Fueling Our Future: Transportation Needs
Investigating Ethanol from Forest Products

By Melissa Jaeger

Unit Overview

"Fueling Our Future: Transportation Needs, Investigating Ethanol From Forest Products" is written to be part of a nine week 8th grade science exploratory course that explores the energy resources available to citizens of Michigan, their feasibility, their environmental, social, and economic impact. Students will be introduced to the concept of a need to replace gasoline as they think about questions on the opening survey about how the high prices of gasoline are impacting how they move from one place to another. After this, students will discuss and then journal about what characteristics an ideal fuel would have. Through activities simulating the processing of ethanol, power points, readings, and discussion students will investigate how well ethanol would fit the ideal fuel description.

Sources Consulted

Sources are cited for at the end of each lesson. The outline of the unit follows the outline of the course with the exception of burning wood – not included mostly because of time. Lesson one is a survey with follow-up discussion. In developing the survey questions I followed the guidelines Nick Johnson shared with us as well as the "do's and don'ts" he adapted from the work of Kathy Halvorsen. Topics and information in the power point preceding the discussion were presented by Dr. Barry Solomon and Dr. David Shonnard in our introductory morning.

Looking at the SEPUP kit and conversations with Mike Gaule gave me the idea for lesson 2. The protocol for the activity was researched by comparing several fermentation activities.

Lesson 3 allows students who would not be able to use the software or have access to it understand how GIS can be used to analyze the feasibility of a particular area for a biofuels plant. Dr. Ann Maclean and Lucas Spaete provided pdf files of the maps used in the lesson.

Lesson 4 uses the idea of determining the energy stored in fuels from the SEPUP kit but the protocol was developed using the soda can calorimeter, a standard food science lab that determined the caloric content of nuts. The second lab combine Maria Janowiak's and David Flashpohler's lab to determine biomass grown in the last 10 years.

Lesson 5: The distillation demo idea came from Dr. Shonnard's discussions on the life cycle and the SEPUP kit – the protocol is standard organic chemistry distillation. The idea to show that the cellulosic material won't produce as much ethanol without pretreatment also came out of the lab where we learned what a cellulosic material must undergo before the fermentation process with Dr. Shonnard and Jill Jensen.

Lesson 6 tries to pull the life cycle information into one place that was presented by Dr. Shonnard. As my students would not be able to follow the computer program and I don't have money to purchase it they will use the totals given from the Argonne National Las Well to Wheel report.

Learning Objectives

Student will be able to

- Describe the basic steps of production of ethanol and gasoline
- Compare the fossil fuel and greenhouse gas emissions in the production and use of corn ethanol, cellulosic ethanol, and gasoline
- Give at least 2 scientific or social advantages to use cellulosic ethanol over corn ethanol or gasoline
- Give at least 1 scientific or social disadvantage of using cellulosic ethanol

Michigan Content Expectations

Science E1.1C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).

Science E1.2g Identify scientific tradeoffs in design decisions and choose among alternative solutions.

Science E1.2j Apply science principles or scientific data to anticipate effects of technological design decisions.

Science E2.2B Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.

Science E2.4A Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.

Math D.AN.08.01 Determine which measure of central tendency (mean, median, mode) best represents a data set, e.g., salaries, home prices, for answering certain questions; justify the choice made.

Math D.AN.08.02 Recognize practices of collecting and displaying data that may bias the presentation or analysis.

Lesson Plans: Teacher's Guide pages 4-12

DISCLAIMER/NOTE: THESE LESSON PLANS ARE WRITTEN FOR TEACHERS WHO ARE EXPERIENCED CHEMICAL SCIENCE TEACHERS WHO UNDERSTAND STANDARD LAB SAFETY PROCEDURES. OBVIOUSLY WEAR SAFTEY GOGGLES AND FOLLOW OTHER APPROPRIATE SAFETY RULES WHEN WORKING WITH CHEMICALS AND OPEN FLAMES.

Student Pages: Follow teacher pages on page 14-27

Assessments are at the end of each lesson in the teacher pages

Lesson 1: Journal entry of the perfect fuel.
Lesson 2: See lesson 5
Lesson 3: Group presentation of plant location
Lesson 4: Results of calorimeter lab and biomass calculation
Lesson 5: Life cycle inputs and outputs (number 8)
Lesson 6: Essay

Lesson 1: Anticipatory Set: Assessing students' views on using gasoline and ethanol.

Time: 2 days
Materials needed:

- Survey – 1 copy per student
- Overhead of survey or projection of survey
- Power point: Discussion of Survey Results
- Power Point: Perfect Fuel Discussion

1. Students take survey.
2. Students put tally on projected survey marking their own choices
3. Tally results.
4. Have students calculate the mean, median, and mode for question 1 and 5.
5. Discuss which measure of central tendency best describes the data.
6. Model how to find the percentage of each response, for example if 15 out of 20 students chose that they ride a bike once a week, divide 15/20 * 100 to find that 75% of students surveyed ride their bike once week.
7. Total the number of choices for answer 6.
8. Students should work as a group to display the data in a graph.
9. Graphs should be shared with class and compared. Ask students how the different graphs focus on different pieces of the data – does one way influence how you interpret the data more than another?
10. Show power point: Discussion of Survey Results
11. Show power Point: Perfect Fuel Discussion Use talking points to discuss students' ideas of the perfect fuel.
12. FORMATIVE ASSESSMENT: writing assignment
    - Describe the perfect fuel.

