NAVIGATING™ NUCLEAR
Energizing Our World

STEM PROJECT STARTER
Sun Earth Origin Energy

Topic

Nuclear Fusion and Fission: Think Nucleus Binding Energy

PROJECT DETAILS

Course
Earth/Space Science

Grade Span
6-8

Duration
x2 45–60-minute sessions

Concept
The Sun and Earth as the Origin of Energy

Overview

This project provides students with the opportunity to learn about natural nuclear reactions in the sun and in the naturally-occurring Oklo reactor. They will research the feasibility, advantages, and disadvantages of nuclear fusion and fission that occur naturally in our universe as an abundant source of power on Earth. They will also use data to compare the difference in scale between commercial (human-made) fission and fusion generators compared to the sun as a fusion generator. Finally, they will use the data they gather to explain the phenomenon of either human-made fusion or fission and use this explanation to propose possible applications of their chosen phenomenon.

Essential Question

How can nuclear fusion and fission reactors change how we power our lives?

Materials

- Exploring a Natural Fission Reactor student handout
- Investigating Naturally Occurring Nuclear Reactions student handout
- Scalable Energy student handout
- Nuclear Fusion and Fission: Think Nucleus Rubrics student handout

Procedure

Think Energy

1. Display the image of a star.

2. Encourage students to look closely and try to observe as many details as possible.
   Give students five minutes to jot down answers to the following questions:
   - What do you see? Remind students to only report on things they actually see in the image.
   - What do you think about that?
   - What does it make you wonder?
   - Facilitate a group discussion about the questions.
   - Ask students to use the following stems when sharing: "I see...," "I think...," "I wonder...."
3. Summarize with students that the intense pressures at the sun's core fuse the nuclei of hydrogen to form nuclei of helium. This fusion reaction releases energy in the form of heat and light energy from the sun. Students will explore where else natural nuclear reactions occur.

Create

Naturally Occurring Nuclear Reactions

1. Explain to students that they will use literacy strategies to investigate the feasibility, advantages, and disadvantages of nuclear fusion and fission that occur naturally in our universe as an abundant source of power on Earth. Students will gather evidence using videos and text. Distribute the *Nuclear Fusion and Fission: Think Nucleus Rubrics* for students to track the requirements of the project.
2. Provide students with the capture sheet *Investigating Naturally Occurring Nuclear Reactions*. Guide students to complete the investigative topic section by summarizing the project ask.
3. Display each of the following videos and distribute the *Exploring a Natural Fission Reactor* reading. Invite students to capture their evidence using the capture sheet.

   Fusion Powered Explained (6:15)
   Nuclear reactions release energy. Nuclear fusion reactions do this by combining, or fusing, two nuclei. Where does the energy come from in a nuclear reaction?

   What is Nuclear Fission (2:58)
   Nuclear fission releases energy when splitting a nucleus. Where does nuclear fission occur?
4. Invite students to use their evidence to summarize the following prompt provided on their *Investigating Naturally Occurring Nuclear Reactions* capture sheet.
   Prompt: Consider the examples of naturally occurring nuclear fusion (sun) and fission (Oklo reactor) reactions. Would it be possible to use these reactions as a power source on Earth? What is an advantage and a disadvantage of using each of these two examples as sources of power on Earth? You may need to consult additional resources to answer this question.

   Sample Answer: Using the Oklo reactor as a source of power on Earth would be infeasible because it is no longer working. That reactor was only running for a few million years around two billion years ago. Its primary disadvantages would be that it occurred in only one area. Its biggest advantages, if it were still running, would be that it would require no energy to run because it occurs naturally and the large potential energy of fission can be harnessed. Using the sun as a source of power on Earth is already feasible and becoming more widespread. The main advantage is that the sun provides energy everywhere on Earth. However, its main disadvantages are that it needs to be stored for use at night, during cloudy days, and during winter months when much less sunlight is available. In addition, solar cell farms cover large swaths of land to collect the diffuse sunlight.

Connect

Energy Sources

1. Guide students to use the *Scalable Energy* capture sheet for students to compare the scale of human-made compact fusion/fission generators and the potential energy available in wind and solar energy using data.

   Prompt on capture sheet: How many wind turbines would be required to produce the power that an average nuclear fission plant generates? Show your work.

   Sample Answer: The number of wind turbines required to produce the power of an average nuclear plant is 800 MW / 5 MW = 160 wind turbines. Most wind farms only operate 30% of the time, so a better answer is a number greater than 160 wind turbines 160/30% (or 160/0.3 = 533) with an upper bound of 530 wind turbines.

2. Next, invite students to research the applications of compact (human-made) fusion and fission and their possible applications. Students should describe one application of fusion and one application of fission.

