Building a Biofuels System-Flow Diagram

Overview: Students establish the order of production of cellulosic ethanol from photographs, determine the energy and matter inputs into each portion of the system, and then expand the system boundaries to determine where raw materials for some items in the photographs originated.

Materials for each group

- Large piece of craft paper (approx. 2 x 3 ft)
- Printed set of photographs (attached)
- Printed set of six process tools (attached)
- Tape or glue
- Scissors
- Marker

Procedure:

Day 1:

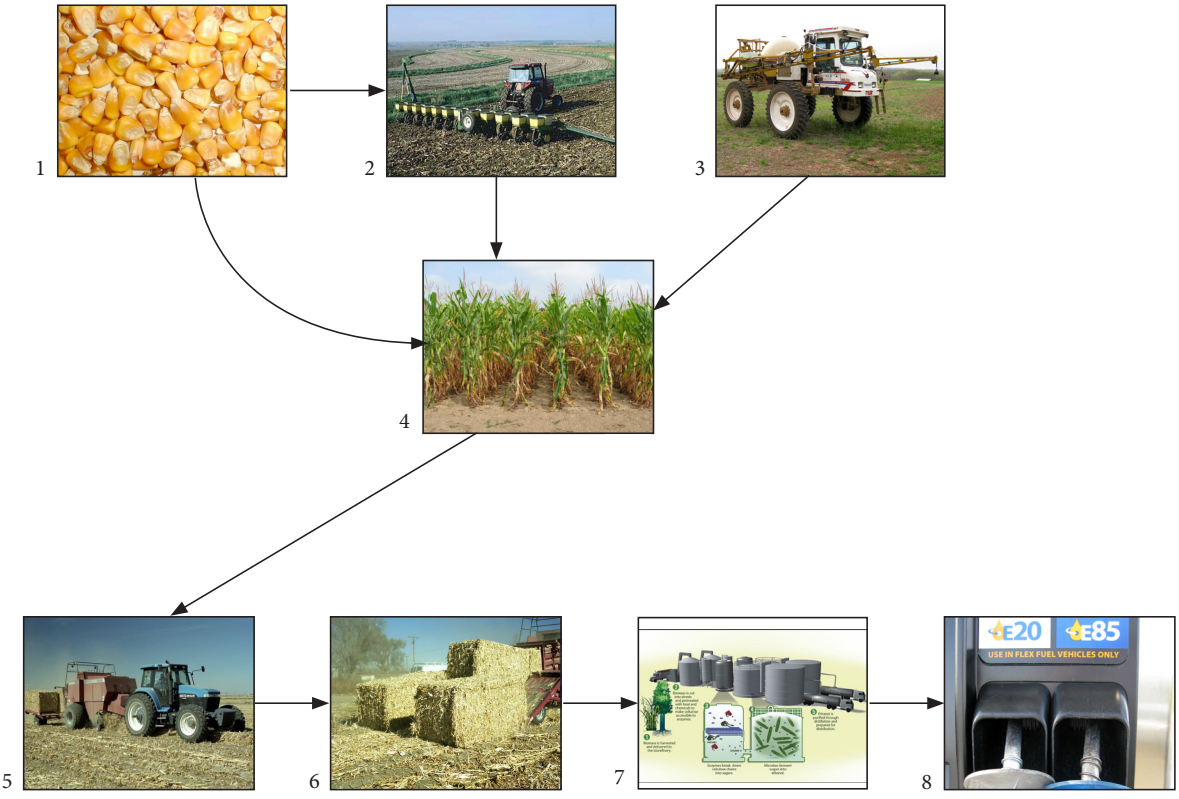
1. Discussion question: Why are scientists searching for new ways to produce new liquid fuels? Have the students provide several reasons (*limited fossil fuel supply, energy independence, global climate change concerns, higher fuel prices, etc*).
2. Show the students a container of ethanol as one possible substitute. Ask them to think about how ethanol is produced (*corn grain, sugar cane, potatoes, etc*). Where does the energy in the container ethanol (*sun*)? Are fossil fuels needed to produce ethanol as well (*yes*)?
3. Discuss the concept of a Life Cycle Assessment (LCA) as a way to assess the environmental impact of all steps in a process and a way to compare one process with another.
4. Step one in an LCA is to create a system-flow diagram showing the steps in your process. Break students into teams of four and provide each group with a set of images showing the stages of biofuel production from corn stover (not in order). Ask students to create a system-flow diagram on the craft paper showing how ethanol from corn stover is produced. They should add arrows showing how materials flow from one step to another.