Sources:

Johnson, Nick "Sample Interview Questions" and "Do's and Don'ts" handout from Future Fuels of the Forest Teacher Institute, July 7, 2008

Shonnard, David "Overview of Energy and Future Fuels: Assessing Social, Economic, and Environmental Considerations of Energy" Lectures and PowerPoint from Future Fuels of the Forest Teacher Institute, July 7, 2008

Solomon, Barry "Overview of Biofuels Sources: Grain and Cellulosic and Biodiesel Ethanol Production and Use in the U.S." Future Fuels of the Forest Teacher Institute, July 7, 2008

Lesson 2: "What is needed to create Ethanol, a plant-based fuel?"

Time: 1 day

Materials Needed:
Per group:

- 3 250 mL Erlenmeyer flasks each fitted with 2 hole stopper
- 3 thermometers
- 3 pieces of glass tubing – about 10 cm
- 3 45 cm of plastic tubing
- 3 250 mL beaker
- 30 mL of yeast suspension (directions below)
- 30 mL corn syrup
- 30 mL table sugar
- 30 mL sawdust
- 20 drops of bromothymol blue
- 45 mL yeast suspension
- record sheet

per class

- balance

Baker's yeast ferments simple monosaccharides such as glucose and disaccharides such as sucrose aerobically into carbon dioxide and sugar. The mass of the carbon dioxide lost during incubation can show the rate of the fermentation reaction. Fermentation depends on the acidity and the concentration of alcohol.

Advanced preparation:
For each lab group prepare the following:

Following standard safety procedures insert into each 1-holed-stopper a piece of glass tubing. Attach a 45 cm length of plastic tubing to the glass tubing. On the morning of the activity, make the yeast suspension by dissolving 1 package of yeast into 100 mL of warm water. Carefully add another 100 mL of warm water and swirl to mix. 1

1. Ask students how plants can be used as an energy source?
2. Many students will suggest burning wood, sawdust, pellet, or corn – lead then to processing plant material by fermentation.
3. Introduce lab using following key points:
    - Plants make sugar through the process of photosynthesis – review the photosynthesis reaction. Students should be able to explain that energy from the sun is stored in the sugar, which is then used by the plant, or animal that eats the plant.
    - Respiration is when the organism releases the energy from the sugar – this can occur aerobically (with oxygen) to yield carbon dioxide, water, and released energy or anearobically (with oxygen) to make ethanol, carbon dioxide, and released energy.
    - One form of biofuels is ethanol – it can be burned to release energy
    - Ethanol is made through fermentation
    - Today we will be setting up 3 different fermentations and finding how and why they are different and what use they will be for our energy needs

4. Have students set up reaction flasks following directions on the lesson 2 student sheet.
5. Record all results on lab sheet
6. Explain fermentation using the PowerPoint: FERMENTATION
7. Assessment: Graph and questions at end of lab activity

*Emphasize that the number of carbon dioxide molecules is equal to the number of ethanol molecules produced and that we will be monitoring the reaction through the mass lost as the carbon dioxide gas leaves the flask. Each day students will start the class taking the mass of the reaction set up.

Sources:

Schollar, John, and Benedikte Watmore "Practical Fermentation A Guide for Schools and Colleges" http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/PDF/FermSG.pdf accessed September 11, 2008

"Antibiotics in Action" http://www.chemheritage.org/educationalservices/pharm/antibiot/activity/yeast.htm accessed September 11, 2008.

SEPUP "Ethanol" kit.

Lesson 3: Using GIS to determine a suitable location for an Aspen based cellulosic plant.

Time 1 day

Materials needed

- PDF files of GIS colored maps printed on transparencies - 1 set per group
- PDF file of Aspen_bio printed grayscale on paper – 1 per student

1. Ask students "What do we need to know to determine whether we could build a profitable ethanol plant here in Michigan?"
    a. List ideas on board
    b. Brainstorm ways we can determine if we had enough feedstock for a plant.
2. Hand out map 1: Aspen_bio in grayscale to each student and as colored transparency Aspen_bio to each group
3. Have students study map and find area most covered with aspen
4. Ask question "Will it be possible to harvest the aspen in the area?"
5. Distribute Map 2: Public
6. Have students study area that they have chosen to determine if the aspen they are looking at is held in public ownership. Discuss which aspen trees could be for sale (those help by private individuals)
7. Have student roughly highlight were private holdings are on their black and white map. This will be difficult – once they had struggled a bit move on to discussion. Discuss that GIS software can make maps that combine different layers of data.
8. Distribute Map 3:Aspen_private.
9. Explain that a cost analysis using current fuel prices was done to determine how far away aspen could be harvested and money would still be made when the ethanol was made. This is 75 miles. The ethanol plant would also have to be within 2 miles of a major road. – Hand out 75-mile circles.
10. Have students use the circle to estimate where the most aspen cover in private ownership is. Are there many spots or just one? Discuss
11. Assessment: Have students present to class area that they have picked and justify their choices.

Sources

Maclean, Ann "Utilizing GIS technology to understand where and how much woody biomass is available for biofuel production**"** Lab and Lecture from Future Fuels of the Forest Teacher Institute, July 9, 2008

Spaete, Lucas Northern Michigan Aspen Maps developed using GIS technology per request

Lesson 4:Is aspen a renewable resource?

Time 2 days

Materials needed:

- Pop can calorimeter per group
  - Pop/soda can
  - Stand
  - "Alcohol style" lab burner
  - Thermometer
- Graduated cylinder
- Balance
- Aspen tree cookies
- Ruler

Lab 1: Putting on the pounds"

1. Share with students that the biomass in the area of the maps in the last lesson was 2,364,806 tons. Today we want to know how long would it take for that much biomass to grow.
2. Have students follow lesson 5 "putting on the pounds"
3. Estimate the number of trees in the 2,364,806 tons of biomass (change to pounds then divide by the number of pounds in a tree)
4. Calculate how long it would take to grow that much biomass.

