Objectives	Assessments
Participants are able to track energy in its various forms (solar and chemical) in the conversion of sunlight to biomass to fuel.	Activities, review, end quiz.
Participants can name one reason that biofuels are a step toward a more sustainable fuel source.	Discussion, end quiz.
Participants value research about alternative natural fuel sources generated from biomass.	End quiz.

Standards

PS3.D (9-12) Photosynthesis is the primary biological means of capturing radiation from the sun; energy cannot be destroyed, it can be converted to less useful forms.

Materials (per student group)

- Mortar and Pestle
- Dried Corn
- Ziploc Bags
- Sugar
- Yeast
- Biospoons
- Warm Water
- Corn Grits
- Enzyme
- Alcohol Burner
- Ethanol (can be substituted with ethyl alcohol)

Preparation

Prepare corn, sugar, and yeast in containers or bags. Place each set of materials in a group basket or bucket for easy pickup and cleanup. Prepare all demonstrations.

Introduction/Engagement:

1. Begin by asking the students “Who knows what we’re learning about today?” If they do not know, tell them “Biofuels.” Either way, follow up with the question “What are biofuels?” You can record answers for assessment reasons, or simply proceed by saying letting students know that today they will get to explore what biofuels are and how they are made in detail.

2. **Discussion:** Ask "Who can tell me what fuel (the kind in your car) is? What is it made out of? Are there any other kinds of things that we can turn into fuel?" Perform a Think-Pair-Share (T-P-S) about things that can be used to make fuel for a car/things that cannot fuel a car. For middle grades and lower, use cards with pictures and names of different items on them (corn, swift grass, algae, petroleum, rocks, metal, etc.) and have the kids sort the cards into "can be used for fuel" and "cannot be used for fuel." Add tape or sticky tack to the back of the cards so that students can post them on the board.

   After participants have shared their answers, go through the items and correct any mistakes (hold plants off until the end). When you get to plants, ask why some think that plants can be used (if no one thought that they could be, ask again if anyone thinks that they can). Ask what "bio" means, referring to biology if necessary (life), and where BIOfuels (emphasize bio) might come from. Ask "is it really possible to make a fuel from plants than can be used in a car?"
3. **Demo:** Perform this demonstration a safe distance from the students. Take a small amount of ethanol in an alcohol burner and explain to students that this has been made from plant matter. Explain that cars use fuels for combustion, and ask (by raise of hands) who thinks that this is capable of clean combustion. Wearing appropriate safety equipment, set the ethanol on fire. You may say something to the effect of: "Today we're going to learn how this (hold up corn, plants, etc.) can turn into this (hold up ethanol, still on fire).

Task:

4. **Discussion:** Explain to students that today we will be tracking energy. Where does the energy to make a plant come from? What does a plant require to live? This should lead to the idea that plants require carbon dioxide and energy from sunlight. Place a "CO2 + Sunlight" picture on the board and draw an arrow to a "biomass" picture.
5. **Discussion:** Ask "What do you think the first step of turning plants into a fuel is?" The answer is physical processing – or grinding. Lead students to this by asking facilitating questions. *(Optional) You may also review physical changes at this time.*
6. **Discussion:** Discuss/review observations briefly if students aren't familiar with making good observations. Good observations are highly descriptive, use an appropriate combination of the senses, and are recorded in detail.
7. **Hands-on Activity:** Have students use a mortar and pestle to grind up the plant, making observations. What part of the ground up plant do you think that we use? The answer – the mushy watery stuff, which is filled with cellulose. Cellulose is the sugar (energy) created by the plant in the process of photosynthesis.
8. **Discussion:** Follow up by talking about how this process looks in the real world. Put the "harvesting/processing/cellulose" picture on the board, drawing an arrow to it from "biomass." Show what corn looks like at this stage by passing around a vial of processed corn.
9. **Discussion:** Can we use this by itself? The answer is "no" – much like our own bodies, we have to make the energy more accessible. Does anyone know what our body uses to

do this? The answer is enzymes. Enzymes are specialized molecules that speed up the process of changing chemical structures.

