POWERING THE FUTURE LEARNING LAB

FUELING STEM INNOVATION

ENERGY EXPLORATIONS CURRICULUM

This program includes virtual classroom visits and hands-on science kits developed by the America's Car Museum education team that explore the principles of energy and design. Museum educators will facilitate engaging hands-on activities for your students and will provide supplemental videos to further explore the various concepts covered during the live sessions.

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BOEING

Powering the Future Learning Lab

LESSON ONE: WHERE DOES ENERGY COME FROM?

State Farm presents
LeMay America's Car Museum®

WHERE DOES ENERGY COME FROM?

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.

Renewable vs. Nonrenewable Energy

<u>Nonrenewable Energy Sources:</u> Fuels that cannot be easily made or "regenerated" in a short period of time. We can use up nonrenewable fuels; nonrenewable fuels are finite.

Examples: oil, natural gas, propane, uranium, and coal

Nonrenewable energy sources come out of the ground as liquids, gases, and solids. We use crude oil to make liquid petroleum products such as gasoline, diesel fuel, and heating oil. Propane and other hydrocarbon gas liquids, such as butane and ethane, are found in natural gas and crude oil.

All fossil fuels are nonrenewable, but not all nonrenewable energy sources are fossil fuels

- Coal, crude oil, and natural gas are all considered fossil fuels because they were formed from the buried remains of plants and animals that lived millions of years ago.
- Uranium ore, a solid, is mined and converted to a fuel used at nuclear power plants. Uranium is not a fossil fuel, but it is classified as a nonrenewable fuel.

<u>Renewable Energy Sources:</u> Fuels that can be easily made or "regenerated"—generally within a human's lifetime. We can never use up renewable fuels.

Examples: hydropower (water), solar, wind, geothermal, and biomass

WHERE DOES ENERGY COME FROM?

What role does renewable energy play in the United States?

Up until the mid-1800s, wood supplied nearly all of the nation's energy needs. As more consumers began using coal, petroleum, and natural gas, the United States relied less on wood as an energy source. Today, the use of renewable energy sources is increasing, especially biofuels, solar, and wind. Renewable energy plays an important role in reducing greenhouse gas emissions. When renewable energy sources are used, the demand for fossil fuels is reduced. Unlike fossil fuels, non-biomass renewable sources of energy (hydropower, geothermal, wind, and solar) do not directly emit greenhouse gases.

In 2016, about 10% of total U.S. energy consumption was from renewable energy sources. About 55% of U.S. renewable energy use is by the electric power sector for producing electricity, and about 15% of U.S. electricity generation was from renewable energy sources in 2016. The consumption of biofuels and other nonhydroelectric renewable energy sources more than doubled from 2000 to 2016, mainly because of state and federal government mandates and incentives for renewable energy. The U.S. Energy Information Administration (EIA) projects that the use of renewable energy in the United States will continue to grow through 2040.

Why don't we use more renewable energy?

In general, renewable energy is more expensive to produce and to use than fossil fuel energy. As with most things, it is difficult for large changes to be made. In this case, not only would converting to a renewable energy grid require people to change their opinions of the ways things have "always been done", but the energy infrastructure would need to be completely rebuilt and transformed—this costs a lot of money up front! Favorable renewable resources are often located in remote areas, and it can be expensive to build power lines from the renewable energy sources to the cities that need the electricity.

In addition, renewable sources are not always available:

- Clouds reduce electricity from solar power plants.
- Days with low wind reduce electricity from wind farms.
- Droughts reduce the water available for hydropower.

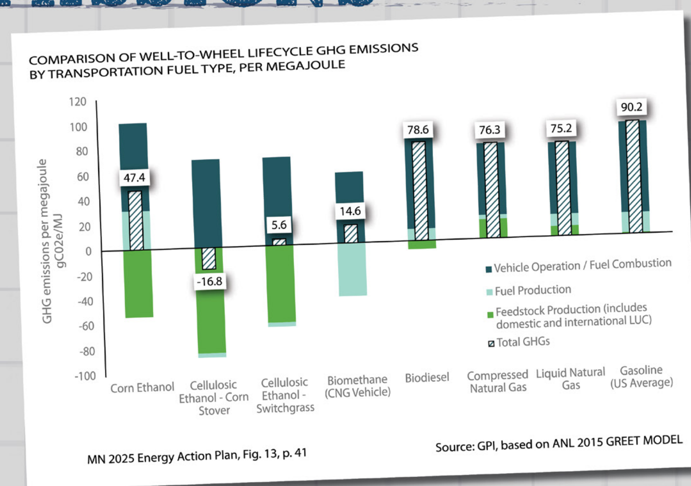
What is the Carbon Cycle, and why do we care?

The carbon cycle describes the process in which carbon atoms continually travel from the atmosphere to the Earth and then back into the atmosphere. Carbon dioxide is a greenhouse gas that traps heat in the atmosphere. We need it to stay warm. Without greenhouse gasses, our planet would freeze and we would be unable to sustain life. However, humans have been dramatically increasing the amount of carbon dioxide we put into the atmosphere by burning fossil fuels. We have more CO2 in our atmosphere now than we have in the last 420,000 years.