Lab 2: How much ethanol do we need to replace a gallon of gasoline: calorimeter lab

5. Review standard safety procedures for using and open flame
6. Have students follow the lab procedures for the calorimeter lab
7. Post lab discussion:
   1. *Is the energy content the same for the ethanol and kerosene* [No, the ethanol has less energy per gallon]
   2. Share with students that you need about 1.4 gallons of ethanol to have the same amount of energy in 1 gallon of gasoline.
   3. *How much corn, wood chips, or switch grass does it take to make a gallon of fuel? Share the information below.*

Feedstock	*Gallons per quantity*	*per acre*		*Mass per bushel*
Corn	*2.8 gal/bushel*	*150 bushels/acre*	*53 gallons per acre*	*0.05 gal/pound*
Switchgrass	*72 gallons/ton*	*8 tons per acre*	*576 gallons per acre*	*0.036 gal/pound*
woodchips	*52.6 lbs/gallon*			*0.02 gal/pound*

4. *If there are 2,364,806 tons of biomass in the study area how much ethanol could be produced is all of the private landowners sold there land?*

2,364,806 tons * 2000 lbs/ton * 0.02 gal/lbs = 94,592,240 gallons or the energy equivalent of

94,592,240 gal EtOH /1.4 gal EtOH per gasoline = 67,565,886 gallons gas

5. *While this seems like a large number, according to "How Stuff Works Website" the United States consumes approximately 400,000,000 (400 million) gallons of gasoline per DAY. How long would the ethanol produced from Northern Michigan woods last?* [not even a day]
6. *How long would it take to grow enough ethanol for one day?*

Sources

Grossman, John, "The Heat Content of Nuts and Snack Foods" **http://www.woodrow.org/teachers/chemistry/institutes/1988/foodheat.html** accessed Aug 2, 2008

Flaspohler, David "Measuring changed in ecosystem biodiversity due to land use changes using avian populations" lecture and PowerPoint from Future Fuels of the Forest Teacher Institute, July 8, 2008

"How much gasoline does the United States consume in one year?" How stuff Works http://auto.howstuffworks.com/question417.htm accessed Aug 11, 2008

Janowiak, Maria "Role of Biofuels in Carbon Sequestration in Northern Forests" Lecture and Powerpoint Future Fuels of the Forest Teacher Institute, July 11, 2008

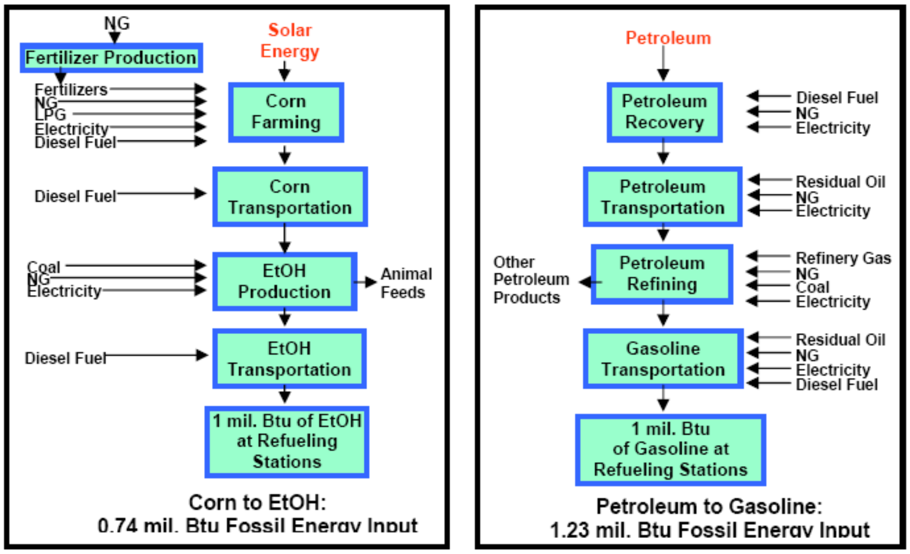
Roth, Amber "Activity: Putting on Pounds" Future Fuels from the Forest Teach Institute at Michigan Technological University CD

Lesson 5 Distillation Demo and Post Fermentation Lab

Time 2 days

Review background information on energy inputs in the process of making corn ethanol and gasoline

This figure illustrates the energy inputs used to produce and deliver a million British Thermal Units (Btu) of ethanol (EtOH) and petroleum gasoline to a refueling station.



As you can see, the *fossil* energy input per unit of ethanol is lower—0.74 million Btu fossil energy consumed for each 1 million Btu of ethanol delivered, compared to 1.23 million Btu of fossil energy consumed for each million Btu of gasoline delivered.

Some of the confusion arises over the fact that some of the *total* (not fossil or petroleum) energy used in the production of ethanol is "free" solar energy used to grow the corn in the first place. Indeed, if you include the solar energy inputs, it is true that you "spend" between 1.5 and 2.0 Btu to produce a Btu of ethanol… but since the solar energy is free, renewable and environmentally benign, we shouldn't care.

