FUTURE U.

Boeing 360 Experience: Sustainable Aviation

Objectives

Students will:

- Compare and contrast renewable and nonrenewable energy sources
- Explain the importance of sustainable aviation fuels
- Research, experiment, and analyze the sustainability and efficiency of different sustainable aviation feedstocks

Overview

The Sustainable Aviation 360 Experience transports students around the world as they investigate how to make aviation environmentally sustainable through the use of biofuels. During the experience, students will explore three locations—a steel mill, a landfill, and a commercial forest—as they learn about the processes used to convert different feedstocks into fuel that can power planes. After the experience, students will apply what they have learned as they continue to research and experiment with various feedstocks in order to prepare recommendations for expanding Boeing's use of sustainable aviation fuels.

Grade Range

6–8

Timing

60 minutes

Materials Needed

- Devices with Internet access, at least one per every 2–3 students
- *Boot Up* handout, one per student
- Printed copies of the *Renewable Vs. Non-Renewable Energy Resources* article, enough for half the class (or the ability to access bit.ly/38BzfuU on a device)
- *Experience* handout, one per student
- Scissors, for the class to share
- Glue, for the class to share
- *Reorient #1* handout, one per student
- *Reorient #2* handout, one per student
- *Reorient #2* experiment materials:
    - For group of 3–4 students:
        - 15 grams of potato
        - 15 grams of corn kernels

  - 15 grams of one type of fruit
  - 6 grams of yeast
  - Three 20-ounce plastic bottles
  - 3 balloons
  - Measuring tape (or string and a ruler)
- For the class to share:
  - Scales, at least two
  - Something with which to grind the fruits and vegetables: hammer, mortar and pestle, rolling pin, etc.
  - Painter's tape
  - Markers
  - Faucet with warm water

Boot Up

Tell students that they will soon be participating in a simulation in which they explore how biofuels—which are a renewable energy source—are able to power planes. Explain that in order to understand the experience, it is important for students to understand the characteristics of renewable and non-renewable energy sources.

Divide students into pairs, and give a *Boot Up* handout to each student. Also distribute one *Renewable Vs. Non-Renewable Energy Resources* article to each pair, or instruct pairs to access the article on a device using bit.ly/38BzfuU.

Instruct students to read through the *Boot Up* directions and begin. When students finish, encourage pairs to share their responses to the final question.

Experience

Distribute an *Experience* handout (2 pages) to every student and review the instructions. Explain that students will be responsible for using the cards on page 2 to recreate the correct sequence of events for each biofuel as they move through the 360 Experience.

When the experience is complete, students should compare their sequences with a peer and then paste them on Page 1 so they can be referenced later.

Reorient

Two activity options are available for students to apply and synthesize their learning:

Reorient #1:

Student pairs will take on the role of process engineers as they investigate each of the experience's biofuels more thoroughly. Larger groups will then collaborate to provide a recommendation to Boeing on the biofuel they believe is the most effective, cost-efficient, and sustainable.

Reorient #2

Small groups will experiment with yeast fermentation to test the efficiency of new feedstocks. After examining three different feedstocks and tracking their fermentation over the course of one week, students will assess the viability of each feedstock as a sustainable biofuel source.

National Standards

Next Generation Science Standards

- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- Disciplinary Core Idea ESS3.D: Global Climate Change: Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5).

Standards for Technological Literacy

- 9H. Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

Common Core English Language Arts Standards

- CCSS.ELA-LITERACY.CCRA.R.1: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.
- CCSS.ELA-LITERACY.CCRA.W.1: Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence.
- CCSS.ELA-LITERACY.CCRA.W.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- CCSS.ELA-LITERACY.CCRA.SL.4: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

Boot Up Handout

Directions: You are about to learn more about *how* airplane power is shifting from fossil fuels (a non-renewable energy source) to biofuels (a renewable energy source). But before you do, it's important to understand *why* this is important.

With a partner, read the *Renewable Vs. Non-Renewable Energy Sources* article. As you learn about these energy sources, fill out the chart below.

Advantages of Renewable Energy Sources	**Similarities**	**Advantages of Non-Renewable Energy Sources**
Disadvantages of Renewable Energy Sources		**Disadvantages of Non-Renewable Energy Sources**

Then discuss and write: Based on what you learned about the advantages and disadvantages of renewable and non-renewable energy sources, why do you think air travel is shifting its focus to renewable energy sources?

_____

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FUTURE U.

Directions:

1. Cut out the cards on Page 2 before you begin the 360 Experience.
2. Then unscramble your cards and place them in the correct order in the flowcharts below as you get a behind-the-scenes look at the processes used to create three different types of sustainable aviation fuel.

Source	Feedstock	Lab Procedure	Sustainable Aviation Fuel ✓ Complete
Commercial Forests			Sustainable Aviation Fuel ✓ Complete
Landfills			Sustainable Aviation Fuel ✓ Complete
Steel Mills			Sustainable Aviation Fuel ✓ Complete

Forest residue (brush such as branches and fallen trees or remains from a harvest) that is removed in order to enhance forest health and safety can be used to create biofuels.