ENERGY EXPLORATIONS VIDEO

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.



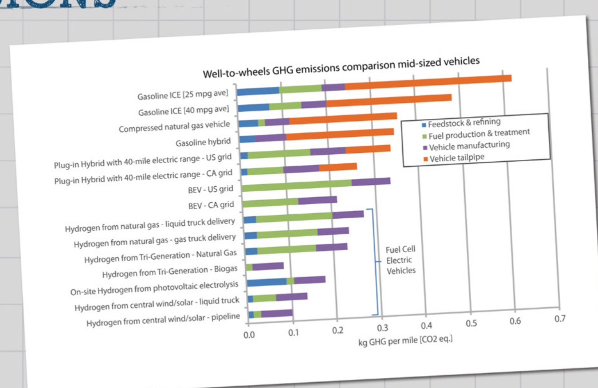
ELECTRICITY AND VEHICLE EMISSIONS

There are two main types of vehicle emissions:

- **Air pollutants** contributing to smog, haze and air quality
- **Greenhouse gases (GHG)** including carbon dioxide and methane

Both categories of emissions can be evaluated on a direct basis and a well-to-wheels basis.

- **Direct emissions** are emitted through the tailpipe, as well as through evaporation from the vehicle's fuel system and during the fueling process—hydrogen-powered, all-electric, and plug-in hybrid electric (while in all-electric mode) vehicles produce zero direct or tailpipe emissions.
- **Well-to-wheels** emissions include air pollutants and greenhouse gases (GHG) related to fuel production, processing, distribution and use (direct emissions).



Advanced Power and Energy Program University of California at Irvine, 2013

Electric Emissions:

All-electric vehicles don't even have a tailpipe, but emissions may be produced by the source of electrical power, such as a power plant. In regions that use relatively low-polluting energy sources for electricity generation, PHEVs and EVs typically have a well-to-wheel emissions advantage over similar conventional vehicles running on gasoline or diesel. In regions that depend heavily on conventional fossil fuels for electricity generation, PHEVs and EVs may not demonstrate a well-to-wheel emissions benefit.

Hydrogen Emissions:

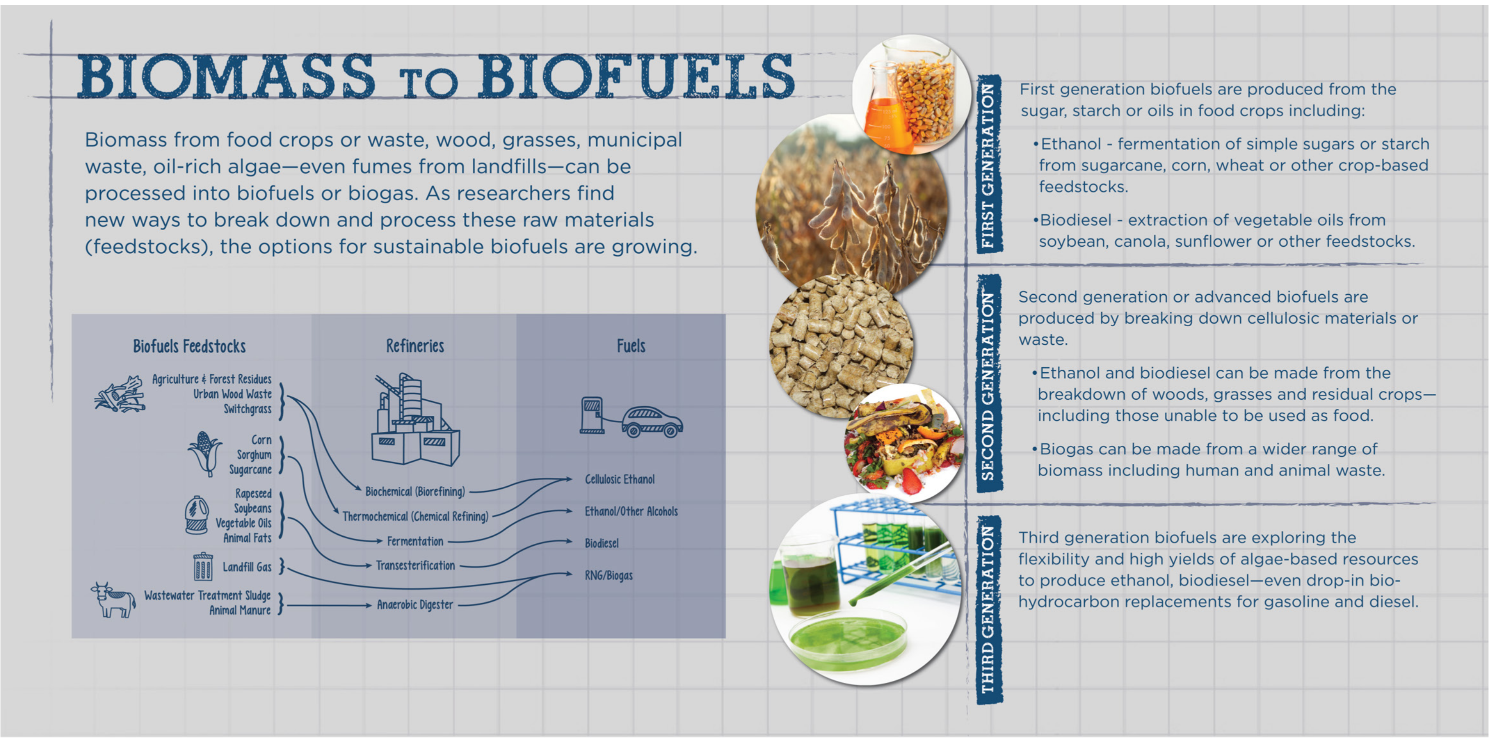
Hydrogen fuel cells are an energy technology that produces only electricity and water vapor. Hydrogen can be produced using renewable energy sources such as wind or solar, which avoids the harmful emissions from producing other kinds of energy.

