POWERING THE FUTURE LEARNING LAB

FUELING STEM INNOVATION

BIOFUELS BASICS CURRICULUM

Discover the world of biofuels as a more sustainable option for fuel through a fun, interactive game. Then students transform into agronomists to turn plants into energy through the fermentation process.

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POWERING THE FUTURE LEARNING LAB

BIOFUEL BASICS

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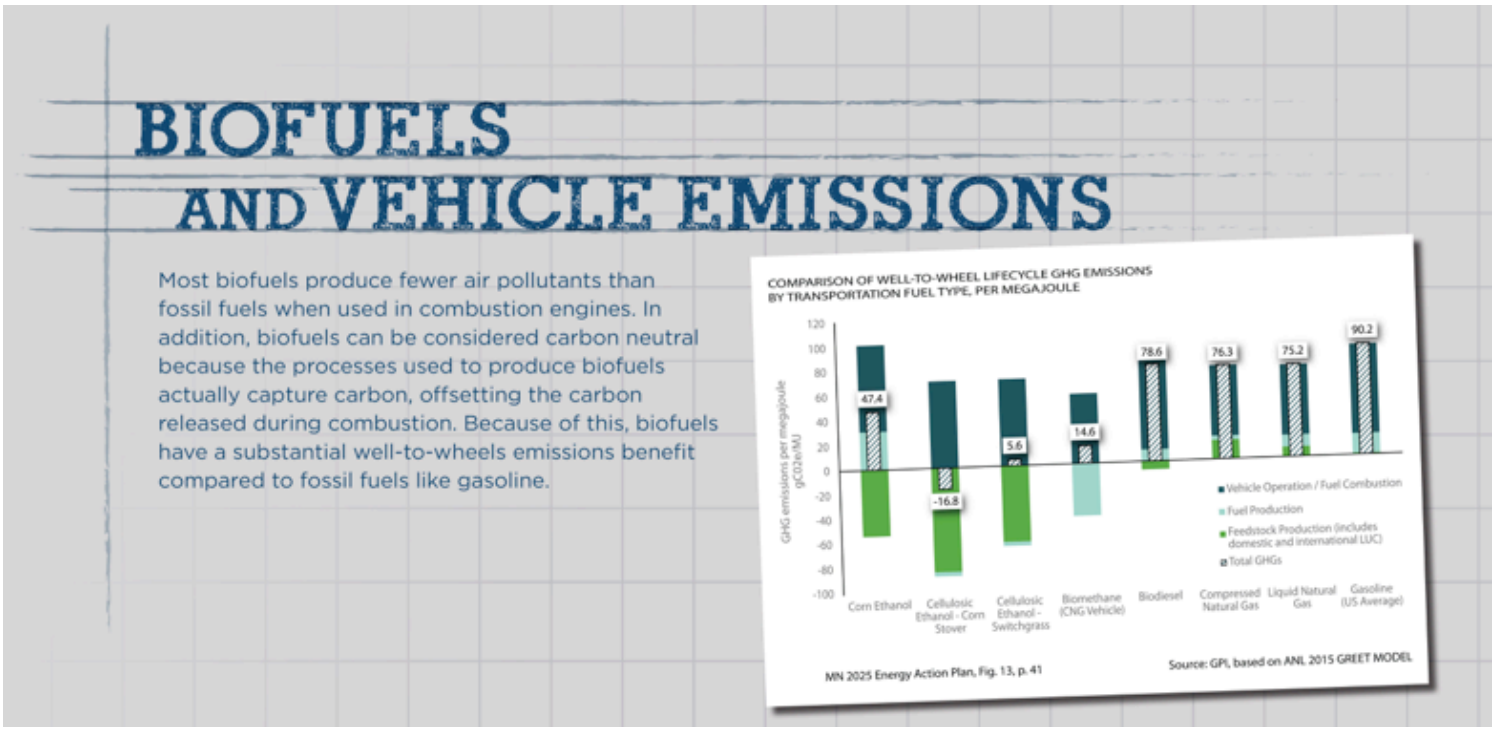
BIOFUEL BASICS

INTRODUCTION:

Since the rise of the automobile, car designers and engineers have explored using different fuels to power vehicles. While gasoline became the main fuel due to its energy potential (amount of energy by volume) and availability, over time the negative consequences of using fossil fuels to power our cars have become more and more apparent. There are three main concerns:

1. There is a finite supply of fossil fuels—fossil fuels are nonrenewable meaning that there is a fixed amount of supply on the earth and that supply cannot be replenished in a lifetime.
2. Currently, and throughout history, the United States has relied on other countries to meet the demand for fossil fuels (gasoline)—the United States doesn't produce enough fossil fuels to meet the nation's demand. By reducing our use of fossil fuels, we can increase our energy independence.
3. Today's combustion engines work by burning fuel, in most cases gasoline or diesel (a fossil fuel). Byproducts from this process exit the car as exhaust. These emissions are the main source of pollutants from automobiles. Emissions from individual vehicles are relatively low, but emissions from millions of cars on roads all over the world add up, becoming the largest source of environmental pollutants to date.

Because of these environmental, political, and economic reasons, the need and desire to find alternative solutions to fossil fuel usage is on the rise. Biofuels are playing a part in a more sustainable solution moving forward!

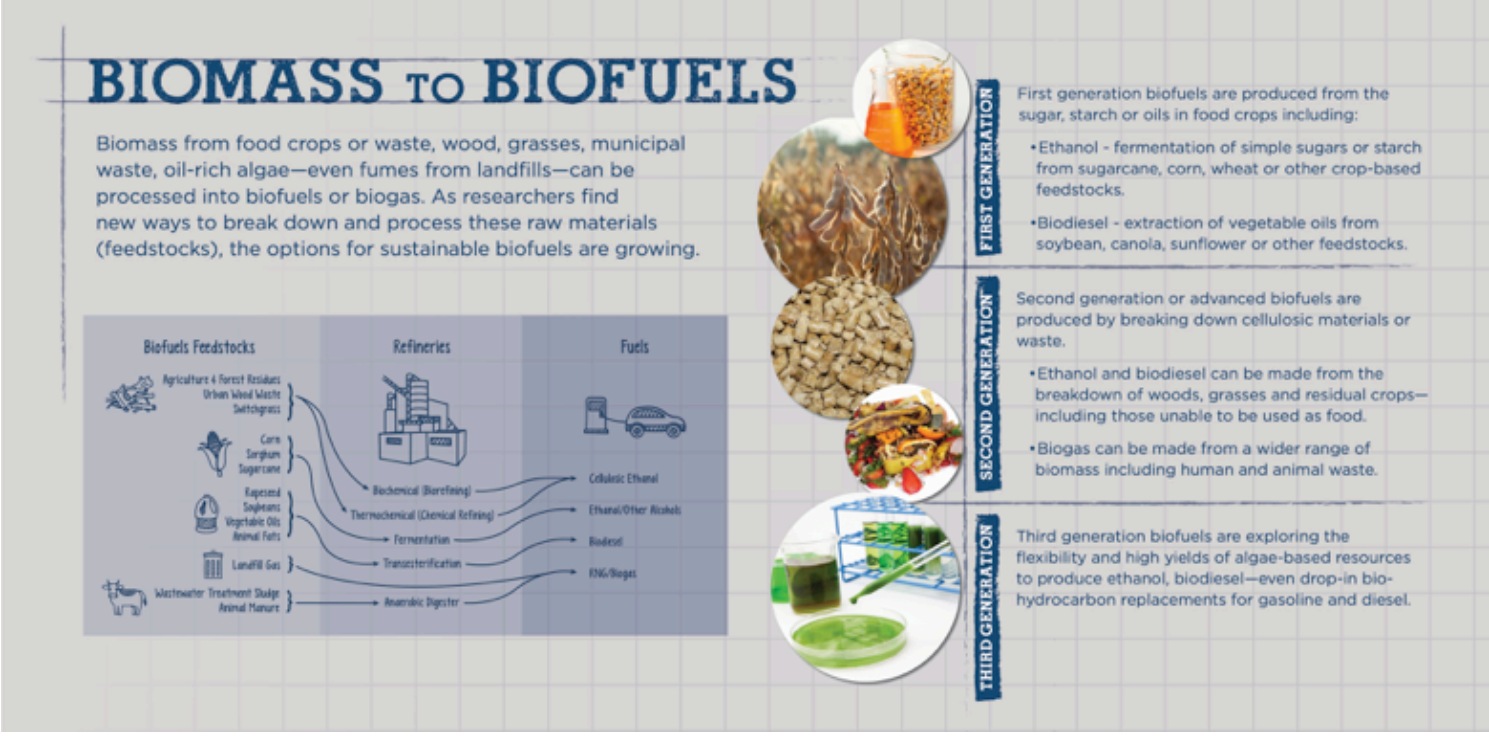


Powering the Future learning Lab @ LeMay – America's Car Museum

BIOFUEL BASICS

What are Biofuels?
Organic material from plants and animals is called biomass. Biomass can include wood, grasses, crops, garbage—even animal or human waste. It can be burned directly or converted to other usable forms of energy (biofuels) such as methane gas, ethanol or biodiesel for transportation fuels. The most common forms of biofuels are ethanol and biodiesel, but there are also renewable natural gas (RNG) and butanol.

In the United States, ethanol fuel is made primarily from corn. Biodiesel is typically made from soybean oil, but can also come from other plants like sunflowers and recycled oils from restaurants.



Powering the Future Learning Lab @ LeMay – America's Car Museum

Biofuels are blended in small amounts into gasoline and diesel helping to reduce emissions and increase energy security. Biofuels can also be used in higher blends in cars and trucks made or modified to utilize this renewable fuel. Ethanol is commonly blended at a 10% to 15% in most gasoline in the U.S. Ethanol is also available as E85 (or flex fuel) containing more than 50% ethanol to gasolline. Biodiesel can be blended and used in many different concentrations. The most common are B5 (up to 5% biodiesel) and B20 (6% to 20% biodiesel). B100 (pure biodiesel) is typically used as a blendstock to produce lower blends and is rarely used as a transportation fuel.