   Sample Answer: An application of fusion could be to power deep-space rockets. They would carry little, light fuel and be able to efficiently travel vast distances. An application of fission is to power submarines and other naval vessels or remote villages in Alaska.

National Standards

Next Generation Science Standards

Obtaining, Evaluating, and Communicating Information	PS1.A: Structure and Properties of Matter	Crosscutting Concept
Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or now supported by evidence.	Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1) **PS3.A: Definitions of Energy** The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.	**Energy and Matter** Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system.

Investigating Naturally Occuring Nuclear Reactions

STUDENT HANDOUT

Investigative Topic:	
Evidence from Fusion Video	
Evidence from Fission Video	
Evidence from Reading	
Evidence from ______________________	
Evidence from ______________________	

Consider the examples of naturally occurring nuclear fusion (sun) and fission (Oklo reactor) reactions. Would it be possible to use these reactions as a power source on Earth? What is an advantage and a disadvantage of using each of these two examples as sources of power on Earth? You may need to consult additional resources to answer this question.

____

____

____

____

____

Exploring a Natural Fission Reactor

Nuclear reactions occur every day all around us. For example, unstable isotopes of different elements decay into stable isotopes regularly. But there are larger self-sustaining nuclear chain reactions that occur. The sun is one example. In the sun's core, pairs of hydrogen nuclei are fused into helium nuclei. This fusion generates energy (~10 MeV).

Historically, there was a self-sustaining nuclear fission reaction in the Oklo region of Gabon, a country in estern Africa. This region contains large amounts of uranium buried underground. Approximately 1.7 billion years ago, the conditions were right for the uranium to begin a fission reaction. This reaction continued to operate for a few million years. Each fission generates energy (~200 MeV).

The energy produced by these natural nuclear reactors was about 100 kilowatts, which would power approximately 1,000 lightbulbs. As a comparison, ten million lightbulbs could be powered by commercial pressurized boiling water reactor nuclear power plants. They produce about 1,000 megawatts.

This is the only naturally occurring self-sustaining nuclear fission reaction that has been discovered on Earth. Scientists discovered it because of the ratios of different isotopes they found in uranium from the Oklo region. It had operated around two billion years ago and continued to operate for up to one million years in a stable manner. The radioactive products of the nuclear fission were safety contained. This has provided scientists and engineers with important evidence that long-term geologic storage of nuclear waste is possible.

Scalable Energy

STUDENT HANDOUT

Directions: Using the data provided below, answer the series of questions comparing the scale of human-made compact fusion/fission generators and the potential energy available in wind and solar energy. Note that the values in the Number of Plants/Turbines column show the number of nuclear fission plants operating worldwide in 2018 (99 in the United States) and a rough estimate of the number of wind turbines operating in 2018.

Energy source	Number of Plants/Turbines (2018)	Average Power Generated per Plant/Turbine
Nuclear fission plants	435	800 MW
Potential wind turbines	341,320 (as of 2016)	5 MW

How many wind turbines would be required to produce the power that an average nuclear fission plant generates 100% of the time? Show your work below.

Research the applications of compact (human-made) fusion and fission and its possible applications. Describe one application of fusion and one application of fission.

Evaluation Criteria

Your answer will be evaluated based on the following criteria:

- Advantages are correct and well-described for both the sun and the Oklo reactor.
- Disadvantages are correct and well-described for both the sun and the Oklo reactor.
- The feasibility of using both the sun and the Oklo reactor as a source of power on Earth is correct and explained.

Rubric

Criteria	2	1	0
Advantages	At least one correct and well-described advantage is given for the sun and for the Oklo reactor.	One correct and well-described advantage is given for the sun or the Oklo reactor, but not both, or at least one poorly described advantage is given for both the sun and the Oklo reactor.	Advantages are incorrect or missing.
Disadvatages	At least one correct and well-described disadvantage is given for the sun and for the Oklo reactor.	One correct and well-described disadvantage is given for the sun or the Oklo reactor, but not both, or at least one poorly described disadvantage is given for both the sun and the Oklo reactor.	Disadvantages are incorrect or missing.
Feasibility	The feasibility is correct and well-described for both the sun and the Oklo reactor.	The feasibility is poorly described for both the sun and the Oklo reactor, or it is well-described for only one example.	The feasibility is incorrect or missing.

Evaluation Criteria

Your answer will be evaluated based on the following criteria:

- Clear, correct calculation of the number of wind turbines

Rubric

Criteria	2	1	0
Calculation	Calculation clear, concise, and correct.	Calculation is unclear or poorly organized.	Calculation is incorrect or missing.

Evaluation Criteria

Your answer will be evaluated based on the following criteria:

- Describe one application for fusion and one for fission

Rubric

Criteria	2	1	0
Applications	Applications are well-described, complete, and accurate.	Applications are poorly described.	Applications are incorrect or missing.