ARE BIOFUELS THE ANSWER?

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.

ARE BIOFUELS THE ANSWER?

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.

ARE BIOFUELS THE ANSWER?

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:

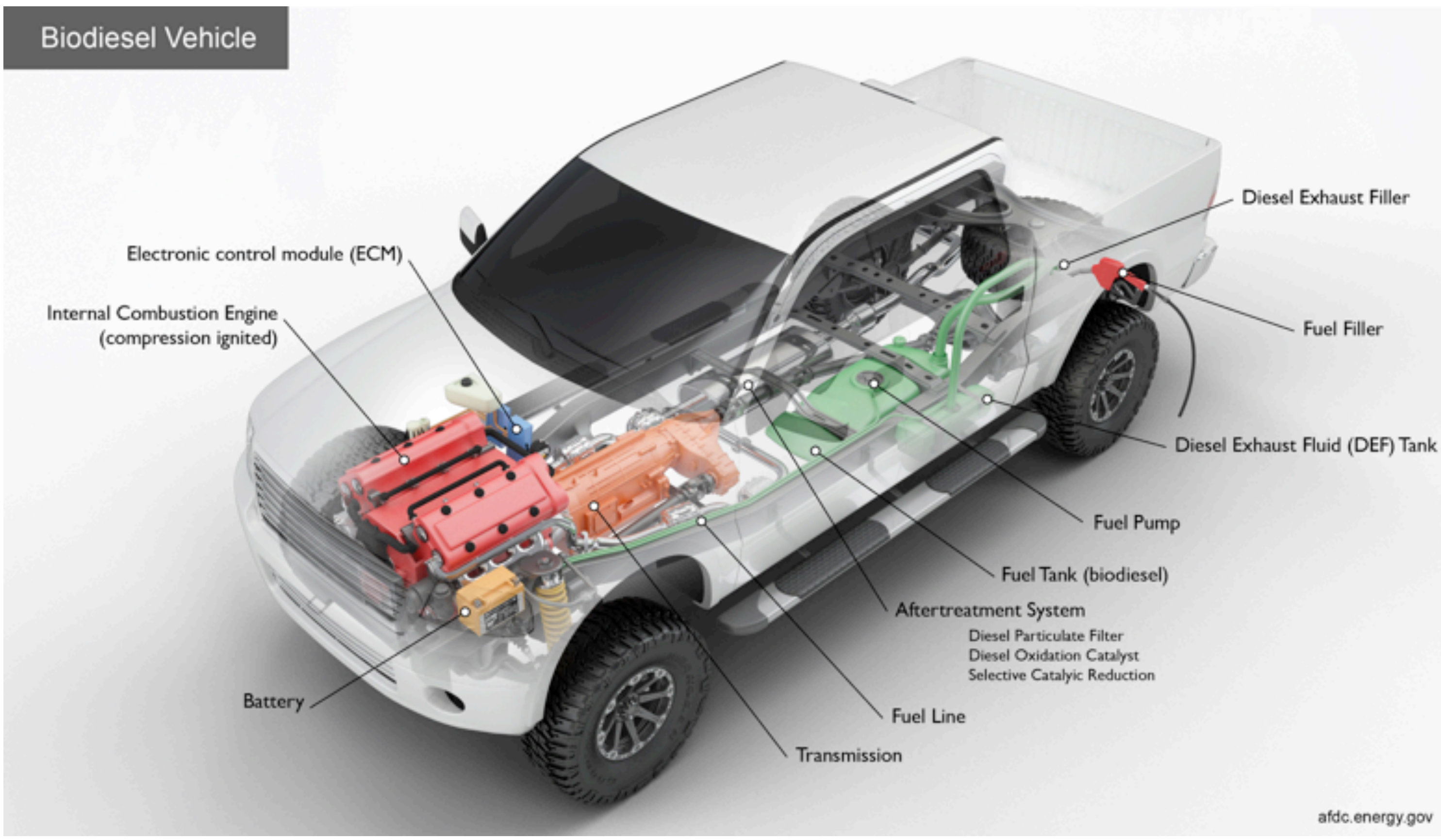
These fuels are made from algae. While they are still in the research and development stage, they are showing much promise for producing a more environmentally friendly sustainable replacement for fossil fuels.