BIOFUEL BASICS

Biofuel Benefits:

- Biofuels are less toxic than fossil fuels and many are biodegradable.
- Biofuels can be produced here in the United States from renewable resources, providing domestic jobs and energy security.
- The combustion of biofuels including biodiesel and ethanol produces fewer pollutants than fossil fuels.
- The US government considers biofuels to be carbon neutral, because the carbon that is released by these fuels is the same carbon that is captured when crops are grown to make these fuels.
- Biofuels cause far less damage than petroleum fuels if spilled or released into the environment.

First Generation Biofuels:

Biodiesel:
Biodiesel is the second most common biofuel and can be used in diesel-powered vehicles and equipment or as heating oil. An advantage of using biodiesel is that it is a renewable resource that can be produced from new or waste vegetable-based oil. Producing biodiesel from waste vegetable oil from restaurants and other sources reduces the waste that would normally end up in a landfill. Biodiesel is made by extracting the glycerin from oil using heat, ethanol or methanol and potassium hydroxide or sodium hydroxide. After the removal of the glycerin you must also remove the methanol before use either by recapturing or evaporation, as it is too volatile to remain in the fuel.

Unfortunately, biodiesel has lower energy potential when compared to petroleum-based diesel, so it requires more fuel for the same outcome. Also, the cloud point (temperature that wax starts to form making the fuel too viscous for the system) happens at a much higher temperature, which limits cold temperature usage.

Ethanol:
Ethanol is the most common biofuel and can be produced from any vegetable matter (feedstock). However, plants like corn that are high in sugar and easy to break down, produce more ethanol in the same process compared to other feedstock like wood.

Ethanol's main benefits are that it is renewable and it burns significantly cleaner than fossil fuels.

However, like biodiesel, ethanol has very poor energy potential (1.3 gal. E85 ethanol = 1 gal. gasoline) and there are drivability concerns in cold weather. Significant energy and resources are also required to grow, harvest, and convert plant matter into ethanol, and ethanol is corrosive and non-lubricating, so it requires special fuel systems.

