



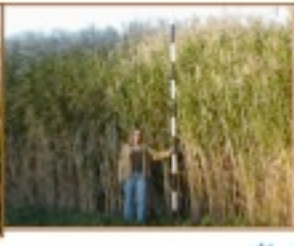
Cellulosic Ethanol: the science and corresponding learning opportunities

Sara Krauskopf and John Greenler

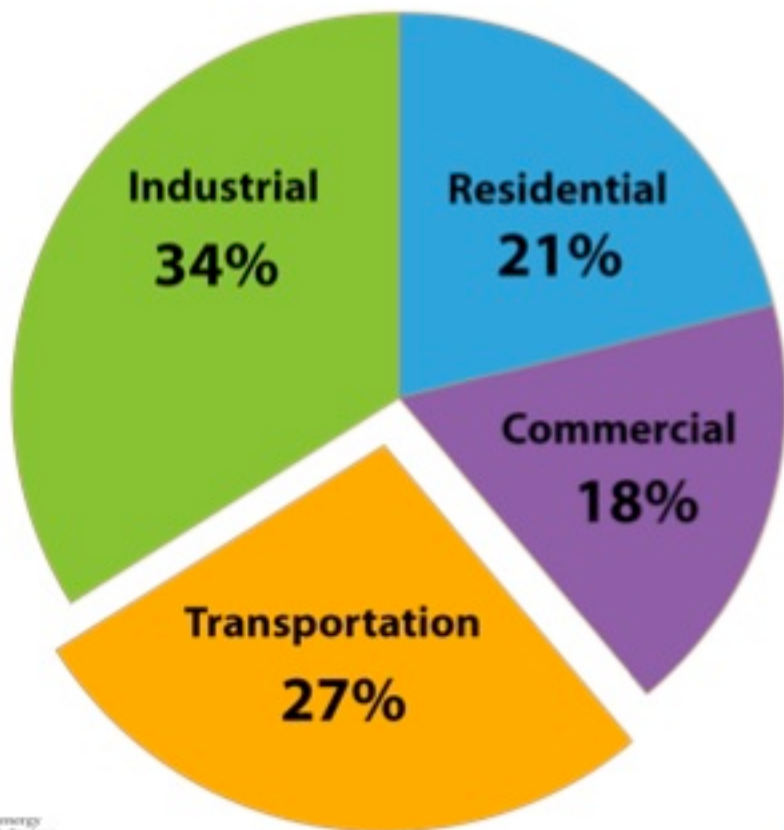
NSTA

March 20, 2010

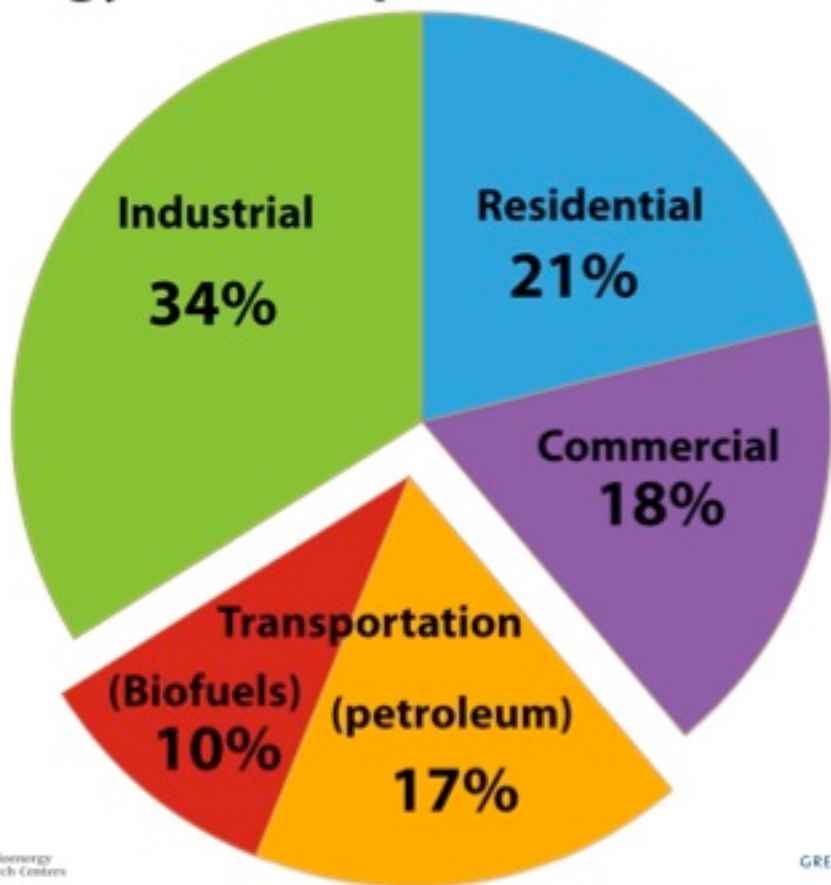
- ✘ Second Generation Biofuels
- ✘ Core Teaching Concepts Addressed
- ✘ Activity Sampling