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 CO_2 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.

ARE BIOFUELS THE ANSWER?



ARE BIOFUELS THE ANSWER?

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
- Observation Notebooks

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."

ARE BIOFUELS THE ANSWER?

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.

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.

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 Observation 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:
- What happened when they mixed warm water, sugar, and yeast? What kind of chemical reaction happened?
- What was the circumference of their balloons once inflated?
- How successful was the energy generated by fermentation?
- What other kinds of materials can they mix to create a similar chemical reaction?

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 Earth and Human Activity Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

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

MS-PS1-2 Matter and its Interactions 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 Matter and its Interactions Gather and make sense of information to describe that synthetic materials come from natural resources and impact society

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POWERING THE FUTURE LEARNING LAB

ENERGY NOTEBOOK

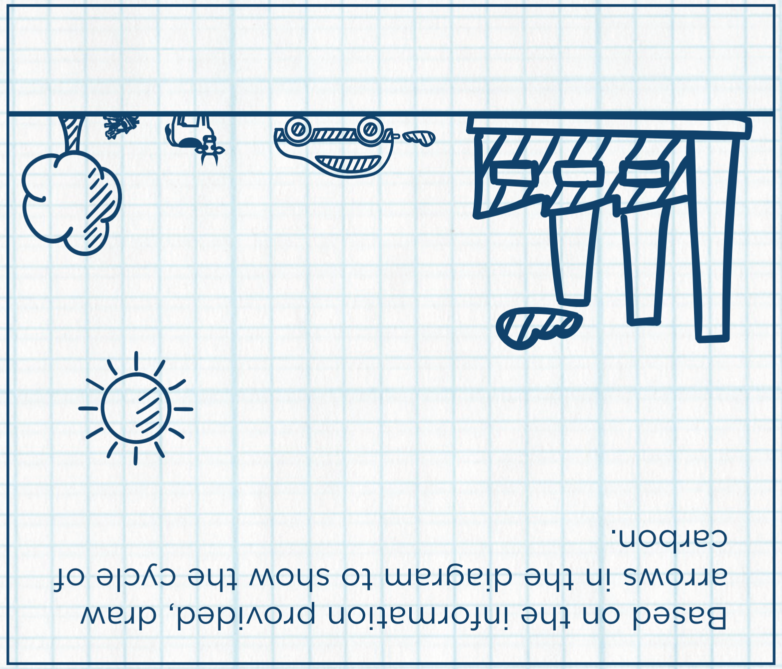
NAME ____________________

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.



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:

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		

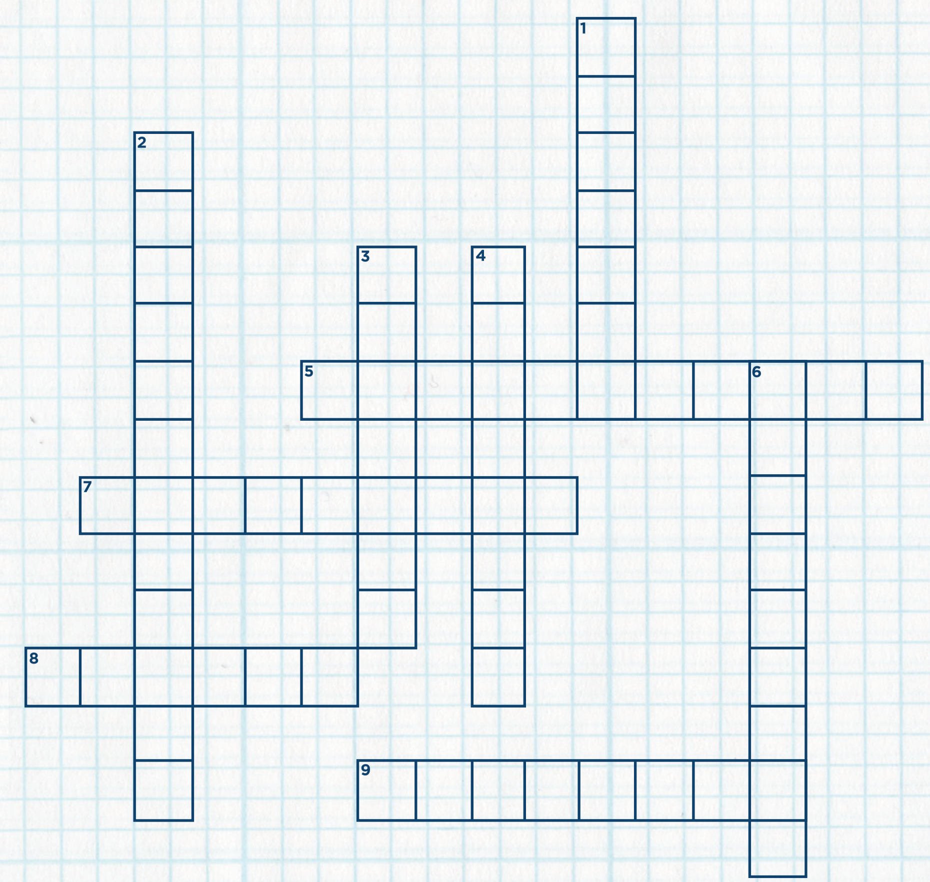
UNFOLD ME FOR MORE FUEL FUN!

