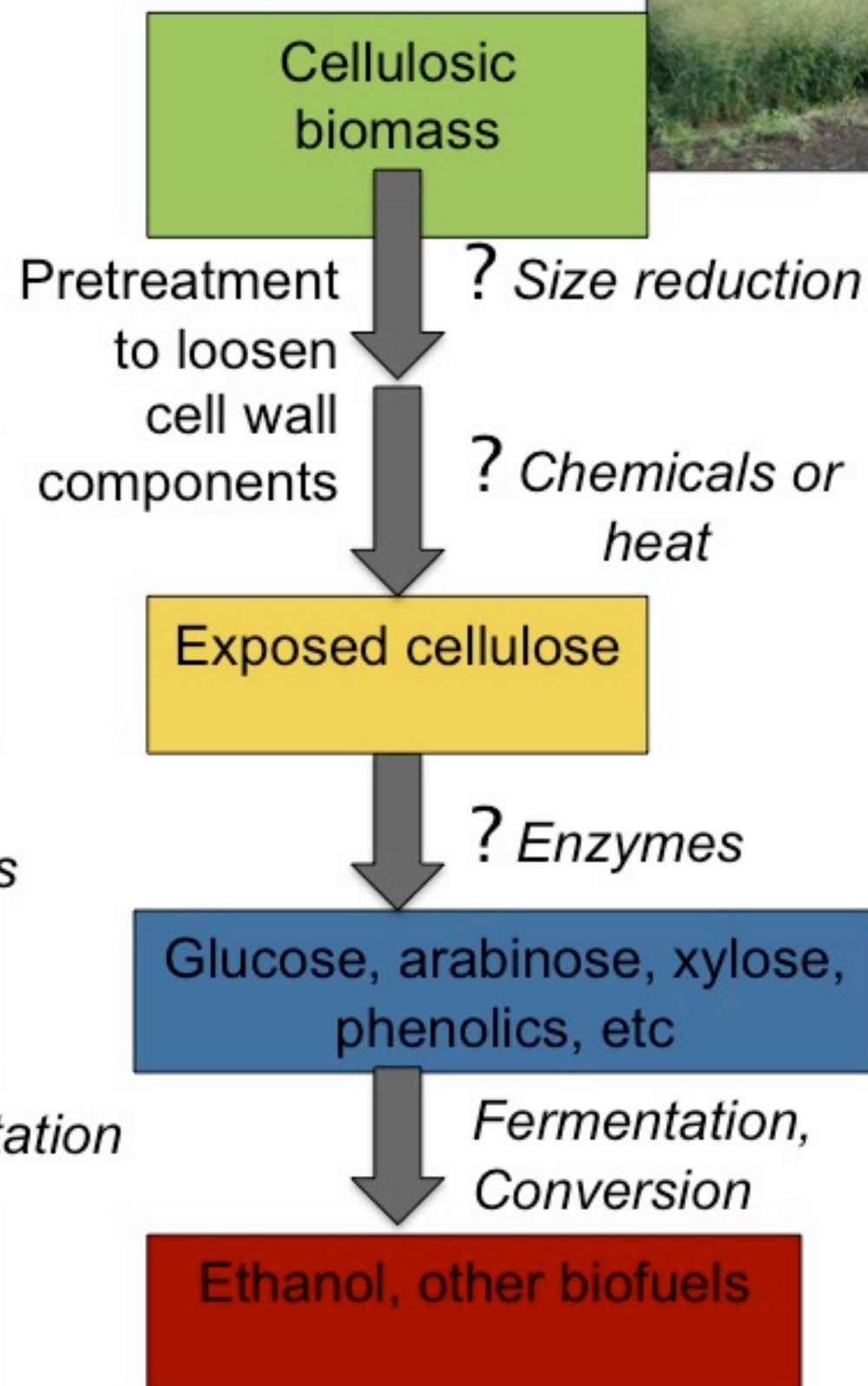
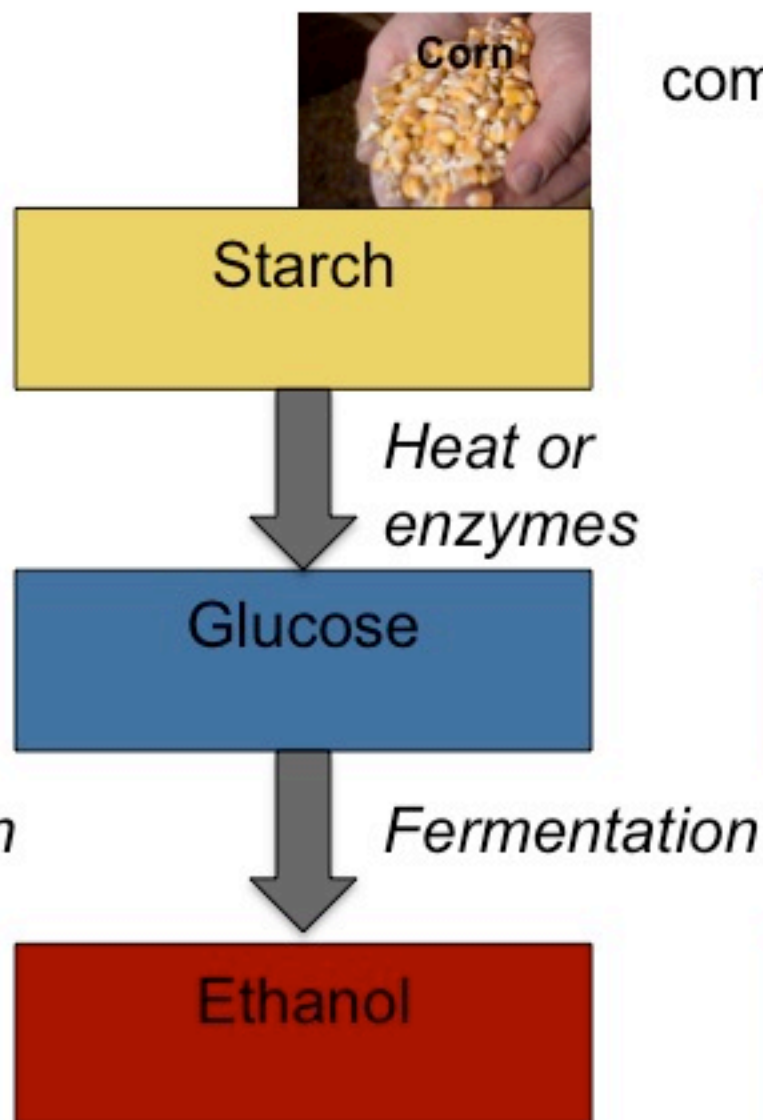
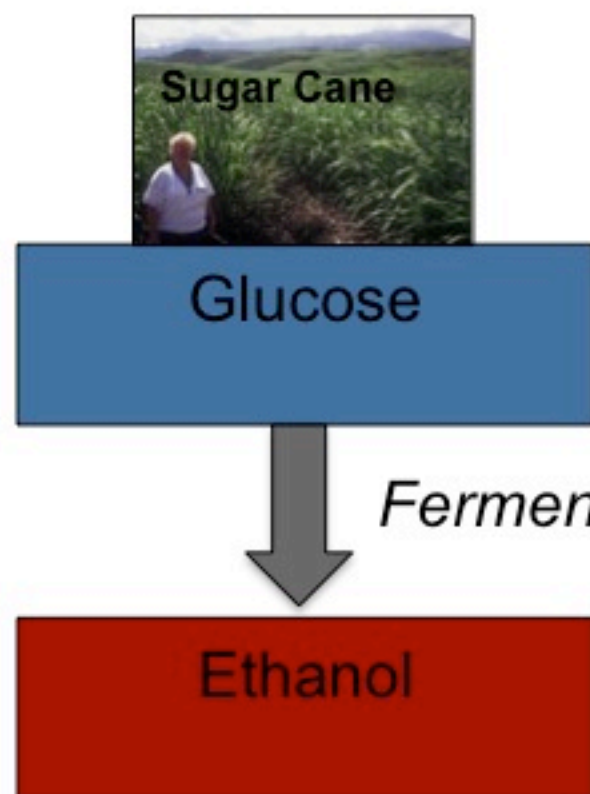