Source: http://www.chicagocleancities.org/PDFs/Wang2005Summary.pdf

Materials needed:

- Standard Distillation equipment (condenser, tubing, water and heat source)
- Fermentation flasks set up in lesson 1

1. Have students take final measurements of mass.
2. Collect class data and find average mass lost for each reaction type.
3. *Is this fuel ready for use?* [No, might share that is disgusting etc]
4. *What could be done to this fuel?* [Students may suggest filtering but very few would have the idea of distillation]
5. Explain distillation – include that different substances have different boiling points and that substance can be separated using this.
6. **Demonstrate** the distillation of the one of the flasks following standard distillation technique learned in chemistry. Skip the demonstration if you are unfamiliar with this and describe it instead. Discuss as the distillation occurs
    1. *What resources are needed to distill the ethanol?* [Energy source for heat]
    2. *How can the heat for this be produced?* [Burning natural gas as we are in demo, an electric hotplate or stove, some other fire]
    3. *Could wood or wood products be burned to "boil" the ethanol?* [Yes]
7. As distillation continues discuss the results of the lab.

1. *Why did the water in the water trap turn blue?* [Carbon dioxide was being formed]
2. *Which feedstock produced the most ethanol?* [The sugars produced about the same amount where the cellulose produced less]
3. *Which feedstock took showed the fastest fermentation rate?* [The sugars rates were similar but the cellulose were much slower]
4. *Could the sawdust or other wood products be fermented?* [Students should recognize that the fermentation of the sawdust did not yield enough ethanol. This is the spring board to discuss the life cycle of cellulosic ethanol]

8. Explain to students that wood stores the sugars produced in photosynthesis as complex sugars and that these sugars need to be broken down before fermentation can occur at a good rate.
9. Distribute handout showing life cycle of corn and cellulosic ethanol. Be sure to point out that the products from the acid hydrolysis (pretreatment) can be burned to distill the ethanol.
10. Discuss where fossil fuels are needed and where carbon dioxide is released. Be sure to include that the carbon dioxide release in burning and fermentation is balanced because of the carbon dioxide taken in when the plant was photosynthesizing.
11. <u>Formative Assessment:</u> Students should use a red marker to indicate at each stage where fossil fuels are consumed in the process and in a blue marker indicate in which step greenhouse gas emissions – mainly carbon dioxide are released.
12. Once distillation is complete pour 1-2 mL contents into a watch glass and set on fire. Burning indicates that it is at least 50% ethanol.

Sources:

Shonnard, Dave Using Life Cycle Assessment Techniques to Evaluate Future Energy Sources" Lecture and PowerPoint from Future Fuels of the Forest Teacher Institute, July 10, 2008

Shonnard, Dave "Technology for processing tree biomass to energy." Lab and Lecture from Future Fuels of the Forest Teacher Institute, July 9, 2008

Lesson 6: Assessment

Time: 1 day

Advance preparation:
Read "Argonne National Laboratory Ethanol Study:Key Points found at
http://www.chicagocleancities.org/PDFs/Wang2005Summary.pdf

Materials
"Lesson 6" graphs per student

1. Distribute the graphs to the students
    - The first graph compares the amount of greenhouse gas emissions between a gallon of E85 and E10. The comparisons are made between refined gasoline, wet vs. dry mill process ethanol made from both corn and cellulosic feedstocks.
    - The second graph compares the amount of energy in British Thermal Units (BTU) to make one BTU worth of gasoline and ethanol from different processes.
    - The last graph compared greenhouse emission of several fuels.
2. Discuss graphs to be sure students are interpreting the correctly.
3. Assign students the following writing task

Does ethanol from forest products fit the description of an in ideal fuel? Support your choice with at least 5 facts from this unit. Your essay will include both positive/advantages and negatives of ethanol. If you can predict a solution to a negative, please address it.

Suggested grading:
Students should select a fuel choice and compare the following to the other fuels

- Energy used to make the fuel
- Greenhouse gas emissions
- Efficiency of the fuel
- Availability of the fuel compared to consumption

Sources

Shonnard, Dave and Jill Jensen "Life Cycle Assessment of Cellulosic Ethanol: Comparison of Conventional Gasoline with E85 and E10." Lab and Lecture from Future Fuels of the Forest Teacher Institute, July 9, 2008

Wang, Michael, "Argonne National Laboratory Ethanol Study:Key Points"
http://www.chicagocleancities.org/PDFs/Wang2005Summary.pdf accessed on Aug 11, 2008

LESSON 1: Survey

Name: ___________

1. How many cars, trucks, and/or vans does your family own? __________
2. List the make and models of the vehicles your family owns if you know them.

   ____

   ____

   ____

3. Do your parents or family discuss the price of gasoline? _____________________

4. Place a check in the box that describes how often do you do each of these activities to save money or use less energy?

Activity	Once a day	Couple of times a week	Once a week	Couple of times a month	Once a month	Couple of times a year	Once a year or less
Walk							
Ride a bike							
Scooter							
Skateboard							
Ride with a friend (carpool)							
Carpool with someone other than a friend							
Ride a bus							
Ride a train							

Ethanol is a liquid biofuel that cars can be mad to run on. Today flex fuel cars can run on a mixture of ethanol and gasoline called E85 (85% ethanol). Most cars are able to run on E10 (10% ethanol). Diesel running vehicles can run on biodiesel.