5. After you approve of the system-flow diagram (see figure 1), ask students to complete a process tool diagram for images 2-7, focusing on the process they see using the most energy in that image. If the students need a prompt to fill in the tool, show them the *Process Tool Choices* page in this packet. Sample answers for the process tool are found on page 3.

Day 2:

6. Share the diagrams as a class and choose one to pin up on the board to expand upon. Ask students, "Have we shown all the places where fossil fuels are used in this system? Are fossil fuels necessary to create any of the items we have up here?"
7. As you talk, work outwards from the photographs, adding bubbles and arrows representing additional inputs connected to the starting diagram. (See figure 2).
8. Pose these questions: "Could we quantify the energy inputs in this system-flow diagram? Could we easily and fairly quantify *everything* we have on this diagram?" Discuss the necessity of setting system boundaries when conducting a life cycle assessment. You cannot move into the quantification of the steps if your system is too large and difficult to measure. Reasonable boundaries must be set to do an assessment.

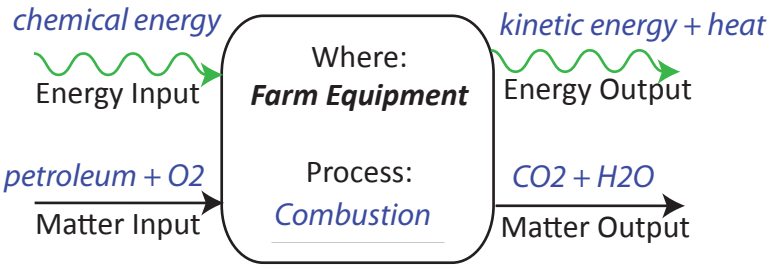
Figure 1. System-Flow Diagram



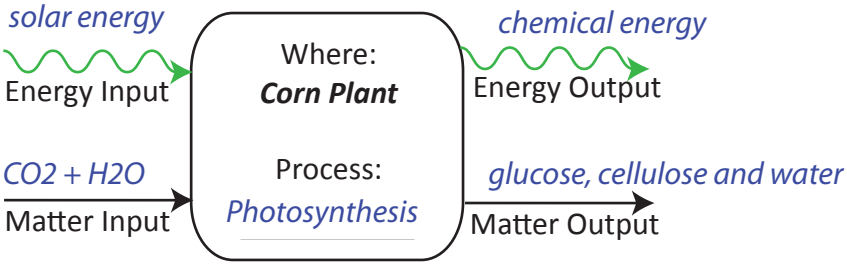
Sample process tool answers

Numbers refer to photographs in Figure 1. Students are asked to fill in the process tool for the dominant activity they see in the photograph, so multiple answers are possible depending upon the process they choose. Teachers may wish to lead students towards particular processes with certain photographs. Students do not need to complete process tools for photographs #1 and 2.