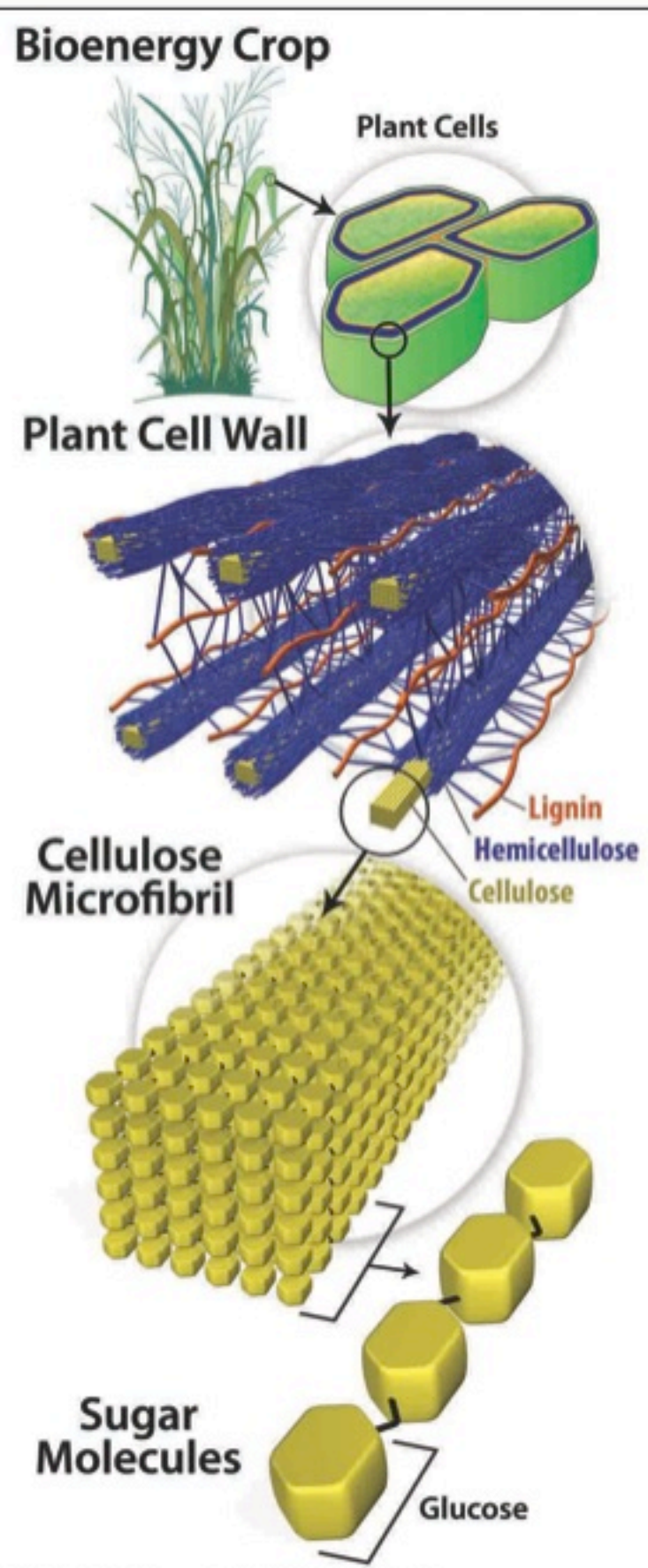
Quantitative Modeling of Biofuels Life Cycles

Hurdles to creating cellulosic ethanol



Plant Cell Wall Structure

- ✧ Cellulose—primary carbohydrate goal for extraction
- ✧ Hemicellulose—carbohydrate, harder to convert to fuel
- ✧ Lignin—may be burned for heat/electricity



Sources of cellulose

- ✖ Corn stalks, leaves, and husks (stover)
- ✖ Grasses grown as crops
- ✖ Prairie grasses
- ✖ Sawdust and woodchips
- ✖ Yard waste
- ✖ Any plant!



Corn Stover



Switchgrass

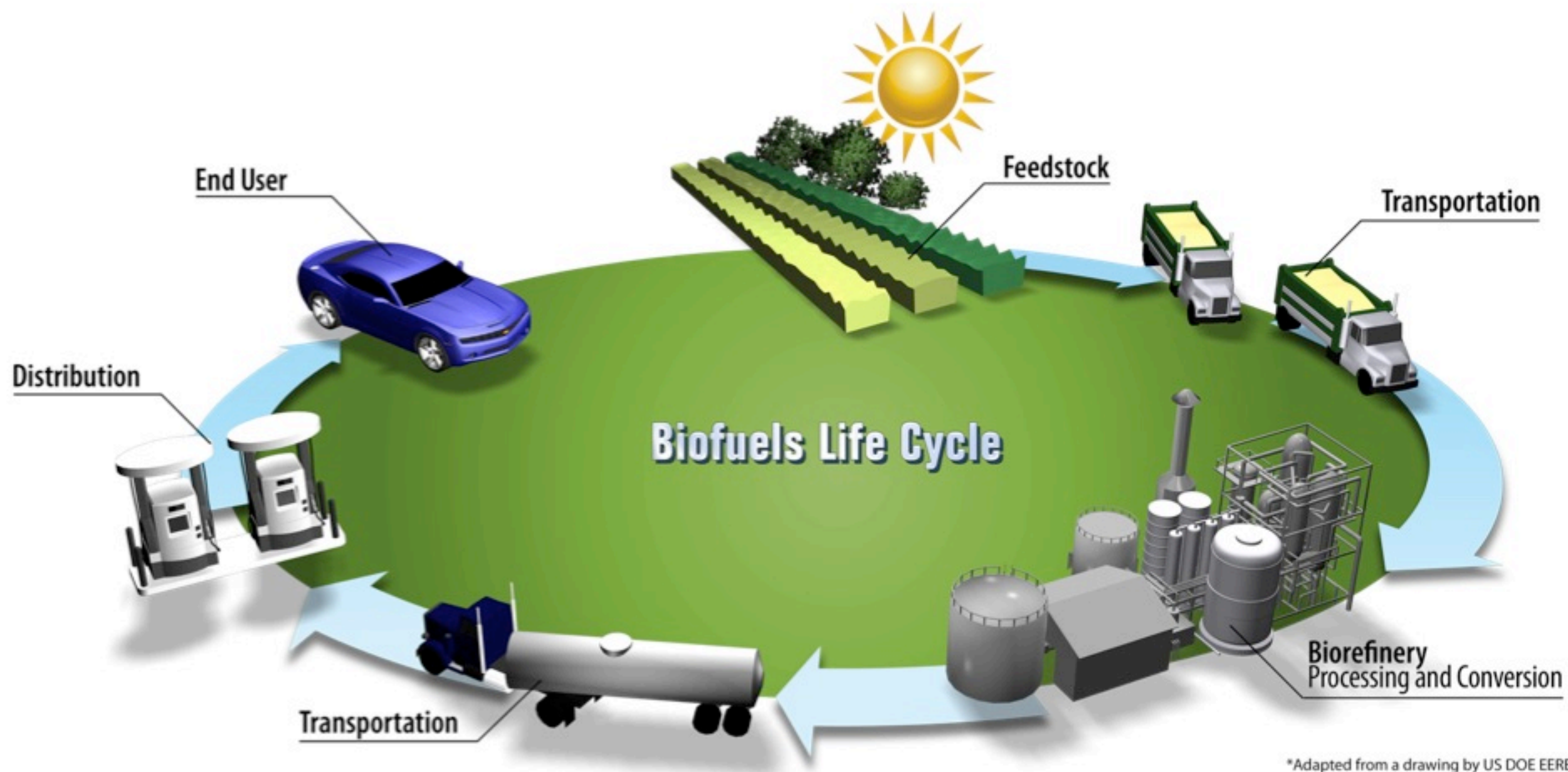
**Diverse
Prairie**



Crop variation

✖ Different crops have different needs

- Water
- Fertilizer
- Temperature
- Sunlight
- Soil
- Pest protection



*Adapted from a drawing by US DOE EERE

Life Cycle Assessment

- ✖ Process that examines and measures all of the inputs and outputs for a process
- ✖ Accounts for all steps
- ✖ Used to make comparisons of different processes that have the same end goal