THIS IS MY RIDE OF THE FUTURE...

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.

BIOFUEL BASICS

OBSERVATION WORKSHEET

During the experiment:

Record your observations and measurements.

Start time:____________ End time:____________

Time	0 min	5 min	10 min	15 min
Measure the width of the balloon in centimeters				
Make observations & record 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?

____

____

____

POWERING THE FUTURE LEARNING LAB

LESSON TWO:
IT'S ELECTRIC!

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AMERICA'S CAR MUSEUM®

INTRODUCTION:

Thousands of years before humans were able to use electricity as an energy carrier, ancient Egyptian text noted the existence of electric fish, known as "Thunder of the Nile". In ancient Greece, Thales of Miletus discovered that if amber is rubbed hard enough, dust particles begin to stick to it. However, it would not be until the 1600s that electricity was studied further in depth by William Gilbert. Gilbert studied electricity and magnetism, and made the distinction between static electricity and the lodestone effect. Several scientists continued to study electricity in the 17th and 18th century, including Benjamin Franklin, who allegedly tied a metal key to the bottom of a kite and flew the kite in a storm. Franklin observed sparks jumping from the key to his hand, proving lightning is electrical. Additionally, several more scientists in the 19th century advanced the understanding of electricity through rigorous study and invention, including but not limited to Alexander Graham Bell, Thomas Edison, Nikola Tesla, etc.

Primary vs. Secondary Energy Sources

It is common for folks to think of electricity as a primary energy source, when it is in fact a secondary energy source! This means that we cannot utilize electricity without first getting that energy from somewhere else.

<u>Primary Energy Source</u> - Energy sources that can be used directly as they appear in the natural environment: coal, oil, natural gas and wood, nuclear fuels (uranium), the sun, the wind, bodies of water, etc.

<u>Secondary Energy Source</u> - Energy sources that are made using a primary source. Electricity is a secondary energy source, and can be generated by a number of different primary sources.

So, What Exactly is Electricity?

Electricity is the flow of electrical power or charges, and it gets its power from the conversion of other sources of energy (sun, wind, water, coal, oil, nuclear, etc.). The energy sources we use to make electricity can be renewable or nonrenewable, but electricity itself is neither renewable or non-renewable. When electricity gathers in one place it is known as static electricity, and electricity that moves from one place to another is called current electricity.

Lightning occurs when static electricity turns to current electricity. When ice and water particles in storm clouds collide, it creates big electrical charges (bolts) that travel to the ground below or to nearby clouds. Another example of static electricity: when you shuffle your feet across the carpet, then get a shock when you touch something or someone else.

Batteries are an example of electrical energy. For instance, you can use batteries to power a flashlight. When you turn on the flashlight, the battery inside begins to supply electrical energy to the lamp, causing it to give off light. All the time the switch is on, energy is flowing from the battery to the lamp; eventually all of this energy is turned into light and heat, and the battery runs flat.

Because electricity is a secondary energy source, it is also an energy carrier. An energy carrier is a secondary energy source that is an efficient and safe way to move energy from one place to another. Energy carriers must be refined or generated from a primary source of energy before they can be used. Batteries and gasoline are examples of energy carriers.

How does Electricity Work?

Everything in the universe is made of atoms, which are tiny particles that contain protons, neutrons, and electrons. Protons and neutrons are inside the atom's nucleus or center, and the electrons orbit the nucleus. Protons have a positive charge, while electrons have a negative charge; neutrons are neutral and have no electrical charge. In this state, the atom is neutral because the number of protons is equal to the number of electrons. When outside forces upset the balance, the atoms may gain or lose an electron, and it's the movement of these lost electrons that produces electricity.

Various energy sources are used to generate electricity. For example, the large turbines in wind farms harness the wind's kinetic energy when the wind causes the blades of the turbine to spin rapidly around a rotor. The rotor is connected to the main shaft of the turbine, which spins the generator, disturbing the electrons and producing electricity.

We use transformers to make power of one voltage level into another voltage level. A transformer is a device that transfers electrical energy from one electrical circuit to another and is an important part of our electrical systems.

For an electric current to happen, there must be a circuit. A **circuit** is a closed path or loop around which an electric current flows. Materials that allow electric current to pass through them easily, called conductors, can be used to link the positive and negative ends of a battery, creating a circuit. An open or broken circuit will not allow current to flow.

Batteries are devices that can store electricity. Some are rechargeable, some are not. They store direct current, or DC electricity. Chemicals inside the battery store the energy, and when the battery is used, the chemical energy changes into electric energy. The chemical reactions that occur in a battery are exothermic reactions, which means they produce heat. These chemical reactions move the electrons around to create an electric current.