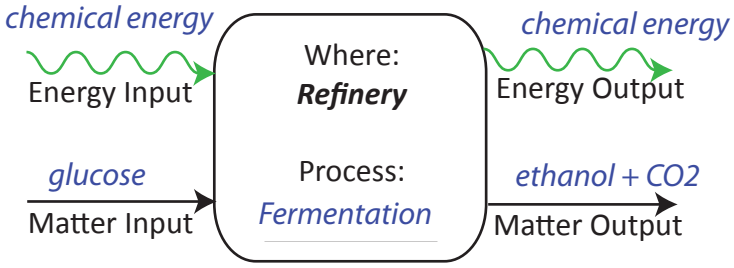
2,3, 5,6



4



7



7

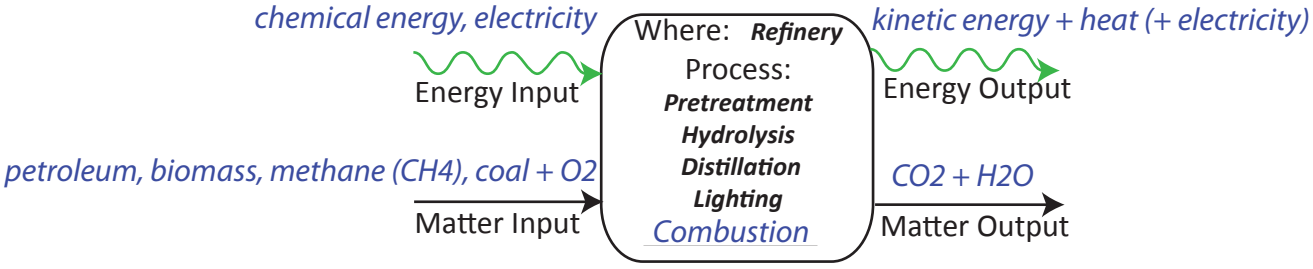
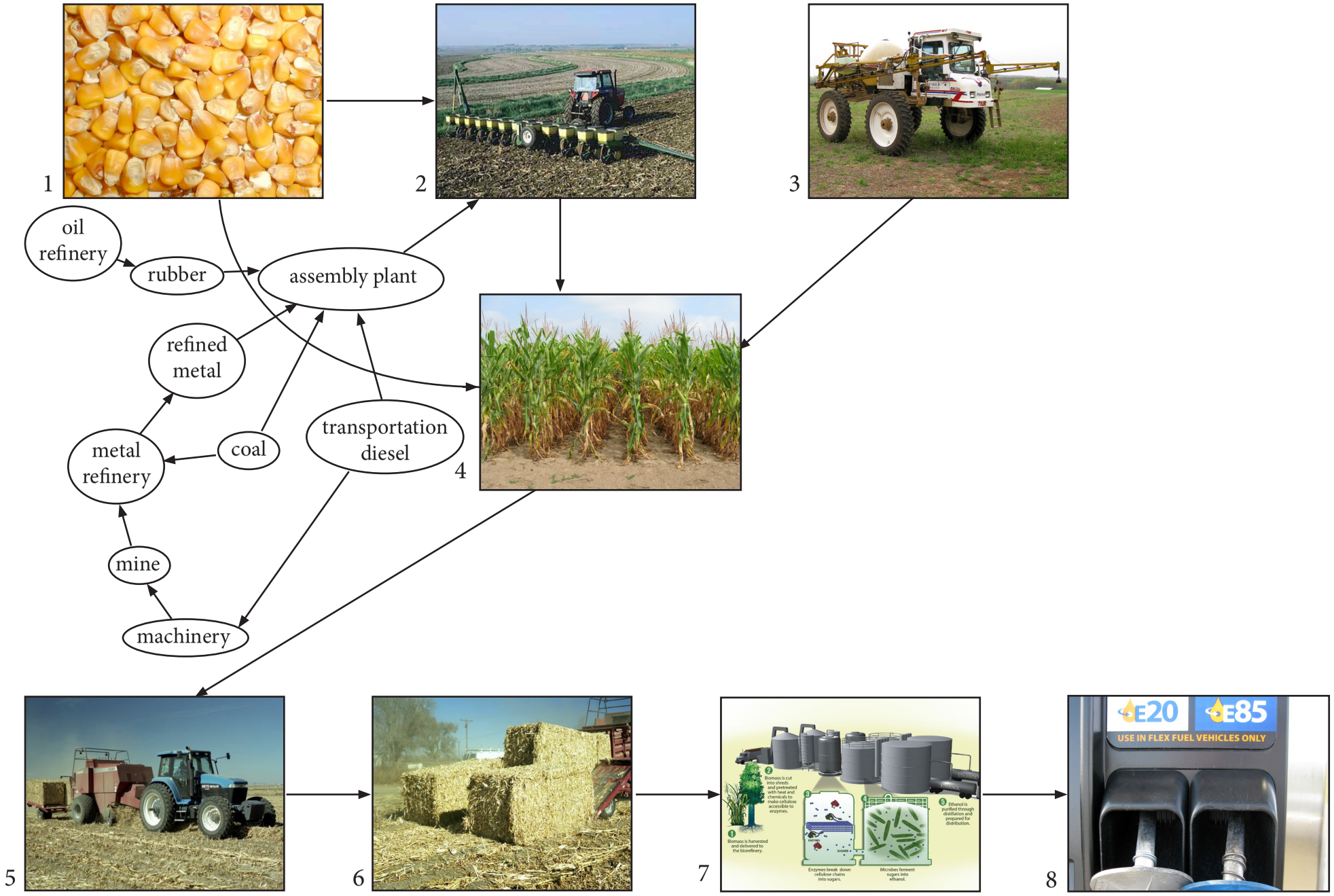
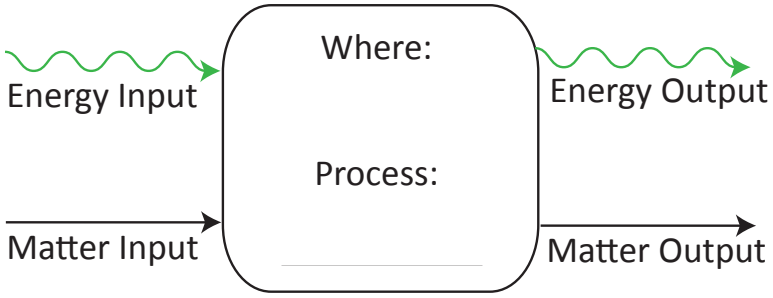
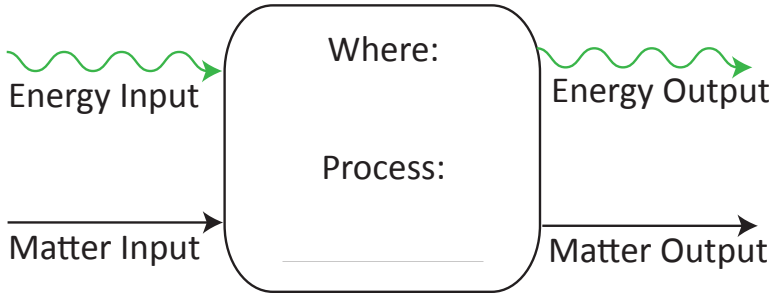