Inputs

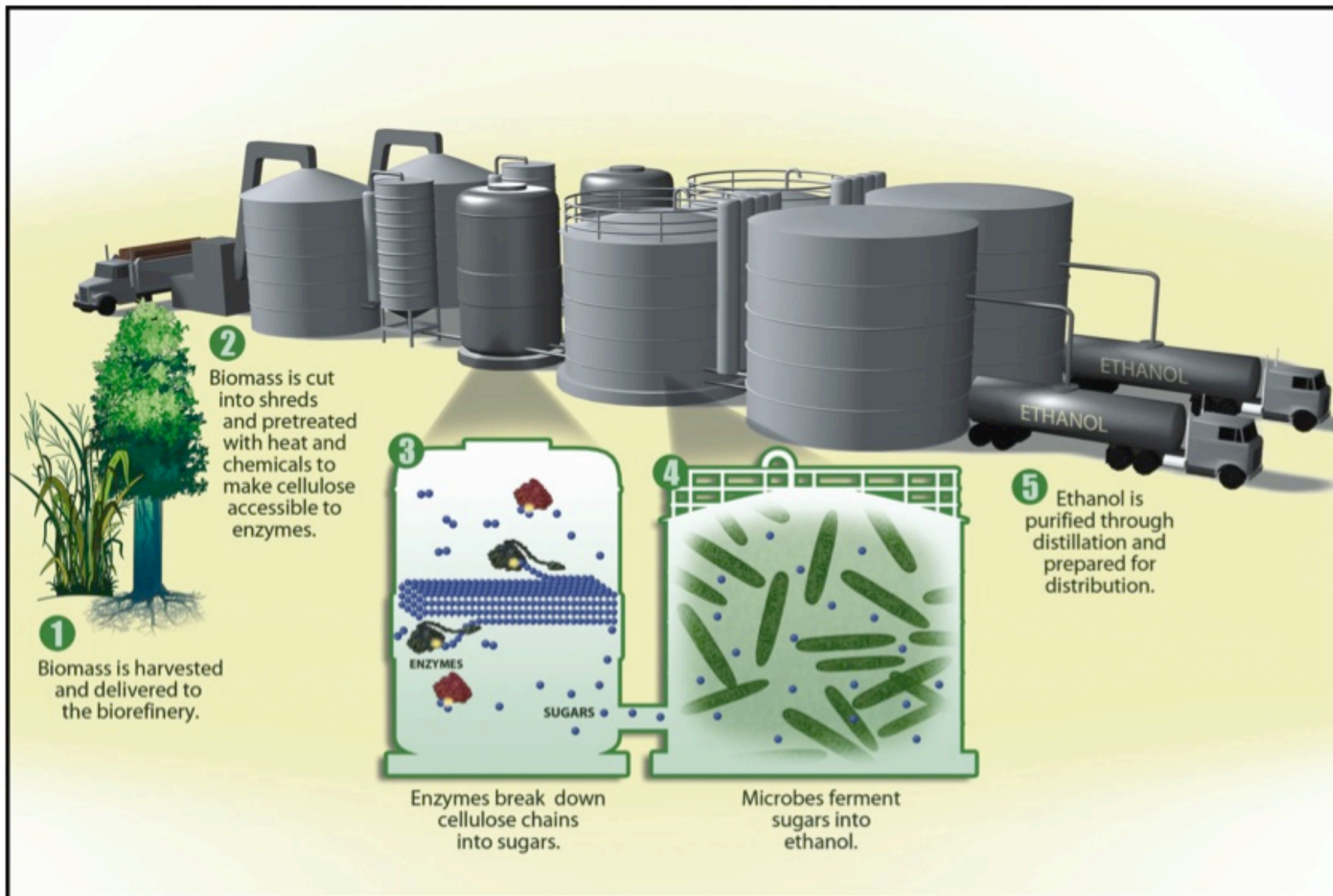
- ✖ Fuel, chemicals, water, land, sunlight
- ✖ Equipment for harvesting and planting
- ✖ Method of transporting crop to plant
- ✖ Processing machinery and energy to run it

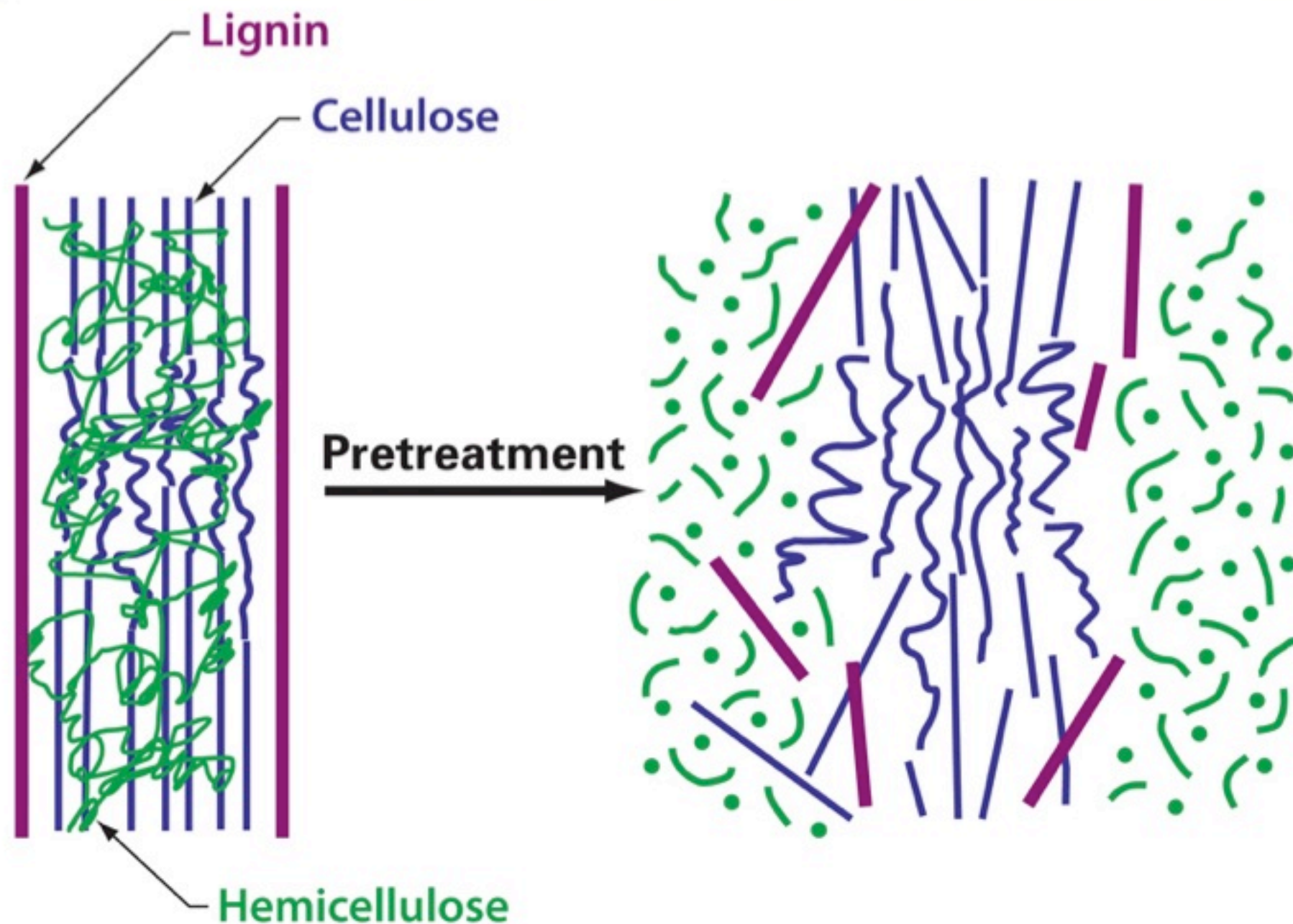


Outputs

- ✖ Ethanol
- ✖ Coproducts (electricity, animal feed, heat)