5. Have you ever heard of biofuels before today? ___________________

6. For which of the following reasons would you consider using a biofuel in your car? Check all that apply

   - ❑ Lower cost that gasoline
   - ❑ Lower greenhouse gas emissions that gasoline
   - ❑ Lower other types of pollution than gasoline
   - ❑ Made in the USA

Lesson 2: Fermentation Basics

Names: ________________________

1. Gather the following materials
   - 3 250 mL Erlenmeyer flasks
   - 3 1 hole stopper fitted with a glass tubing attached to plastic tubing
   - 3 250 mL beakers
   - 30 mL of yeast suspension (directions below)
   - 30 mL corn syrup
   - 30 mL table sugar
   - 30 mL sawdust
   - 60 drops of bromothymol blue
   - 45 mL yeast suspension
   - 3 rubber bands
2. Label each beaker as “corn”, “sugar” and “sawdust”
3. Put 30 mL of the substance that matches the label.
4. Add 15 of the yeast suspension to each beaker
5. Place stopper into neck of flask and pinch off the tubing and rubber band it.
6. Find the mass of the flask and its contents.
7. Add 150 mL of water into each BEAKER.
8. Unpinch the plastic tubing, keeping the rubber band around the tubing for later.
9. Put end of plastic tube into the water of the 250 mL beaker.
10. Add 20 drops of bromothymol blue to the water in each beaker.
11. Mass the entire apparatus and record below
12. As you come into class each day, pinch off the tubing and rubber band it as you take it out of the water, dry tubing off. Find mass of the system. Do this for at least 5 days. Leave any weekend day blank.
13. Graph the change in mass using a different color for each substance.

FERMENTATION DATA TABLE

SUSBTANCE BEGIN FERMENTATED	Corn syrup	Sugar	Sawdust
Starting mass			
Mass after 1 day			
Mass after 2 days			
Mass after 3 days			
Mass after 4 days			
Mass after 5 days			
Mass after 6 days			
Mass after 7 days			
Total mass change			

Lesson 2: Fermentation Basics
Names: ________________________

Questions:

14. Which type substance produced the most ethanol? _______________
15. Which substance took the least amount of time to ferment? _________
16. Explain how you know the answers to 1 and 2:
17. Based on this lab, do you think it is possible to ferment sawdust with the process, support your answer with data from your lab.

Lesson 4 Lab1: Putting on Pounds

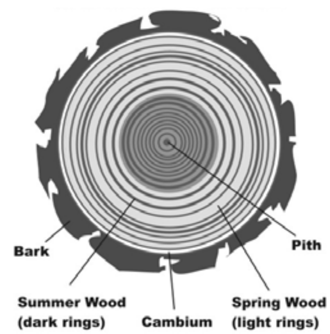
Name: ___________________

Modified lesson originally developed by Amber Roth <amroth@mtu.edu>, Michigan Tech School of Forest Resources & Environmental Sciences

Description: As forest resources are increasingly being used for bioenergy and biofuel industries, foresters must be able to calculate the amount of mass, or biomass, for standing trees in a forest. To do this, foresters calculate the biomass of individual trees and project these estimates across a forest stand. For this activity you will estimate the tree biomass accumulated during the last ten years.

Objectives: Estimate tree biomass and average annual growth rate

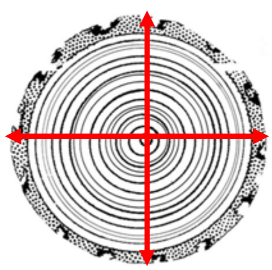
Materials Needed:
Aspen Tree cookie
Metric ruler and/or tape measure
Calculator
Pencil
Allometric equation for tree species of cookie used



Instructions:

<u>Part 1:</u> Calculate biomass for whole tree

Step 1: With pencil, draw two perpendicular lines that pass through the cookie's pith as indicated in the diagram. Make all measurements in this activity along those lines (guides). Measure the two diameters in cm and calculate an average. This is the average diameter at breast height, D.



Diameter 1: _______ cm
Diameter 2: _______ cm
Average Diameter: _______ cm

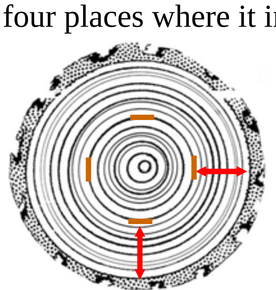
Step 2: Calculate biomass for whole tree.
To calculate tree biomass, we use a standard allometric equation of the form $M=aD^b$ where M is aboveground tree biomass (dry weight; kg), D is the diameter at breast height (cm), and "a" and "b" are species specific coefficients.

For **aspen** cookies, use the equation $M=0.08\ D^{2.35}$
For **balsam fir** cookies, use the equation $M=0.17\ D^{2.16}$

Insert your total tree biomass (M) estimate in Part 3.

<u>Part 2:</u> Calculate biomass accumulated in the last ten years

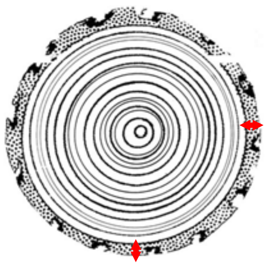
Step 1: From the bark inward, count 10 summer wood (dark) rings. Mark this ring with a pencil mark at the four places where it intersects your guides.



Step 2: Measure inner diameter of the wood between your pencil marks. Take a second measurement at a right angle to the first.

Inner diameter 1: _______ cm
Inner diameter 2: _______ cm

Step 3: Measure width of bark. Take a second measurement 90 degrees from the first.



Bark Width 1: _______ cm
Bark Width 2: _______ cm

Step 4: Add together all measurements from Steps 2 and 3 and divide by two. This is the average diameter at breast height estimate for this tree 10 years ago.

Average diameter: ________ cm

Step 5: Calculate biomass of the tree 10 years Use the same allometric equation as in Part 1. Use the diameter as your answer to step 4.

For **aspen** cookies, use the equation $M=0.08\ D^{2.35}$

Insert your 10 years ago tree biomass estimate (M) in Part 3.

Part 3: Calculate biomass accumulated during the last 10 years and the average annual growth rate during that time.