10. **Demonstration:** Hold up a bag of corn grits (about 2 cups) and warm water (prepared using package instructions). Have students contribute a few observations about the corn grits, leading them to the idea that they have a thick consistency. Add ½ Tbsp. of enzyme and shake. Ask if anyone notices a difference. The students should notice that the bag of corn grits becomes noticeably thinner in consistency. Show what corn looks like at this stage by passing out small vials of biofuels in this stage of processing. Place the "enzymes convert cellulose to sugars" picture on the board.
11. **Discussion:** Even once the enzymes have converted cellulose, is it ready for use in a vehicle? The answer is no – we must undergo another process called fermentation (place the "fermentation" picture on the board). Does anyone know what fermentation is? Record answers, then provide a formalized definition of: "Fermentation is the process of using yeast or bacteria to metabolize sugars without oxygen (anaerobic respiration)." Quickly help kids to create their own definition of what this means, then indicate that we will watch the process of fermentation to discover what happens as a result.
12. **Discussion:** *(Optional) Review chemical changes and how they are different from physical changes.* Explain that before participants can begin, they will have to know what to look for. What observations can we make about a chemical reaction? What are some signs that a chemical change is taking place? (Precipitate forms, bubbles/gas forms, color change, temperature change, light, etc.).
13. **Instructions/Safety:** Quickly run through the instructions for the activity. Ask what potential safety concerns might be. Allow students to take a minute to put on the appropriate PPE (goggles and gloves, if desired).
14. **Hands-on Activity:** Have students follow instructions to complete the reaction processes. They should set up their fermentation bottles, then record detailed observations at timed intervals in their handout.

Sense-Making

15. **Discussion**: Lead a discussion amongst students, asking "What happened during the process of fermentation? What did you observe/notice? What do you think happened here? After the chemical change, do we have the same output as we had input?" The answer to this is clearly "no," as the output has both changed in appearance, there was an increase in gas, and the signs of a chemical change were observed. During this process, cellulose was also converted into glucose, which is an easier to access sugar.
16. **Discussion:** Follow up by asking: "Can we use this as it is for fuel? Why/why not?" The answer is that it still requires refinement. Place the "Purification and Refinement" picture on the board.
17. **Discussion/Demo:** In the end, why biofuels? Why not gasoline? There are many reasons, but three that students should walk away with:
    a. *Reason 1:* Demonstrate both fuel and ethanol burning with a watch glass a safe distance above both. Have participants make observations about how the fuel

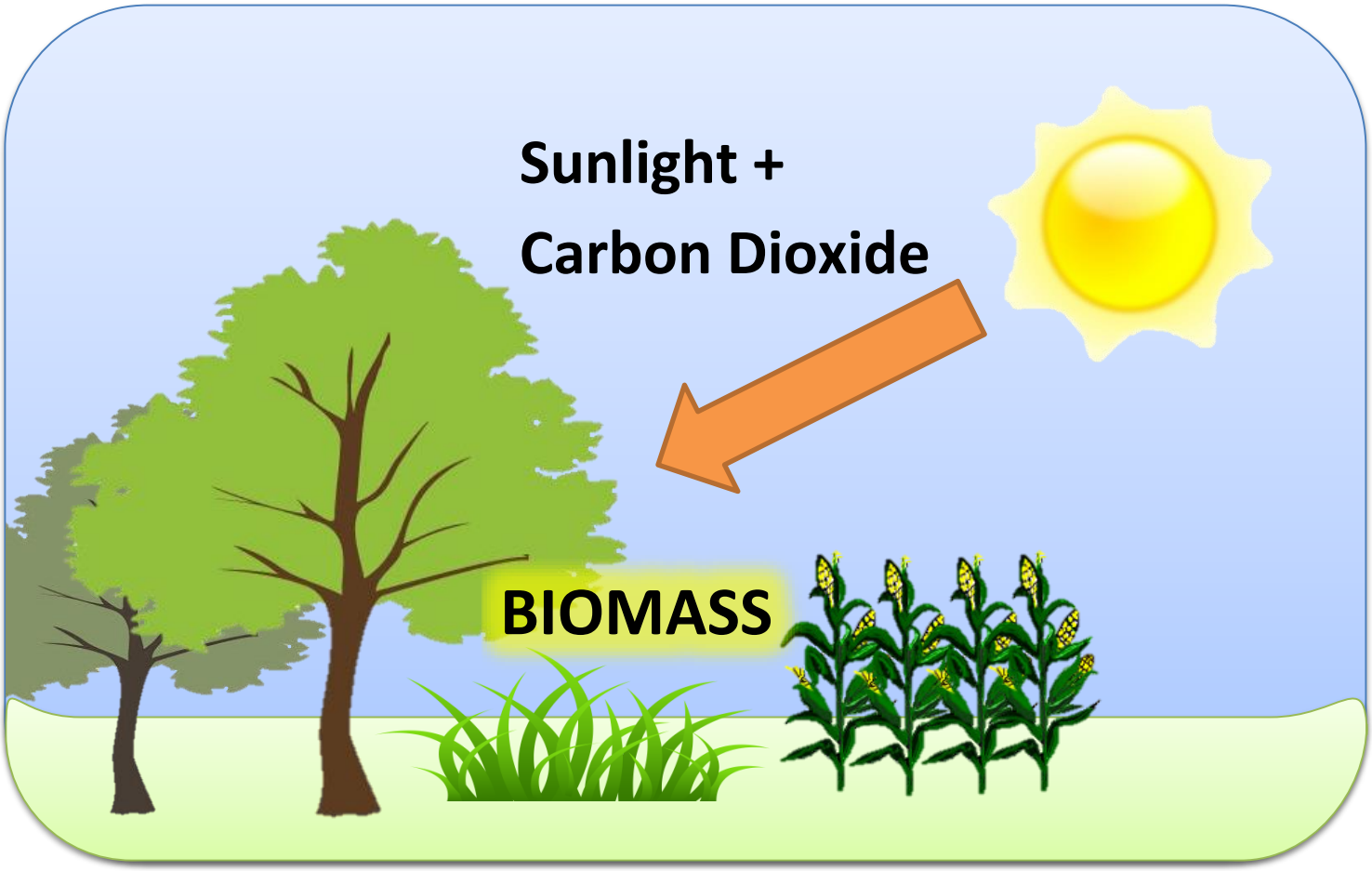
burns and about the glass. One reason to rely on biofuels is to remove this excess pollution – although biofuels still emit, carbon dioxide, they are a cleaner burning fuel.