How Cellulosic Ethanol is Made

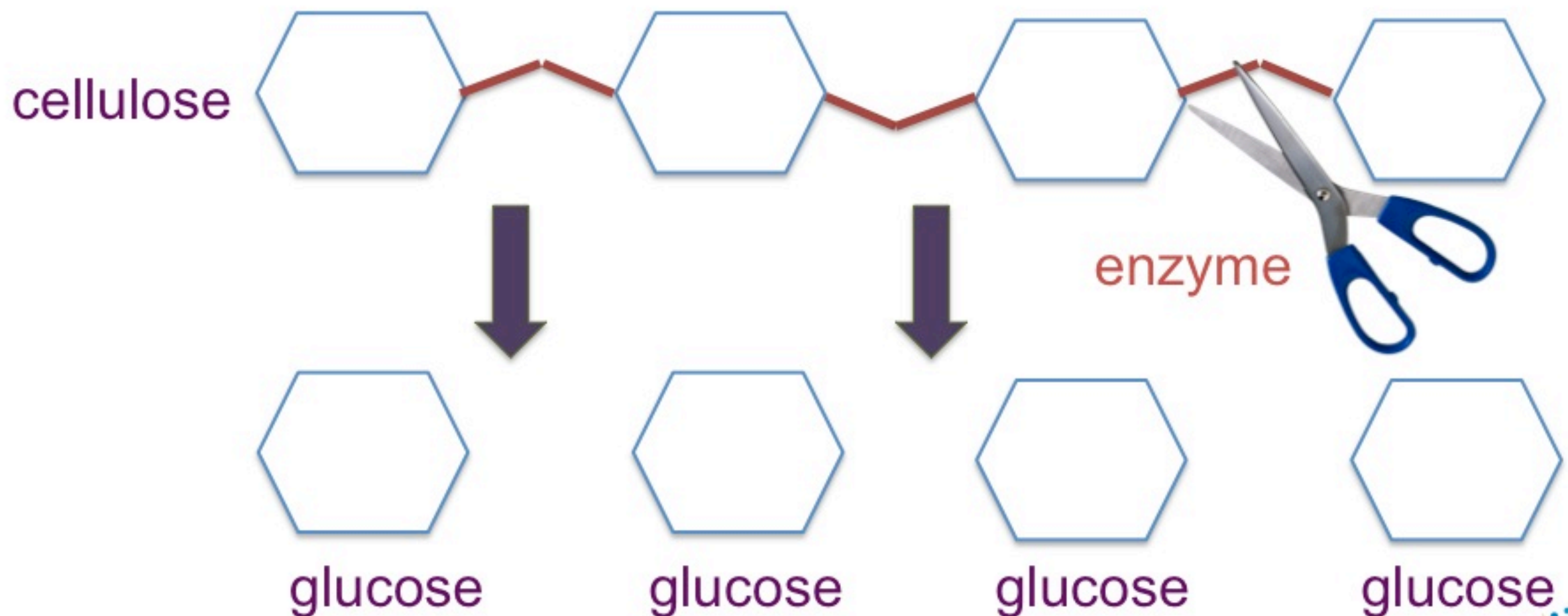




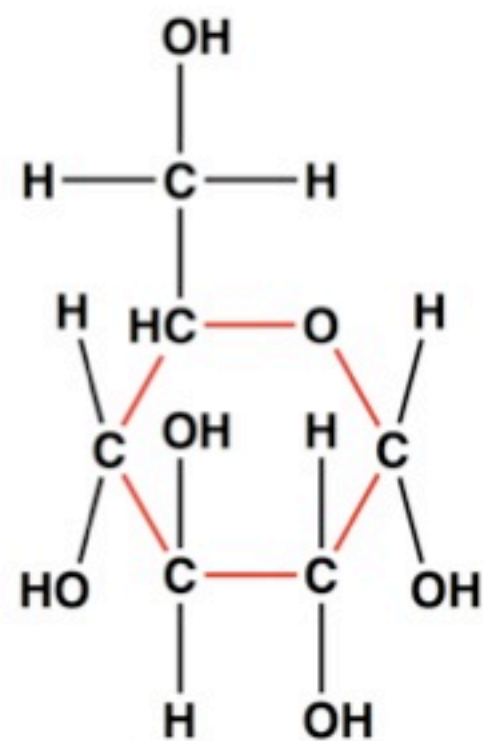
Goal of **pretreatment** is to open up cell wall and expose cellulose.

Enzyme Hydrolysis

Cellulose must be broken into individual glucose molecules using enzymes before fermentation can occur.



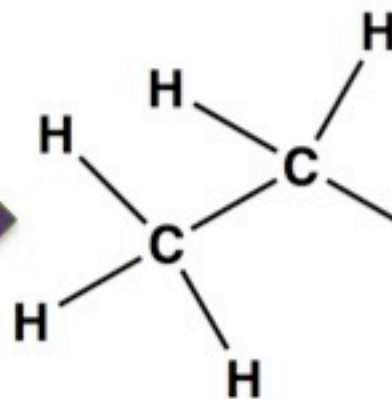
Standard **fermentation**:
enzymes in yeast convert glucose
into ethanol and carbon dioxide.



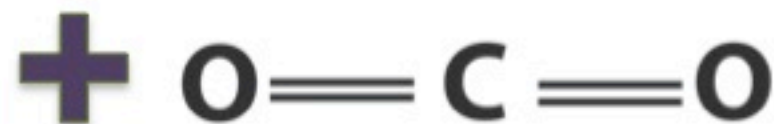
glucose



yeast



2 ethanol

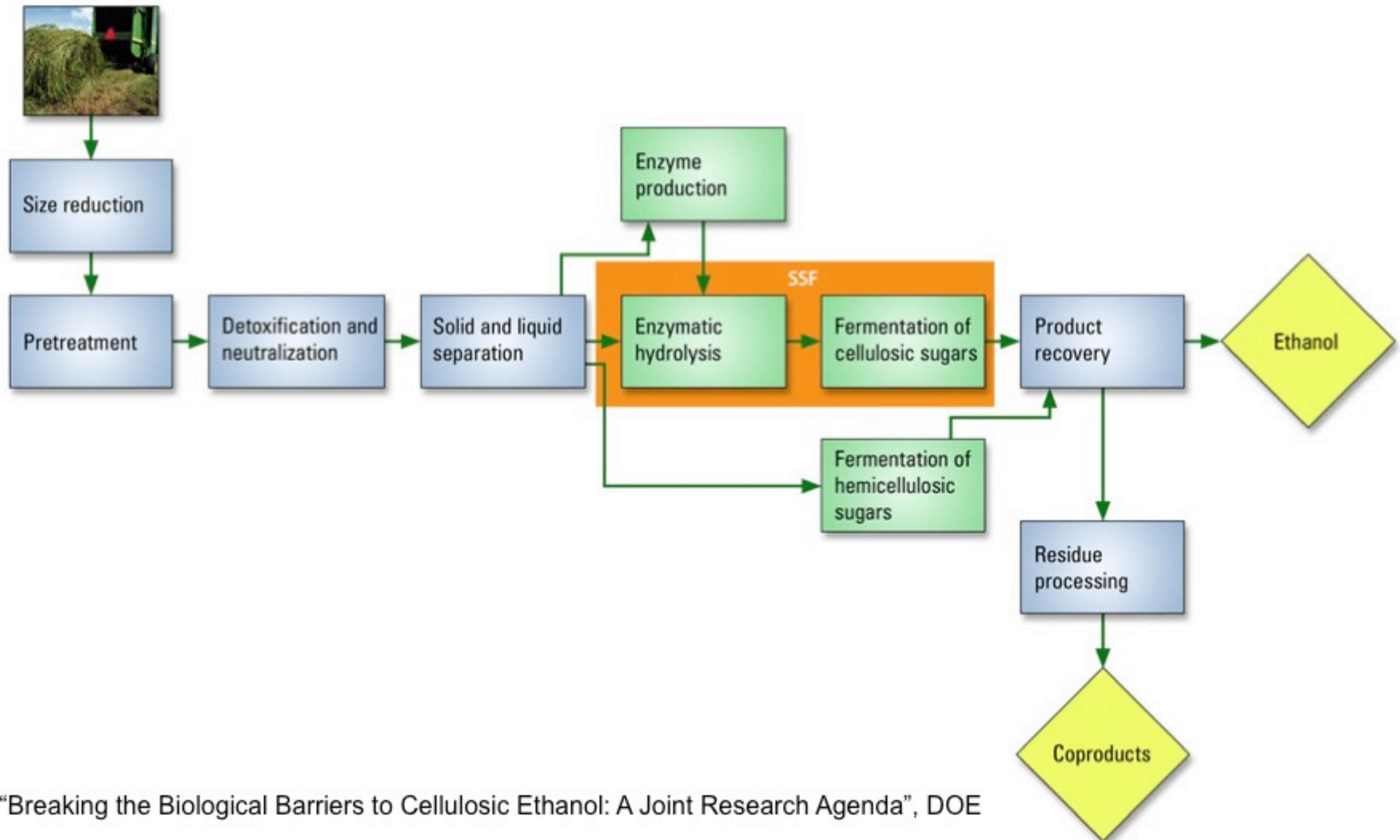


2 carbon dioxide

CO₂



How Cellulosic Ethanol is Currently Made



"Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda", DOE

Supplementary Slides

Chemical Application

Nitrogen
Fertilizer

Phosphorus
Fertilizer

Potassium
Fertilizer

Pesticide

System Boundary for the Production of Cellulosic Ethanol with Respect to Greenhouse Gas Emissions

