**NATIONAL GEOGRAPHIC**

# Using Waste Heat to Generate Electricity

Students research waste heat technology and on-site electricity generation using a set of research questions. They identify an example of waste heat capture and use it as a case study. Then they create a podcast to explain how waste heat capture works, using their case study as an example.

**GRADES**

9 - 12+

**SUBJECTS**

*English Language Arts, Geography, Human Geography*

**CONTENTS**

3 PDFs, 12 Links

# OVERVIEW

Students research waste heat technology and on-site electricity generation using a set of research questions. They identify an example of waste heat capture and use it as a case study. Then they create a podcast to explain how waste heat capture works, using their case study as an example.

For the complete activity with media resources, visit:

http://www.nationalgeographic.org/activity/using-waste-heat-generate-electricity/

# Program

# DIRECTIONS

## 1. Activate students' prior knowledge.

Ask students what they feel on the bottom or sides of a laptop that has been on for a while. Discuss how the heat they feel represents lost efficiency; some electricity is being wasted when it is converted to thermal energy. Ask: *How would the total amount of energy resources needed to run the laptop for an hour change if fewer resources were converted to thermal energy? What if you could trap and use the thermal energy?* Expand the discussion to household appliances that give off heat, such as a dryer or an oven. Ask: *Have you ever wanted to leave the kitchen on a hot day when the oven is on? What benefits might there be if that waste heat (thermal energy) could be captured and used to heat your home or your water? How would that help to conserve energy?* Explain that industrial operations, such as manufacturing and electricity generation, can produce large quantities of waste heat. Waste heat capture is a way to repurpose and use the waste heat.

## 2. Examine and discuss a diagram showing waste heat capture.

Project the Waste Heat Capture diagram for students to see. Use the diagram to describe how waste heat can be captured from an industrial process, such as a glass-melting furnace, and used to heat water to create steam. That steam can then be used to turn a turbine and generate electricity. The steam could also be used to power another mechanical process within the factory or to pre-heat water so less energy would be required from other resources to heat the water to the required temperature. Waste heat could also be used to heat the factory directly. Explain that cogeneration is a type of waste heat capture that takes advantage of the wasted thermal energy from thermoelectric power plants to intentionally generate both electricity and useful heat from a single source. Cogeneration can increase the efficiency of a power plant from 30 to 80 percent.

## 3. Give students an overview of the case study podcast task.

Explain that students will conduct research to learn more about various ways waste heat can be captured and used in different settings. Distribute copies of the worksheet Waste Heat Capture Notes, and introduce the following research questions: *What is waste heat? How do industrial processes produce waste heat? What is the main impact of waste heat on the*

*environment? How can waste heat be captured and transformed into electricity? How can industry use waste heat with cogeneration technology?* Explain that as students research these questions, they will identify a specific example of waste capture technology that they will later use as the subject of a podcast.

## 4. Model search strategies and have students conduct research using the web.

Divide students into small groups. Have each group review the research questions and make sure they understand what each question is asking. Then have each group generate a list of key words to use in researching the questions. Have groups share their results with the class and create a master list of possible search terms. Have students review the master list and add any synonyms or related search terms that they think might be useful. Ask them to identify which search terms they might use together in a search to increase their chances of getting a good result. Display a search page for the whole class to see, and type in one or more of the search terms. Scroll through the search results on the first screen and model how to categorize each one as potentially useful or not for the inquiry, based on what you can tell from the heading and visible description on the search page. Then model how to assess each potentially useful link by clicking on the link to determine who created the resource, to evaluate the professionalism and authority of the website, and to identify any inherent biases. Type in another set of one or more search terms, and have students assess the results in their small groups. Once you are comfortable that students understand how to use the search terms and evaluate search results, have them begin researching in their small groups. Have them use the Waste Heat Capture Notes worksheet to answer the research questions. Remind students to identify useful, reputable resources. Encourage students to note any potential case studies during their research. When students have completed their research, discuss their findings as a class.

## 5. Introduce the podcast task.

Explain that groups will now focus on a specific example of a place that uses waste heat for generating electricity, heating, cooling, and/or doing other work. Explain that they will create a podcast that uses that case study to describe and explain the capture and use of waste heat. Distribute the Podcast Rubric and review it with students. Play a Future Tense, Nova, National Geographic News, or Natural Selections podcast, or any other podcast of your choice. Have each student take notes about what they feel is successful or not successful as

they listen. Play at least one additional podcast, again asking students to note successes and pitfalls. Have students share their notes with the class and generate a class list of best practices and pitfalls for podcasts.

