GREAT LAKES BIOENERGY RESEARCH CENTER

Script for Life Cycle Assessment of Carbon in Biofuel Production Powerpoint and Video

Slide 1: Life Cycle Assessment of Carbon in Biofuel Production

Slide 2: A life cycle assessment, or "cradle to grave" study, is an analysis of materials and/or energy moving through a biological process. In this case, we will look at the production and consumption of ethanol. A life cycle assessment can help to weigh the pros and cons of using ethanol over gasoline in terms of energy use, carbon dioxide emissions and other environmental factors. It's not just about how much carbon is in one gallon of gasoline compared to one gallon of ethanol. Life cycle assessments look at all the steps along the way, from planting a crop, to harvesting it, to transporting it, to refining it, to vehicle use.
There are many different steps in the production of ethanol. We're following the path of carbon all the way from the atmosphere, to the plant, to the engine in your car, and then back into the atmosphere. In this video, watch for where the carbon atoms enter the cycle, what compounds they form, how they get rearranged, and in what molecules they are released.

Slide 3: We'll start with photosynthesis. Carbon dioxide enters the leaves of plants where it is chemically changed into the sugar, glucose, using energy from the sun. Glucose, which is a simple sugar, is the building block for more complex carbohydrates such as starch and cellulose. These carbohydrates create the bulk of the plant, called biomass. Biomass can be anything from trunks of poplar trees, to corn stalks, to blades of switchgrass. All of this biomass contains an enormous amount of carbon. In fact, cellulose is the most abundant biological molecule on earth! This biomass can be used to create ethanol.

Slide 4: Once the biomass crop reaches maturity, it is harvested and transported to a refinery, where it will be turned into ethanol.

Slide 5: In a traditional ethanol refinery, the biomass passes through many complex steps. We'll explain the details later on. This slide demonstrates the reorganization of the carbon atoms in carbohydrate molecules into ethanol and carbon dioxide. Most of today's refineries use yeast or E. coli to ferment the plant sugars, such as glucose, into ethanol. At this point the carbon in the carbon dioxide molecules is released as waste and the carbon in the ethanol molecules are kept for later use.

Slide 6: The ethanol from the refinery is then transported to gas stations and other places where it can be put into vehicles.

Slide 7: When you fill up your gas tank with ethanol, you are pouring carbon-containing molecules into your car. Your engine releases the energy in the ethanol in a process called combustion. In order to release the energy stored in the chemical bonds of the ethanol molecule, the carbon atoms are rearranged into smaller carbon dioxide molecules.

Slide 8: The carbon dioxide released during combustion enters the atmosphere. Some of these carbon dioxide molecules may be taken up by plants for photosynthesis.

Slide 9: As with gasoline, making ethanol depends heavily on carbon-based fuels for production. Carbon plays an even bigger role in this process than we've already described. So far we've shown how plants took in carbon dioxide from the atmosphere to synthesize more biomass. That biomass was harvested and taken to a refinery where it was fermented into ethanol. That ethanol was then taken to a gas station, where you filled your tank and carbon dioxide was released from the tailpipe when you subsequently drove your car. The life cycle assessment calculates those inputs, but also considers fuel inputs that aren't always obvious to us in our everyday lives. Let's look at other places carbon-based materials are used in this system.

Slide 10: We started the process with photosynthesis and the growing of a biomass crop. Farmers use a great deal of fossil fuels to produce those crops. For example, many fertilizers are created using natural gas, CH4. Farm machinery to plant, weed, and harvest crops normally run on petroleum fuels like diesel. Upon combustion in the engines of this machinery, carbon dioxide is released into the atmosphere. We often forget that the efforts of the farmers to bring us modern-day biofuels, burn fossilized carbon-based fuels in the process.

Slide 11: As we mentioned earlier, refining biomass into ethanol is complex. First, the biomass is chopped or ground up so it can be refined more easily. Chemicals and enzymes are added to further break down the plant matter into simpler molecules, then yeast or E. coli are used to ferment the carbohydrates into ethanol. The last step of refining is distillation, which results in highly concentrated ethanol for use in a vehicle. A great deal of energy from heat and electricity is used throughout this process to convert the plant biomass into ethanol. Traditionally, energy comes from the combustion of fossil fuel based hydrocarbons like coal and natural gas. These fuel sources are used to light the plant, run the equipment, and refine the biomass. Any time fossil fuels like these are burned, carbon dioxide is released into the atmosphere. However, if the refinery uses nuclear, solar, or hydroelectricity for power, no carbon byproducts are produced because hydro-carbon fuels are not used. If the refinery uses fossil fuels for electricity and heat, it will release carbon dioxide that will take millions of years to recycle into fossil fuels. In a cellulosic operation, the refinery may instead burn waste biomass for heat or electricity. By burning biomass, the refinery is releasing carbon atoms from the sugars inside the plant biomass, which were originally captured by the plant during photosynthesis. Burning biomass releases carbon dioxide into the atmosphere that can be quickly recycled into new biomass during photosynthesis.

Slide 12: Another carbon consumer often overlooked is the transportation system that moves raw materials and finished products. Harvested crops are transported from farms to the refinery, and ethanol is transported from the refinery to gas stations. Petroleum is normally used to fuel the vehicles in this system. When these vehicles burn fuel, carbon dioxide is released and returns to the atmosphere.

Slide 13: For our life cycle assessment we tracked the carbon inputs and outputs through the cellulosic ethanol production system. It started with carbon dioxide in the atmosphere, moved into carbohydrates in plants, which went to the refinery, then into ethanol to power your vehicle, and ended back with carbon dioxide being released into the atmosphere. Along the way inputs from farming practices, transportation systems and the refinery itself changed the carbon balance of the system. Scientists are currently researching ways to increase the efficiency of the process and reduce fossil fuel inputs into the system.
Reviewing the entire process, what would it take to make this system carbon neutral?