Second Generation Biofuels:

These fuels are produced from cellulosic fuel crops that can be grown on land generally unsuitable for food crops. The waste products from food crops can also be used.

BIOFUEL BASICS

Renewable Natural Gas (RNG):
Renewable Natural Gas (also known as biomethanol, biomethane or biogas) can be produced from waste biomass. Some ready sources are landfills and sewage treatment facilities.

Some benefits of RNG are:

- RNG can be turned into a clear water soluble liquid that is biodegradable.
- RNG can be used in conventional engines and can be delivered within our existing infrastructure.
- RNG uses an existing waste stream for its source.

Unfortunately, like both ethanol and biodiesel, RNG has lower energy potential when compared to fossil fuels like gasoline.

Renewable Diesel (RD):
There are several methods of producing Renewable Diesel the most common is Hydrotreated Vegetable Oil (HVO). It is produced using a similar method as fossil diesel with almost identical performance, enabling it to be a direct replacement fuel i.e. drop-in biofuel. RD can also be produced from waste oils and fats. Another method for producing RD is discussed below as a third generation biofuel.

Third Generation Biofuels:

These fuels are made from algae. While they are still in the research and development stage, they are showing much promise for producing a more environmentally friendly sustainable replacement for fossil fuels.

Renewable Diesel (RD):
Hydrothermal liquefaction of algal biomass is showing great promise in producing oil suitable for the production of RD.

Butanol:
Recent research spawned by a field-wide emphasis on sustainable energy sources has allowed for the usage of another biofuel: Butanol. Historically, its production has come from fossil-based sources, but recently, scientists have discovered that butanol can be produced from biomass, especially algae and poplar trees (wood.)

What sets butanol apart from the other biofuels is that it actually has very good energy potential. In fact, butanol's energy potential is almost equal to gasoline. Additionally, it is sustainable and requires very little land and resources to produce, leading to less CO2 emissions. Butanol is still in the early stages of research and testing, but it may be one of the best options as a drop-in biofuel to power our vehicles in the future.

BIOFUEL BASICS

GOAL:

Students comprehend the chemical process of fermentation and its association with biofuels.

OBJECTIVES:

- Students observe and record three different fermentation processes utilizing sugar, starch, and cellulose
- Students hypothesize reasons for the differences in the resulting outcomes of the fermentation processes for each type of biomass
- Students apply their observations to understand that fermentation is the chemical process of converting sugar to ethyl alcohol and that it produces energy

MATERIALS:

- Packets of yeast (or the equivalent) for each student
- Teaspoons for each student
- Starch, sugar, or cellulose for for each student
- Two cups of warm water in thermos to keep warm (or access to warm water)
- Balloons for each student
- Beakers or bottles holding 16 ounces of water for each student
- Masking tape
- Sharpies
- Measuring tapes

SET-UP:

1. Set beaker, balloon, sharpie, and measuring tape at each student's work area.
2. Place yeast at each student's work area (with teaspoon if applicable) and either sugar, starch, or cellulose.
3. Place container of warm water at front.

DISCUSSION:

Begin by handing out the Investigation Notebooks and having a conversation about biofuels to introduce the lesson and gauge the students' existing knowledge of the subject matter. Explain that automotive engineers and researchers today are spending a lot of resources on alternatives to fossil fuels to power our vehicles. Fuels for our vehicles fall into three categories and each has its pros and cons. Some of the fuels that they are looking at are being used in cars on the road today and others are still in the early stages of research. Ask students to share some examples of ways that we currently power our vehicles. Students may suggest gasoline or electricity. Explain that those two options fall into two of the three larger categories: Fossil Fuels and Secondary Energy Carriers. The other category is Biofuels. Ask students if they have ever heard of biofuels, and if so, do they have any examples they can share. If they have not, ask if they have any guesses based on the word including "bio" and "fuels."

BIOFUEL BASICS

Share that biofuels are produced using biomass or organic material from plants and animals. Biomass can include wood, grasses, crops, garbage-even animal or human waste. It can be burned directly or converted to other usable forms of energy. Some students may have heard of ethanol, a biofuel made mostly from sugar found in corn, which is added to most of the gasoline in the United States. But there are actually a lot of different types of biofuels: such as methane gas, or biodiesel for transportation fuels. And there is a case to be made that biofuels might be the fuel of the future.