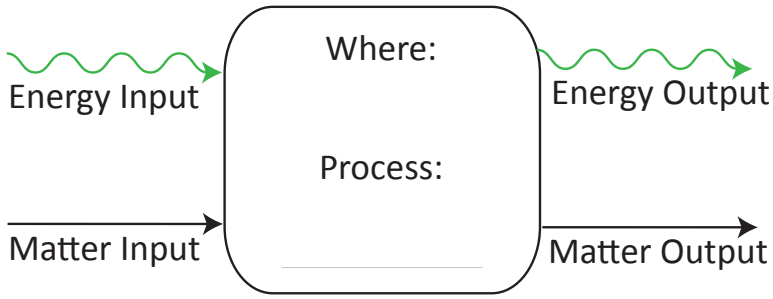
Figure 2. Sample concept map addition.



Process Tool Template







Process Tool Choices

Energy Inputs and Outputs

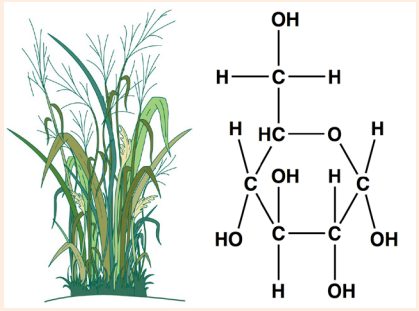
Electricity

HEAT

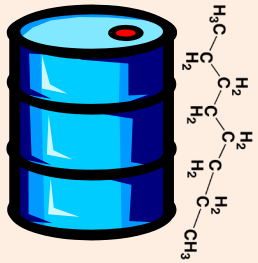
Chemical Energy

Kinetic Energy (motion)