U.S. Energy Consumption, 2004

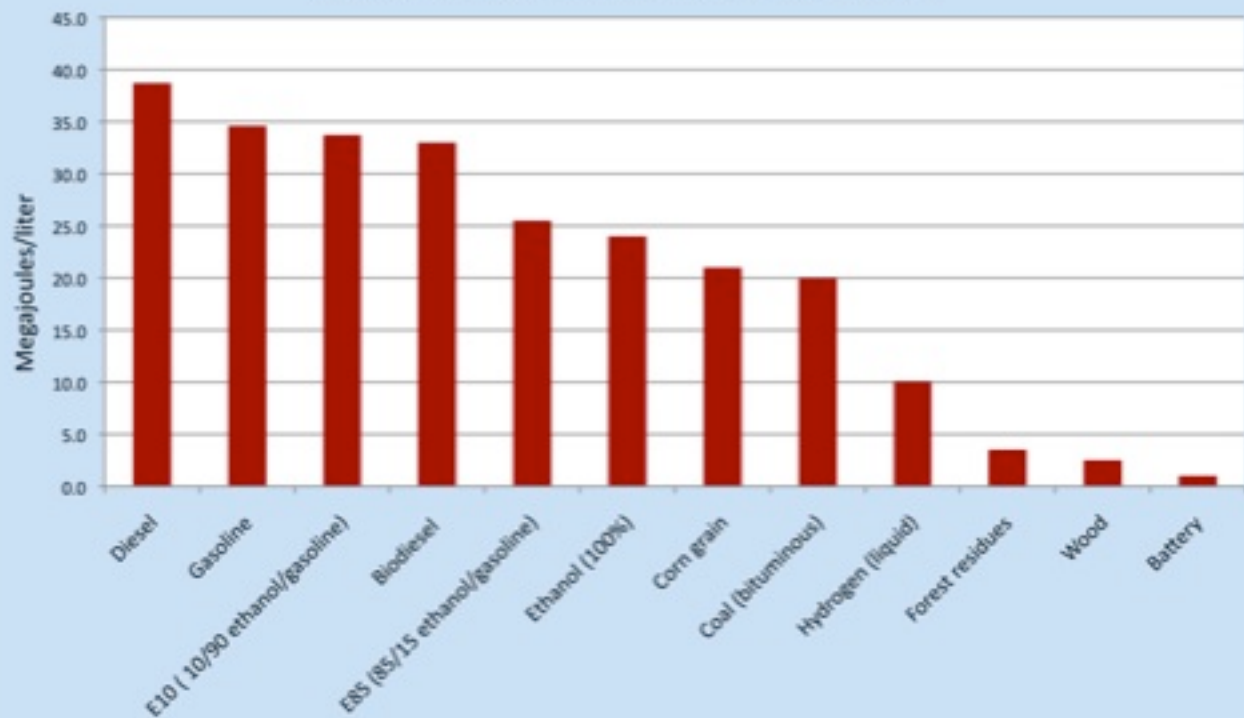


U.S. Energy Consumption, Biofuels Potential

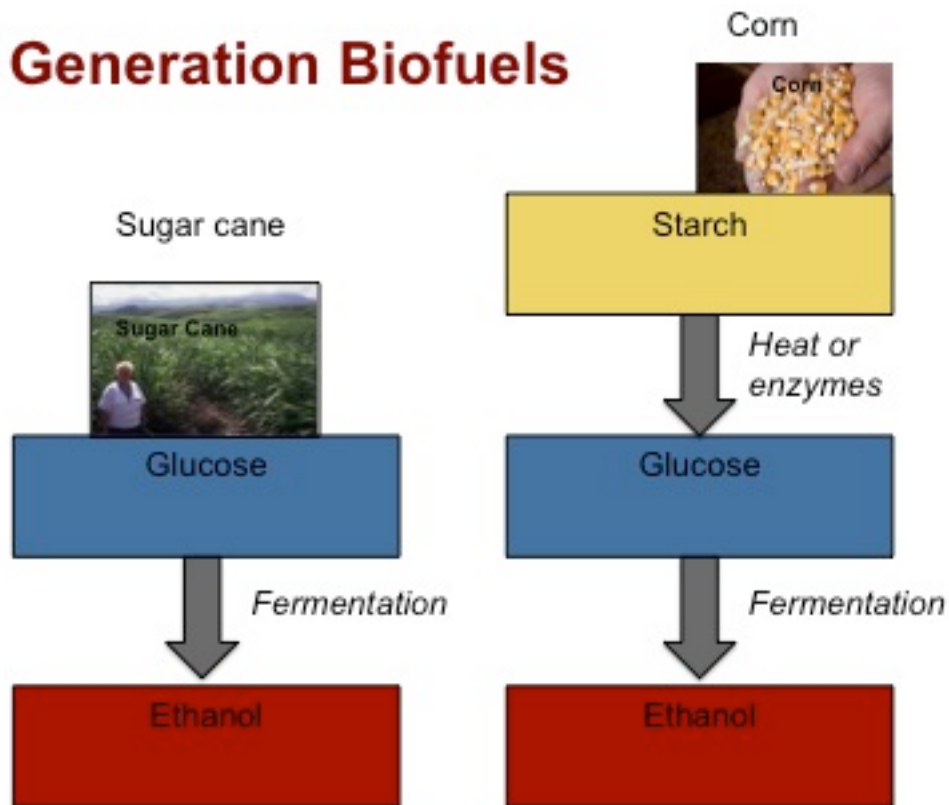


Energy Densities by Volume

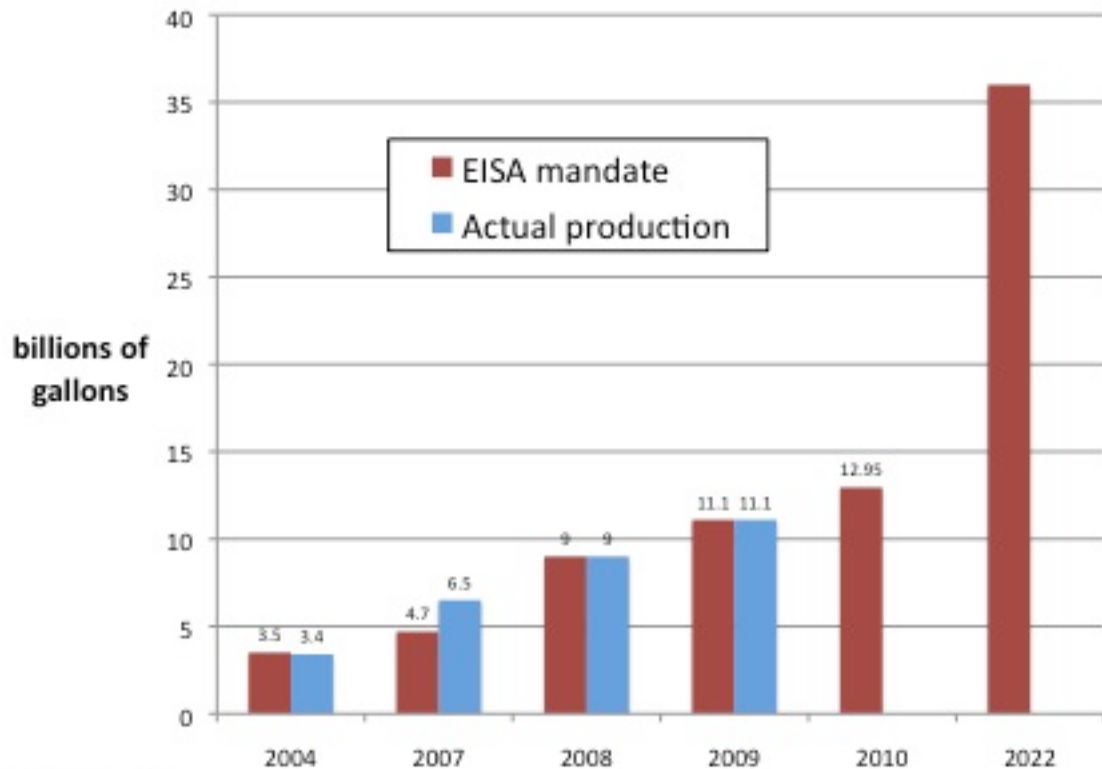
Cleveland, C. J. and R. Kaufmann, 2008, Fundamental Principles of Energy, Encyclopedia of Earth
http://www.eoearth.org/article/Fundamental_principles_of_energy



First Generation Biofuels



Federal Mandate for Biofuels Production vs Actual



Concerns with Corn Ethanol

- ✦ Annual crop
 - Dependent on chemical inputs
 - Soil erosion, water quality problems
 - Little below ground carbon storage
- ✦ Food versus fuel
- ✦ Reduced wildlife habitat
- ✦ Impacts on biodiversity