Capacitors are electronic devices that store electrical energy. They are similar to a battery, but can be smaller, lightweight, and capacitors charge or discharge much quicker. Capacitors consist of at least one pair of electrical conductors, often in the form of metallic plates or surfaces separated by an insulator. Capacitors are used in timing devices, as filters (circuits that let only certain signals to flow), for tuning (radios and TVs), in stabilizing voltage and power flow in electric power transmission, etc. Large supercapacitors can also be used instead of batteries. Although batteries and capacitors perform the same function of storing energy, they do it differently. Batteries store and distribute energy linearly while capacitors store and distribute energy in short bursts.

SECONDARY ENERGY CARRIERS VIDEO

IT'S ELECTRIC!

GOAL:

Students gain a better understanding of electricity as a secondary energy source and how it is used as an energy carrier by building a battery-operated fan to power their final project.

OBJECTIVES:

- Students build a battery-operated fan
- Students understand that the wind produced from the fan is from a completed electrical circuit using chemical energy converted into electrical energy
- Students recognize that electricity cannot be utilized without first harnessing energy from a primary source

MATERIALS:

- Two AA alkaline batteries
- Battery holder with alligator clips
- Motor
- Fan Blade

SET-UP:

1. Students should have their kits nearby and ready to go!

PROCEDURE:

Begin the program by reviewing primary energy sources with students. Once students feel comfortable with the concept of primary energy sources and where they come from, facilitate a discussion on secondary energy sources, tying it directly into electricity if they do not make the connection on their own. Ask them what comes to mind when they think of the word "electricity" and allow time for everyone to share. Define what electricity is and how we are able to convert primary energy sources into energy using different examples. Further the conversation about electricity by talking about it at the molecular level and explaining that, in order for it to travel, a circuit needs to be complete.

Following the electricity conversation, introduce the activity for today. Explain to students that they will be utilizing some of the materials in their kits to create a battery-operated fan that will produce the wind needed for their final project. Some students will be able to figure out how to build it on their own, but it is always a good idea to review step-by-step instructions with everyone:

- Place the fan blade on the knob on the motor.
- Put the batteries into the battery holder, explaining how to match up the positive and negative ends.

- Using the alligator clips, students can connect their battery packs to the small copper pieces on the motor. This step can be a bit tricky. remind students to be gentle with the copper pieces as they are delicate and can break off easily. If a student mentions that their fan is "blowing backwards", have them reverse their clip connection; this allows for an interesting conversation if time allows.

After they have built their battery-operated fan, ask students to keep it safe in their kit, and to not play with it too much, otherwise the batteries will drain. It is also recommended that they unclip their alligator clips from the motor to ensure the copper connectors will not become damaged while in storage.

FURTHER INVESTIGATION:

- When students begin testing their wind-powered cars in the final activity, they can use their battery-operated fans, or any fans they have at home. How might a plug in electric fan work differently than a battery-operated fan? What different results might the students expect?
- For more hands-on experimentation of circuits, consider using snap circuits as a way for students to have more open-ended exploration of assembling the circuits.
- For more battery exploration, consider a lesson around building a non-traditional battery, such as a potato or lemon battery.

STANDARDS ADDRESSED:

Next Generation Science Standards (NGSS):

4-PS3-2 Energy Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3 Energy Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS3-4 Energy Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*

MS-PS1-6 Matter and its Interactions Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*

HS-PS3-5 Energy Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

POWERING THE FUTURE LEARNING LAB

LESSON THREE: WIND-POWERED CARS

State Farm PRESENTS LeMAY AMERICA'S CAR MUSEUM®

WIND-POWERED CARS

INTRODUCTION:

The wind has been used as a source of energy for thousands of years. Most notably, sailboats have transported goods and people all over the world, with the earliest representation of a sailboat appearing in a painting found in Kuwait from between 5000 and 5500 BCE. Sailboats convert the wind's kinetic energy into kinetic energy for moving through the water. Similarly, windmills and modern wind turbines convert the kinetic energy in the wind into more useful forms of energy that help humans with various forms of work. For example, windmills may help farmers with processing their crops, and modern wind turbines convert the wind's kinetic energy into electrical energy. Any way it is captured and converted, the wind's kinetic energy has the potential to be a viable source of renewable energy.

GOAL:

Students gain a better understanding of the wind's potential as an energy source and further develop their understanding of kinetic energy as they plan, design, and problem-solve to successfully complete a design challenge. Students will utilize design thinking and engineering processes to create a small-scale, wind-powered car that can convert the wind's kinetic energy (by way of a small battery-powered fan) into kinetic energy to move the car from one point to another.

OBJECTIVES:

- Students design and build a wind-powered car
- Students understand that the energy from the wind is transferred to the car causing it to move
- Students recognize that both the movement of the wind and the movement of the car are examples of kinetic energy
- Students explore the design process as they experiment, test, and revise their designs

MATERIALS:

- Car Kits (Wooden Chassis, 2 Sets of Wheels in Each)
- Scissors
- Tape (Scotch and Masking)
- Glue Sticks
- Colored Pencils/Crayons
- Scratch Paper for Sketching
- Popsicle Sticks/Skewers (various sizes)
- String
- Cardboard
- Paper (various colors and weights)
- Paper cups (various sizes)
- Paper Plates
- Fan (from last lesson)
- Observation Worksheet and Pencil (for recording results—a class roster may also be helpful)
- Other Materials as Available: Cloth Scraps, Recycled Materials, Craft Materials, Brads, Hot Glue Guns and Glue Sticks, Hole Punchers, etc.