Further the conversation by asking the big question: why do we care? Why are companies, governments, schools, etc. putting so much time and energy into researching new fuels? Ask students to turn to the Renewable vs. Non-renewable energy section of their Investigation Notebooks and explain that fuels are either renewable or non-renewable forms of energy. Ask students if they can share a definition for each and then some examples of each. What concerns do we have about using fossil fuels like gasoline?

1. There is a finite supply of fossil fuels—fossil fuels are non-renewable, meaning there is a fixed supply on the earth and that supply cannot be replenished in a lifetime.
2. Currently, and throughout history, the United States has relied on other countries to meet the nation's demand. By reducing our use of fossil fuels, we can increase our energy independence.
3. Today's combustion engines work by burning fuel, in most cases gasoline or diesel (a fossil fuel.) Byproducts from this process exit the car as exhaust. These emissions are the main source of pollutants from automobiles. Emissions from individual vehicles are relatively low, but emissions from millions of cars on roads all over the world add up, becoming one of the largest source of environmental pollutants to date.Place yeast at each area (with teaspoon if applicable) and either sugar, starch, or cellulose.

Explain that because of these environmental, political, and economic reasons, the need and desire to find alternative solutions to fossil fuel usage is on the rise. Biofuels are playing a part in a more sustainable solution moving forward!

PROCEDURE:

Explain to students that they will be completing a fermentation experiment. Each student should have the materials to blow up a balloon by creating ethanol, thus generating heat from the process of fermentation—the chemical breakdown of a substance. Make sure students understand that ethanol is a biofuel. Along with learning the positives and negatives of various fuels while playing the game, they will also demonstrate how we produce biofuels, in this case ethanol.

How can we make fuels from plants?

- Biofuels like ethanol and butanol are produced by yeast (fungus), bacteria and other microbes through a process called fermentation that converts plant sugars to alcohol compounds.
- Plant sugars come from three main sources: glucose, which is dissolved into plant fluids and makes them taste sweet, starch, which is a chain of glucose molecules that is found in things like corn and potatoes, and cellulose, which makes up the cell walls of plants and allows them to stand up straight. Cellulose is the most abundant of the three in nature.

Each student will have a packet of yeast, needed for the fermentation process, as well as either a sugar, starch, or cellulose. Have students write what component they have on a piece of masking tape and attach it to the beaker. Then, prepare the balloon. Once they have placed the dry ingredients in the beaker, have students add the warm water and instruct them to put the balloon on top. Ask students what evidence they think they might find that fermentation has occurred. Explain that they will need to make observations and measurements in their Investigation Notebooks during the experiment. Show students the worksheet they will be referencing and emphasize the need to make predictions and inferences. Show how they can make measurements of balloon circumference and where they can record observations. Students will be recording observations at 5-minute intervals.

WRAP-UP DISCUSSION:

Ask students to share their observations from the fermentation experiment: How successful was the energy generated by fermentation? Which food source was most successful and why do they think that?

FURTHER READING:

- Alternative Fuels Data Center – https://afdc.energy.gov/
- Biofuels – https://learnbioenergy.org/
- National Energy Education Development – https://www.need.org/
- The Center for Bioenergy Innovation – https://cbi.ornl.gov/
- America's Car Museum – Powering the Future https://www.americascarmuseum.org/explore/exhibits/powering-future-learning-lab/

STANDARDS ADDRESSED:

Next Generation Science Standards (NGSS):

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-5 Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred

MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society

GLOSSARY:

Biofuels – Fuels derived directly from living matter (biomass).

Biomass – Organic material from plants and animals.

Emissions – Waste gases given off by industrial and power plants, automobiles and other processes.

Energy Density – The amount of energy that can be stored in a given mass of substance or system.

Fermentation – The chemical breakdown of a substance.

Fossil Fuel – A natural fuel, such as coal, oil, or gas, which was formed from the remains of living organisms in the geological past.

