Ethanol Lesson

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America's Ethanol Supporters

Preface

Essential Questions

Day-to-Day Plans

Supplies and Materials

Reference Sources

Concepts and Performance Objectives

Key Terms

Teacher Notes

Acknowledgements

Preface

Ethanol is a renewable energy processed from agricultural products with a high starch content, such as corn kernels. Starch ethanol processing plants mill the corn and then use enzymes to break down the starch into simple sugars. The milled corn seed with enzymes are then mixed with warm water and yeast. The yeast consumes the sugars during an anaerobic fermentation process, producing ethanol and carbon-dioxide. Processing plants separate the ethanol from fermentation coproducts using distillation. Fermentation coproducts, such as distillers grains can be used as a high protein animal feed.

Congress created the renewable fuel standard (RFS) program to reduce greenhouse gas emissions and expand the nation's renewable fuels sector while reducing reliance on imported oil. This program was authorized under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007. Every year, the Renewable Fuel Standard requires more renewable fuel to be blended into our nation's transportation fuel. The goals of the Renewable Fuel Standard include reducing U.S. dependence on foreign oil, rejuvenating rural America, expanding the renewable fuel industry, and decreasing greenhouse gas emissions. When ethanol combusts, it releases fewer pollutants than traditional gasoline. The total carbon dioxide emitted from ethanol is also less than gasoline.

In the future, new technologies will allow us to efficiently produce ethanol from other agricultural products, such as cellulosic material. Corn stalks and cobs are agricultural coproducts made of cellulose that can be converted into ethanol.

In this lesson, students will research the history of ethanol, produce ethanol from corn products, discuss the benefits of the Renewable Fuel Standard, and combust ethanol to measure its energy content and coproducts.

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. Industry, innovation, and technology led to the development of starch-based ethanol.	• Make a poster board describing the history and development of ethanol. (Activity 1)
2. Ethanol plants use fermentation to convert corn into biofuels and animal feed products.	• Make ethanol and distillers grains from ground corn seed and corn starch. (Activity 2)
3. The United States government developed the Renewable Fuel Standard (RFS) program with the intent of reducing greenhouse gasses, increasing renewable fuel production, and decreasing dependence on foreign oil.	• Research the RFS program and debate the benefits of the program from multiple perspectives. (Activity 3)

4. Biofuels provide consumers with energy choices that can improve rural economies and benefit the environment.	• Compare energy content, coproducts, and cost of ethanol and kerosene. (Activity 4 and Activity 5)
5. Advancing technologies are used to convert cellulosic components of corn into ethanol.	• Produce ethanol from cellulosic corn-based material. (Activity 6)

Essential Questions

1. How and where is ethanol produced?
2. How can agriculture support the development of renewable energies?
3. How does ethanol production and usage impact the environment?
4. What is the process for making ethanol?
5. What coproducts are created while making biofuels like ethanol?
6. What is the Renewable Fuel Standard?
7. How does ethanol benefit rural communities?
8. What are the coproducts of ethanol combustion?
9. How does the energy content in ethanol compare to fossil fuels?
10. What are new agricultural sources for ethanol?

Key Terms

Act	A formal decision, law, or the like by the legislature, ruler, court, or other authority.
Alternative Energy	Energy, as solar, wind, or nuclear energy, that can replace or supplement traditional fossil-fuel sources, such as coal, oil, and natural gas.
Bromthymol blue	A dye used as an acid-base indicator.
Calorie	A unit used in the measurement of energy equal to 4.18 joules; the amount of energy required to raise one gram of water one degree Celsius.
Carbon dioxide	A colorless, odorless gas constituting 0.03 percent of unpolluted air. It is absorbed by green plants through the leaf stomata and is used as the source of carbon for manufacturing sugars, starches, proteins, and fats. The burning of fossil fuels has put so much CO2 in congested cities that the concentration may reach more than three times the background (normal) level. This is causing a "greenhouse effect," resulting in a slow warming of the earth's surface.
Cellulose	An inert, complex carbohydrate which makes up the bulk of the cell walls of plants.
Cellulosic ethanol	Ethanol produced from cellulosic material.
Combustion	The act or process of burning. A chemical reaction in which a fuel reacts with oxygen to form carbon dioxide, water, and energy.
Coproduct	Something produced jointly with another product.
Distillation	The process of purifying a liquid by successive evaporation and condensation.
Distillers grains	A cereal coproduct of the distillation process that can be used for animal feed.
Emission	Something that is emitted or discharged.
Ethanol	Ethyl alcohol; most commonly derived by fermentation of plant materials; used as a fuel substitute/replacement for petroleum based fuels.
Fermentation	A chemical reaction in which a ferment causes an organic molecule to split into simpler substances.
Fossil Fuel	A deposit of organic material containing stored solar energy that can be used as fuel. The most important are coal, natural gas, and oil.
Greenhouse effect	Natural effect that releases heat into the atmosphere near the earth's surface.
Greenhouse gas	Gases in the lower atmosphere that cause the greenhouse effect.

Non-renewable energy	Those sources of energy that can't be replaced in a reasonable amount of time, such as the fossil fuels--oil, natural gas, and coal.
Octane	The ability of a fuel to resist engine knock or ping during combustion.
Particulates	Finely divided solid or liquid particles in the air or in an emission. Include dust, smoke, fumes, mist, spray, and fog.
Petroleum	An oily, thick, flammable, usually dark-colored liquid that is a form of various hydrocarbons, occurring naturally in various parts of the world and commonly obtained by drilling: used in a natural or refined state as fuel.
Renewable energy	Renewable resources; resources that can be replaced after use through natural means.
Starch	Complex carbohydrate consisting of molecules of sugar units or saccharides linked in branched or straight chains.
Yeast	A yellowish substance composed of microscopic, unicellular fungi of the family *Saccharomycetaceae*, which induces fermentation in juices, doughs, warts, etc.

Day-to-Day Plans
Time: 15 days

Day 1 – 2:

- Present **Concepts**, **Performance Objectives**, **Essential Questions**, and **Key Terms** to students in order to provide a lesson overview.
- Present **Ethanol History and Production** which includes the video, **How is ethanol made?** and **Ethanol Process Graphic**.
- Provide a copy of **Ethanol Activity 1 – Productive History** to students.
- Students work in pairs to complete *Ethanol Activity 1 – Productive History***.**

Day 3:

- Provide a copy of **Ethanol Activity 2 – Production and Coproducts** to students.
- Students work in pairs to complete Part One of *Ethanol Activity 2 – Production and Coproducts***.**

Day 4 – 6:

- Present **Ethanol Importance and Policy**.
- Provide a copy of **Ethanol Activity 3 – Community** and **Role Card** to each student.
- Students will use their Role Card to prepare for a debate on developing an ethanol plant.
- Students will complete *Ethanol Activity 3 – Community*.

Day 7:

- Students work in pairs to complete *Ethanol Activity 2 – Production and Coproducts*.

Day 8 – 9:

- Provide a copy of **Ethanol Activity 4 – Combustion** to students.
- Students work in pairs to complete Part One of *Ethanol Activity 4 – Combustion*.

Day 10 – 11:

- Provide a copy of **Ethanol Activity 5 – Energy** to students.
- Students work in pairs to complete *Ethanol Activity 5 – Energy*.

Day 12 – 14

- Present **Cellulosic Ethanol** which includes the videos **The Future of Ethanol** and **Biomass: A New Opportunity**.
- Provide a copy of **Ethanol Activity 6 – Technology** to students.
- Students work in pairs on *Ethanol Activity 6 – Technology*.

Day 15:

- Students work in pairs to complete *Ethanol Activity 6 – Technology*.
- Distribute **Ethanol Lesson Check for Understanding**.
- Students complete *Ethanol Lesson Check for Understanding* and submit for grading.
- Use **Ethanol Lesson Check for Understanding Key** to grade student assessments.

Teacher Notes

Ethanol Activity 1 – History

Students make a poster explaining the history, processing, use, and environmental impact of ethanol.

Teacher Preparation
Present **Ethanol Production and History** before starting the activity. Use the video, **How is ethanol made?** and **Ethanol Process Graphic** in the presentation to help explain the production process to students. Below are notes for presentation slides.

- Slide 1: Title slide.
- Slide 2: No notes.
- Slide 3: Use the video, How is ethanol made?, and graphic link on the slide to show students how ethanol and coproducts are produced.
- Slide 4: Ethanol has been used since the start of automobile transportation.
- Slide 5: Early on, many ethanol plants started small as seen in the picture to the left. Over time, the demand for ethanol has grown, as have the production plants, as seen in the picture to the right. The plants seen here show the growth of POET, a production leader in the ethanol industry.
- Slide 6: POET grew from a small family farm to a large ethanol corporation supporting many family farms across the Midwest.
- Slide 7: Local corn producers across the Midwest benefit from ethanol production. These local producers have an effect on the global economy.
- Slide 8: Grain production has increased continuously due to new agricultural technologies and efficiencies.
- Slide 9: No notes.
- Slide 10: How can society utilize the increase of corn production?
- Slide 11: Corn has traditional been used for food and feed. Over the past 30 years, fuel has been an added product due to increase corn yields.

Student Performance
Students research ethanol and construct an educational display to hang in the classroom or hallway. The displays include information outlined in the procedures. Below are recommended resources for students to use for making their displays.

- Growth Energy – **www.growthenergy.org**
- POET – **www.poet.com**
- U.S. Energy Information Administration - **https://www.eia.gov/energyexplained/index.php?page=biofuel_ethanol_home**
- Energy 101 – **www.energy-101.org**

After students complete and display their work, provide time for students to observe each display, have a peer discussion on the impact of ethanol, and answer conclusion questions.

Ethanol Activity 2 – Production and Coproducts

Students will conduct an experiment to produce ethanol from ground corn.

Teacher Preparation
Use a coffee grinder to mill 450 – 500 grams of corn kernels. To provide an overview of the process of biofuel production, you will set up a demonstration sample using 30grams of milled corn. Follow the procedures below to prepare a sample five to seven days before introducing this activity.

Pre-Lab Fermentation

1. Prepare a yeast suspension at a rate of 1g yeast to 20ml water. The water should be 40-50°C. Use one half the total volume of water to dissolve the yeast, and then add remaining warm water. You will need a volume of 15ml total, but it is recommended that you prepare 30-40ml. If an entire yeast packet is used, dissolved the yeast in 100ml water, then bring total volume to 200ml.
2. In a 250ml Erlenmeyer flask, mix 30g crushed corn, 150ml warm water, and 15ml yeast solution.
3. Swirl the flask well to mix contents.
4. Place a two-hole stopper in the top of the flask, with a thermometer and 5cm glass tubing inserted into the holes.
    - NOTE: You may use an immersion thermometer or a LabQuest with a temperature sensor. If using the LabQuest, you will need to place near an electrical outlet to collect data for the duration of the experiment. It is recommended to set the LabQuest to collect data every 15 minutes.
5. Fill a 250ml beaker approximately half full with water. If desired, place 20 drops of bromthymol blue in the water to indicate CO_2 output.
6. Connect a piece of plastic tubing to the glass tubing and place the other end in the beaker of water. This allows CO_2 to escape the flask, but prohibits O_2 from entering and causing an aerobic environment.
7. Place entire apparatus in a warm environment of 25-30°C.
8. Monitor the apparatus daily. If using bromthymol blue as a color indicator, you may want to take pictures of the water solution once or twice daily to share with students later during the in-class demonstration.

Lab Safety and Disposal
Be sure students wear correct PPE for the activity. Review the SDS for **biuret solution** before starting the activity and dispose of in accordance to local, state, and national regulations.

Student Performance
Students observe you demonstrating the fermentation and distillation process using the demonstration fermenter described in the *Teacher Preparation*. Describe the steps in setting up the fermentation chamber. Demonstrate how to distill the ethanol using the protocol below. Then have students complete the activity.

In-class Demonstration

1. Discuss the apparatus set-up, proportions of ingredients used, and observations to date with students. Describe the appearance of the initial mixture and water beaker, changes, and current appearance. If available, show pictures of changes throughout.
2. Remove the stopper from the flask, and gently waft the fumes toward your nose. Describe the aroma to students. Replace the stopper in the flask.

3. Fill the condenser chamber with crushed ice and cold water. Place the condenser in a utility clamp on a ring stand at approximately a 45° angle.
4. Position a 50ml beaker at the base of the condenser unit to catch the distillate.
5. Place the flask on a hot plate.
6. Remove the plastic tubing from the water beaker and connect it to the condenser unit.
7. Turn on the hot plate to medium. Observe the flask, if the solution begins to boil vigorously, turn down the heat to maintain a slow boil.
8. Maintain a slow boil until the thermometer reads 95°C. Turn off the hot plate.
9. When condenser unit stops dripping, observe the volume of the distillate. Discuss ratio of beginning ingredients to fuel produced.
10. Pour a small volume, approximately 2ml, of distillate into a shallow porcelain bowl and light using a long-handled butane lighter to demonstrate the production of fuel.

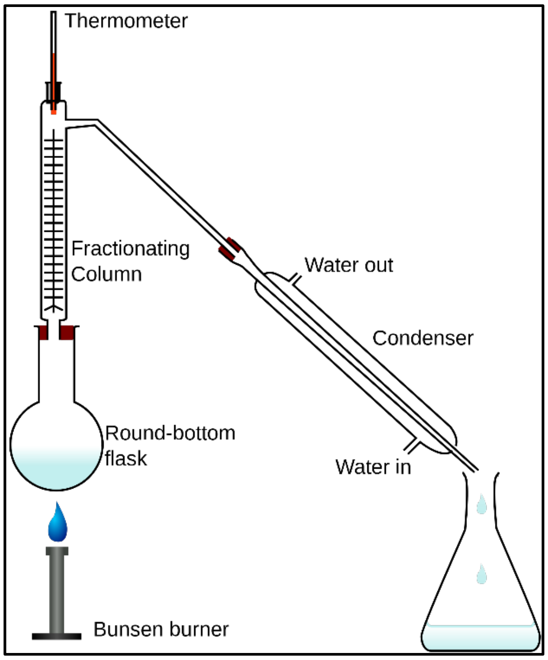

Image courtesy of **https://en.wikipedia.org/wiki/Fractional_distillation**

Figure 1. Sample Distillation Apparatus

Results and Evaluation

When fermentation and distillation protocol are complete, students will submit lab reports for grading.

Ethanol Activity 3 – Community

Students research the Renewable Fuel Standard and use role playing to discuss the impact it has on them.