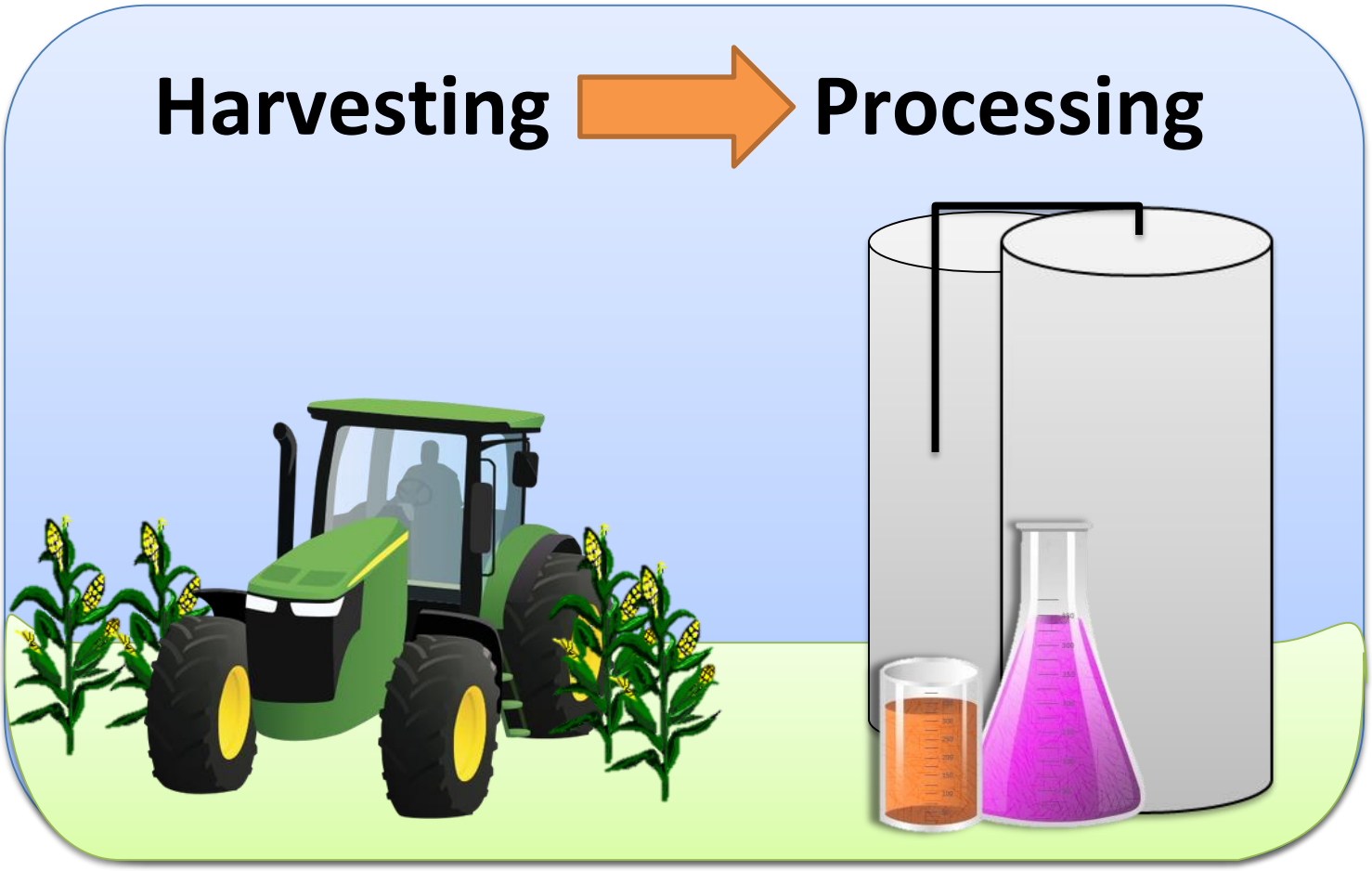
b. *Reason 2:* The second reason is simple. Ask students where the carbon dioxide comes from for fossil fuels. The answer? Underground. We are digging up ancient CO2 and adding this to our environment. But biofuels contribute CO2 too, don't they? To put it simply, no. Biofuels like ethanol return the same Carbon Dioxide that was used in photosynthesis. The environment does not suffer a net gain in carbon dioxide.
c. *Reason 3:* Sustainability! Fossil fuels are limited in supply, and are non-reusable. They take millions of years to form, and cannot be replaced in a timeline that suits our needs. Biofuels, on the other hand, can be grown to suit our needs.