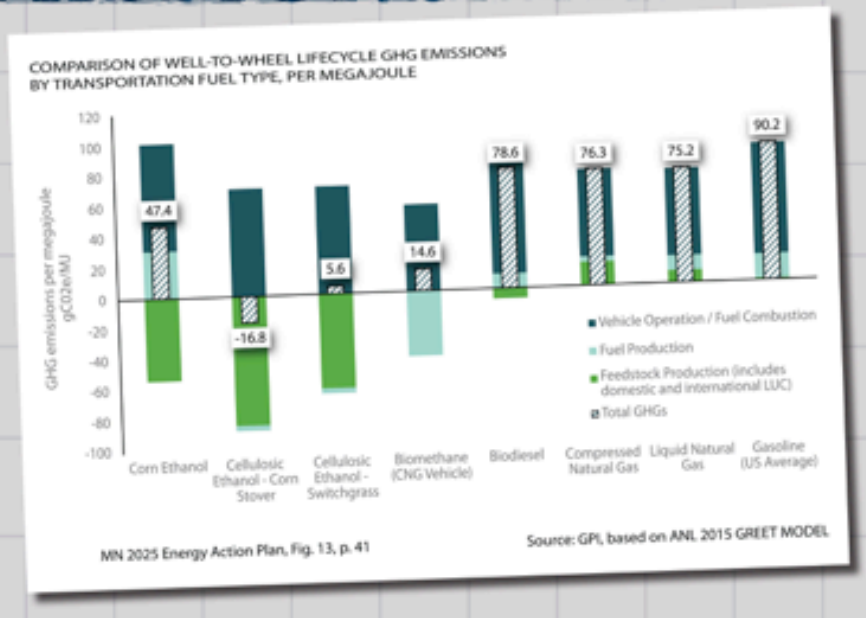
Nonrenewable Energy – Energy sources that have a fixed amount of supply on the earth, because they take a long time to form. Petroleum and natural gas are examples.

Potential Energy – Mechanical or stored energy from an object that comes from factors such as its position relative to others, internal stress, electric charge or its condition rather than motion.

Sustainability – Meeting the needs of the present without compromising the ability of future generations to meet their needs.

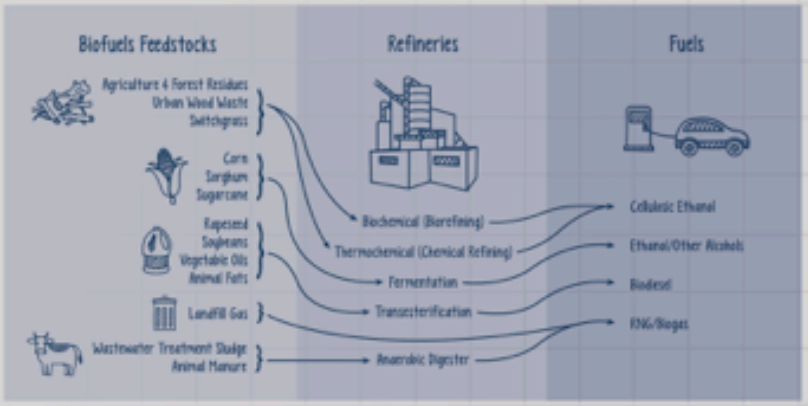
BIOFUELS AND VEHICLE EMISSIONS

Most biofuels produce fewer air pollutants than fossil fuels when used in combustion engines. In addition, biofuels can be considered carbon neutral because the processes used to produce biofuels actually capture carbon, offsetting the carbon released during combustion. Because of this, biofuels have a substantial well-to-wheels emissions benefit compared to fossil fuels like gasoline.



BIOMASS TO BIOFUELS

Biomass from food crops or waste, wood, grasses, municipal waste, oil-rich algae—even fumes from landfills—can be processed into biofuels or biogas. As researchers find new ways to break down and process these raw materials (feedstocks), the options for sustainable biofuels are growing.



FIRST GENERATION

First generation biofuels are produced from the sugar, starch or oils in food crops including:

- Ethanol - fermentation of simple sugars or starch from sugarcane, corn, wheat or other crop-based feedstocks.
- Biodiesel - extraction of vegetable oils from soybean, canola, sunflower or other feedstocks.