**6. Have students identify their case study and create a podcast.**

Have students select from the provided list of case studies or identify their own candidate for a case study from their local region or from their earlier research. Approve all case studies before students begin work. Have each group read about the waste heat capture project they are using as their case study, noting important points. Have students generate an outline that addresses the important points they want to make about waste heat capture, using specific examples from their case study to illustrate those points. Once students have an outline, have them divide up the workload among the group members. Have students script their podcast and identify the location of their case study, using the MapMaker Interactive. Students should check in with you at this point for feedback before recording their podcast.

**7. Have students record their podcast.**

Students can record their podcast on a computer using any sound recording application (for example, Audacity), and then upload the recording into any podcasting program (for example, AudioBoo). Depending on the podcasting program you use, students may also be able to record their podcast directly into the program via a computer microphone or even a phone. Once groups have finished recording their podcasts, have each group use the Podcast Rubric to peer-review another group's podcast. Remind them to give specific, constructive feedback.

**8. Have students publish their podcasts using the MapMaker Interactive.**

Have students revise their podcasts based on feedback from the peer review and record their final version. Then have all groups use the MapMaker Interactive to label the featured locations of their podcasts on a map of the United States. Each group should place a marker on the appropriate location for their case study and use the label tool to number and name the case study. Students can then use the label tool to create a numbered list in the bottom

left area of the map screen. The list should include the number for the case study as recorded on the map label and the URL of the related podcast. Note that the URLs will not be hyperlinked but can be used as reference. Download and save the map.

# TipTeacher Tip

You do not need specialized equipment or programs to record the podcast in step 7. Most computers come with a built-in application to record sound. Free applications such as Audacity simply give students the ability to edit their sound recordings. If you do not have access to sufficient computers and microphones, you can also use a podcasting service such as GCast to record podcasts over the phone.

# Informal Assessment

Use the provided Podcast Rubric to assess the podcasts created by student groups.

# Extending the Learning

Have students research recent technological innovations in waste heat capture technology and create a podcast about the one they find most exciting. Introduce more specialized online research resources such as Google Scholar.

## OBJECTIVES

# Subjects & Disciplines

- English Language Arts
  **Geography**
  - Human Geography

# Learning Objectives

Students will:

- describe how thermal energy can be a byproduct (called waste heat) of traditional industrial processes or on-site power generation

- discuss the main impact of waste heat on the environment at the power plant level or the industry factory level
- identify key words and conduct web research to gather information about waste heat capture
- explain how waste heat can be captured and transformed/converted into electricity and used for heating, cooling, and/or other purposes
- use a case study to explain the use of waste heat for electricity generation, heating, cooling, and/or other purposes

# Teaching Approach

- Learning-for-use

# Teaching Methods

- Brainstorming
- Cooperative learning
- Discussions
- Modeling
- Research
- Writing

# Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Critical Thinking and Problem Solving
- Critical Thinking Skills
  - Analyzing
  - Creating
- Geographic Skills
  - Acquiring Geographic Information

- Organizing Geographic Information
- Science and Engineering Practices
  - Obtaining, evaluating, and communicating information

# National Standards, Principles, and Practices

## ENERGY LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

• **Fundamental Concept 1.4:**
Energy available to do useful work decreases as it is transferred from system to system.

• **Fundamental Concept 6.2:**
One way to manage energy resources is through conservation.

• **Fundamental Concept 7.3:**
Environmental quality is impacted by energy choices.

## IRA/NCTE STANDARDS FOR THE ENGLISH LANGUAGE ARTS

• **Standard 4:**
Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

• **Standard 7:**
Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

## NATIONAL GEOGRAPHY STANDARDS

• **Standard 14:**
How human actions modify the physical environment

## COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **Speaking and Listening Standards 6-12:**
Presentation of Knowledge and Ideas, SL.11-12.4

• **Speaking and Listening Standards 6-12:**

Presentation of Knowledge and Ideas, SL.9-10.5

- **Speaking and Listening Standards 6-12:**

Presentation of Knowledge and Ideas, SL.11-12.5

- **Speaking and Listening Standards 6-12:**

Comprehension and Collaboration, SL.11-12.1

- **Speaking and Listening Standards 6-12:**

Comprehension and Collaboration, SL.9-10.1

- **Speaking and Listening Standards 6-12:**

Presentation of Knowledge and Ideas, SL.9-10.4

## ISTE STANDARDS FOR STUDENTS (ISTE STANDARDS*S)

- **Standard 1:**

Creativity and Innovation

- **Standard 2:**

Communication and Collaboration

- **Standard 3:**

Research and Information Fluency

**Preparation**

**What You'll Need**

### MATERIALS YOU PROVIDE

- Paper
- Pencils

### REQUIRED TECHNOLOGY

- Internet Access: Required
- Tech Setup: 1 computer per small group, Microphone, Projector, Speakers

### PHYSICAL SPACE

- Classroom
- Computer lab

### GROUPING

- Large-group instruction

Hearing-impaired students can complete this activity with adaptation. Require groups to produce a transcript of their podcasts.