Teacher Preparation

Present **Ethanol Importance and Policy**. Below are notes for presentation slides

- Slide 1: Title slide.
- Slide 2: Ethanol benefits our economy while protecting our environment and increasing our national security.
- Slide 3: Crude oil prices have increased much more over time than corn. How can we add value to corn in the future?
- Slide 4: Ethanol is less expensive at the pump for the consumer, but does not have be less expensive than wholesale gasoline.
- Slide 5: Ethanol has had a positive impact on our Nation’s economy.
- Slide 6: World oil production is much higher in other parts of the world than in the United States. The United States has a strong agricultural economy. Ethanol is an answer to reducing our fuel dependence on foreign countries while supporting our agricultural economy.
- Slide 7: The Renewable Fuel Standard was enacted to reduce our dependence on foreign oil.
- Slide 8: Ethanol production will need to increase to meet the future goals of the Renewable Fuel Standard. Additional ethanol will need to be used to meet this goal.
- Slide 9: Currently all engines are designed for gasoline with a 10% ethanol blend.
- Slide 10: Increase use of other recognized ethanol percentages in gasoline can help achieve the Renewable Fuel Standard.
- Slide 11: Many do not understand the facts about ethanol.
- Slides 12 – 14: No additional notes.

Print **Ethanol Activity 3 Community Role Cards** prior to class. You will need two copies for a class of 20. It is recommended to print the cards on cardstock paper. Cut the cards and determine which student will be assigned each role. If you have a student who is capable assuming the role of the representative at the meeting, assign that student the role to chair the meeting. If not, you may chair the meeting.

Student Performance
Students read the scenario and their assigned role. Then they research the Renewable Fuel Standard and determine their discussion points. Students should recognize they do not have to agree with the role they are playing personally to represent the character well.

After students have completed their research, facilitate a mock town hall meeting. Set up the classroom with the representative in the front facing the audience. Remaining students will be seated in the audience. Encourage open discussion and debate.

Results and Evaluation
Assess student presentation and participation during the mock town hall meeting. Each student should turn in typed copy of their statement and summary at the end of the discussion. The statement should include whether they agree with the role they represented and why they did or did not agree with that role. Have a final discussion about how the Renewable Fuel Standard positively impacts the agricultural economy and environment.

Ethanol Activity 4 – Combustion

Use this activity to introduce students to differences in emissions produced by various energy sources. The ethanol represents a renewable energy source produced by agriculture that can be a suitable alternative to fossil fuels. Kerosene represents fossil fuels in this lab; kerosene is used instead of gasoline because of the less explosive nature of the material.

Teacher Preparation
Caution will need to be used for this activity as students will be using an open flame to complete the procedures. When using the LabQuest2 be sure students set up the equipment so they do not burn cords or equipment.

To set up this activity, fill five alcohol burners approximately $^{1}/_{3}$ full of kerosene. Fill an additional five burners $^{1}/_{3}$ full of ethanol. Adjust the wicks so $^{1}/_{8}$ inch of the wick stands above the burner. Light and extinguish each burner. If necessary, adjust wick height. Obtain empty soup or juice cans and punch two holes directly across from each other approximately ½″ from the top of the can.

Demonstrate all procedures prior to students beginning work. Divide students into groups of four. They will work in pairs within their group, but share materials amongst all four.

Student Performance
Students compare the combustion of kerosene and ethanol. They measure the amount of heat energy, carbon dioxide, and soot produced by each fuel to determine the cleanest, most efficient source of energy. They measure heat production by burning the fuel beneath a can containing water. The rise in water temperature will be used to measure heat energy. Next, they extinguish the flame using a plastic bottle. The bottle collects the carbon dioxide produced during combustion. Students use a form of titration to measure carbon dioxide produced by each fuel. Finally, students observe the soot produced on the bottom of the can by each fuel. Students share their data with classmates to calculate a class average.

Results and Evaluation
Students should find the kerosene will produce a large flame with a large amount of soot. Ethanol will produce a much shorter flame with very little soot. Kerosene will produce less heat than the ethanol flame. You can discuss the heat produced with your students using the flame color. The ethanol flame is blue in

color, which is a hotter flame. The carbon dioxide produced by each fuel will be similar. Carbon dioxide is a coproduct of fuel combustion.

Ethanol Activity 5 – Energy

Students use research of fuels during the first day of the activity and lab results from the second day to explain what factors they believe should be considered when deciding on a fuel source.

Teacher Preparation

Before class, fill five alcohol burners approximately $^{1}/_{3}$ full with kerosene. Fill an additional five burners $^{1}/_{3}$ full with ethanol. Adjust the wicks so $^{1}/_{8}$ inch of the wick stands above the burner. Light each burner and extinguish. If necessary, adjust the wick height. Obtain empty soup or juice cans and punch two holes directly across from each other approximately ½″ from the top of the can.

Use caution for this activity as students will be using an open flame to complete the procedures. When using the LabQuest2 be sure that students set up the equipment so they do not burn cords or equipment.

Student Performance

Divide students into groups of four. They will work in pairs within their group, but share materials amongst all four. On day one of this activity, students work in pairs to research the advantages and disadvantages of fossil fuels and biofuels.

Before starting Part Two, it is recommended you demonstrate all procedures prior to students beginning work. Students will compare the energy efficiency of kerosene and ethanol. They burn ethanol and kerosene for the same amount of time while measuring the heat energy produced by the fuels. Then they measure the fuel used. Students use their heat and fuel measurements to calculate the efficiency of each fuel.

Results and Evaluation

They will find kerosene is more energy efficient than ethanol, but ethanol is more cost efficient for the consumer. Table 1 provides potential responses to analysis questions.

Table 1. ***Analysis Questions and Potential Responses***

1. Compare the results to your prediction.	*Answers will vary.*
2. Which fuel produced more energy in three minutes?	*Ethanol will produce more heat energy.*
3. Which fuel was the most efficient?	*Kerosene is more efficient, produce more heat per volume used.*
4. Based upon the results, which fuel do you believe has the most energy per gallon? Why?	*Kerosene, because it had the most energy per gram.*
5. Why would a consumer choose ethanol instead of gasoline?	*Ethanol has a lower cost per calorie of energy produced.*

Ethanol Activity 6 – Technology

In this activity, students determine whether acid treatment, enzyme treatment, or a combination of the two is the most effective technology for producing ethanol from cellulosic biomass.

Teacher Preparation

Before starting the activity, present **Cellulosic Ethanol** which includes the videos **The Future of Ethanol** and **Biomass: A New Opportunity**. Below are notes for presentation slides

- Slide 1: Title slide
- Slide 2: Discuss with students the types of cellulose they would find in their local area.
- Slide 3: Ethanol can now be produced from both cellulosic and starch material for corn. Click on The Future of Ethanol link and play the video.

- Slide 4: Click on Biomass: A New Opportunity and play the video. Note the space the biomass material occupies.

Students complete Part One and Part Two on the first day of the activity. Then the start Part Three on day two by fermenting the solution. Students complete the activity on the third day.

Day One
If you do not have the Celluclast™ enzyme available, prepare a 20% cellulase enzyme solution by mixing 3g cellulase powder into 15ml distilled water. Each group of students needs 2ml of enzyme solution. Grind corn stalks using a coffee grinder, each pair will need 1gram of ground stalks.

Collect materials listed in student activity for Parts One and Two. Prepare stations for students to retrieve ground corn stalks, Celluclast™ enzyme, and sulfuric acid. Set a water bath to 50°C.

Refer to the **Vernier Ethanol Sensor Manual** for information on operating and maintaining the sensor. Students use the ethanol sensor to measure ethanol vapor not liquid. Do not get the sensor wet. The sensor element is protected with Teflon™ tape in case it does get wet. The sensor has a range of zero to three percent. With no ethanol present, the meter will still show a percentage of 0.01. For more information on the ethanol sensor go to **https://www.youtube.com/watch?v=56tZ_62U7F8** for a video explaining use in more detail.

Day Two
Prepare a station for students to retrieve yeast. Adjust the water bath to 37.5°C.

Student Performance
Part One
Students heat-treat all biomass samples and observe physical changes in the samples. They use an ethanol sensor to measure the ethanol concentration of each sample after heat treatment. Students record observations and data.

Review the MSDS sheets for 0.05M sulfuric acid and Celluclast™. Remind students of your safety guidelines and spill procedures. Dispose of waste chemicals in accordance with local regulations.

Monitor students as they extract enzyme from the single container as it can cause skin and eye irritation. Students must wear safety glasses, disposable gloves, and a lab apron to protect their skin and clothing from the enzyme.

Part Two
Students treat the samples with sulfuric acid and Celluclast™ per Table 2. One sample is untreated and serves as the control. The students process samples in a 50°C water bath for 24 hours. Students answer analysis questions on the student worksheet. Example responses are available below.

Table 2. ***Acid and Enzyme Treatments***

Tube	0.05M SO_2	Celluclast™
Tube 1	None	None
Tube 2	2.0 ml	None
Tube 3	None	1.0 ml
Tube 4	2.0 ml	1.0 ml

Students observe physical changes in the samples and use an ethanol sensor to measure ethanol concentration of each sample after treatment. Students record observations and data on the student worksheet. Sample observations and data are recorded below.

Part Three

Yeast is added to each sample to ferment sugars. Students incubate the samples at 37.5°C for 24 hours. Physical changes in the samples are observed. Students use an ethanol sensor to measure the ethanol concentration of each sample after fermentation. Figure 1 shows a sample set of tubes after the final incubation period.

Students record observations and data in their *Laboratory Notebook*. Students answer Part Three Analysis Questions on the student worksheet. See sample results, observations, and analysis question responses below.

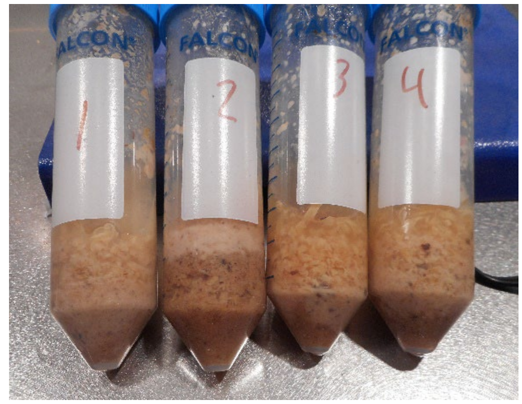

Figure 1. Sample Ethanol Mash

Results and Evaluation

Students should find the combination of acid and enzyme treatment is the most effective in producing cellulosic ethanol. Students will complete a lab report explaining their results.

Table 3. Part Two Analysis Questions and Potential Responses

1. What is the purpose of heating all the samples?	*Heat treatment breaks cellulose into starches and sugars.*
2. Why was the ethanol concentration small after heat treatment?	*Ethanol is produced primarily by fermentation. Little or no fermentation has occurred.*
3. Why are the samples treated with sulfuric acid and Celluclast™ individually and in combination?	*All possible combinations of treatments must be tested to identify the effective treatments.*
4. Fermentation produces ethanol. Why measure for ethanol prior to fermentation?	*Checking ethanol levels at each step verifies that no contamination has occurred.*
5. If both sulfuric acid and Celluclast™ enzyme increase sugar production, which treatment should produce the most ethanol?	*Sample 4, treated with both acid and enzyme should produce the most ethanol.*
6. Tube 1, which has no sulfuric acid or Celluclast™ enzyme treatment is the control sample. What is its purpose?	*Tube 1 is used to verify no ethanol is produced other than by the processes tested.*

Table 4. *Observations and Ethanol Production*

Tube #	Observations	Heat Treatment Results	Acid/Enzyme Treatment Results	Fermentation (Yeast) Result
Tube 1 (Control)	**Appearance**	*Amber colored water Corn stover layered at bottom Woody odor*	*Golden brown water Corn stover layered at bottom Slightly stronger woody odor*	*Cloudy water Corn stover Yeasty odor*
	Ethanol %	**0.057%**	**0.320%**	**0.885%**
Tube 2 (SO_2)	**Appearance**	*Amber colored water Corn stover layered at bottom Woody odor*	*Clearer water Corn stover layered at bottom Stronger woody odor*	*Cloudy water Corn stover Yeasty odor*
	Ethanol %	**0.053%**	**0.319%**	**0.913%**
Tube 3 (Cellulase)	**Appearance**	*Amber colored water Corn stover layered at bottom Woody odor*	*Golden brown water Corn stover layered at bottom Reduced odor*	*Yellow water Three layers of corn stover, yeast Yeasty odor*

	Ethanol %	**0.050%**	**0.319%**	**1.010%**
Tube 4 (SO_2 and cellulase)	**Appearance**	*Amber colored water* *Corn stover layered at bottom* *Woody odor*	*Cloudy water* *Corn stover layered at bottom* *Reduced odor*	*Yellow water* *Corn stover* *Yeasty odor*
	Ethanol %	**0.050%**	**0.315%**	**1.345%**

Table 5. ***Part Three Analysis Questions and Potential Responses***

1. What were the ethanol concentrations after the chemical and enzyme treatments, but prior to the fermentation step?	*Answers will vary, but concentrations prior to fermentation should be lower than after fermentation.*
2. Based on the data, formulate a hypothesis about the most effective biomass treatment to produce ethanol and describe an experiment to test your hypothesis.	*Answers will vary, but the proposed experiment should change some variable and measure the resulting change in ethanol concentration. For example: Doubling the heat treatment time will increase ethanol concentration by 25%.*
3. Which treatment, sulfuric acid or Celluclast™, produced a larger increase in sugar production? How do you know?	*The Celluclast™ treatment produced the most sugar. The ethanol content was highest in this mixture and sugar is needed to produce ethanol.*

Ethanol Lesson Assessment

Use *Ethanol Lesson Assessment* on the final day as a formative assessment tool. The answer key is provided below for evaluation and feedback purposes.

1. What industries benefit from ethanol production?

Answers will vary.
Agriculture
Transportation
Industries dependent upon combustibe fuels

2. What are the advantages of using ethanol instead of a fossil fuel?

Ethanol is a renewable fuel that burns cleaner with fewer emissions.

3. How is ethanol produced from corn kernels?

Fermentation occurs when yeast feeds on the starch in the corn and produces ethanol and carbon dioxide. The ethanol is purified from the fermentation mixture using distillation.

4. What is a coproduct of ethanol production?

Distillers grains

5. What is the Renewable Fuel Standard?

The RFS requires fuel companies to purchase and blend renewable fuels with fossil fuels.