SET-UP:

Virtual:

1. Students should have their kits nearby and ready to go!

In-person:

1. Set up the classroom with four separate areas: tables with basic tools (pencils, scissors, tape, glue, etc.) and building materials; an additional supply table with scrap paper, cardboard, ribbon/ string, recycled materials, etc.; a hot glue station with glue guns and paper to catch any melting glue; and a testing area. Each table should have enough supplies for 4-6 students. Sort the materials into different bins and arrange them for easy student access.

2. It may be helpful to display information for students on the design problem and key things to keep in mind while completing the design challenge. On a whiteboard or poster board, display the design problem and helpful hints or reminders for students to reference during build time. Additionally, you may want to have a few samples handy for any students who need a little extra inspiration to get started. These shouldn't necessarily be pointed out initially, as we are really encouraging students to come up with their own solutions.

3. Set up a separate testing area where students can test their cars. Mark a starting line on the floor or at the edge of a 6- or 8-foot table with masking tape. Place the fan directly behind the starting line so the wind is directed toward the finish line. Next place a finish line 6-8 feet from the starting line. Place incremental marks on the floor every 6 inches between the start and target zone. Encourage students to test early and often. Emphasize the importance of using data to help the students make decisions about how to improve their car's design. Consider setting up 2 testing areas to minimize crowding with larger classes.

PROCEDURE:

Begin the session by showing a video depicting real "wind-powered cars". Follow up with a discussion about whether the students could envision these cars becoming a popular form of transportation in the future. The answer is likely no. Ask what some disadvantages to having a wind-powered car might be. Further the conversation by having a discussion surrounding the idea of "plug to pavement". While wind may not be directly used to power vehicles, how is wind used to provide the energy to power electric vehicles? What are some advantages of using wind over other energy sources to provide electricity?

Next, introduce the challenge for today. Explain to the students that they'll be utilizing the basic materials given to them (car chassis and two sets of wheels) as well as the materials in their kits to create a car that moves using the energy of the wind. In this case, the wind energy will come from a the small battery-powered fans they assembled in the last lesson. Inform the students that, at the end of the lesson, they'll be testing their cars to identify how far they can go using different energy sources (the fan or their breath) and on different surfaces (a hard surface like wood floors or a counter top or a soft surface like carpet or a blanket.)

WIND-POWERED CARS

This is a very open-ended project, so there are no constraints on how the students choose to harness the “power of the wind”, but it may be helpful to ask the students to think of some examples of different modes of transportation or machines that convert wind-power into either mechanical, kinetic, or electrical energy to produce some kind of work. Examples may include propellers, windmills, sailboats, gliders, etc.

Inform the students that the majority of the class time will be spent designing and building their cars, however, remind students that they should be constantly testing their vehicles to be sure that they will move successfully and to identify any revisions that may need to be made to make their cars more effective or go further.

Before releasing the students to begin working, give some instruction as to how to put the chassis together (you may want to demonstrate this process, especially for younger students). Instruct students that, when putting their chassis together, they should use the masking tape, not the clear tape, as it does not stick to the wood. Students should only need one piece of tape per set of wheels. Encourage students to really make sure the tape is tight to the wood and that they have rubbed out any air bubbles. This will ensure that their wheels do not fall off mid-run! At this point, it is up to the students to design their cars. Students can begin by sketching out some design ideas or they can dive right into making. (If time allows or if you are administering the lesson over multiple class periods, reviewing the design process and having the students go through the steps—identify problems, ask questions/collect info., brainstorm/sketch, plan and gather materials, etc.—would be appropriate.)

As students are building and testing their designs, challenge them to think about the following questions:

- Does the size of the sail or propeller increase or decrease the kinetic energy of the car?
- Does the shape of the sail (traditional sail or something like a cup) or propeller make a difference in the kinetic energy of the car?
- Does the speed of the fan make a difference in the kinetic energy of the car?
- Does the orientation of the sail or propeller, vertical or horizontal, make a difference in the car’s kinetic energy?
- Does its placement in front of the fan make a difference in the car’s kinetic energy?
- Will the type of sail or propeller material, such as cloth, paper, or plastic, make a difference in the kinetic energy of the car?

After testing their initial designs, encourage students to return to the design process and develop possible solutions to any challenges they are facing and redesign/revise as needed. Periodically give students an update on timing (i.e. You have about 15 minutes left to finish your designs before we’ll want to start our final tests, You have about 5 minutes…, etc.).

Once all students have completed their designs, it’s time for testing! Students will be completing four rounds of testing: using their breath to move their cars on a soft surface, using their breath to move their cars on a hard surface, using the fan to move their cars on a soft surface, and using the fan to move their cars on a hard surface. Once their wind-powered cars come to a complete stop in each testing round, the fan should be turned off (if applicable) and the students should record how far the car traveled.