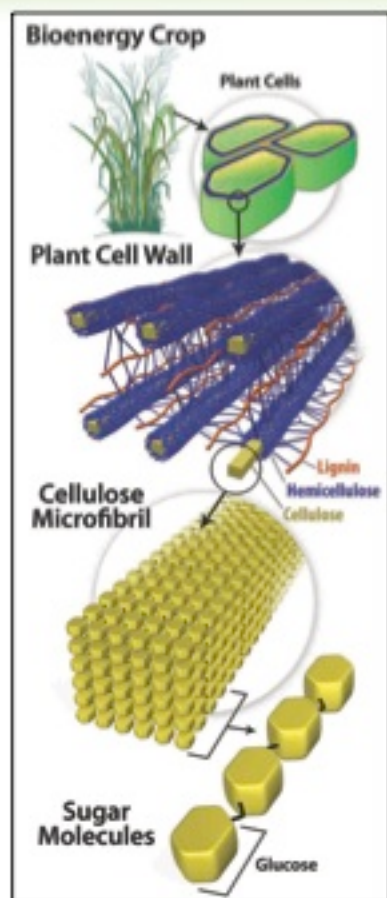
Tillman *et al.* Science 2006
Jordan *et al.* Science 2007
Nash, BioScience 2007
Kennedy, Science 2007
Rosi-Marshall *et al.* PNAS 2007

Renewable Fuel Standard (EPA-2010)

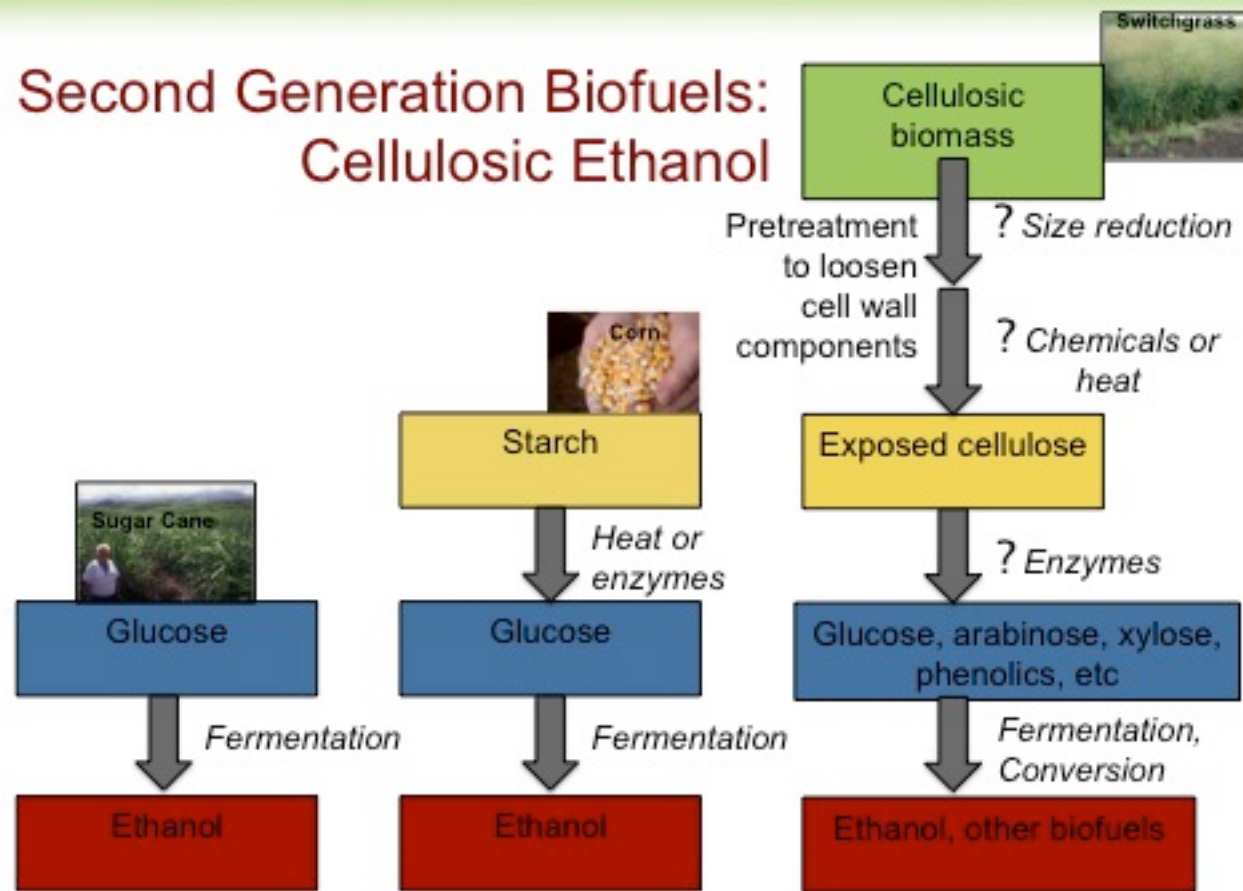
- ✘ 12.95 billion gallons biofuel in 2010
- ✘ 6.5 million from cellulosic ethanol
- ✘ Greenhouse gas reduction vs gasoline:
 - Corn-based ethanol requires 20%
 - “Advanced biofuels” require 50%
 - Cellulosic biofuels require 60%