Step 1: To calculate the total biomass accumulated during the last 10 years, subtract the 10 years ago tree biomass from the total tree biomass.

Total tree biomass from Part 1: ________ kg x 2.2 lbs/kg = _______ lbs
10 years ago tree biomass from Part 2: ________ kg x 2.2 lbs/kg = _______ lbs
Tree biomass accumulated during 10 year's: _______ kg x 2.2 lbs/kg = _______ lbs

Step 2: To calculate the average annual growth rate during 10 years, divide the tree biomass (lbs) accumulated during the 10 years by 10 (used in Part 2).

Average annual growth rate duringthe last ten year's: _____ lbs/yr

Tree cookie graphic credits: www.nj.gov and www.state.sc.us.

Allometric equations from Ter-Mikaelian, M.T. and M.D. Korzukhin. 1997. Biomass equations for sixty-five North American tree species. Forest Ecology and Management 97:1-24.

Lesson 4: Lab 2

Names: ________________________

Question: How much ethanol is needed to replace a gallon of gasoline?

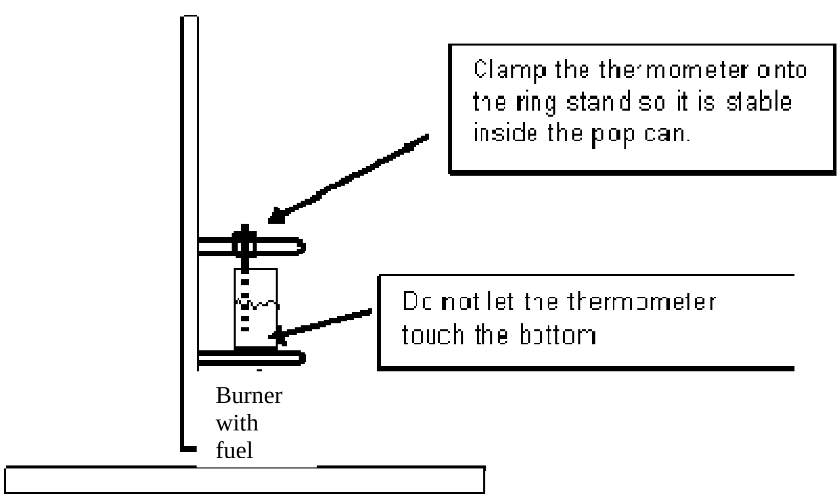
When gasoline or ethanol is burned energy is released. We convert this energy in the car engine so we can use the car. We can calculate how much energy is stored in each fuel. Half of the groups will calculate the heat released for kerosene, a fossil fuel produced from crude oil and the other half will calculate the heat release when ethanol is burned.

Materials

- Burner
- Stand
- Pop/soda can
- Thermometer
- Water
- Balance
- 20 mL of fuel

1. Put about 20 mL of fuel into your burner
2. Record the mass of each burner and it's fuel
3. Set up a popcan calorimeters as shown below. Do not let the thermometer touch the bottom

Clamp the thermometer onto the ring stand so it is stable inside the pop can.



4. Put 100 grams of water into the pop can
5. Record the initial temperature
6. Adjust wick so just a small portion is visible.
7. Light the burner and burn fuel for 10 minutes.
8. Using cap extinguish burner.
9. Measure the temperature of the water to determine the temperature change.
10. Mass the burner and remaining fuel.
11. Dump water down sink and refill soda can with 100 mL
12. Repeat steps 5-10 for a total of 3 trials.

DATA TABLE FOR BURNING: ______________________________

	Trial 1	Trial 2	Trial 3	Mean
Starting mass of the burner and fuel				
End mass of the burner and fuel				
Mass of fuel burner				
Start temperature of the water				
Final temperature of the water				
Temperature change				

13. Report temperature change data to teacher.
14. Help average class data
15. Calculate the energy

The energy release when burning the fuel is equal to the amount of energy that the water absorbed, which we can calculate using the following formula

$$E = m * \Delta T *Cp$$

Where

m = the mass of the water in grams (100)

ΔT = the change in temperature of the water as it was heated (use the class average)

Cp = the specific heat of water, this number tells how much energy water needs to increase the temperature by 1 degree Celsius – this 1 calories/gram ^{0}C

15. Calculate the energy content of the fuel per gram. To do this divide the average mass burned by the energy the answer you got for the energy released as the fuel was burned. Remember this is equal to the amount of energy absorbed by the water.

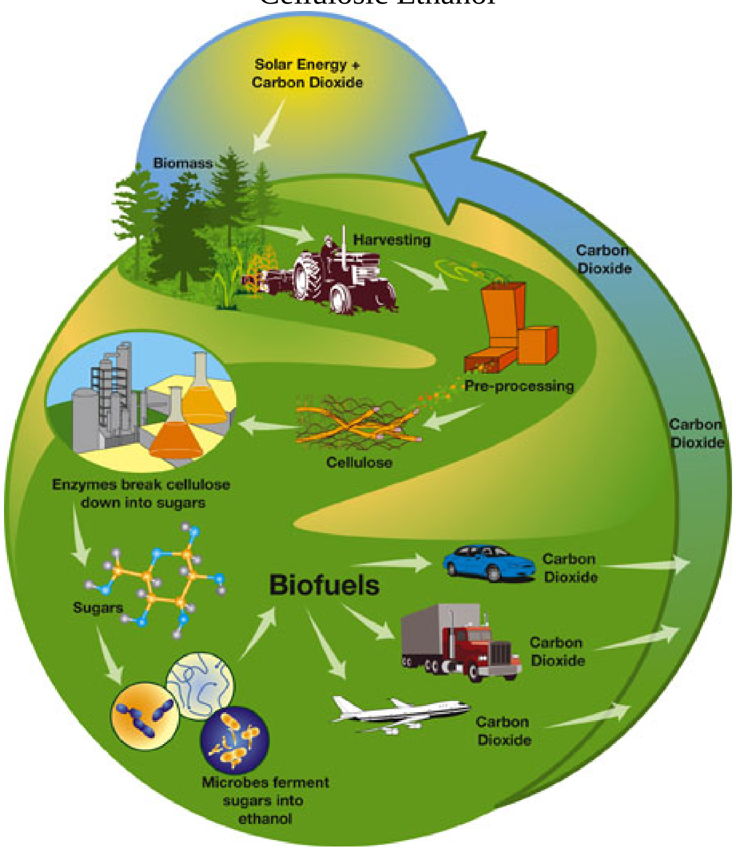
Class Mean for Burning Kerosene and Ethanol

