in a nuclear reactor?

Slide 5

- Explain to students that energy is stored in the nuclei of atoms. When nuclei split, energy is released. Show the image on the screen. Ask students to sequence the chain of events using the image as a guide. Reveal the correct answer by clicking on the slide.
  - This example only demonstrates one atom. We need a lot more to power a city. Uranium is a dense metal. It is found in rocks and soil all around the world. Uranium is an element and has three major isotopes, or three different varieties. Uranium-235 is one of these varieties and it is used as fuel for nuclear power plants.
  - When a neutron strikes a Uranium-235 atom, it releases three neutrons that are available to strike other nuclei. This leads to a chain reaction!
- To demonstrate how this can lead to a nuclear chain reaction, set up a quick demonstration of the principle. Give each student three balls, either ping pong balls or crumpled up pieces of waste paper. These are the "neutrons." Start a chain reaction by releasing a single neutron onto a desk in the middle of the classroom. Direct the students to throw their three balls up in the air in three different random directions if they or their desk is struck by a ball. Each student and his or her desk is a nucleus. It may be helpful to have this demonstration proceed in stages—pause after each round of reactions to identify who will throw their balls before they do so. The reaction should proceed quickly, with an increasing number of "nuclei" releasing "neutrons" after each round.
- After conducting the model of the chain reaction, have students reflect on what they learned. Why does the reaction increase so dramatically? What are ways that the reaction might be able to be controlled?

Slide 6

- Revisit the nuclear reactor animation and ask students the following guiding questions.
  - Where in the nuclear reactor is fission occurring? (in the reactor)
  - What is the water being used for? (to cool down the energy output)

Slide 7

- Explain to students that there is evidence of naturally occurring nuclear reactors. Show the video and ask students to identify some of the similarities human-made reactors have to the naturally-occurring nuclear reactor. Oklo, the two Billion Year Old Nuclear Reactor (4:33)

Day 2 (Slides 8–10)

Slide 8

- Review the graph depicting the annual share of total U.S. electricity generation by source. Note that coal has been significantly declining, natural gas has been increasing, and nuclear has remained steady recently. Ask students: Does this mean that the total amount of nuclear power has remained steady? Why did nuclear and coal power stop texpanding in the late 1980s? Have students use this graph and what they have already learned about nuclear energy to make a prediction about the future use of nuclear power in the United States. Collect the predictions and then evaluate the predictions as a class.

Slide 9

- Distribute the Exploring Energy student activity sheet. Invite student groups of 3–4 to investigate a different energy source to compare and contrast. There will likely be several groups researching the same source, that is okay! Guide students to complete the questions on the student activity sheet using the following link: https://www.eia.gov/energyexplained/index.php?page=home
- Guide student groups that investigate the same energy source to compare their research results. Then, ask all students to leave their papers at their desk.
- Distribute the Exploring Energy Gallery Walk student activity sheet and invite students to walk around the room to identify the risks and benefits of each energy source. Examples of risks: For coal, these could include the risks to coal miners, carbon emissions, asthma from pollution, and the problem of disposing of coal ash. For natural gas, these could include carbon emissions and emissions of methane, which is an even stronger greenhouse gas than carbon dioxide. For a wind farm, these could include noise pollution, risks to birds and bats, and the mining and smelting of material to make the wind turbines and windmill blades. For a large solar farm, these could include the toxic processes involved in producing solar panels and the mining of the material that forms solar panels. After students have created this list of risks, assign one to two students to each risk and direct them to find statistics about or further descriptions of the risks.

Slide 10

- Ask students to rank the power sources as a class by the level of risk associated with them. Students should conclude that all energy sources have benefits and risks but they will likely be surprised that nuclear ranks low. Review the benefits of nuclear energy using the slide.

Day 3 (Slides 11–13)

Slide 11

- Explain to students that one of the risks identified with nuclear energy is what to do with the fuel rods once they are no longer usable. This is referred to as "used fuel." Used nuclear fuel is highly radioactive and continues to generate heat for decades. Most used fuel is stored on site at the facility where it was created. This creates some risks. However, there are many solutions to this problem, including material, biological, or cultural innovations. One of the ideas was proposed for disposing of used fuel was to shoot it into the sun. However, there are risks that the vessel carrying the used fuel would blow up and spread radiation around the world, and others worry that it could be a calling card to extraterrestrial intelligences that would alert them to our presence.
- Tell students that they will be working in small engineering teams to identify other strategies or develop new ideas of how used fuel can be removed or contained. There may be existing ideas out there to build on or completely new ideas to consider!