Cellulosic Biofuels

- ✧ Cellulose is the most abundant biological material on Earth
- ✧ Found in cell walls
- ✧ Lack efficient way to break down plant material and convert it into fuel
- ✧ Cell wall composition varies

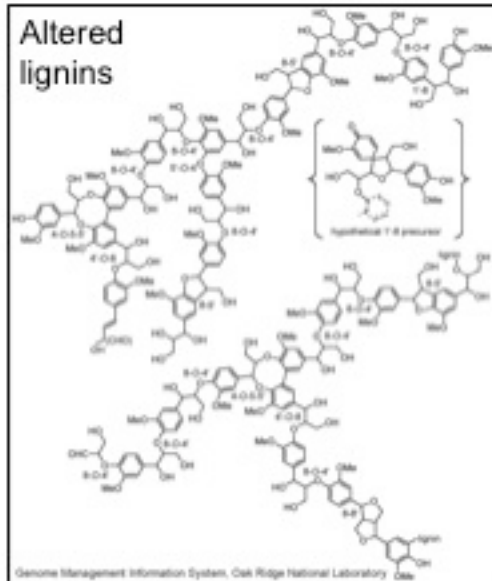


Second Generation Biofuels: Cellulosic Ethanol



Plant Breeding for Greater Biofuels Potential

Altered
lignins



Varieties of corn for bioenergy