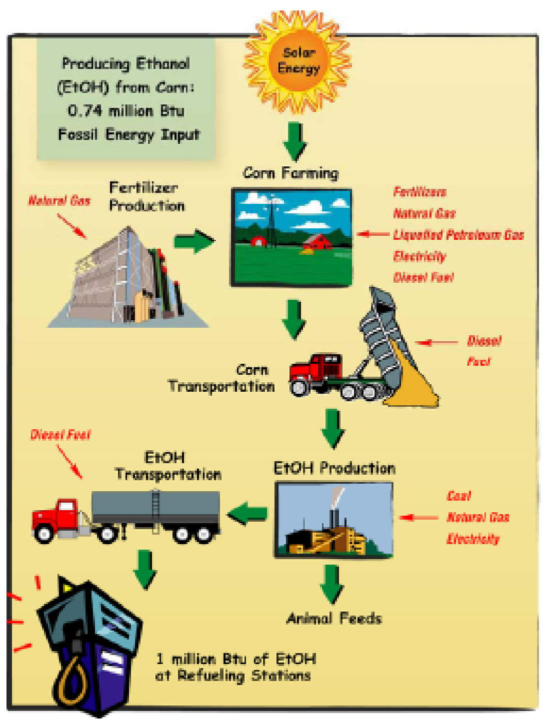
	KEROSENE	ETHANOL
Mean temperature change for 100 grams of water ^{0}C		
Mean mass of fuel consumed in grams		
Mean energy content of fuel in cal/g		

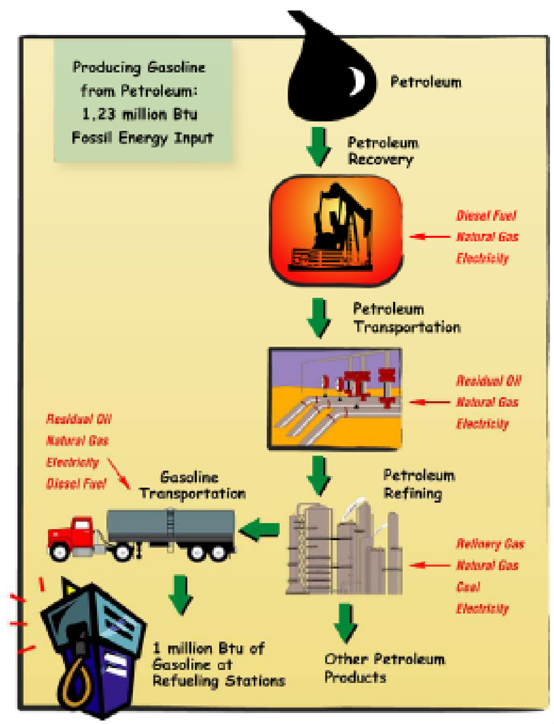
Lesson 5: Life Cycles Name: ________________

Mark in red steps that have energy going in and mark in blue all steps where carbon dioxide is given off.