In the lab, organic and carbon-containing feedstock is placed under heat and pressure until it breaks down into a mixture of carbon monoxide, carbon dioxide, and hydrogen. This mixture of gases can then be built back up into sustainable aviation fuel!

When organic household waste decomposes, it releases carbon into the atmosphere. To create biofuel, this waste is removed from the landfill before it begins to decompose.

In the lab, feedstock gases are fed into large vats where different types of bacteria are growing. The bacteria absorb these gases and convert them into ethanol or other bio-alcohols. Once the alcohol is separated from the vat's water, it can be blended with gasoline or chemically converted into jet fuel!

Before it leaves through smoke stacks and pollutes the atmosphere, waste gas is captured and used to create sustainable aviation fuel.

In the lab, a process called Pyrolysis uses a combination of high pressure, high temperature, and a lack of oxygen to transform the feedstock into gas. The gases then travel through a condenser, where they are cooled and transformed into a liquid called biocrude oil. Once hydrogen is added to the biocrude oil during a second step called hydrotreating, it is transformed into a drop-in fuel that can be substituted for jet fuel!

Reorient #1 Handout, Page 1 of 2

Directions: You learned during the 360 Experience that industrial waste, community waste, and forestry residue can all be converted into sustainable aviation fuel.

You will now continue to research these feedstocks as you take on the role of a process engineer. Process engineers design, implement, and optimize industrial and chemical processes. In this position, you will further investigate each of these biofuels in order to provide a recommendation to Boeing for the biofuel that you believe is the most effective, cost-efficient, and sustainable.

Step 1: With a partner, use the research links below to learn more about each feedstock and answer the chart's questions.

Feedstock	**In your own words: How is this waste converted into biofuel?** **Tip:** Use your *Experience* handout to help you!	**What are some of the pros and cons of this feedstock? Consider how the biofuel's production process and use affects the environment.**
Forest Waste Research Links: • tinyurl.com/uurmq8f • tinyurl.com/uxpkt7f		
Community Waste Research Links: • tinyurl.com/y34dejv5 • tinyurl.com/scuqh94		
Industrial Gas Waste Research Links: • tinyurl.com/yckaxcph • tinyurl.com/y28s6z52		

Step 2: Pair with another group to form a committee of process engineers. Share your notes from Step 1 with each other, and then develop a recommendation that answers the following question:

> *If Boeing were to focus on one sustainable aviation fuel moving forward, which one would you recommend? Consider the process required to develop and use this fuel in large quantities, its effects on the environment, and how easily it can be replenished.*

Prepare your recommendation below!

Background: Did you know that the United States is the world's largest producer of ethanol?

In the 360 Experience, you explored how industrial gases can be processed to produce ethanol. Ethanol can also be produced from other natural sources through a process called fermentation. During fermentation, yeast and/or bacteria ingest sugar from feedstock in a low oxygen environment. This process produces ethanol, which can then be mixed with gasoline to power transportation!

Instructions: Today you will experiment with yeast fermentation to test the efficiency of potential feedstocks. It will ultimately be your job to determine how viable (or capable) each feedstock may be as a sustainable biofuel source.

Follow the steps below to complete your experiment:

1. Place two grams of yeast in each of the three bottles.
2. Grind the potato, corn, and fruit separately until a pulp is formed. Then measure out 15 grams of each, and place each one in a separate bottle.
3. Use the painter's tape to label each bottle with the feedstock inside ("potato," "corn," etc.).
4. Pour a little warm water into one deflated balloon at a time, until it begins to fill up slightly. Then immediately place the balloon on top of one of the bottles. The water should drop into the bottle, and the bottle will be sealed by the balloon.
5. Once each bottle is topped with a balloon, use the measuring tape (or the string and ruler) to measure the diameter of the balloon at its widest point. Then fill out the first row of the chart below with the date, feedstock types (potato, corn, etc.), balloon diameter, and any other observations you may have.
6. Shake the bottles until their contents are mixed, and place them in a warm or sunny part of the classroom.
7. Over the next seven to ten days, measure and observe the balloons at least four more times—each time noting your observations in the chart below.
8. When your observations are complete, move on to Part 2!

Date:	Feedstock Type	Balloon diameter	Other observations

Part 2:

1. **Review your experiment's results:** If carbon dioxide and ethanol were produced during fermentation (i.e. when the yeast in your balloons consumed the feedstock), what conclusions can you make?

   Hint: The growth of each balloon can help you gain a better idea of how much ethanol each feedstock may be capable of producing!

2. **Then discuss and write:**
   - Which feedstock seemed to produce the most ethanol? _____
   - Which feedstock produced ethanol the most quickly/efficiently? _____
   - Which feedstock was least efficient? _____
   - Did you observe anything else that may be important to note?
3. **Conclude:**
   - If you were to recommend that Boeing consider using one of the three feedstocks that you just tested, which one would you recommend and why?

   - What else may you need to test or consider in order to strengthen your recommendation?