6. How does the Renewable Fuel Standard impact rural communities?

Answers will vary.
The RFS increases rural economic support for local energy production and consumption.

7. How do the coproducts of ethanol combustion compare to fossil fuel combustion?

Both ethanol and fossil fuel emit carbon dioxide when combusted. Fossil fuels produce more carbon dioxide than ethanol along with additional pollutants.

8. What factors should a consumer consider when choosing a combustible fuel?

Answers will vary.
Fuel cost
Octane ratings
Emissions
Local support of economy

9. What are the advantages and disadvantages of cellulosic ethanol?

Answers will vary.
Cellulosic ethanol is produced from agricultural products not being utilized for fuel, making full use of the crop.
Cellulosic waste materials is removed from farmer's fields and used for fuel production.

Supplies and Materials

APP	Qty/ 20	Qty/ 30	Unit	Item Specifications	Vendor
Activity 1	10	15	Each	Poster boards	Local
	10	15	Sets	Assorted markers	Local
	10	15	Each	Glue sticks	Local
	10	15	Pairs	Scissors	Local
Activity 2	10		Each	250ml beaker	Ward's
	10		Each	50ml beaker	Ward's
	10		Each	Thermometer	Ward's
	10		Grams	Yeast	Local
	1	2	Each	Microwave	Local
	10		Each	250ml Erlenmeyer flask	Ward's
	300	450	Grams	Crushed corn	Local
	4	6	Each	Electronic balance	Ward's
	10	15	Each	Two-hole stopper	Ward's
	10	15	Each	5cm glass tubing	Ward's
	40	60	Ft	Plastic tubing	Lab-Aids
	10	15	Each	Bromothymol blue	Ward's
	1	1	Each	Coffee grinder	Local
	10	15	Each	Condenser	Lab-Aids
	20	30	Lbs	Crushed Ice	Local
	10	15	Each	Utility clamp	Ward's
	10	15	Each	Ring stand	Ward's
	1	1	Each	Porcelain Bowl	Ward's
	1	1	Each	Butane lighter	Local
	10	10	Each	Test tube	Ward's
	10	10	Each	Eye dropper	Ward's
	30	45	ml	Biuret solution	Ward's
	20	30	Each	Safety glasses	Ward's
	20	30	Each	Lab apron	Ward's
	20	30	Pair	Nitrile or plastic gloves	Ward's
Activity 4	10	15	Each	LabQuest2	Vernier
	10	15	Each	Temperature Sensor	Vernier
	10	15	Each	Forceps	Ward's

APP	Qty/ 20	Qty/ 30	Unit	Item Specifications	Vendor
	20	30	Each	Empty soup cans	Local
	10	15	Each	Butane lighter	Local
	10	15	Each	125ml plastic bottle with lid	Ward's
	20	30	Each	Stirring rods	Ward's
	20	30	Each	Single hole stoppers	Ward's
	10	15	Each	Ring stand	Ward's
	10	15	Each	10cm ring	Ward's
	10	15	Each	Utility clamp	Ward's
	10	15	Each	100ml graduated cylinder	Ward's
	20	30	Each	30ml graduated cups	Lab-Aids
	10	15	Each	Beaker tongs	Ward's
	5	8	Rolls	Paper towels	Local
	10	15	Each	Water	Local
	5	8	Each	60ml burner with kerosene	Lab-Aids
	5	8	Each	60ml burner with ethanol	Lab-Aids
	5	8	Each	Bromthymol blue (BTB)	Lab-Aids
	5	8	Each	Sodium hydroxide dropper	Lab-Aids
	20	30	Each	Safety glasses	Ward's
	20	30	Each	Lab apron	Ward's
Activity 5	5	8	Each	60ml burner with kerosene	Lab-Aids
	5	8	Each	60ml burner with ethanol	Lab-Aids
	5	8	Each	Electronic Balance	Ward's
	10	15	Each	10cm ring	Ward's
	10	15	Each	Utility clamp	Ward's
	20	30	Each	Stirring rods	Ward's
	20	30	Each	Single hole stoppers	Ward's
	10	15	Each	Ring stand	Ward's
	10	15	Each	10cm ring	Ward's
	10	15	Each	100ml graduated cylinder	Ward's
	20	30	Each	Empty soup cans	Local
	10	15	Each	Metric ruler	Local
	20	30	Each	Safety glasses	Ward's
	20	30	Each	Lab apron	Ward's
Activity 6	1	1	Each	Water bath	Ward's
	10	15	Grams	Ground corn stalks	Local
	1	1	Each	Coffee grinder	Local
	5	8	Each	Permanent marker	Local
	5	8	Each	Electronic balance	Ward's
	20	32	Each	50ml falcon tubes	Amazon
	5	8	Each	Test tube racks	Ward's
	5	8	Each	Test tube tongs	Ward's
	5	8	Each	LabQuest2	Vernier
	5	8	Each	Ethanol sensor	Vernier
	5	8	Roll	Teflon^{TM} tape	Local
	5	8	Pair	Scissors	Local
	5	8	Each	Hot plate	Ward's
	5	8	Gal	Distilled water	Local
	5	8	Each	400ml beaker	Ward's
	5	8	Each	250ml beaker	Ward's
	55	8	Each	100ml graduated cylinder	Ward's
	5	8	Each	Weigh dishes	Ward's

APP	Qty/ 20	Qty/ 30	Unit	Item Specifications	Vendor
	5	8	Each	Plastic spoon	Local
	10	16	Each	1ml graduated pipets	Ward's
	1	1	Bottle	50ml Celluclast enzyme	Sigma
	1	1	Bottle	0.05M sulfuric acid, 500ml	Ward's
	1	1	Jar	Yeast, 4oz.	Local
	20	30	Each	Safety glasses	Ward's
	20	30	Each	Lab apron	Ward's
	20	30	Pair	Nitrile or plastic gloves	Ward's

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Acknowledgements

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Name____

Ethanol Activity 1 – History

Purpose

With the world population growing, the need for new energy sources is increasing. Society uses renewable and non-renewable sources of energy to meet daily needs to operate electrical appliances, drive cars, heat homes, and endless other tasks.

Forward thinkers and entrepreneurs have been considering alternative energies for decades. Biofuels are an alternative energy source developed and utilized to benefit the environment and economy. Biofuels made from plants, such as ethanol, are blended in gasoline used in vehicles. Ethanol was always intended to be the leading fuel of choice for automobiles. When Henry Ford created the Model T in 1908, he designed its engine to run on ethanol and gasoline. Ethanol can be produced from a variety of agricultural crops. Agricultural producers in the Midwest United States produce starch-based ethanol. During the 1970's and 1980's, the corn used for starch-based ethanol came from the surplus grain supply to create a critical market for American agriculture. A coproduct produced during starch-based ethanol production valuable to agriculture is distillers grain. Distillers grain are the solid materials remaining after ethanol has been distilled. Distillers grain contains protein, fiber, and oil making it a quality animal feed.

What is the history of ethanol used as an energy source? How is corn-based ethanol produced? What are its environmental benefits?

Materials

Per pair of students:

- Computer with internet access and printer
- Classroom textbooks
- Poster board
- Assorted markers
- Glue
- Scissors

Per student:

- Pencil

Procedure

Work with your partner to design and construct a display to educate the public about ethanol. When you have completed your educational display, share your findings with the class.

Part One – Research and Display

1. Draw a corn kernel in the center of the poster to represent the energy source. Make sure the image is large enough to see detail, leaving enough room to add images around the edges of the illustration.
2. Use the internet and classroom textbooks to research the following about ethanol.
    - History of ethanol and ethanol as an energy source
        - How ethanol was discovered as an energy source
        - Who introduced ethanol as an energy source
        - When starch ethanol processing from corn was developed
        - Current amount of ethanol available
        - Future availability and production potential of ethanol
        - Physical characteristics

- Ethanol production and processing
  - A map identifying areas of the United States currently producing ethanol and areas with potential to produce this source in the future
  - How ethanol is produced and/or processed
  - Production costs
  - Materials and infrastructure needed to process/or produce ethanol
  - Annual ethanol production
  - Coproducts produced during the ethanol production process.
- Ethanol Usage
  - Annual consumption
  - Materials and infrastructure needed to use ethanol
  - Where and how it is used
- Environmental information
  - Environmental impact of ethanol production
  - Environmental impact of ethanol use
  - Byproducts produced during production and use
- Agricultural Impact
  - How agriculture consumes and or/produces ethanol

3. Type, print, and organize your information on the display board. See Figure 1 for an example.
4. Display your research as instructed by your teacher.
5. Discuss with your peers the impact ethanol has and will have on your community. Your teacher will lead the discussion.

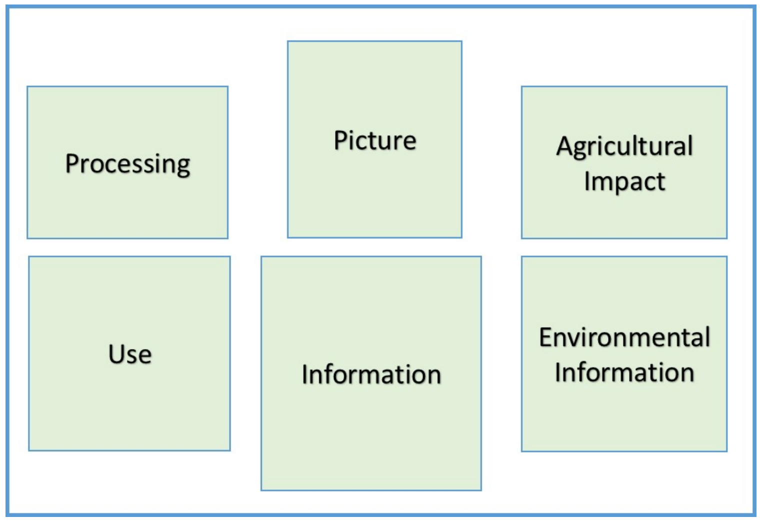

Figure 1. Sample Display Layout

Conclusion

1. How can agriculture provide an alternative energy source?

2. What are the advantages and disadvantages of using ethanol as an energy source?

3. Where is ethanol produced and used near you?

4. What are ways to get ethanol to areas where it is not as available?

Name____

Ethanol Activity 2 – Production and Coproducts

Purpose

Ethanol is a renewable fuel blended with, or used as, a substitute for gasoline. It is effective in reducing carbon monoxide levels, ozone pollution, and greenhouse gases in auto exhaust. Presently, ethanol producers ferment most ethanol from readily available sugars found in plant products. Corn and agricultural products can be milled and mixed with enzymes to be broken down into simple sugars. During fermentation, yeast microorganisms consume simple sugars to produce energy, carbon dioxide, and ethanol. A coproduct from starch-based ethanol are distillers grains that can be used as high protein animal feed. Distillers grains are high in protein and energy. Another coproduct is carbon dioxide. Carbon dioxide can be consumed by next years corn crop during photosynthesis by the corn plants.

What is the process for making ethanol from starch in a corn kernel? How can we identify the nutrient content of the coproducts?

Materials

Per student:

- Safety glasses
- Lab apron
- Plastic or nitrile gloves
- Pencil

Per pair of students:

Part One

- 250ml beaker
- 50ml beaker
- Thermometer
- Yeast
- Water
- Microwave
- 250ml Erlenmeyer flask
- Crushed corn
- Electronic balance
- Two-hole stopper
- 5cm glass tubing
- 2ft plastic tubing
- Bromothymol blue

Part Two

- Condenser
- Crushed Ice
- Utility clamp
- Ring stand
- Porcelain bowl
- Butane lighter

Part Three

- Test tube
- Biuret solution
- Eye dropper

Procedure

View your teacher's demonstration of fermentation and distillation. Then ferment ethanol from ground corn. and distill the ethanol from the distiller grain coproduct.

Part One – Ethanol Production

1. Observe your teachers fermentation and distillation demonstration.

2. Put on PPE and tie back long hair.
3. Use a microwave to heat a 200ml of water in a 250ml beaker to 40-50°C.
4. Pour approximately 10ml of water into a 50ml beaker.
5. Add 1g yeast to 10ml of warm water.
6. Stir the water and yeast mixture until dissolved.
7. Add 20 ml of the remaining warm water to the mixture.
8. In a 250ml Erlenmeyer flask, mix 30g crushed corn, 150ml warm water, and 15ml yeast solution.
9. Swirl the flask well to mix contents.
10. Place a two-hole stopper in the top of the flask, with a thermometer and 5cm glass tubing inserted into the holes.
11. Fill a 250ml beaker approximately half full of water. If desired, place 20 drops of bromthymol blue in the water to indicate CO_2 output.
12. Connect a piece of plastic tubing to the glass tubing and place the other end in the beaker of water. This allows CO_2 to escape the flask, but prohibits O_2 from entering and causing an aerobic environment.
13. Place entire apparatus in a warm environment of 25-30°C.
14. Monitor the apparatus for three days. Record the appearance of the flask and beaker in Table 1 of the student worksheet.

Part Two – Ethanol Extraction

1. Remove the stopper from the flask, and gently waft the fumes toward your nose. Describe the aroma to in Table 1 the student worksheet. Replace the stopper in the flask.
2. Fill the condenser chamber with crushed ice and cold water. Place the condenser in a utility clamp on a ring stand at approximately a 45° angle.
3. Position a 50ml beaker at the base of the condenser unit to catch the distillate.
4. Place the flask on a hot plate.
5. Remove the plastic tubing from the water beaker and connect it to the condenser unit.
6. Turn on the hot plate to medium. Observe the flask, if the solution begins to boil vigorously, turn down the heat to maintain a slow boil.
7. Maintain a slow boil until the thermometer reads 95°C. Turn off the hot plate.
8. When condenser unit stops dripping, observe the volume of the distillate.
9. Answer *Part Two Analysis Questions*.
10. Have your teacher pour a small volume, approximately 2ml, of distillate into a shallow porcelain bowl and light using a long-handled butane lighter to demonstrate the production of fuel.

Part Three – Ethanol Coproducts

1. Pour 3ml of the coproduct solution from the flask into a test tube.
2. Add five drops of biuret solution to the coproduct solution in the test tube. Biuret solution turns from blue to violet in the presence of protein.
3. Dispose of biuret/coproduct mixture as instructed by your teacher.
4. Answer *Part Three Analysis Questions*.