SECOND GENERATION

Second generation or advanced biofuels are produced by breaking down cellulosic materials or waste.

- Ethanol and biodiesel can be made from the breakdown of woods, grasses and residual crops—including those unable to be used as food.
- Biogas can be made from a wider range of biomass including human and animal waste.

THIRD GENERATION

Third generation biofuels are exploring the flexibility and high yields of algae-based resources to produce ethanol, biodiesel—even drop-in bio-hydrocarbon replacements for gasoline and diesel.

INVESTIGATION NOTEBOOK

NAME _____

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ENERGY SOURCES

Draw a picture or write a sentence describing energy:

Draw a picture or write a sentence describing fossil fuels:

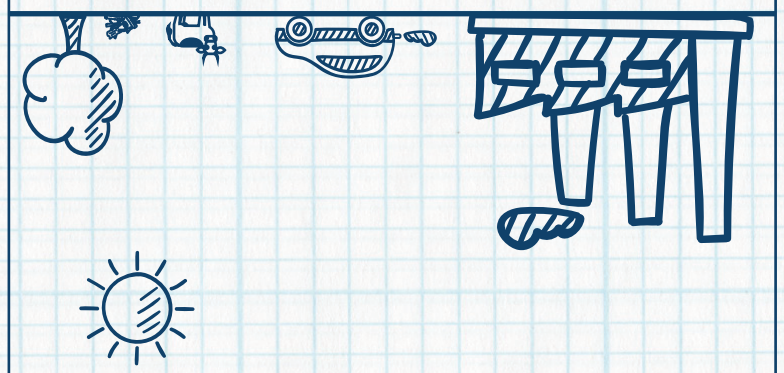
Draw pictures or list examples of renewable energy sources:

CARBON CYCLE

How does the carbon cycle work?

Humans breathe in oxygen and breathe out carbon dioxide (CO_2). Plants work the opposite way, they breathe in the CO_2 that humans and animals breathe out and they create oxygen using the process of photosynthesis. When organic material (plants and animals) decomposes the carbon that was contained in it is released into the ground. After millions of years, this carbon transforms into fossil fuels. When these fuels are burned, carbon dioxide is released into the atmosphere.

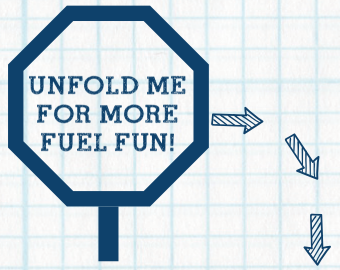
Based on the information provided, draw arrows in the diagram to show the cycle of carbon.



RENEWABLE VS NON-RENEWABLE ENERGY

What are some pros and cons of renewable vs. non-renewable energy?

Use the table to organize your ideas!



	RENEWABLE	NON-RENEWABLE
PROS		
CONS		

BIOFUELS & FERMENTATION: HOW CAN WE MAKE FUEL FROM PLANTS?

Experimental procedure:

1. Each student will be assigned one of three plant sources for your yeast.
2. Label your test tube with your assigned plant source, and add one teaspoon of your food source and one teaspoon of yeast. Mix contents.
3. Add 10mL of warm tap water to your test tube. As soon as the water is added, secure a balloon to the opening of the test tube.
4. Mix test tube gently and return to its stand. Watch for changes.
5. Take measurements and make observations at 5 minute intervals.

Before the experiment: Record your assigned food source and make predictions.

1. Which food source was assigned to your group: _____
2. What changes do you predict will happen over time?

_____

_____

During the experiment: Record your observations and measurements.