Slide 12

- Summarize with students by distributing the THINK-PAIR-SHARE Summary activity sheet. Provide time for students to complete the first column of the capture sheet for the four statements individually. Then, invite students to share their responses with a partner to complete the second column. As a pair, students should decide what they will share with the rest of the class.
  - Nuclear power consists of nuclear reactions that generate heat.
  - Many stated risks of nuclear energy will be inaccurate, including the explosive potential, radiation release, and the hazards to people near the nuclear reactors.
  - The biggest benefits of nuclear power include that it is a low-carbon and other pollutant-emitting energy source, the fuel is cheap, and that it is safer than other power sources such as coal plants.
  - Nuclear power generally generates electricity by heating water into steam that turns a turbine attached to a generator, which generates the electricity.

Extension
Slide 13

- Direct students to examine examples of the uses of nuclear power (e.g., electricity generation, space probes, nuclear submarines). They should apply what they learned throughout the lesson to explain the science behind one of them. You may want to break up the class into small groups to complete this project. Their explanation of the use of nuclear power should address at least one misconception from the beginning of the lesson. They will create a presentation on their example that includes multimedia elements.
- To start, they may want to use the following resources.
  Nuclear electricity generation:
  https://www.nrc.gov/reading-rm/basic-ref/students/what-is-nuclear-energy.html
  https://geoinfo.nmt.edu/resources/uranium/power.html
  Nuclear-powered space probes:
  https://www.energy.gov/articles/history-nuclear-power-space
  https://www.energy.gov/ne/nuclear-reactor-technologies/space-power-systems

https://www.energy.gov/ne/nuclear-reactor-technologies/space-power-systems/next-generation-radioisotope-generators

Nuclear submarines:
http://americanhistory.si.edu/subs/operating/propulsion/reactor/index.html
http://americanhistory.si.edu/subs/const/anatomy/boomers/index.html
https://www3.epa.gov/radtown/submarines-aircraft-carriers.html
http://navylive.dodlive.mil/2014/09/30/the-u-s-navys-nuclear-submarine-force-a-60-year-legacy-of-excellence/

Evaluating Claims about Nuclear Energy
Fact or Misconception

STUDENT HANDOUT

Claim	What I think I know: Fact or Misconception	What I now know: Fact or Misconception
1. A nuclear reactor can explode like a nuclear bomb.		
Evidence:		
2. Nuclear energy is bad for the environment.		
Evidence:		
3. Nuclear power releases dangerous amounts of radiation into the atmosphere.		
Evidence:		
4. Nuclear power plants are some of the safest and most secure workplace facilities in the U.S.		
Evidence:		

Exploring Energy

STUDENT HANDOUT

Directions

Your job is to research one of the energy sources below and apply this knowledge to societal issues. When you have chosen or been assigned an energy source, place a check next it below.

_____ solar _____ wind _____ geothermal

_____ nuclear _____ fossil fuel

Exploring Energy!	
How much do we currently use this technology in the United States and in the rest of the world?	What applications do we use this energy source for?
How long does it take to produce this type of energy and how fast is it being consumed?	What are the societal and environmental issues associated with using this energy source?
What are the risks and benefits of this energy source?	
Risks	Benefits

Exploring Energy Gallery Walk

STUDENT HANDOUT

Energy Source	Risks	Benefits
Solar		
Wind		
Geothermal		
Nuclear		
Fossil Fuels		
Evidence:		

Name: _____ Partner's Name: _____ Date: _____ Pd.: ____

STUDENT HANDOUT

THINK-PAIR-SHARE Summary

Energy Source	What I learned that supports this	What My Partner learned	What We Will Share
Nuclear power consists of nuclear reactions that generate heat.			
Many stated risks of nuclear energy are inaccurate, including the explosive potential, radiation release, and the hazards to people near the nuclear reactors.			
The biggest benefits of nuclear power include that it is a low-emission energy source, the fuel is cheap, and that it is safer than other power sources such as fossil fuel plants.			
Nuclear power generally generates electricity by heating water into steam that turns a turbine attached to a generator, which generates the electricity.			