Conclusion

1. What does the color of the solution indicate about the nutrient content of the coproduct solution?

2. What ingredients are needed for producing ethanol?

3. What main products are produced from corn?

4. What other potential coproducts could be produced from starch-based ethanol?

Name____

Student Worksheet

Table 1. ***Fermentation Observations***

Days	**Day 1**	**Day 2**	**Day 3**
Flask observations			
Beaker observations			

Part Two Analysis Questions

- What is the ratio of beginning ingredients to fuel produced?
- What factors could affect the amount of fuel produced?
- How do you know you have distilled ethanol?

Part Three Analysis Questions

- What type of coproduct is in the flask?
- What type of nutrient is in the coproduct?
- What could the coproduct be used for?

Name____

Ethanol Activity 3 – Community

Purpose

Throughout history, government has played an important role implementing laws and regulations that protect the environment and improve the economy. Congress created the renewable fuel standard (RFS) program to reduce greenhouse gas emissions and expand the nation's renewable fuels sector while reducing reliance on imported oil. This program was authorized under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007.

The RFS has helped provide consumers with real choice and savings at the pump while strengthening our economy, delivering greater energy independence, and improving our environment. The RFS requires fuel companies to purchase and blend renewable fuels with fossil fuels. Each year the amount of renewable fuel required to be blended increases. The national goal of the RFS is to reduce greenhouse gas emissions, expand the renewable fuels industry in the United States, and to reduce the United States dependence on foreign oil.

How does the Renewable Fuel Standard impact local communities and citizens?

Materials

Per student:

- *Activity 3 Community Role Card*
- Computer with Internet access
- Pencil

Procedure

For this activity, you will role-play a community member concerned with the Renewable Fuel Standard. Pay attention to the complexities of decision-making where people having different points of view are involved.

Part One – The Situation

Your newly elected United States Representative is on a committee investigating the possibility of repealing the Renewable Fuel Standard. Your representative is unfamiliar with the RFS and would like to hear from constituents about how the RFS has impacted them. She is holding a townhall meeting to hear from community members like you in your local area.

Part Two – Determining Your Role

Read the role card you were given with information about an individual impacted by or concerned with the Renewable Fuel Standard. You will play the role of this individual for the remainder of the activity. You may not agree with your assigned role, but often agriculturalists must learn to see issues from other perspectives. As a part of your involvement at the upcoming townhall meeting, you are expected to engage in a round table discussion on the Renewable Fuel Standard. To prepare, research the RFS and write a position statement for your role. Include each of the following items in your statement.

- An introduction of who you are.
- A statement explaining your position on the Renewable Fuel Standard, the impact it has on you, and why you feel this way.
- A list of three other community members you feel should be involved in the decision making process and why you think they should be there.

- Three questions you have about the Renewable Fuel Standard that other community members may be able to answer.

You and your fellow classmates will present your positions on the Renewable Fuel Standard to the class. You may be called upon to answer questions that other students may have. Once all classmates make their statement, write a summary of what you have learned about the impact of ethanol and the Renewable Fuel Standard. Include whether you agreed with the role you represented and why you did or did not agree with that role.

Conclusion

1. Why do you think opinions tend to vary concerning energy production?

2. What important factors influenced the creation of the RFS through the Energy Policy Act of 2005 and its expansion under the Energy Independence and Security Act of 2007?

3. What differences and similarities are there between how decisions are made in this activity and how they happen in your community?

4. What skills did you learn from this activity and how could apply them in the real world?

Activity 3 Community Role Cards

Make 2 copies for a total of 20 roles for students.

Community Member You are a local homeowner with a flex fuel vehicle (FFV). You are concerned about greenhouse gas emissions and the affect they will have on the environment.
Downtown Business Owner As a downtown business owner, you understand ethanol's potential to reduce consumer costs at the gas pump and have seen an increase in business since the opening of the ethanol plant in town.
Community Member You are a local homeowner and resident with a vehicle that uses gasoline. You are concerned about the fluctuation in oil prices and how they affect your costs to commute to the neighboring town for work.
Wildlife Biologist You are local biologist who has seen a change in wildlife populations over the past 10 years and are concerned that it may be due to climate change caused by greenhouse gas emissions.
Ethanol Plant Executive You are strongly in favor of ethanol production and helped plan the construction of an ethanol plant in town. As an executive you oversee 75 workers and managers at the ethanol plant.
Gas Station Owner You are the owner of a gas station. You sell gasoline blended with 10% ethanol and E85 ethanol,
Ethanol Plant Employee You moved to town because of the construction of the ethanol plant.
City Council Person You have seen the ethanol plant bring new industry to your community and the benefits to the local economy. You also understand the rural farm economy and how it supports local businesses in town.
Crop Farmer You are a fourth generation farmer who owns 2000 acres and grows corn and soybeans. You market your crops and sell corn to the local ethanol plant.
Beef Farmer You are a new beef farmer who owns 200 acres and raises beef cows. You purchase distillers grains from the ethanol plant in town.

Name____

Ethanol Activity 4 – Combustion

Purpose

Cleaner burning. Energy efficient. Environmentally friendly. E85. The labels and promotion of vehicles and other energy consuming products make many of these claims. But what do they mean? Is ethanol better for the environment than gasoline?

Most energy used in the United States consists of burning a combustible material and harnessing the heat, or energy, produced. The burning of combustible materials releases harmful gases and soot into the air. Typically, fuels producing more soot tend to be more harmful to the environment and to people's health. Fuels producing more heat per unit produce more energy.

There are many methods to compare the efficiency and the environmental impact of fuels. To determine efficiency, the heat released during the combustion process may be measured. Environmental impacts can be measured by the particulate matter, or soot, released into the air and by the amount of carbon dioxide produced. Carbon dioxide is a greenhouse gas found in the lower atmosphere. The increase of greenhouse gasses in the atmosphere can cause global temperatures to rise.

A common method to determine the presence of particular substances is through the use of indicators. An indicator solution changes color in the presence of the material for which you are testing. Bromthymol blue (BTB) is an indicator that turns yellow in an acidic solution and blue in a basic solution. When carbon dioxide is suspended in water, it forms carbonic acid. BTB can be used to indicate the presence of carbon dioxide in water. Sodium hydroxide is a base used to neutralize acidity. The amount of sodium hydroxide required to neutralize the solution indicates the concentration of carbon dioxide in the solution.

When collecting data, scientists use visual indicators as well as measurements. Data collected using visual observations is called qualitative data while measured data is called quantitative data. What qualitative and quantitative data can you use to compare fuels?

Materials

Per pair of students:

- LabQuest2
- Temperature sensor
- Forceps
- 2 empty soup cans
- Lighter
- 125ml plastic bottle with lid
- 2 stirring rods
- 2 single hole stoppers
- Ring stand
- 10cm ring
- Utility clamp
- 100ml graduated cylinder
- 2 30ml graduated cups
- Beaker tongs
- Paper towels
- Water

Per group of four students:

- 60ml burner with kerosene
- 60ml burner with ethanol
- Bromthymol blue (BTB)
- Sodium hydroxide (NaOH)

Per student:

- Lab apron
- Safety goggles
- Pencil

CAUTION – You will be burning combustible materials, refer to local safety lab procedures for burning items.

Procedure

In this laboratory, you and a partner will investigate the efficiency and environmental impacts of two combustible fuels – kerosene and ethanol. Then you will compare the amount of heat released from combustion, particulate matter produced, and carbon dioxide emitted for each fuel source by collecting qualitative and quantitative data.

Part One – Predictions

In complete sentences on *Activity 4 Student Worksheet*, write a prediction of what you believe will occur in terms of heat released, soot production, and carbon dioxide emissions for each fuel source.

Part Two – Preparation

1. Pour 10ml of water into each of the two graduated 30ml cups.
2. Add two drops of bromthymol blue (BTB) to each cup.
3. Swirl each cup to mix the liquids thoroughly.
4. Set cups aside until Part Four.

Part Three – Heat Released

1. Obtain a burner from your teacher. You will conduct three different tests on one fuel source, then exchange burners with the other pair in your group and repeat the tests.
2. Put on your safety goggles and tie back long hair.
3. Prepare the LabQuest2.
    - Connect the temperature sensor to the LabQuest2 and turn the LabQuest2 on.
    - Choose **New** from the *File* menu. On the *Meter screen*, select **Rate** on the touch screen.
    - Change the *data-collection rate* to 0.2 samples/second. Set the *data collection length* to 240 seconds.
4. Set up the apparatus as demonstrated by your teacher. (See Figure 1.)
    - Use the graduated cylinder to measure and pour 100ml of cold water into the can.
    - Insert a stirring rod through the holes in the top of the can and hold it in place with two one-hole stoppers. Position the can 5cm (~2 inches) above the burner.
    - Use a utility clamp to suspend the temperature sensor in the water. The sensor should not touch the bottom or side of the can.

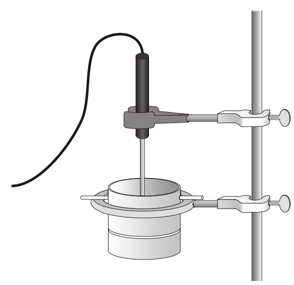

Figure 1. Apparatus.

5. Start collecting data.
    - Use the lighter to ignite the wick. Position the burner directly below the center of the water-filled can. CAUTION: Always keep hair and clothing away from open flames.
    - Tap the green start arrow to begin collecting data.
    - A real-time graph of temperature vs. time will be displayed on the LabQuest2 screen during data collection.
    - Temperature readings (in °C) can also be monitored to the right of the graph.
6. Stir the water slowly and continuously using a stirring rod until data collection stops.
7. After data collection has stopped, analyze the graph to find maximum and minimum temperature of the water.
    - Choose **Statistics** from the *Analyze menu*.

- Record the Maximum (final) and Minimum (starting) temperature values recorded during data collection in Table 2 of *Activity 4 Student Worksheet*.
- Select OK.

8. Store the data from the first run by selecting the **File Cabinet** icon.

Part Four – Carbon Dioxide Emissions

1. Pull the burner away from the ring stand.
2. Remove the cap from the plastic bottle.
3. Carefully place the opening of the bottle over the flame.
4. Hold it snugly against the metal casing of the burner until the flame is extinguished.
5. With the bottle still inverted, raise the bottle just enough to screw on the cap.
6. Turn the bottle right side up.
9. Uncap the bottle and quickly pour one graduated cup of the water and BTB mixture into the bottle. Your goal is to let as little oxygen into the bottle as possible.
10. Recap the bottle immediately.
11. Shake the bottle so the solution mixes with the gas.
12. Pour the solution from the bottle back into the graduated cup.
13. Observe the contents and record in Table 1.
14. Add NaOH one drop at a time to the solution while your partner swirls the solution until the blue color returns and is the same as the second cup.
15. Record the number of drops of NaOH required to return the solution to the original color.

Part Five – Clean Up

1. Empty the can of water and place upside down on a paper towel. Use the beaker tongs to move the can as the can and water may still be hot.
2. Dispose of the BTB solutions as instructed by your teacher.
3. Rinse the graduated cups.

Part Six – Comparison Fuel

1. Exchange burners with the other pair in your group to test the fuel source you have not tested.
2. Repeat Part Two, Three, Four, and Five with the second fuel source and a new soup can.

Part Seven – Particulate Matter

1. Locate your two soup cans.
2. Compare the amount and color of particulate matter on the bottom of each can.
3. Record your observations on Table 1 of *Activity 4 Student Worksheet*.
4. Clean up as instructed by your teacher.

Part Eight – Compare Quantitative Data

Compare the two samples by viewing both sets of quantitative data on one graph.

- After data collection is complete, select **Run 2** on the touch screen and select **All Runs**. Both runs will now be displayed on the same graph.

- Examine the data points along the displayed curve. To examine the data on the displayed graph, select any data point. As you move the examine line right or left, the temperature values of each data point are displayed to the right of the graph.
- Use the displayed graph to fill in Table 2 and answer the analysis questions on the student worksheet.

Part Nine – Analysis

1. Share your results with your classmates as instructed by your teacher.
2. Record the results of the other groups in Table 3 on *Activity 4 Student Worksheet*.
3. Determine the class average for temperature change and drops of NaOH for each fuel.
4. Write a lab report on your findings.

Conclusion

1. Why do you think gasoline is used more than other substances for a common energy source?

2. What are the advantages and disadvantages of burning biofuels versus burning gasoline?

Name____

Activity 4 Student Worksheet

Table 1. ***Predictions***

Kerosene prediction:
Kerosene is a petroleum-based fuel used as jet fuel and a heat source.
Ethanol prediction:
Ethanol is a biofuel produced from plant matter used as a gasoline alternative.

Table 2. ***Data Collection***

	Ethanol	Kerosene
Color of BTB solution with carbonic acid		
Drops of NaOH required to neutralize		
Particulate matter on can		
Initial Temperature		
Final Temperature		
Change in Temperature		
Notes		

Analysis Questions

- Which substance produced the most amount of soot? Least?
- Which substance produced the most amount of heat? Least?

Table 3. ***Class Average***

Group	Ethanol			Kerosene		
	Δ in temp	NaOH	Particulate	Δ in temp	NaOH	Particulate
Average						

Name____

Ethanol Activity 5 – Energy

Purpose

When you go to the gas station to purchase fuel, there are many types to choose. Besides different forms of fossil fuels, such as gasoline and diesel, the station may sell renewable fuels, such as ethanol or biodiesel. Many vehicles today use both fossil and renewable fuels. What type of fuel should you choose?

Consumers consider engine performance, cost, availability, environmental impact, and efficiency before deciding on a fuel to purchase. The octane rating of a fuel impacts engine performance. The octane rating determines the amount of compression needed in the engine for a fuel to ignite. Fuels with low octane rating ignite under less compression than fuels with a high octane rating. If a fuel ignites too early in the combustion process due to a low octane rating, a pinging or knocking noise may be heard coming from the engine. Ethanol has a high octane rating. Ethanol can be blended with gasoline in place of chemicals to increase the gasoline's octane rating and engine performance.

Consumers use fuel efficiency to determine fuel cost. Calculate fuel efficiency by measuring the heat energy released during combustion. Fuels absorb and release energy when they combust. The energy a fuel produces depends upon the number and types of bonds holding the fuel molecule together. Heat energy is measured in calories. The greater the number of calories of heat produced per gram of fuel, the more potential energy the fuel has.

What factors should you consider when choosing a fuel? Which fuels are more cost efficient?