Start time:_____ End time:_____ Total time (min):_____

Time	0 min	5 min	10 min	15 min
Measure the width of the balloon and calculate its estimated volume: $V=4/3\pi(d/2)^3$				
Record observations & measurements (changes in appearance, smell, etc)				

After the experiment: Analyze and interpret your results. Summarize what you know about the substance in the test tube before and after the experiment:

1. What changes occurred during the experiment?

_____

_____

2. What evidence do you have?

_____

3. Propose an explanation for the changes you observed.

_____

4. Compare your results to the results with other food sources. What differences did you observe?

_____

_____

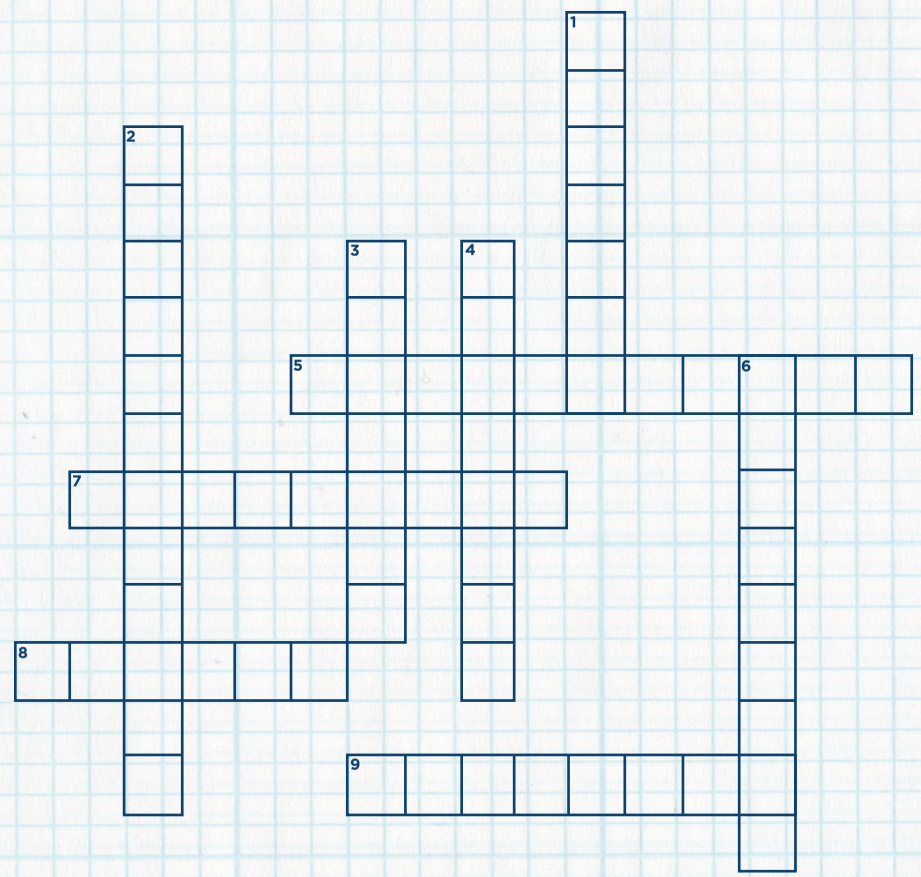
5. Propose an explanation for those differences.

_____

R	E	N	G	I	N	E	M	V	K	G
E	L	E	C	T	R	I	C	I	T	Y
N	G	J	J	N	L	Q	M	M	F	K
E	N	I	L	O	S	A	G	U	B	W
W	O	R	R	E	E	W	T	J	T	T
A	B	E	M	T	U	U	I	C	G	K
B	R	W	S	C	R	F	L	N	Z	J
L	A	O	L	E	A	E	O	Q	D	T
E	C	P	D	B	A	R	B	I	P	R
J	W	L	M	N	G	R	X	Y	B	L

Word Bank

Gasoline
Biofuel
Clean
Car
Future
Power
Electricity
Renewable
Carbon
Wind
Steam
Engine



Across

5. These energy sources are created over millions of years from the remains of living organisms. (Two words)
7. Energy sources that can be replenished within our lifetime are called this.
8. This type of vehicle combines the benefits of gasoline engines and electric motors.
9. This type of fuel cell can be used to power an electric motor without harmful emissions.

Down

1. This alcohol fuel is made from the fermentation of sugars found in plants.
2. Energy sources that have a limited amount of supply on the earth are called this.
3. This fuel source uses organic matter from plants and animals.
4. This petroleum product powers most vehicles in the United States.
6. These are the gaseous products of internal combustion engines. Some are pollutants.