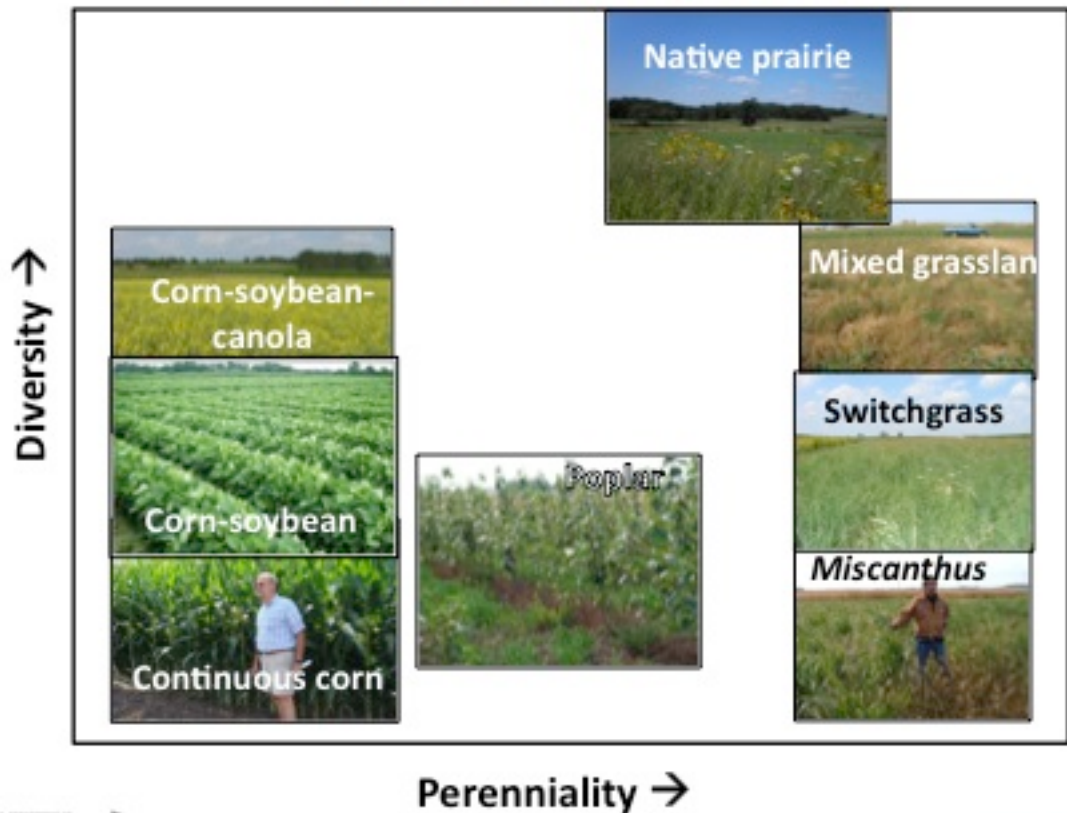
Biofuel Cropping Systems

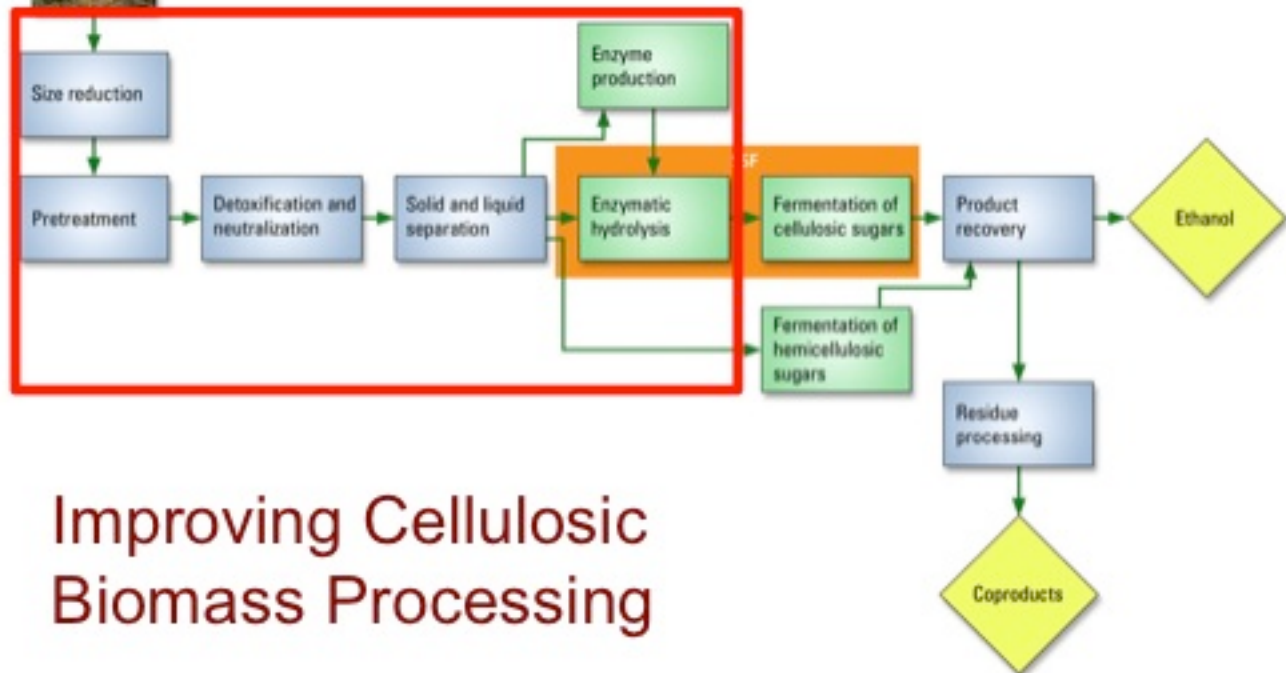


GLBRC Cropping systems experiment
Arlington ARS (WI) & Kellogg Biological Station (MI)

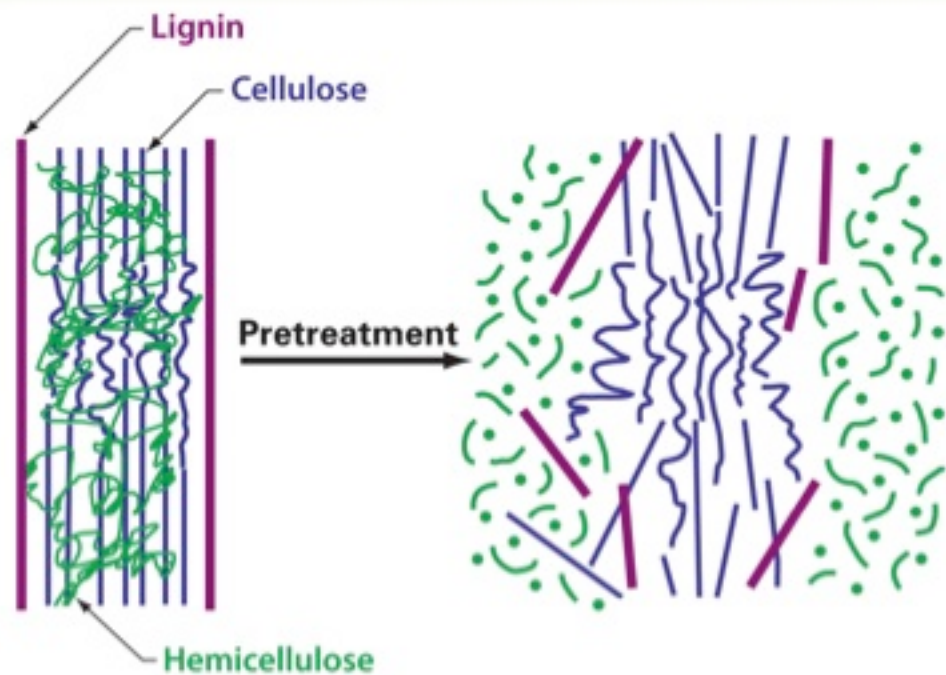
8 systems x 5 replicate blocks - Established 2008

Feedstock Options





Improving Cellulosic Biomass Processing



Goal of **pretreatment** is to open up cell wall and expose cellulose.