Materials

Per student:

- Pencil
- Safety glasses
- Lab apron
- Calculator

Per group of four students:

- 60ml fuel burner with kerosene
- 60ml fuel burner with ethanol
- Long handled butane lighter
- Electronic balance

Per pair of students:

- Computer with Internet access
- Ring stand
- 10cm ring
- Utility clamp
- Metric ruler
- LabQuest2
- Vernier temperature sensor
- Empty soup can
- 100ml graduated cylinder
- 2 stirring rods
- 2 single hole stoppers

Procedure

Your group will break into two pairs and research the advantages and disadvantages of fossil fuels and ethanol. Each pair will choose a fuel to burn. You and your partner will burn the chosen fuel and measure the number of calories per gram. Finally, your group will compare the results.

Part One – Biofuel Background

1. Work with your partner to research the advantages and disadvantages of both fossil fuels and ethanol. Use the websites listed to begin your research.

Resources

- How Stuff Works: Biofuels vs Fossil fuels: **http://auto.howstuffworks.com/fuel-efficiency/biofuels/biofuel-fossil-fuel.htm**
- Ethanol Facts: **https://growthenergy.org/fast-facts/**

2. Record three advantages and disadvantages of biofuels and fossil fuels in Table 1 of *Activity 5 Student Workshee*t.
3. Predict whether ethanol or kerosene will be a more efficient producer of energy on the student worksheet.

Part Two – Apparatus Setup

Your teacher will demonstrate how to setup the apparatus before beginning Part Two.

1. Decide who will test ethanol, a biofuel, and who will test kerosene, a fossil fuel.
2. Put on your safety glasses and lab apron. Tie back long hair.
3. Use an electronic balance to measure the mass of the burner containing the assigned fuel. Be sure the cap is on the burner.
4. Record the initial mass of the fuel container in Table 2 of *Activity 5 Student Worksheet*.
5. Prepare the apparatus as demonstrated by your teacher. (See Figure 1.)
   - Set the burner on the platform of the ring stand and remove the cap.
   - Place the 10cm ring on the ring stand.
   - Fill the can with 100ml of water using a graduated cylinder.
   - Insert a stirring rod through the holes in the top of the can and hold it in place with two one-hole stoppers. Position the can 5cm (~2 inches) above the burner using the 10cm ring.

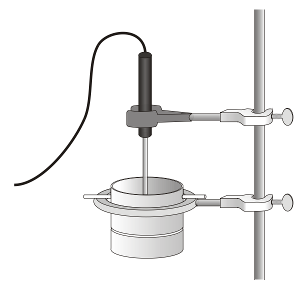

Figure 1. Apparatus Setup

6. Setup up the LabQuest2.
   - Turn on the LabQuest2.
   - Plug in the temperature sensor into Channel 1.
   - Change the units to °C.
   - Choose New from the File menu. On the Meter screen, select Rate on the touch screen.
   - Change the data collection rate to 0.2 samples/second. Set the data collection length to 180 seconds.
   - Tap OK.
7. Use a utility clamp to hold the temperature sensor so 2 – 3cm of the sensor is in the water without touching the sides or the bottom of the can.

Part Three – Fuel Combustion

1. Start data collection on the LabQuest2 by tapping on START.
2. Quickly, light the wick with the lighter. CAUTION: Always keep hair and clothing away from open flames.
3. Stir the water slowly and continuously using a stirring rod.
4. After data collection stops, extinguish the flame by placing the cap over the wick.
5. Analyze the data.

- Choose Statistics from the Analyze menu
- Record the Maximum (final) and Minimum (initial) temperatures recorded during data collection in Table 2 on the student worksheet.

6. Use the electronic balance to measure the final mass of the fuel container with the cap on and record in Table 2.
7. Calculate the change in temperature by subtracting the initial temperature from the final temperature and record in Table 2.
8. Calculate the change in mass by subtracting the final mass from the initial mass and record in Table 2.
9. Complete Table 2 by sharing data with your group.

Part Four – Fuel Efficiency

One calorie is equal to the heat energy required to raise the temperature of 1g of water 1°C. Figure 2 shows the equation for finding calories. One milliliter of water is equal to 1 gram of water.

$$\text{calories} = \text{mass of water (grams)} \times \frac{1\text{ calorie}}{\text{gram }^\circ\text{C}} \times \Delta\text{T(final temp-initial temp)}$$

Figure 2. Calorie Equation

1. Use the data from Table 2 to calculate the number of calories each fuel produced. Show your work in Table 3 on the student worksheet and circle your answer.
2. Calculate the fuel efficiency by finding the number of calories in each gram of fuel.
    - The calories per gram is equal to the calories the fuel produced divided by the fuel burned (change in mass). Show your work in Table 3 on the student worksheet and circle your answer.

$$\text{calories per gram} = \frac{\text{calories}}{\text{gram of fuel}}$$

Figure 3. Efficiency Equation

3. You purchase fuel by volume, convert the number of calories per gram of fuel into calories per ml by multiplying the calories per gram times the density of the fuel. Figure 4 contains the density calculations for each fuel. Show your work in Table 3 on the student worksheet and circle your answer.

Ethanol Density Calculation	Kerosene Density Calculation
calories per ml = calories per gram × 0.78g/ml	calories per ml = calories per gram × 0.82g/ml

Figure 4. Fuel Density Equations

4. There are 3785ml per gallon. Multiply the number of calories in each fuel by the 3785 to find the total calories in a gallon of ethanol and gallon of gasoline. Show your work in Table 3 on the student worksheet and circle your answer.
5. The current price of a gallon of ethanol is $2.00 and a gallon of gasoline is $2.75. Use the equations in Figure 5 to find the cost per calorie of ethanol and gasoline.

Ethanol Cost Calculation	Kerosene Cost Calculation
$\text{Cost per Calorie} = \frac{\$2.00}{\text{Calories}}$	$\text{Cost per Calorie} = \frac{\$2.75}{\text{Calories}}$

Figure 5. Cost per Calorie Equations

6. Answer analysis questions on the student worksheet

Conclusion

1. How do you determine the amount of energy in a fuel?

2. Why is fuel efficiency an important factor to consider when choosing a fuel?

3. What other factors should you consider besides energy efficiency when selecting a fuel?

Name____

Activity 5 Student Worksheet

Table 1. ***Fuel Comparison***

Biofuels	
Advantages	
Disadvantages	
Fossil Fuels	
Advantages	
Disadvantages	

- Based upon the advantages and disadvantages listed, what factors besides efficiency influence the use of biofuels?

Prediction: Will ethanol or kerosene be more efficient? Why?

Table 2. *Fuel Measurements*

Fuel	Initial Mass (g)	Final Mass (g)	Change in Mass (g)	Initial Temp. (°C)	Final Temp. (°C)	Change in Temp (°C)
Ethanol						
Kerosene						

Table 3. *Energy Efficiency*

Fuel	Calorie Calculation	Calories per Gram Calculations	Calories per Milliliter Calculations	Calories per Gallon Calculation	Cost per Calorie Calculation
Ethanol					
Kerosene					

Analysis Questions

- Compare the results to your prediction.
- Which fuel produced more energy in three minutes?
- Based upon the results, which fuel do you believe has the most energy per gallon? Why?
- Why would a consumer choose ethanol instead of gasoline?

Name____

Ethanol Activity 6 – Technology

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Purpose

What fuels will be used to power cars and trucks in the future? Inventors have developed cars powered by electricity, ethanol, and natural gas. Will one of these energy sources dominate, or will a different source emerge?

Our nation's transportation system has been built nearly exclusively to run on fuels derived from crude oil including gasoline and diesel fuel. There has never been a realistic pursuit of a 'perfect' energy. Oil companies have used use this to detract from ethanol. Because oil is a finite resource and because of its impact on our ecosystem and environment, other fuel sources such as biofuels have and continue to be developed. In addition, ethanol is added to fossil fuels to increase the octane level of fuel and optimize engine performance. As we continue to replace gasoline with ethanol, the emergence of cellulosic along with starch ethanol presents unique opportunities to do so.

Cellulose is a potential source of ethanol. Scientists are developing new technological processes to ferment cellulosic material into ethanol. Cellulose is a structural component of plant cell walls. Biomasses, such as leaves, stems, husks, and wood chips, contain cellulose. These biomasses do not contain high levels of sugar or starch. Cellulose can be broken down into sugars and starches, and then fermented into ethanol. First, processors chop, cut, and heat the cellulosic material. Next, a chemical treatment with sulfuric acid or enzymes breaks chemical bonds within the cellulose to form starches and sugars. Finally, yeast fermentation of the sugars and starches yields ethanol.

Fermenting agricultural products with readily available starches is less expensive than fermenting cellulosic products. However, cellulosic materials are currently waste byproducts that could be utilized in the future. Cellulosic materials such as corn stalks and cobs left in the field after harvest have fuel potential. Reducing the cost and increasing the efficiency of cellulosic ethanol technology will require investment and research into these processes.

What treatment combination is the most effective breaking down cellulose and producing ethanol from corn byproduct material? Experiment with physical and chemical processes to discover the answer.

Materials

Per student:

- Safety glasses
- Lab apron
- Nitrile or plastic gloves
- Pencil

Per class:

- Water bath
- Ground corn stalks

Per group of four students:

- Permanent marker
- Electronic balance
- 4 50ml falcon tubes with caps
- Test tube rack
- Test tube tongs
- LabQuest2
- Vernier ethanol sensor
- Teflon™ tape

Per group of four students:

Part One

- Scissors
- Hot plate
- Distilled water
- 400ml beaker
- 250ml beaker
- 100ml graduated cylinder
- Weigh dishes
- Plastic spoons

Part Two

- 2 1ml graduated pipets
- Celluclast™ enzyme
- 0.05M sulfuric acid solution

Part Three

- Yeast
- Weigh dish
- Plastic spoon

Procedure

Work with your group to examine biomass treatment methods for producing cellulosic ethanol from corn stalks. Compare the effects of each treatment and select the most efficient process.

Part One – Heat Treatment

1. Answer the following prediction questions on *Ethanol Activity 6 Worksheet*.
2. Pour approximately 200ml of tap water into a 400ml beaker. Place the beaker on a hot plate and bring the water to a boil. While the water heats, continue the lab procedure.
3. Label four falcon tubes 1 through 4.
4. Place the tubes in the test tube rack.
5. Remove the caps from the tubes.
6. Use a 100ml graduated cylinder to add 20ml of distilled water to each falcon tube.
7. Use a balance, weigh dish, and scoop to add 1.0g of ground corn stalks to each tube. Make sure the corn stalks are completely covered by water.
8. Place caps loosely on tubes.
9. Place tubes in the boiling water for 10 minutes.
10. Turn off the hot plate.
11. Using the tongs, place the tubes in the test tube rack, and allow the tubes to cool.
12. Set up the ethanol sensor.
    - Remove the tip of the cap from the ethanol sensor as seen in Figure 1.
    - Remove old Teflon™ tape.
    - Cut a 1.5cm piece of Teflon™ tape.
    - Cover the cap entirely with new tape and inspect the tape for gaps or wrinkles.
    - Place the tip over the tape and secure it.
    - Turn on the LabQuest2.
    - Plug in the ethanol sensor into Channel 1.
    - Wait 5 minutes for the sensor to warm up. Complete Steps 13 – 14 while you wait.

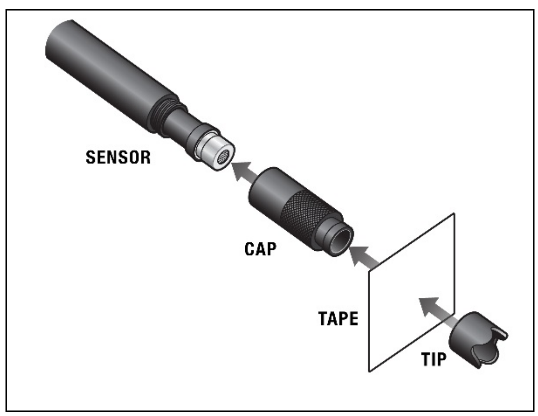

Figure 1. Ethanol Sensor

13. Remove caps from tubes.
14. Observe the physical appearance, such as color, texture, and smell, of each tube. Record your observations in Table 1 on the student worksheet,

15. Measure the ethanol concentration of each heat-treated mixture.
    - Hold the ethanol sensor approximately 3cm above the liquid mixture in the tube.
    - Wait for the reading to stabilize on the Meter screen.
16. Record the results for each heat-treated mixture on the student worksheet.

Part Two – Chemical and Enzymatic Treatment

1. Label one clean graduated pipet "Acid" and another clean graduated pipet "Celluclast."
2. Using the labeled graduated pipets add 0.05M sulfuric acid and Celluclast™ enzyme to the tubes as indicated in Table 2.

Table 2. ***Acid and Enzyme Treatments***

Tube	0.05M Sulfuric Acid	Celluclast™
Tube 1	None	None
Tube 2	2.0 ml	None
Tube 3	None	1.0 ml
Tube 4	2.0 ml	1.0 ml

3. Fasten the caps tight on the falcon tubes. Swirl the tubes.
4. Loosen the caps on the tubes and place the tubes in a water bath at 50°C for 24 hours.
5. Clean the lab as instructed by your teacher.
6. Answer the analysis questions on the student worksheet.
7. After the incubation period, remove the tubes from the water bath and place in the test tube rack.
8. Set up the ethanol sensor as you did in Part One, Step 12, and complete Steps 9 – 10 below while the apparatus warms up.
9. Remove the caps from the tubes.
10. Observe the physical appearance of the material in each tube and record in Table 1 in your *Laboratory Notebook*.
11. Measure the percentage of ethanol in each tube using the ethanol sensor and record the results in Table 1 in your *Laboratory Notebook*.

Part Three – Fermentation

1. Measure one gram of yeast using an electronic balance, weigh dish, and scoop.
2. Pour the yeast into Tube 1.
3. Tighten the cap and swirl the mixture.
4. Loosen the cap on the tube to allow gasses to escape during fermentation.
5. Repeat Steps 1 – 4 for Tubes 2, 3, and 4.
6. Place the tubes in a water bath at 37.5°C for 24 hours. Clean up as instructed by your teacher.
7. After the incubation period, set up the ethanol sensor as you did in Part One, and complete Steps 8 – 10 during the warm up period.
8. Remove tubes from water bath and place them in a test tube rack.
9. Remove caps from each tube.
10. Observe physical appearance of the material and record in Table 1.
11. Measure the percentage of ethanol using the ethanol sensor and record results in Table 1.