18. **Discussion:** Ask "What can the refined version become? Just biofuels?" Show how it can be used to replace petroleum in plastics, and discuss environmental impacts. Pass out biospoons, demonstrating one example of petroleum-replacement uses.

Conclusion

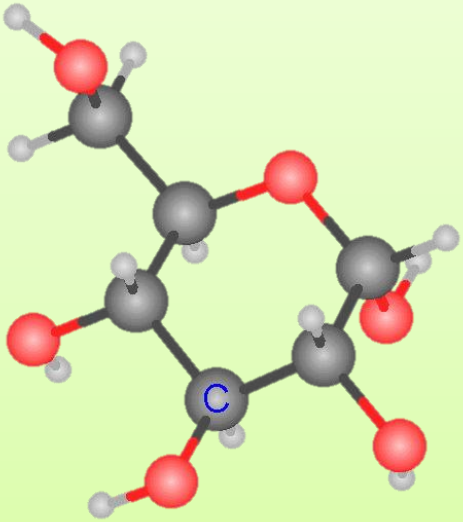
19. **Quiz:** Review the energy steps from the board, then ask who thinks that they know the steps. Remove the pictures and quiz the students, asking them to draw and present the process of converting biomass to fuel and following energy from the sun to your car (bonus points for students who draw carbon dioxide as a result of your car, and double bonus points for those who draw an arrow back to the beginning of the process). Students can also complete this by arranging mini-pictures. You can run this like a competition with a "winner" and a special prize, but in the end, all individuals that appear to try their best during this quiz should receive a free biospoon.
20. **Review (optional):** Ask students what they know about biofuels, including one reason that they are a step in the right direction. Have them return to their answers at the beginning of the lesson to compare.


Sunlight +
Carbon Dioxide
BIOMASS


Harvesting
Processing

Processing

Enzymes break cellulose down into sugar



Fermentation

Respiration without oxygen to form ethanol

Purification and Refinement

Respiration without oxygen to form ethanol