Improving Biomass Processing

- Discover and improve natural cellulose-degrading enzymes
- Analyze a range of plant materials and pretreatment conditions
- Impact of pretreatment by-products on biofuel yield



BIO-PROSPECTING



Herbivore Dung

- Cows
- Horses
- Rabbits

Insects

- Beetle larvae
- Ants
- Other Herbivores

Compost

- Ant
- Human

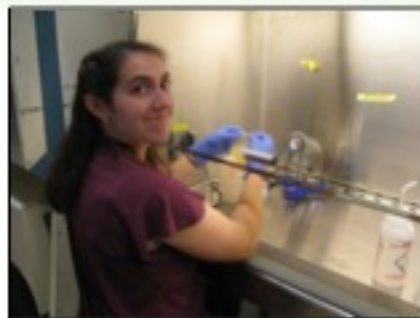
BIO-PROSPECTING



D Mead, Lucigen

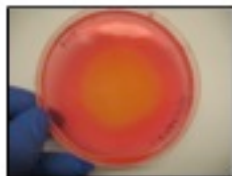


Genome Management Information System, Oak Ridge National Laboratory
<http://genomics.energy.gov>



Bioprospecting for Cellulose-Degrading Microbes

- ✦ Where in the environment are cellulose-degrading microbes found? Why?
- ✦ Choose an environmental sample
- ✦ Isolate on selective media
- ✦ Test for cellulase production

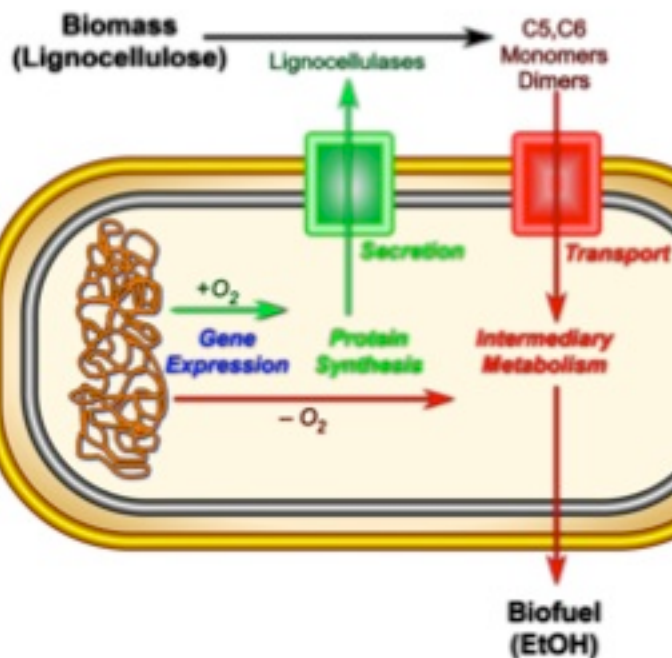


Improving Biomass Conversion

- Improve methods for converting plant biomass into materials that replace fossil fuels
 - **ethanol**
 - hydrogen
 - chemical precursors
 - Other hydrocarbon fuels



Improved Biomass Conversion



1) Aerobic growth: optimize production of extracellular enzymes (lignocellulases)

2) Anaerobic growth: optimize production of enzymes, transporters, & pathways to funnel carbon to fuel production (ethanol, others)

Teaching Concepts

✘ Energy

- Use, alternative forms, conservation

✘ Global Climate Change

- Carbon cycling
- Greenhouse gas emissions, sequestration

✘ Biotechnology

- Genetic engineering, fermentation, enzyme activity, biochemistry

✘ Sustainability

- Land use, water, soil health, food vs fuel, economics

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EDUCATIONAL MATERIALS

Posted on Jan 14, 2009 in [Uncategorized](#) | Comments Off

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[FERMENTATION ACTIVITIES](#)
[SUSTAINABILITY ACTIVITIES](#)
[GENERAL INFORMATIONAL HANDOUTS AND VIDEOS](#)
[MATERIALS FROM THE DEPARTMENT OF ENERGY](#)

FERMENTATION ACTIVITIES:

[Fermentation In A Bag Activity](#)

This is a demonstration table or interactive activity that GLBRC has done at family-style outreach events such as Science Expeditions at UW-Madison. It appeals to a range of younger children, about ages 5-14 or grades K-8. Prep time and set-up are minimal, and students can carry around their portable experiment if desired. This activity can also be easily adapted for classroom use.

Supporting Material:

[Fermentation Bag Labels, Formatted for Avery Label Templates 5163](#)
[Grassoline: Driving Away From Corn Poster](#)

[Fermentation Challenge: Making Ethanol from Cellulose](#)

This high school-level lab demonstration and activity will introduce students to the process of fermenting cellulosic biomass into cellulosic ethanol, along with the challenges researchers face in this area. The demonstration uses a Vernier probe or balloons to measure fermentation rates of different feedstocks to begin the discussion of why some carbohydrates are easily fermented by yeast while others are not. Students can design and carry out their own labs to try to improve fermentation rates of various feedstocks.