12. Clean up the lab as instructed by your teacher.
13. Answer the Part Three Analysis Questions on the student worksheet.
14. Use your answers to prediction and analysis questions along with data tables to write a lab report explaining your findings.

Conclusion

1. Why is the development of cellulosic ethanol dependent on new technological processes?

2. How would the availability of biomass affect development of new biomass energy production?

Name____

Ethanol Activity 6 Worksheet

Prediction Questions

- How will heat treatment affect ethanol production?
- Which treatment, acid or enzyme, will produce more ethanol? Why?

Table 1. ***Observations and Ethanol Production***

Tube #	Observations	Heat Treatment Results	Acid/Enzyme Treatment Results	Fermentation Results
Tube 1	Appearance			
	Ethanol %			
Tube 2	Appearance			
	Ethanol %			
Tube 3	Appearance			
	Ethanol %			
Tube 4	Appearance			
	Ethanol %			

Part Two Analysis Questions

- What is the purpose of heating all samples?
- Why was the ethanol concentration small after heat treatment?
- Why are the samples treated with sulfuric acid and Celluclast™ individually and in combination?
- Fermentation produces ethanol. Why measure for ethanol prior to fermentation?
- If both sulfuric acid and Celluclast™ enzyme increase sugar production, which treatment should produce the most ethanol?
- Tube 1, which has no sulfuric acid or Celluclast™ enzyme treatment, is the control sample. What is its purpose?

Part Three Analysis Questions

- What were the ethanol concentrations after the chemical and enzyme treatments, but prior to the fermentation step?
- Based on the data, what hypothesis would you suggest regarding the most effective biomass treatment to produce ethanol? How would you test your hypothesis?
- Which treatment, sulfuric acid or Celluclast™, produced a larger increase in sugar production? How do you know?

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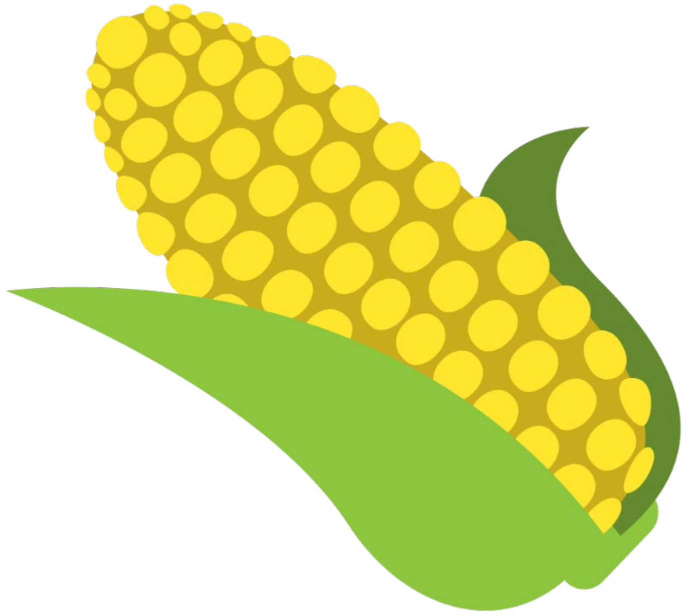
Ethanol History and Production

What is Ethanol?

- Clean burning biofuel
- Produced from agricultural products such as corn kernels
- Used in internal combustion engines



How is Ethanol Produced?

- Field corn processed into flour
- Flour is mixed with recycled water, enzymes and yeast.
  - Enzymes breakdown break up corn starch into sugars
  - Yeast eat sugars and produce ethanol
- Ethanol is distilled from mixture
- Coproducts separated from mixture

- How is ethanol made?
- Ethanol Process Graphic

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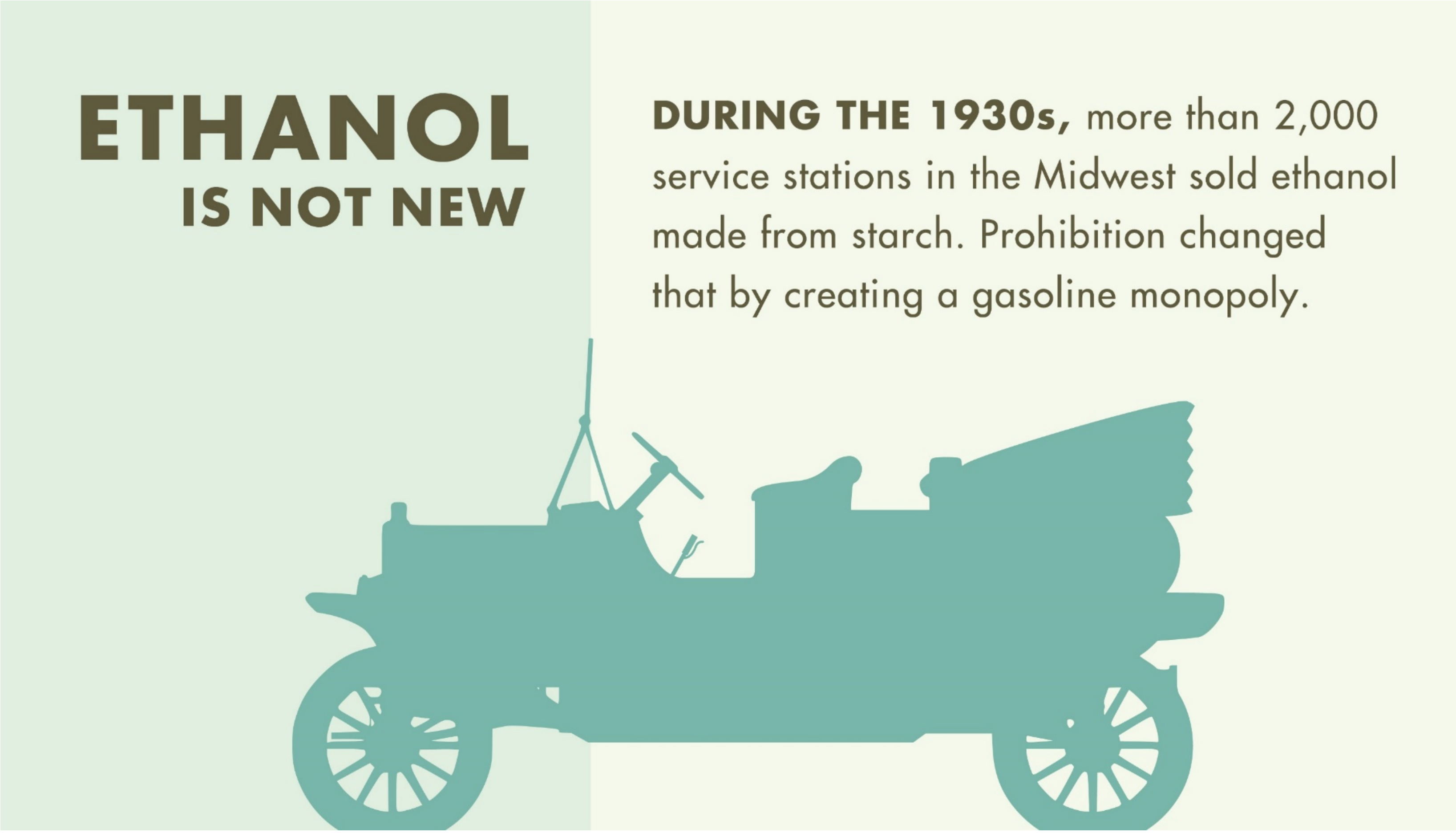
Ethanol History



Ethanol Production Growth

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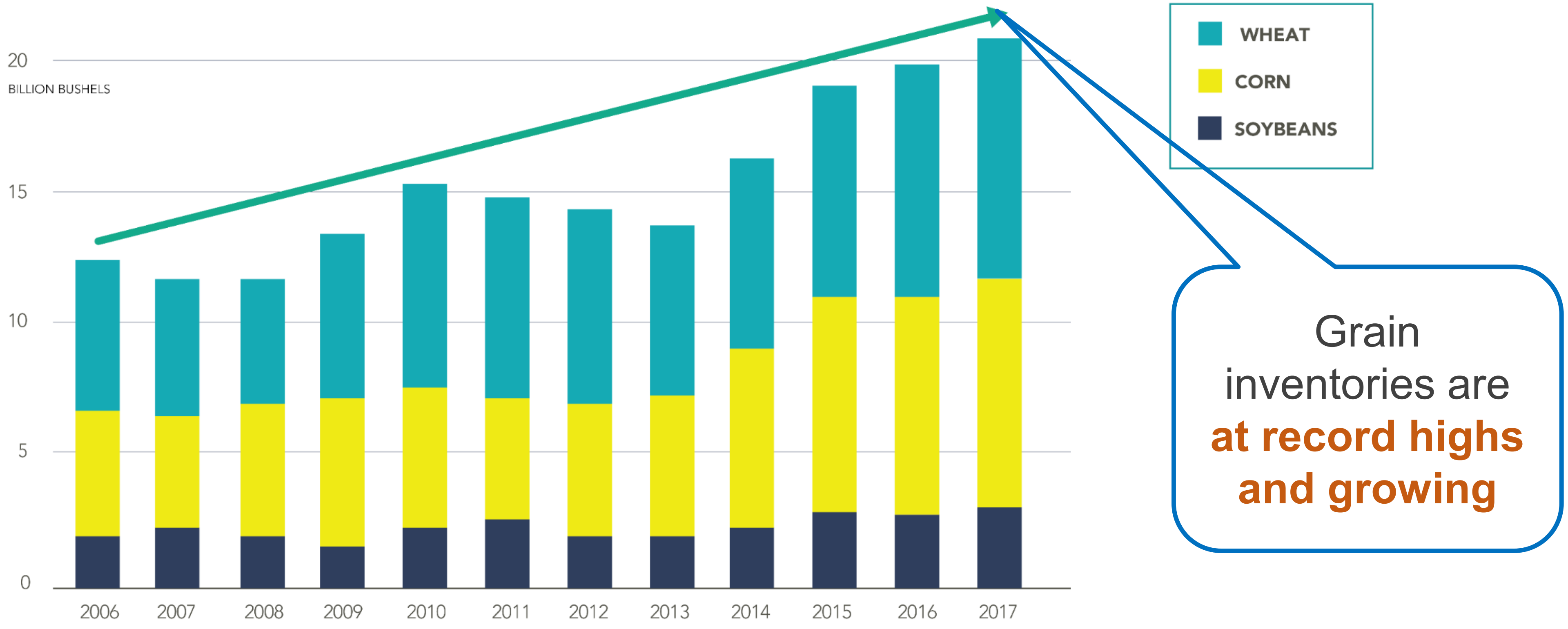
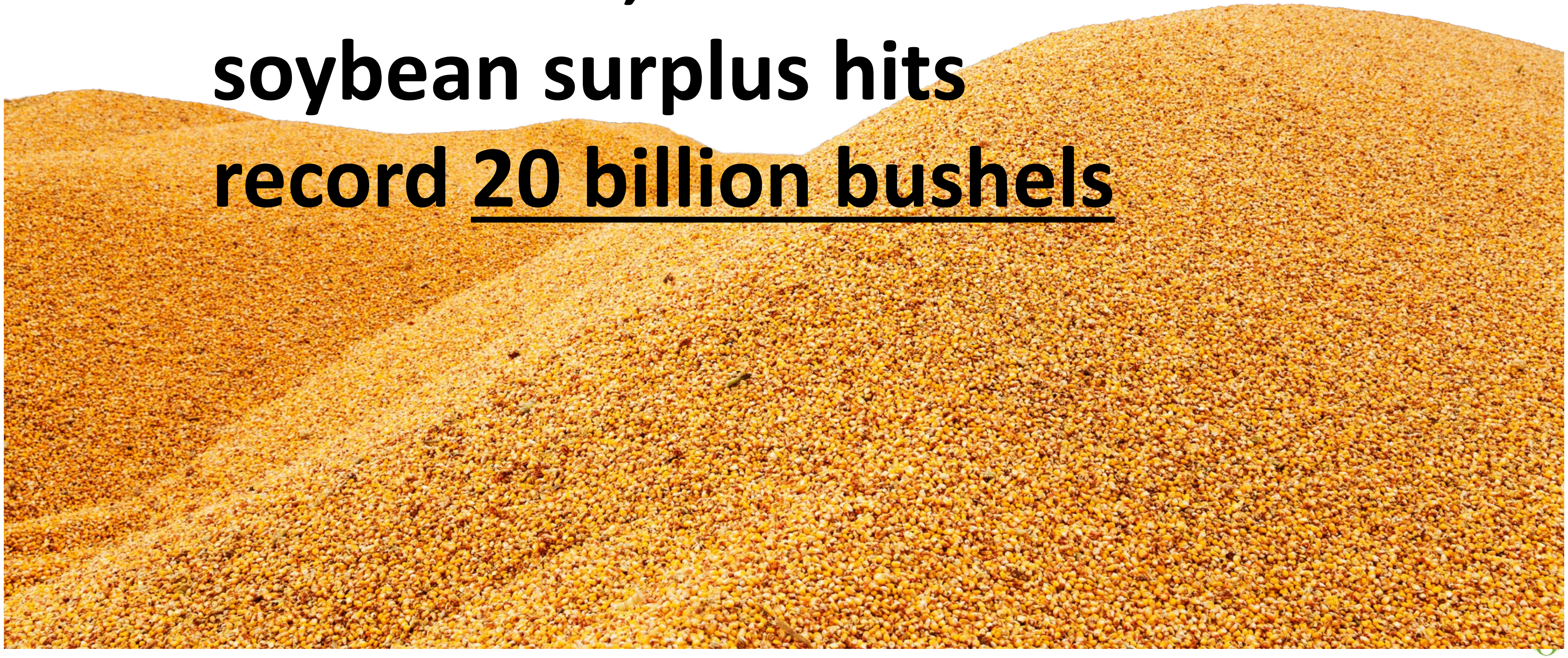
Ag Production Continues to Increase