Ethanol Production

Pretreatment
& Hydrolysis

Neutralization

Fermentation

Separation

One Liter of
Cellulosic
Ethanol

Electricity
Co-Product

Electricity
Sold to the
Grid

Net Primary
Productivity
of Feedstock

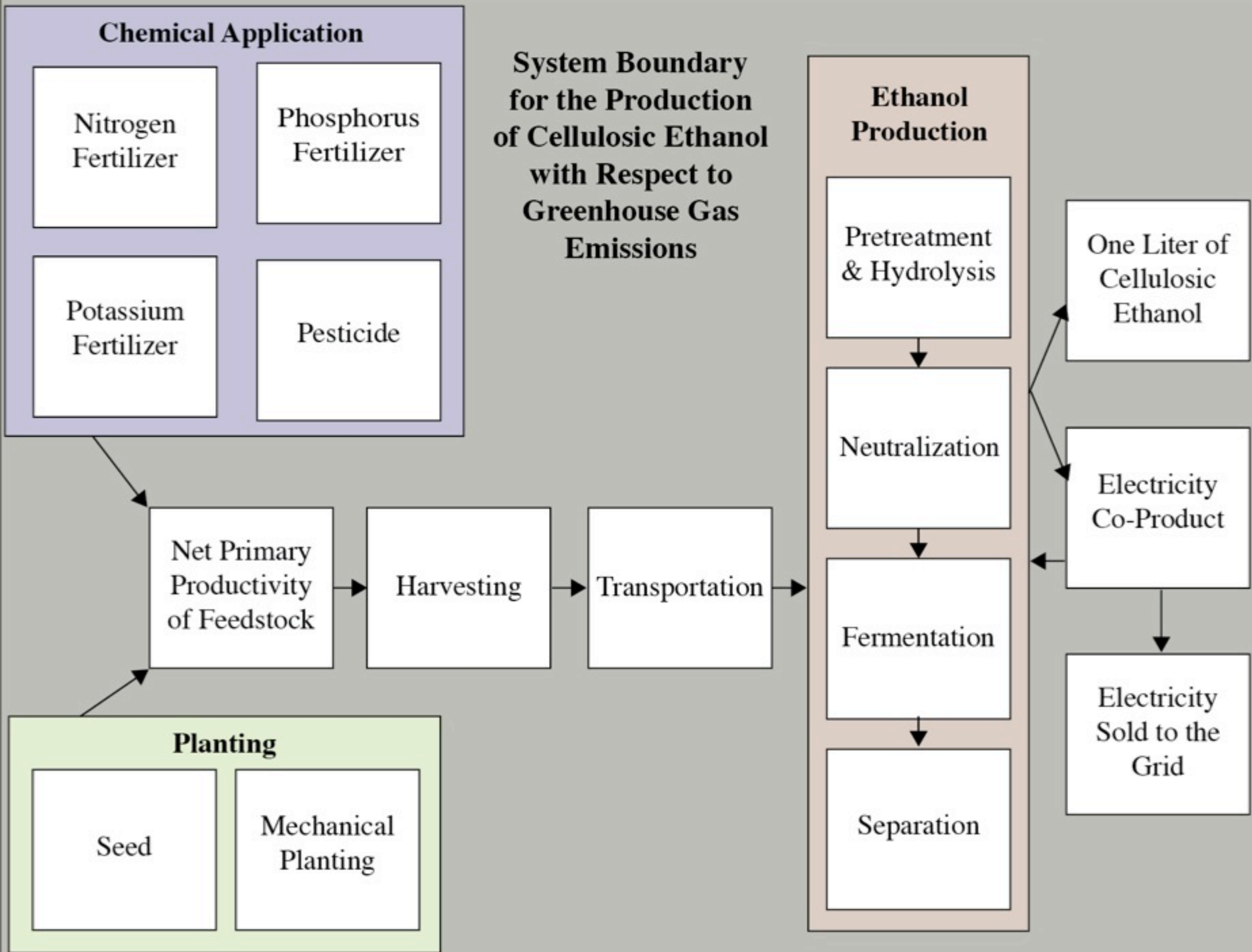
Harvesting

Transportation

Planting

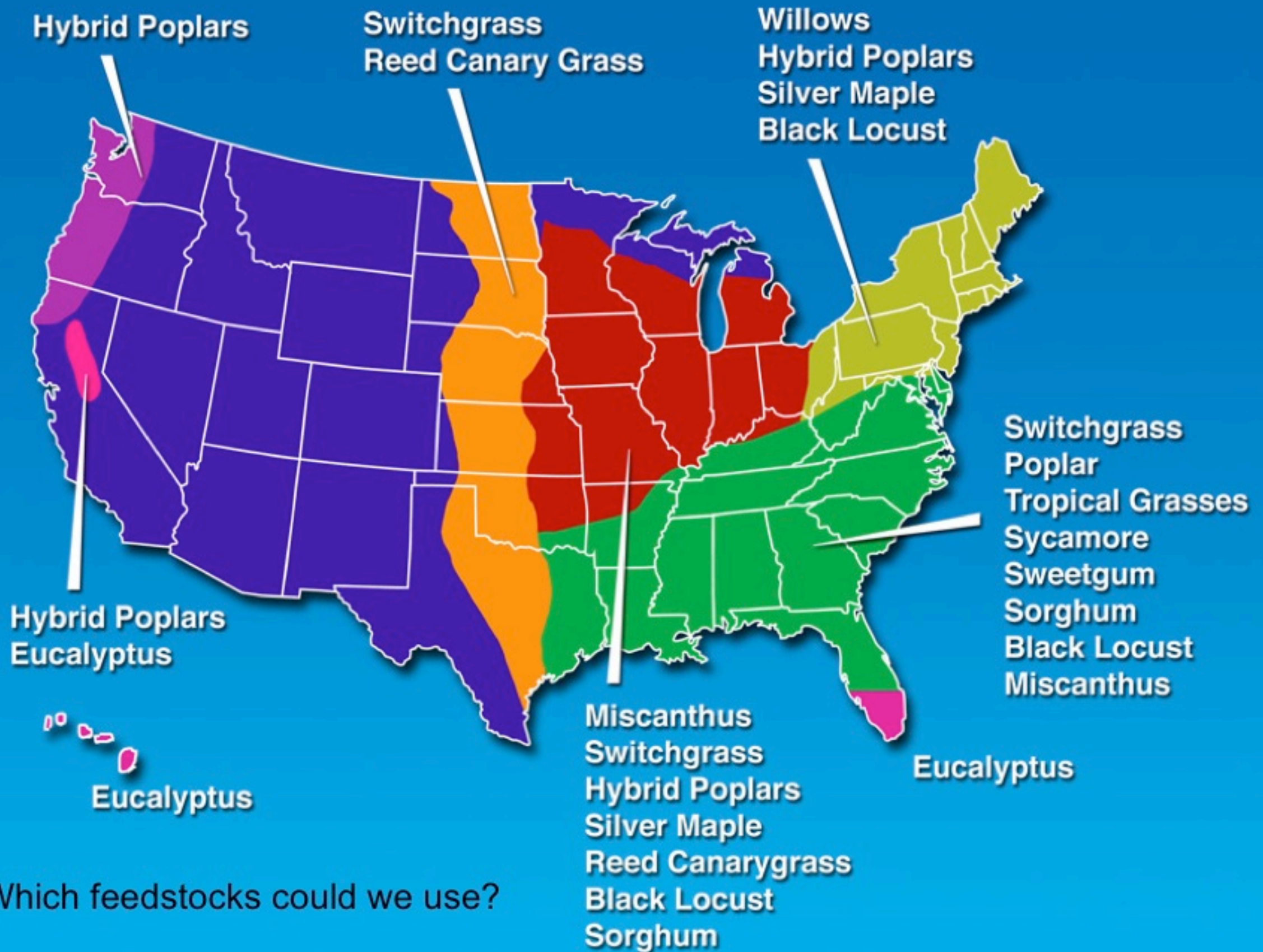
Seed

Mechanical
Planting

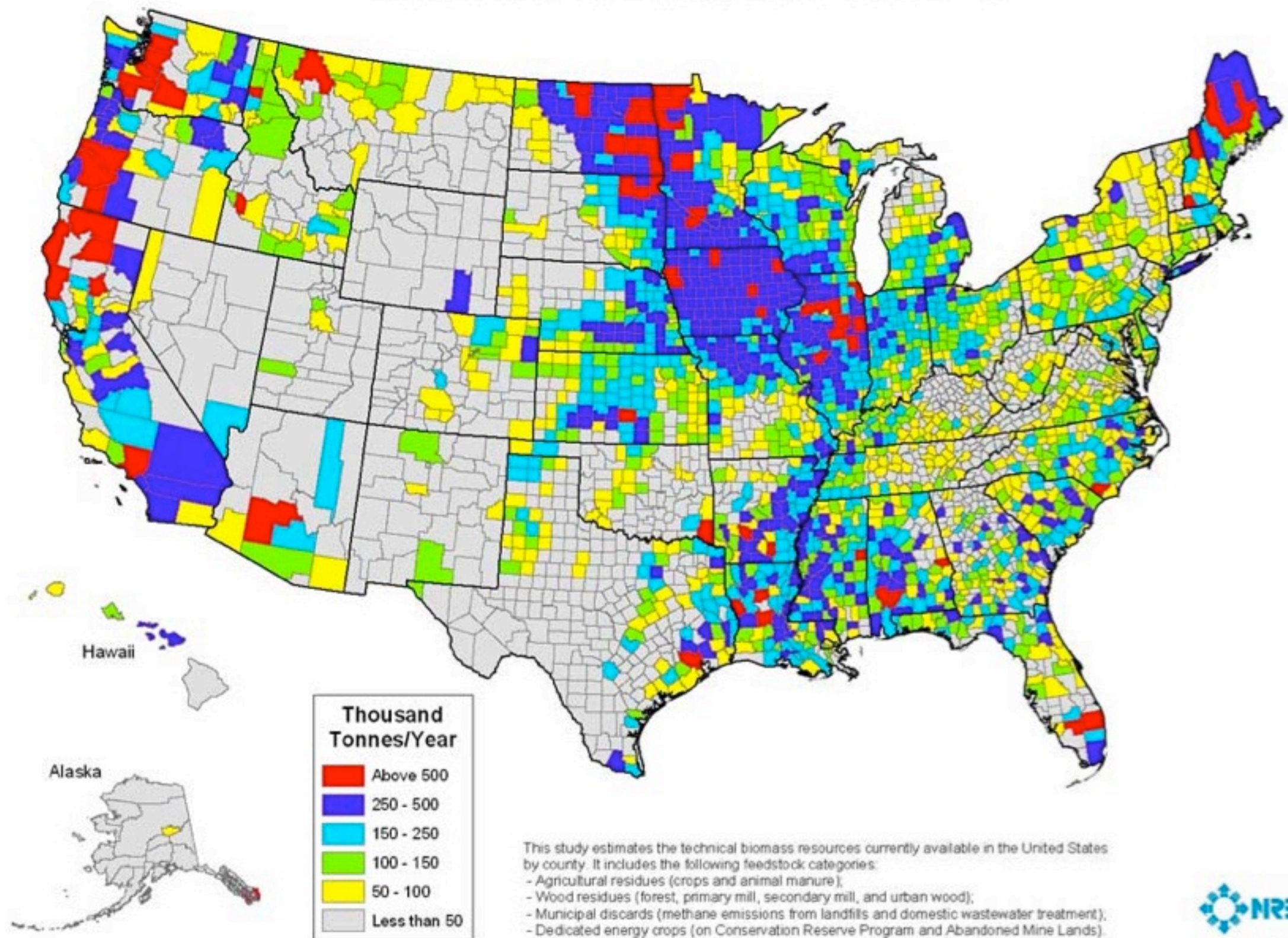