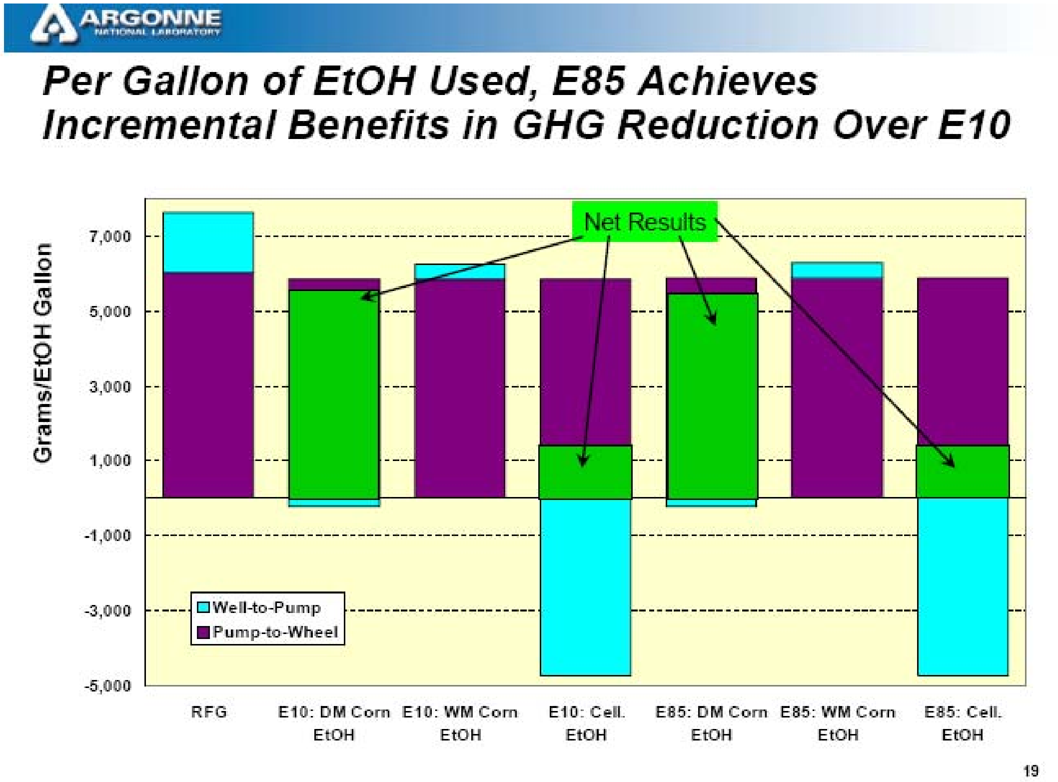
Cellulosic Ethanol







Lesson 6



RFG= Refined gasoline
DM = dry mill process
WM= wet mill process
Cell EtOH= ethanol from a cellulosic feed stock
Corn EtOH = ethanol from corn feedstock

LESSON 6: Energy needed to produce one British thermal unit worth of energy.

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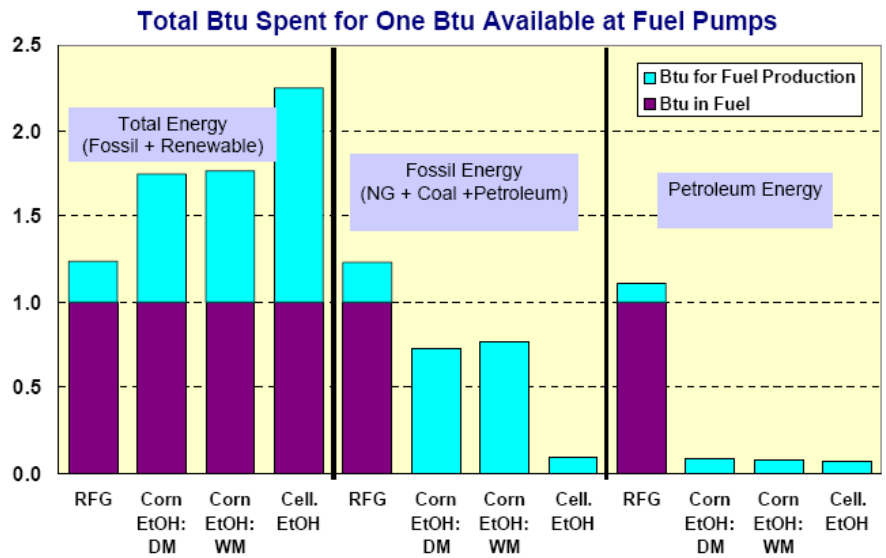
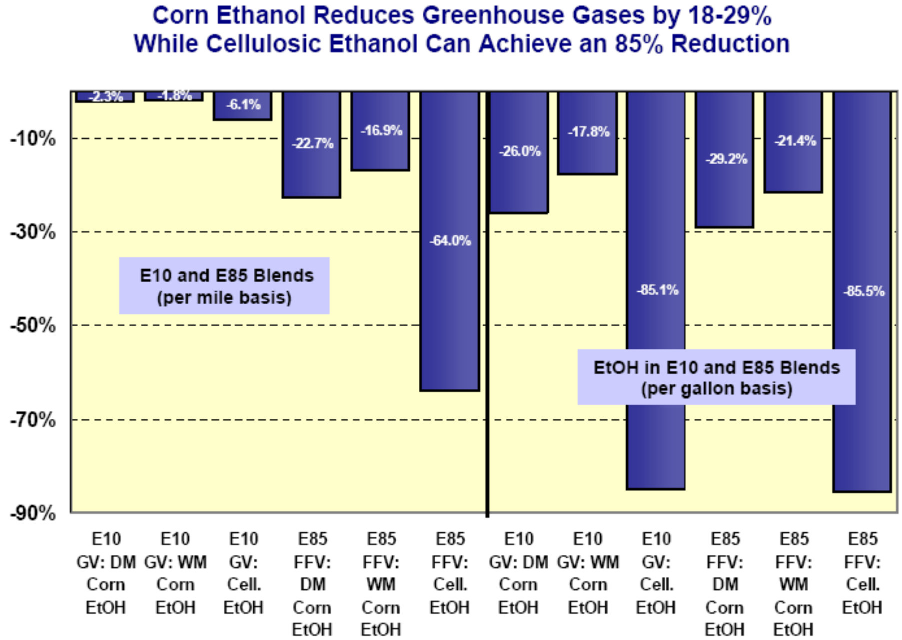


Source: http://www.chicagocleancities.org/PDFs/Wang2005Summary.pdf

LESSON 6: Greenhouse Gas Emission comparison between Ethanol and gasoline.



Guide to abbreviations used:

BTU	British Thermal Units
Cell.	Cellulosic
DM	Dry Mill Process Ethanol
E10	10% Ethanol blend
E85	85% Ethanol Blend
EtOH	Ethanol
FFV	Flexible or Flex Fuel Vehicle
LPG	Liquified Petroleum Gas
NG	Natural Gas
RFG	Reformulated Gasoline
WM	Wet Mill Process Ethanol

Source: http://www.chicagocleancities.org/PDFs/Wang2005Summary.pdf