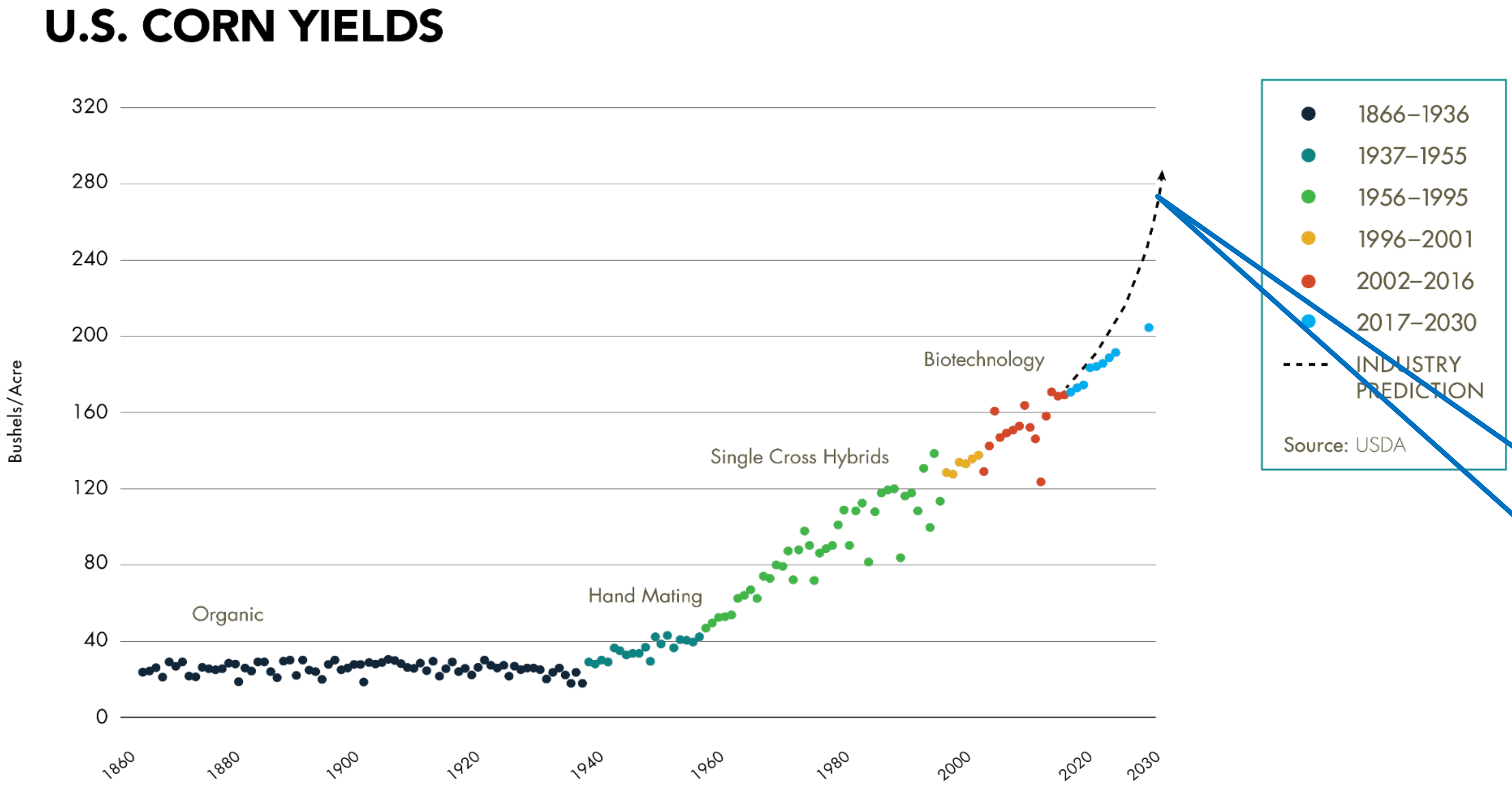


Grain Surplus

World corn, wheat and soybean surplus hits record <u>20 billion bushels</u>

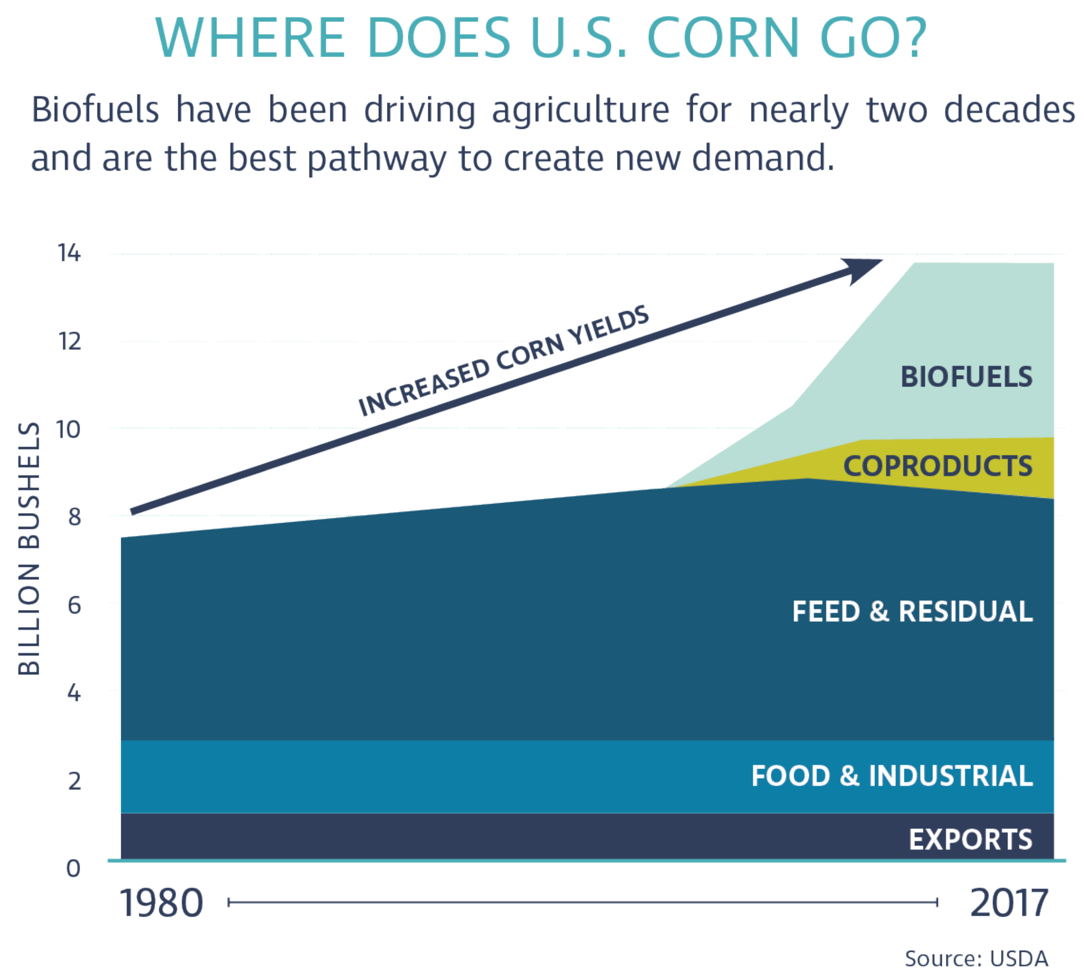


Corn Production

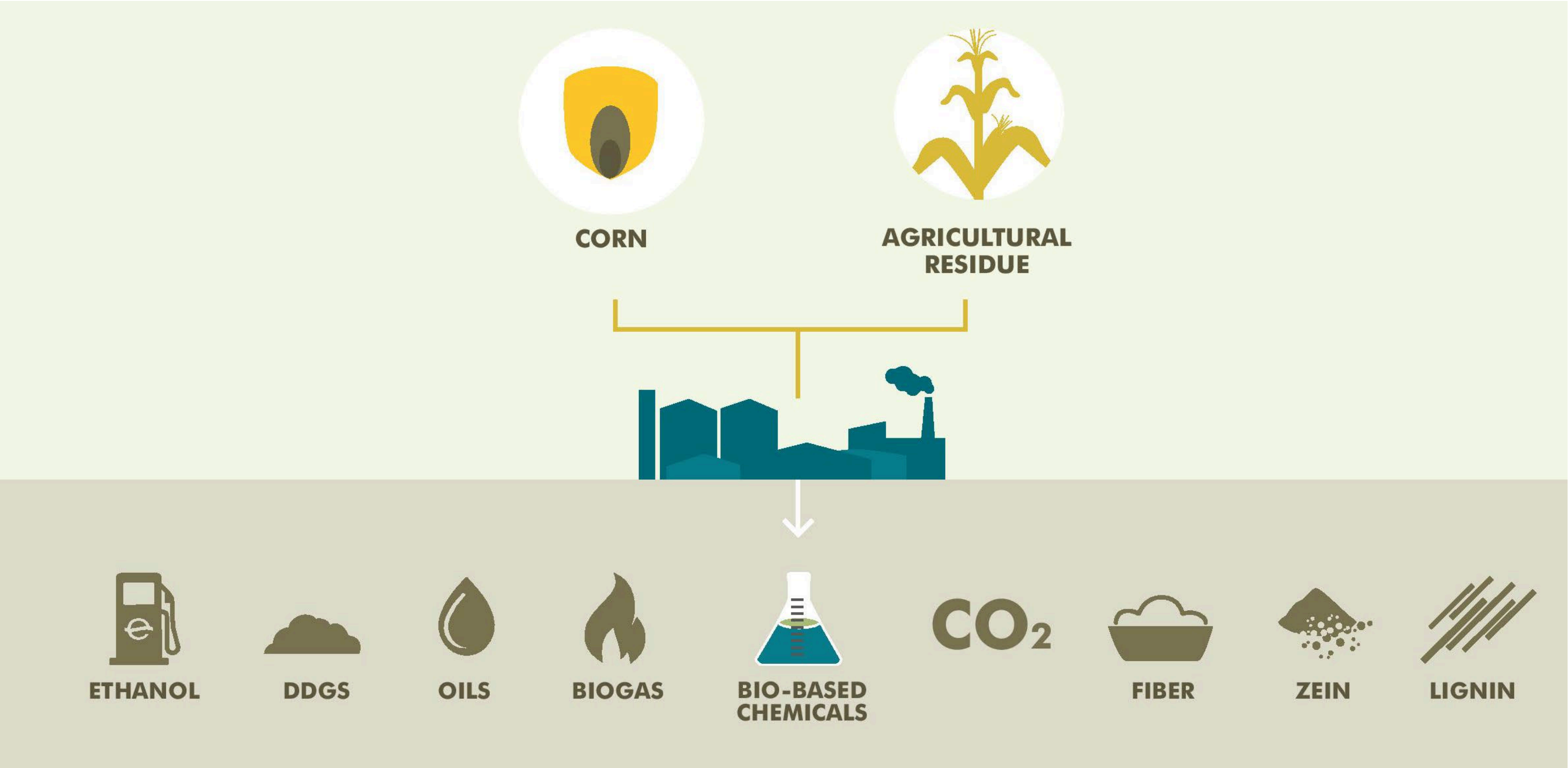


Corn yields continue to grow **rapidly**

Corn Processing



Ethanol and Coproduct Production



Presentation Review

- Mark or highlight three key points
- List two ideas or concepts related to previous knowledge.
- List questions you have about this topic.
- Keep notes organized and available for use throughout the course.

References

- Berven, D., (2018). [POET presentation]. *Biofuels past, present and future*. Sioux Falls, SD.
- POET. (2018). *Products and solutions*. Retrieved from https://poet.com/products