Area comparisons

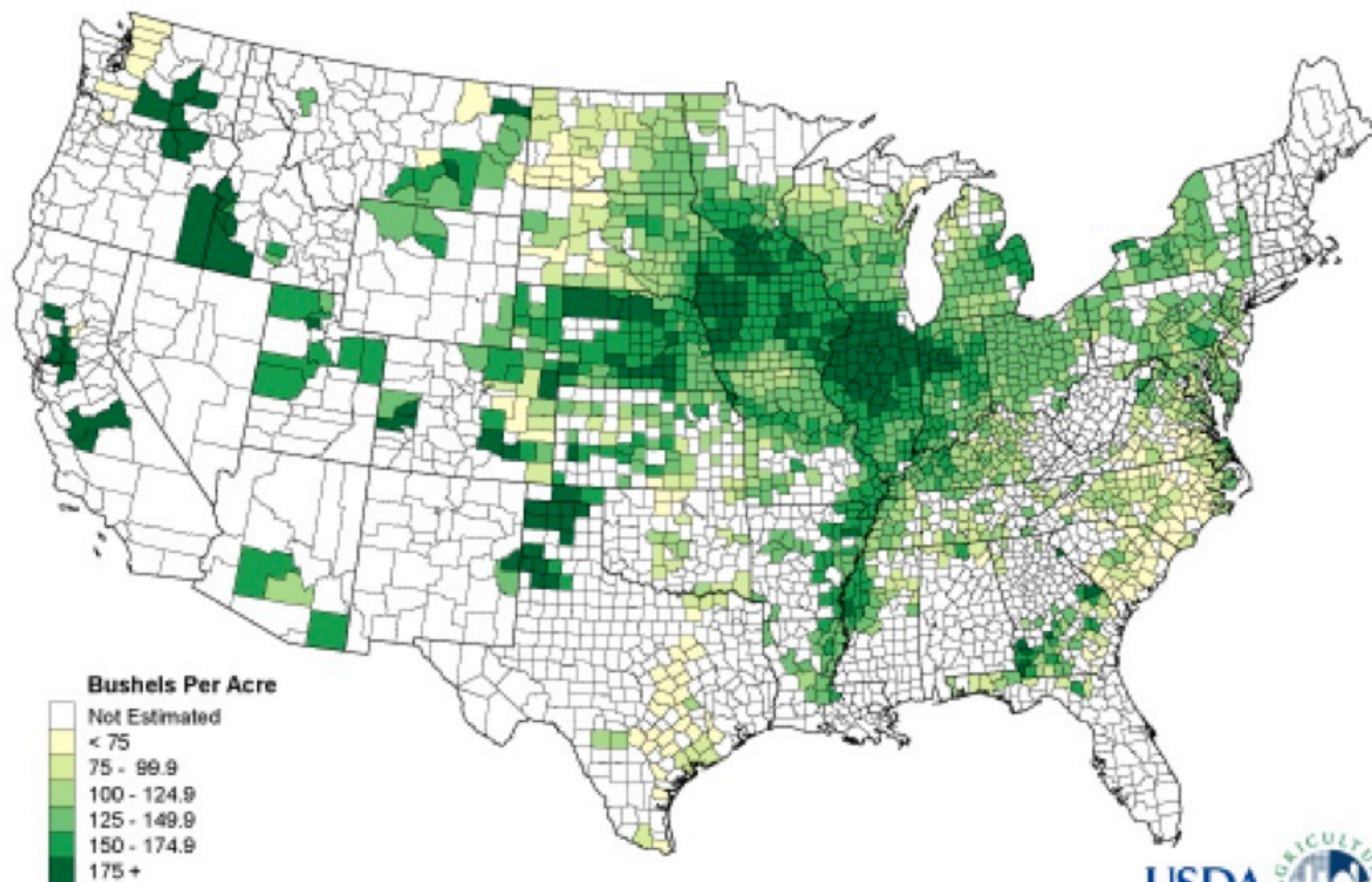
Area Unit	Length (m)	Width (m)	Area (m ²)
hectare (ha)	100	100	10,000
acre	63.6	63.6	4,047
square mile	1609	1609	2,590,000
American football	91.4 (300 ft)	48.8 (160 ft)	4,460
International A Soccer	105	68	7,140



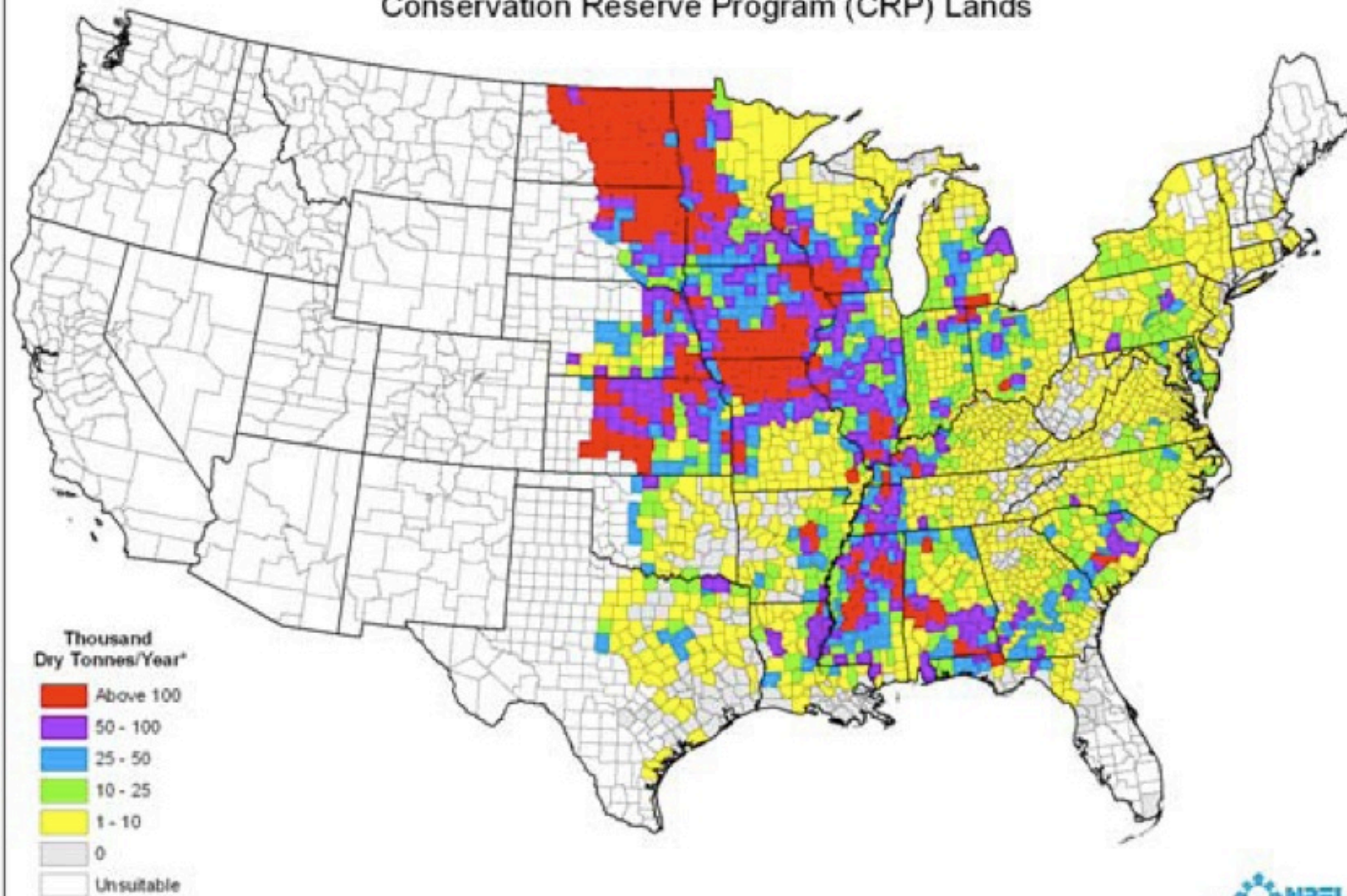
Biomass Resources Available in the United States