[Mini-Fermenter Instructions](#)



ABOUT THE CENTER

Removing
bottlenecks in the
biofuels pipeline.

TEST YOUR BIOENERGY KNOWLEDGE



FROM THE BENCH

GLBRC RESEARCH
PUBLICATIONS

GET INVOLVED IN IDEA EXCHANGE

BIOENERGY



carbon dioxide



Rapidly
recycled
carbon dioxide



Combustion for
energy

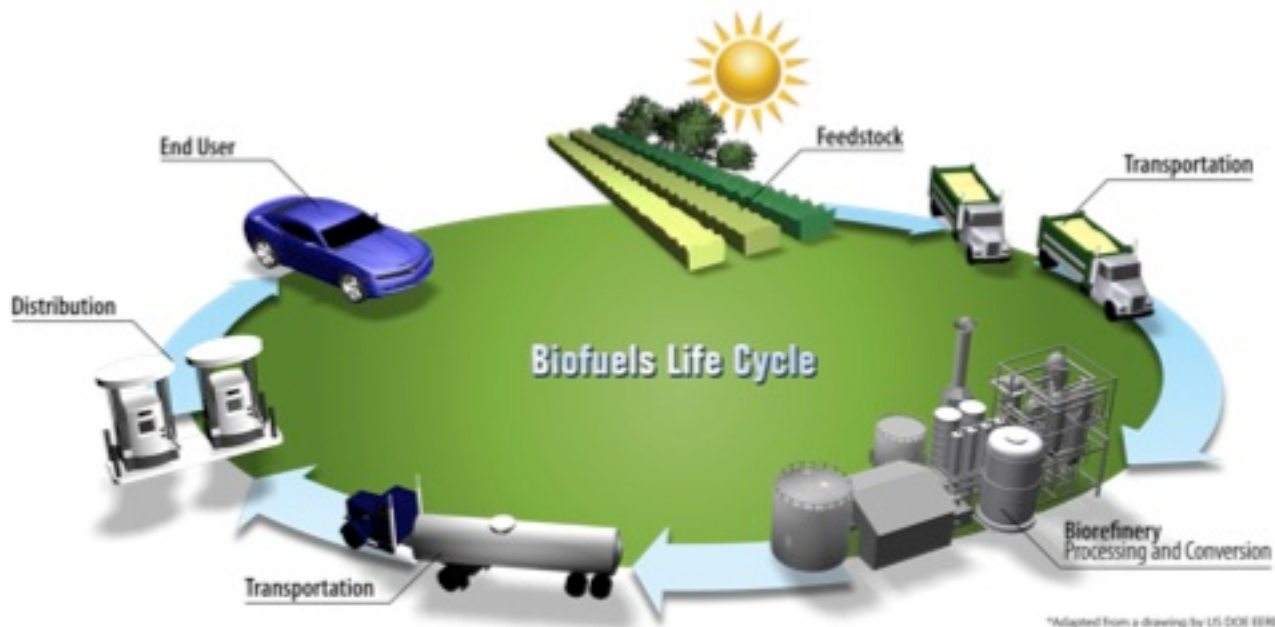


Ancient fossil fuel

Millions of years to form



Biomass



*Adapted from a drawing by US DOE EERE

Photosynthesis



Farming practices



Feedstock Transport



Refining



Product Transport



Fuel combustion



**Energy In
vs.
Energy Out**

PROCESS TOOL



Process Tool Choices

Energy Inputs and Outputs



Electricity



HEAT

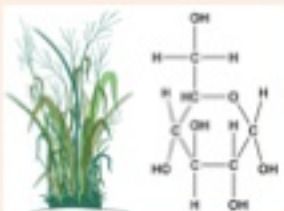
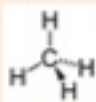
Chemical
Energy

Kinetic Energy
(motion)

Matter Inputs and Outputs



Natural Gas

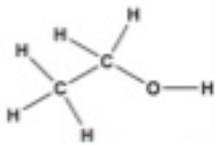


glucose

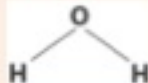
petroleum



carbon dioxide



ethanol



water



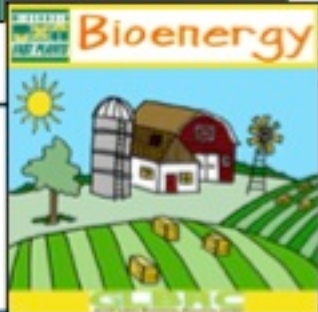
oxygen

GLBRC Education and Outreach

- ✧ Bioenergy Institute for Educators
- ✧ Research Experience for Teachers
- ✧ Educational Research
- ✧ Educational Materials Development and Dissemination
- ✧ Research Experience for Undergraduates



Collaborations



GLBRC Education and Outreach



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