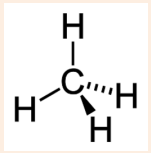
Matter Inputs and Outputs



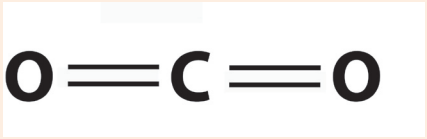
glucose



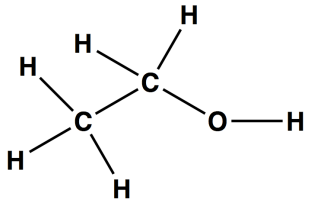
petroleum



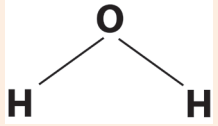
Natural Gas



carbon dioxide



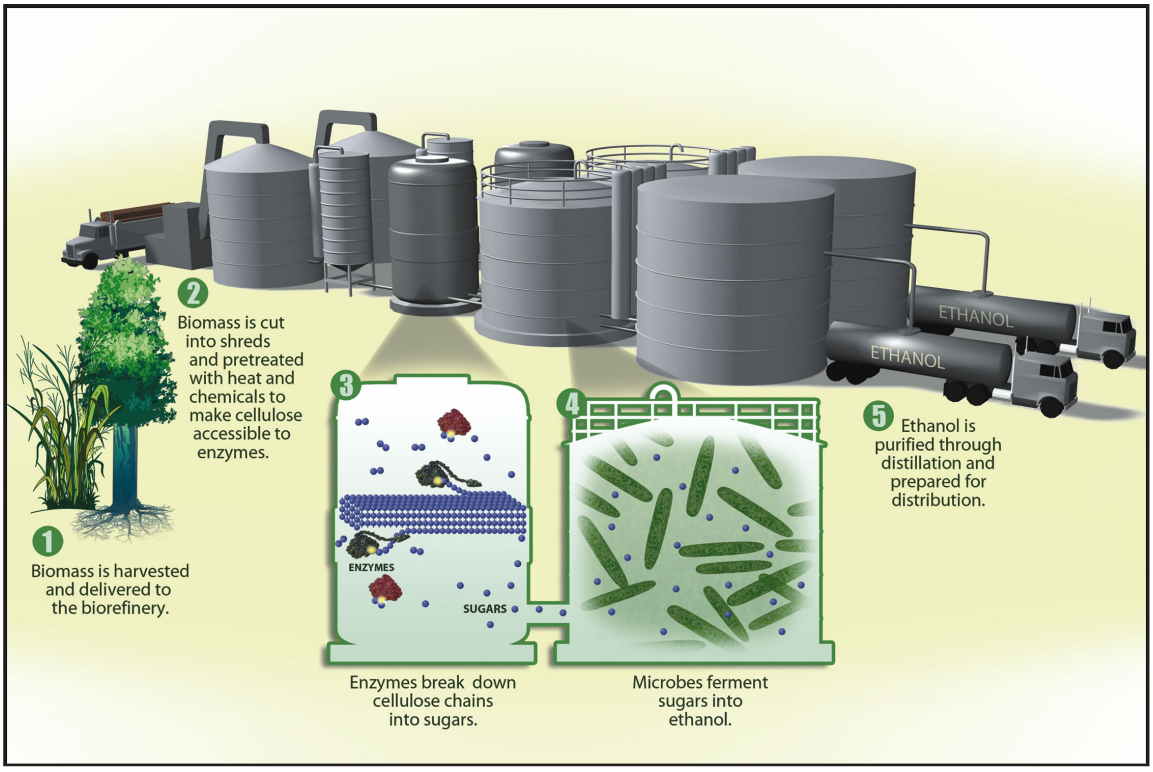
ethanol



water

oxygen


WT
TYLER
REMIER
WIDE TRAK
Patriot
TYLER


1
Biomass is harvested and delivered to the biorefinery.
2
Biomass is cut into shreds and pretreated with heat and chemicals to make cellulose accessible to enzymes.
3
ENZYMES
SUGARS
Enzymes break down cellulose chains into sugars.
4
Microbes ferment sugars into ethanol.
5
Ethanol is purified through distillation and prepared for distribution.
ETHANOL
ETHANOL


E20
E85
USE IN FLEX FUEL VEHICLES ONLY

Image Credits

(numbers correspond to images as used in figures 1 and 2)

1. Birding Store. "Whole Kernel Corn."
   http://www.birdingstore.com/seed_products.html

2. Alexander, Gene. USDA. Iowa "No-till planting of corn in Iowa."

3. Greenler, John. Great Lakes Bioenergy Research Center, Education & Outreach.

4. Krauskopf, Sara. Great Lakes Bioenergy Research Center, Education & Outreach.

5. Gretz, Warren. NREL Staff Photographer. September 2001. Northern Colorado. "Harvesting corn and stover."
   http://www.nrel.gov/data/pix/searchpix.php?getrec=10429

6. Gretz, Warren. NREL Staff Photographer. September 2001. Northern Colorado. "Harvesting corn and stover."
   http://www.nrel.gov/data/pix/searchpix.php?getrec=10434

7. U.S. Department of Energy. "How Cellulosic Ethanol is Made." From Biomass to Cellulosic Ethanol.
   http://genomics.energy.gov/gallery/biomass/detail.np/detail-881.html

8. Greenler, John. Great Lakes Bioenergy Research Center, Education & Outreach.

Activity developed by Scott Kloehn of Sun Prairie High School, Sun Prairie, WI (GHG portion) with Dr. Paul Meier and Julie Sinistore at University of Wisconsin-Madison with funding and other support from the Great Lakes Bioenergy Research Center

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