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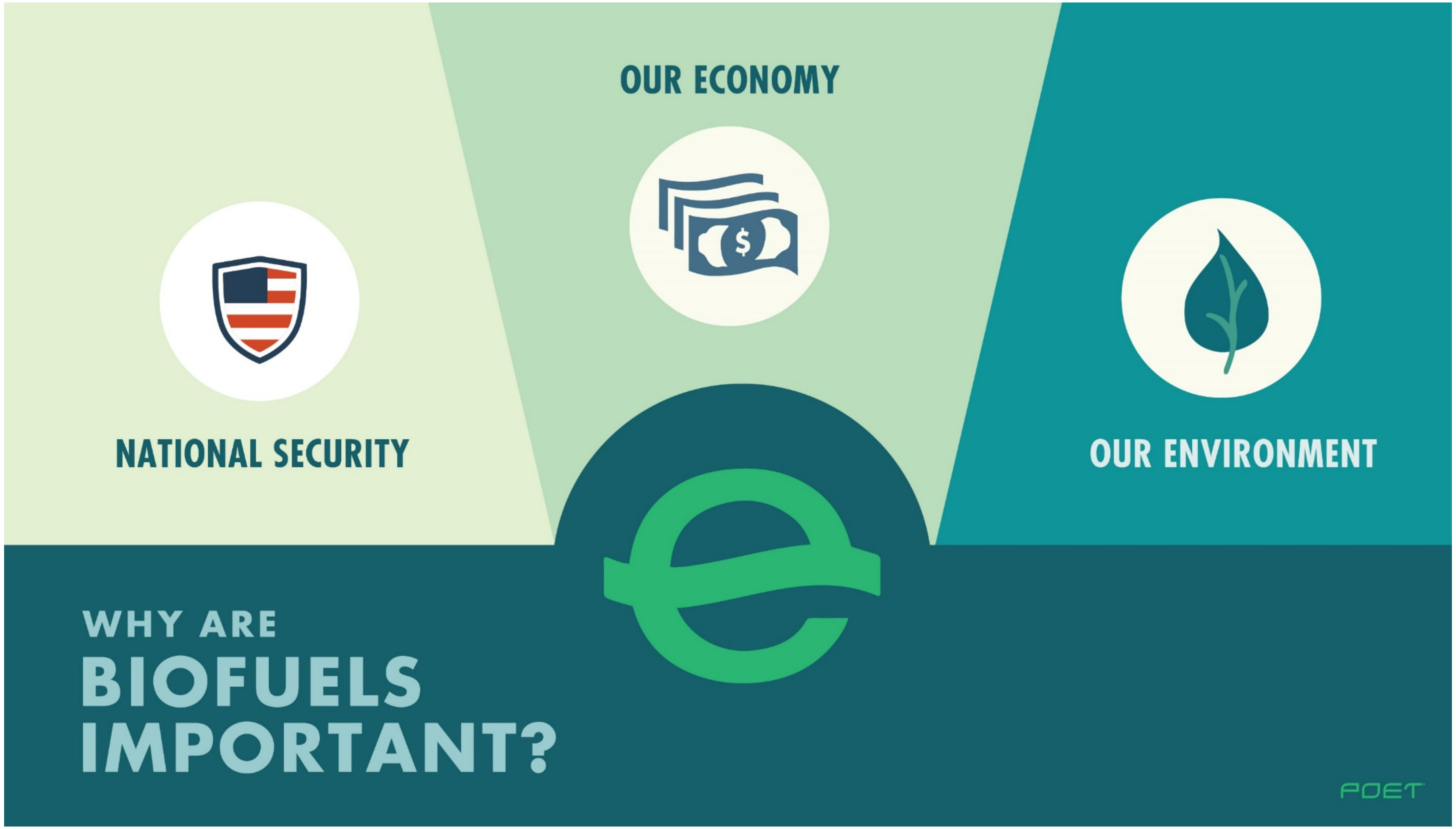
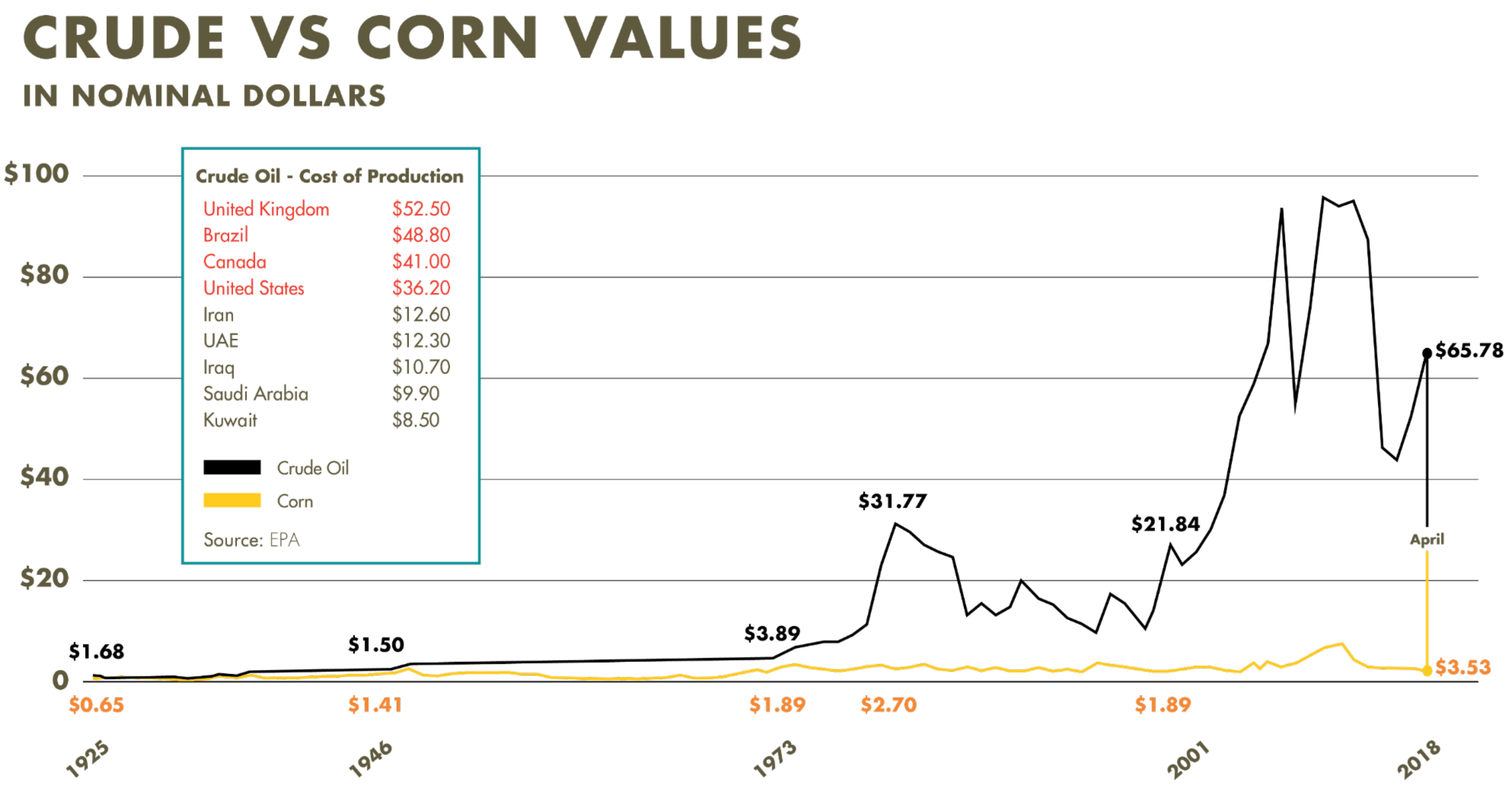
Ethanol Importance and Policy

Importance of Biofuels



Economic



CRUDE VS CORN VALUES
IN NOMINAL DOLLARS
Crude Oil - Cost of Production
United Kingdom $52.50
Brazil $48.80
Canada $41.00
United States $36.20
Iran $12.60
UAE $12.30
Iraq $10.70
Saudi Arabia $9.90
Kuwait $8.50
Crude Oil
Corn
Source: EPA
$100
$80
$60
$40
$20
0
$1.68
$1.50
$3.89
$31.77
$21.84
$65.78
April
$3.53
$0.65
$1.41
$1.89
$2.70
$1.89
1925
1946
1973
2001
2018

Economic

Consumer Savings

- Ethanol replaces some of the most expensive chemicals in the gasoline pool
- Ethanol does not have to be less expensive than wholesale gasoline

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Economic Impact

- $184.5 Billon of Economic Output
- $14.5 Billion in Taxes
- $46.2 Billion in Wages
- 360,000 Jobs

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World According to Oil vs Ag

World Oil Influence

World Agriculture Influence

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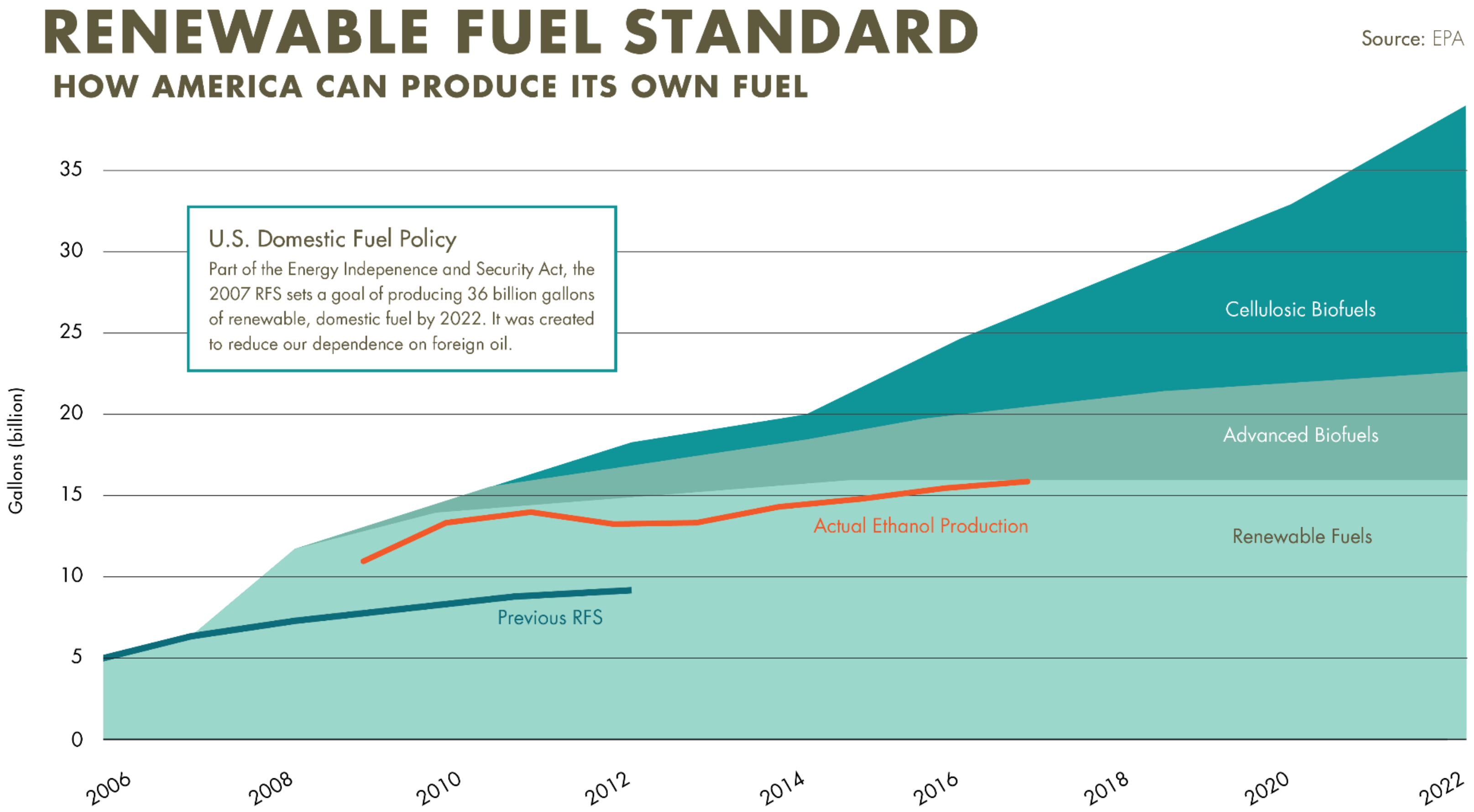
Renewable Fuel Standard

- Decrease Oil Imports
- Increase Air Quality
- Decrease Gas Prices

Renewable Fuel Standard



Ethanol Blends

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Myths and Facts

Myths and Facts

Myths and Facts

MYTH

ETHANOL PRODUCTION CONSUMES 40% OF OUR CORN

FACT

BECAUSE THE ETHANOL INDUSTRY PRODUCES FEED AS A CO-PRODUCT, THE EFFECT IS 17.5% OF THE CORN CROP.

A recent World Bank study showed that high fuel prices are the cause of food price increases, not biofuel production.

Myths and Facts

MYTH

HIGHER ETHANOL BLENDS DAMAGE AUTO ENGINES

FACT

ETHANOL IS A HIGH-OCTANE, CLEAN-BURNING FUEL.

EPA conducted the most exhaustive fuel test ever with E15, and it is approved for 2001 and newer vehicles. Over 95% of gasoline gallons already contain ethanol today.

Presentation Review

- Mark or highlight three key points
- List two ideas or concepts related to previous knowledge.
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References

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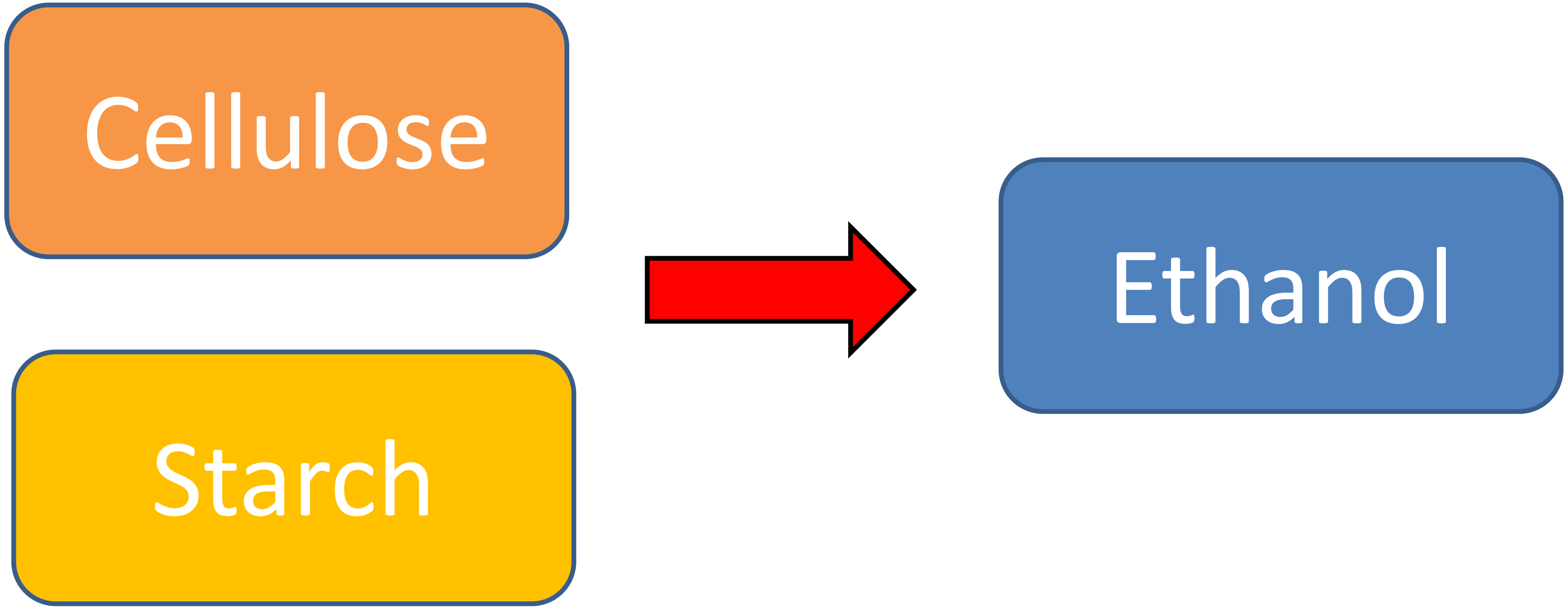
Cellulosic Ethanol

What is Cellulosic Ethanol?

- Cellulose is the world's most abundant compound
  - Provides cellular structure for trees, grass and all things organic
- The industry began research on the cellulosic production process over 15 years ago
- Ethanol is a molecule; regardless of the feedstock, the ethanol is identical
- While not all countries can produce oil, All countries do possess some form of cellulose
- Making energy from waste economically is a win-win for the planet

Integrated Production Model

[The Future of Ethanol]



Biomass Stored Onsight

Biomass: A New Opportunity

Presentation Review

- Mark or highlight three key points
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- POET. (2018). *Products and solutions*. Retrieved from https://poet.com/products

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Name____

Ethanol Lesson Assessment

1. What industries benefit from ethanol production?

2. What are the advantages of using ethanol instead of a fossil fuel?

3. How is ethanol produced from corn kernels?

4. What is a coproduct of ethanol production?

5. What is the Renewable Fuel Standard?

6. How does the Renewable Fuel Standard impact rural communities?

7. How do the byproducts of ethanol combustion compare to fossil fuel combustion?

8. What factors should a consumer consider when choosing a combustible fuel?

9. What are the advantages and disadvantages of cellulosic ethanol?