Corn for Grain 2008 Yield Per Harvested Acre by County



Potential Switchgrass Production on Conservation Reserve Program (CRP) Lands



* Data source: The Oak Ridge Energy Crop County Level Database, December 20th, 1996 version
USDA, Farm Service Agency, County CRP Signup 20 Information, Acreage as of July 2003

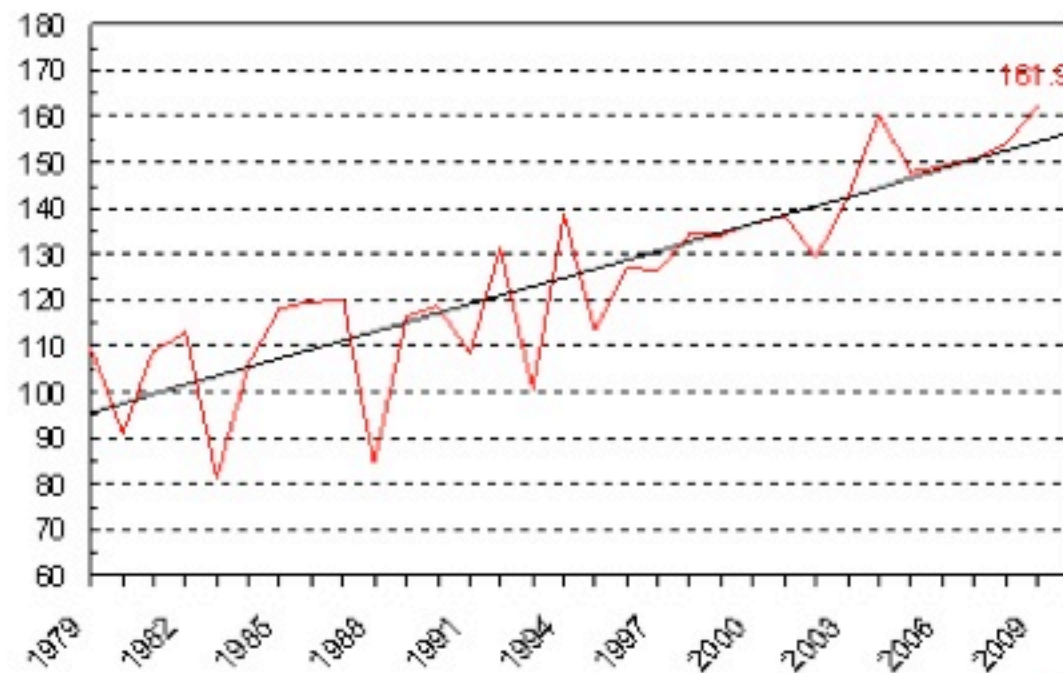


September 2005



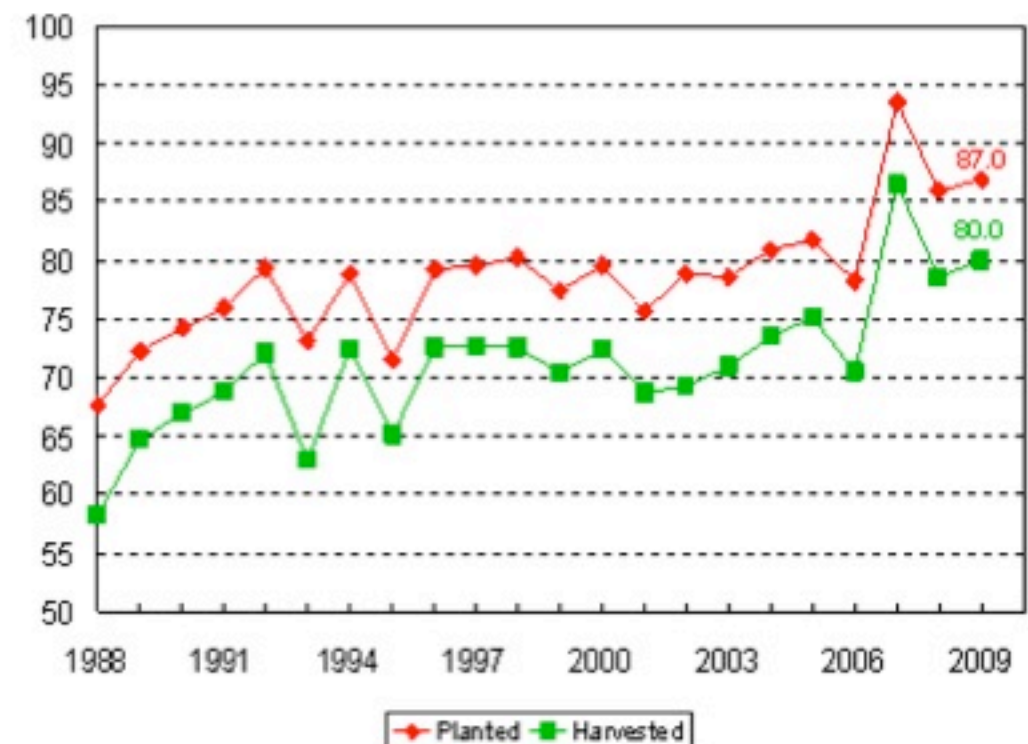