## OTHER NOTES

Because this activity is interdisciplinary, you may want to plan and teach it in collaboration with science, technology, and/or language arts teachers.

Before doing this activity:

- familiarize yourself with the various methods of creating podcasts. Methods can range from simply calling in and leaving a message that becomes the podcast to using computer software to record the podcast on your own. Be sure to read the how-to information provided for whatever method you decide to use; most podcasting websites include extensive online help features.

- review the podcasts from the selected podcast programs listed in step 5, as they change frequently. You can also download a specific podcast in advance. Brief podcasts of 5 minutes or less are best for this purpose.

# BACKGROUND & VOCABULARY

# Background Information

In the United States, industry accounts for one third of the total energy demand. Of that energy, an estimated 20 to 50 percent becomes wasted thermal energy, or waste heat. Since a percentage of energy is converted to heat, the overall efficiency of the system is reduced. Increasing the system's efficiency can conserve energy, as fewer energy resources are required to do the same work. One way to increase a system's efficiency is to capture the heat that is wasted and repurpose it. Recaptured heat can be used to heat a building or to heat water. It can be sold to nearby homes or industry for use. The water can be used on-site in industrial processes or as hot water for general purposes. Waste heat can also be used to generate steam, which can be used to drive mechanical processes or generate electricity. Cogeneration facilities are designed to use one energy resource to create both heat and electricity, taking

advantage of the thermal energy produced in the generation of electricity. Cogeneration and waste heat capture have been in use for hundreds of years. New technologies are making the process possible at lower temperatures than ever before. New technologies are also poised to convert thermal energy directly to electricity, similar to the way photovoltaics convert sunlight directly to electricity.

# Prior Knowledge

["<a href=\"http://energy.gov/eere/education/energy-literacy-essential-principles-and-fundamental-concepts-energy-education\">Energy Literacy Principle 1</a>: Energy is a physical quantity that follows precise natural laws.","<a href=\"http://energy.gov/eere/education/energy-literacy-essential-principles-and-fundamental-concepts-energy-education\">Energy Literacy Principle 2</a>: Physical processes on Earth are the result of energy flow through the Earth system.","<a href=\"http://energy.gov/eere/education/energy-literacy-essential-principles-and-fundamental-concepts-energy-education\">Energy Literacy Principle 3</a>: Biological processes depend on energy flow through the Earth system."]

# Recommended Prior Activities

- None

# Vocabulary

| Term | Part of Speech | Definition |
|------|----------------|------------|
| byproduct | noun | substance that is created by the production of another material. |
| case study | noun | form of problem-based learning, where the teacher presents a situation that needs a resolution. The learner is given details about the situation, often in a historical context. The stakeholders are introduced. Objectives and challenges are outlined. This is followed by specific examples and data, which the learner then uses to analyze the situation, determine what happened, and make recommendations. |
| cogeneration | noun | simultaneous generation of both electricity and heat from the same fuel, for useful purposes. Also called combined heat and power, or CHP. |
| electricity | noun | set of physical phenomena associated with the presence and flow of electric charge. |

| Term | Part of Speech | Definition |
|---|---|---|
| **energy conservation** | *noun* | process of using less energy, or using it more efficiently and sustainably. |
| **energy efficiency** | *noun* | use of a relatively small amount of energy for a given task, purpose, or service; achieving a specific output with less energy input. |
| **energy source** | *noun* | location in which the energy resource (oil, coal, gas, wind, etc.) is converted into electrical energy. |
| **industrial processes** | *noun* | procedures involving chemical or mechanical steps to aid in the manufacture of an item or items, usually carried out on a very large scale. |
| **on-site power generation** | *noun* | systems in which power is generated at multiple sources, close to sites of power consumption, as opposed to having a single, centralized power source. |
| **thermal energy** | *noun* | heat, measured in joules or calories. |
| **thermoelectric power plant** | *adjective* | power plant that uses a temperature difference between two materials to generate electricity. |
| **turbine** | *noun* | machine that captures the energy of a moving fluid, such as air or water. |
| **waste heat** | *noun* | byproduct of a fuel-burning or other industrial process that has no useful application. |
| **waste heat capture** | *noun* | any conservation system whereby waste heat (thermal energy) is captured with the goal of repurposing and using it instead of ejecting it into the environment as a byproduct. |

## For Further Exploration

### Articles & Profiles

- National Geographic News: Tapping Into the Electric Power of Heat

### Maps

- National Geographic Maps: Energy Realities

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