If the car did not make it to the finish line, measure and record the distance it traveled. Once all cars have been tested and the results have been recorded, have a follow-up discussion with the students. You can ask questions including:

- Why do you think some cars were faster/traveled further than the others? What did the most successful cars have in common?
- How did the different variables (energy source and testing surface) affect the results?
- Did anyone have any challenges when designing their cars? What were they and how did you change your design to address them?
- What might you have done differently after seeing the results of the testing?

FURTHER INVESTIGATION:

- Experiment with changing wind speed. How would the cars perform on the highest speed of a larger fan compared to the small battery-powered fans?
- Experiment with the idea of light-weighting. Explain that car companies are finding new ways to make cars weigh less. This will be especially impactful in designing electric vehicles, as it allows them to go further using less electricity, thus diminishing concerns about range. Ask students: What happens if you add weight to your car? What about using lighter materials to build your car? Have students experiment with replacing the wooden chassis with paper or cardboard.
- For older students, present the challenge as a renewable energy-powered car. At the beginning of the session, tell them that the only constraints are that it must move using only a primary energy source. Provide them with the same materials, as well as balloons and rubber bands. See if they come up with different solutions.

STANDARDS ADDRESSED:

Next Generation Science Standards (NGSS):
4-PS3-4 Energy Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

MS-PS3-2 Energy Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

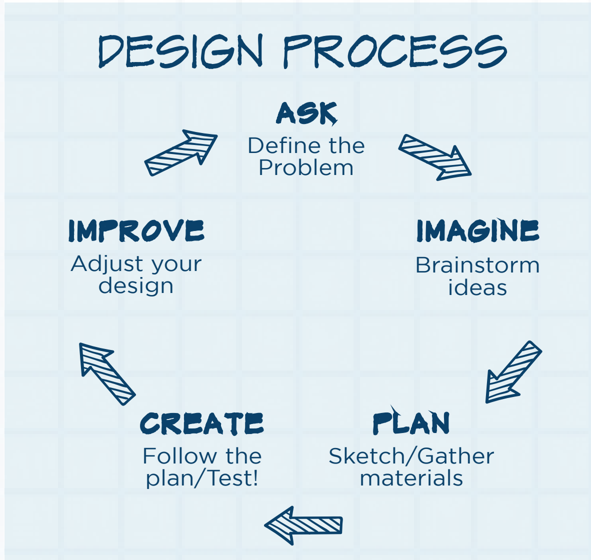
NGSS Disciplinary Core Ideas (DCI):
MS-PS3.A Definitions of Energy A system of objects may also contain stored (potential) energy, depending on their relative positions.

NGSS Science and Engineering Practices (SEP):
[3-5th] Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.

[3-5th] Apply scientific ideas to solve design problems.

WIND-POWERED CARS

OBSERVATION WORKSHEET



During the experiment:

Record your observations and measurements in inches.

Measure how far your car moves when you use the **fan** to move your car forward on a **hard** surface (wood floors, kitchen counter, sidewalk, etc.): __________ inches

Measure how far your car moves when you **blow** to move your car forward on a **hard** surface (wood floors, kitchen counter, sidewalk, etc.): __________ inches

Measure how far your car moves when you use the **fan** to move your car forward on a **soft** surface (carpet, rug, grass, etc.): __________ inches

Measure how far your car moves when you **blow** to move your car forward on a **soft** surface (carpet, rug, grass, etc.): __________ inches

Analyze and interpret your results.

1. Did your car move farther on the hard or the soft surface? ____________________
2. Did your car move farther when you blew or when you used the fan? _________
3. Why do you think that was the case?

____

____

GLOSSARY

Batteries – Devices that can store electricity.

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

Biomass – Organic material from plants and animals.

Capacitors – Electronic devices that store electrical energy.

Circuit – A closed path or loop around which an electric current flows.

Electricity – The flow of electrical power or charges.

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

Energy – The ability to do work or to cause a change.

Energy Carrier – A secondary energy source that is an efficient and safe way to move energy from one place to another. Energy carriers do not exist in nature but must be refined or generated from a primary source of energy. Gasoline and electricity are examples of energy carriers.

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

Energy Transformation – Energy being changed from one form to another.

Fermentation – The chemical breakdown of a substance.

Forms of Energy – Scientific classification of the different types of energy.

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

Natural Resource – Energy resources that can be found within the environment such as wind, petroleum, and uranium.

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.

Primary Energy Source – Energy sources that can be used directly, as they appear in the natural environment: coal, oil, natural gas and wood, nuclear fuels (uranium), the sun, the wind, bodies of water, etc. position relative to others, internal stress, electric charge or its condition rather than motion.

GLOSSARY

Renewable Energy – Energy that can be replenished within our lifetime such as such as energy from the Sun and wind.

Secondary Energy Source – Energy Sources that are made using a primary resource. Electricity is a secondary energy source, and can be generated by a number of different primary sources.

Sources of Energy – Resources found in nature that can be obtained to provide heat, light, and power such as natural gas, coal, wind, and solar energy.

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

Transesterification - A reversible reaction in which one ester is converted into another (as by interchange of ester groups with an alcohol in the presence of a base).

Viscous – Having a thick, sticky consistency between solid and liquid; having a high viscosity.