U.S. Corn Yield

Bushels/Acre

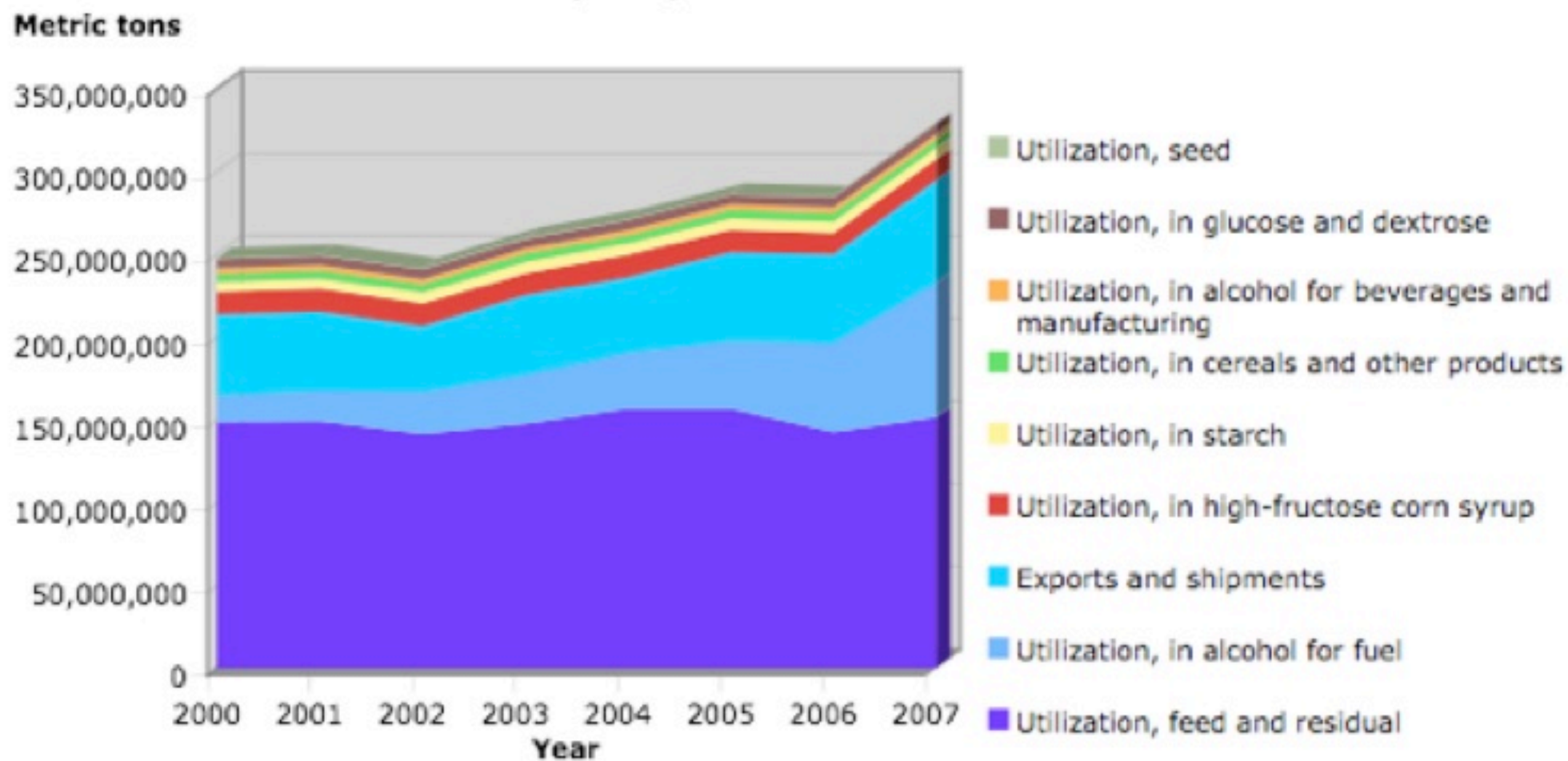


U.S. Corn Acres

Million Acres



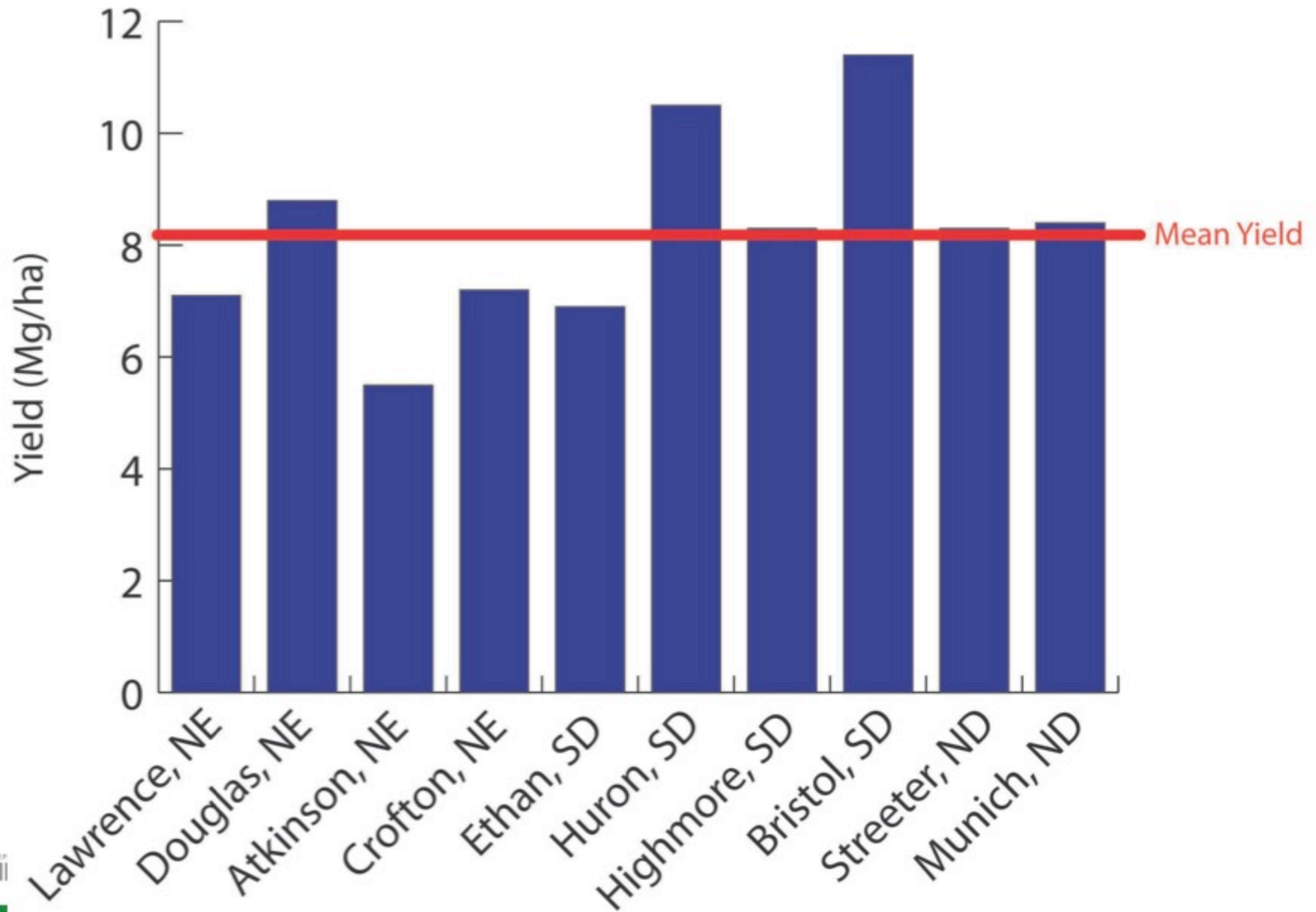
Corn Utilization, USA, 2000-2007



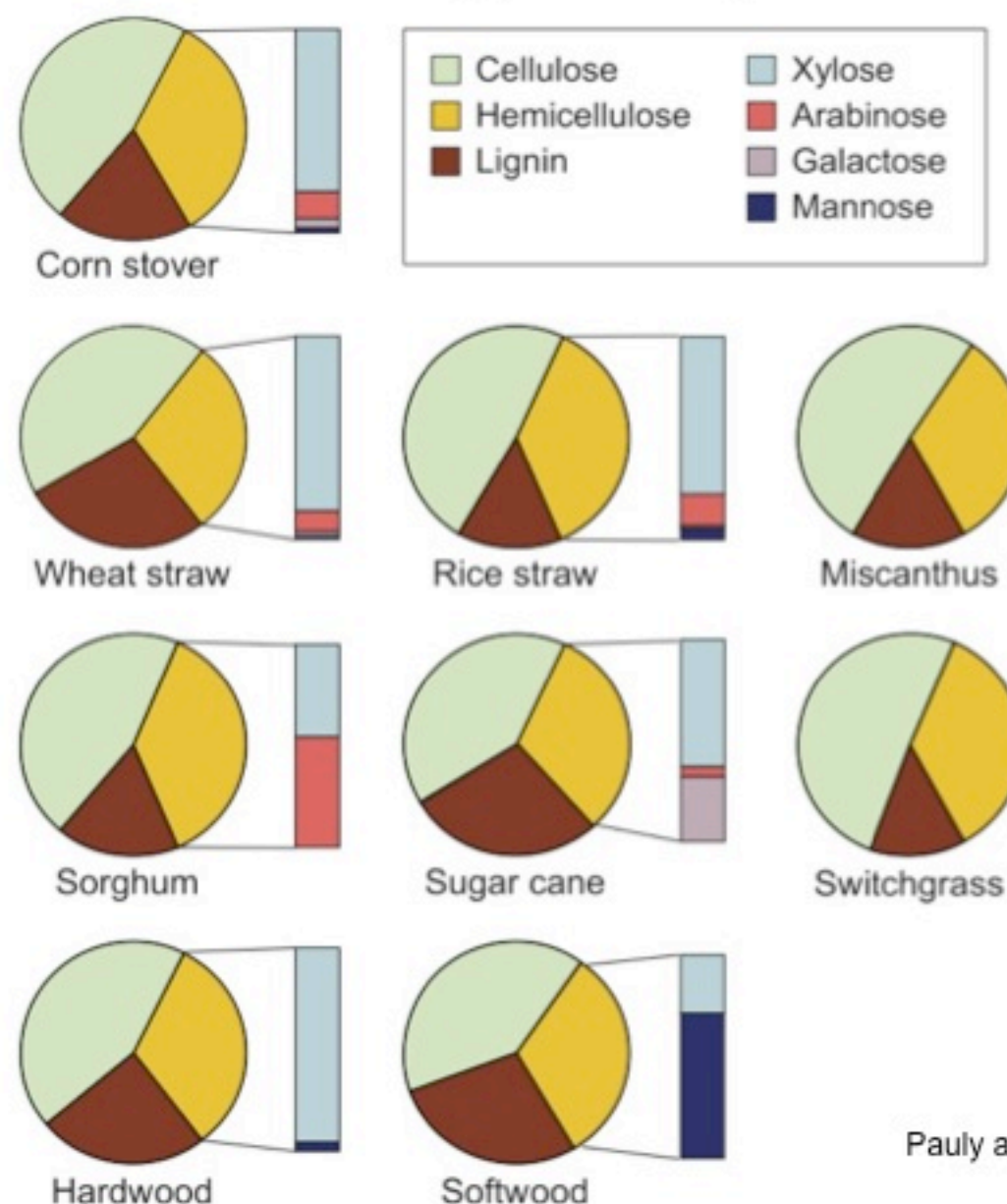
USDA Economic Research Service

Net Energy Values For Switchgrass Fields (Year 4)

(Source: Schmer, Vogel, Mitchell, & Perrin. (2007). Net energy of cellulosic ethanol from switchgrass. PNAS.)



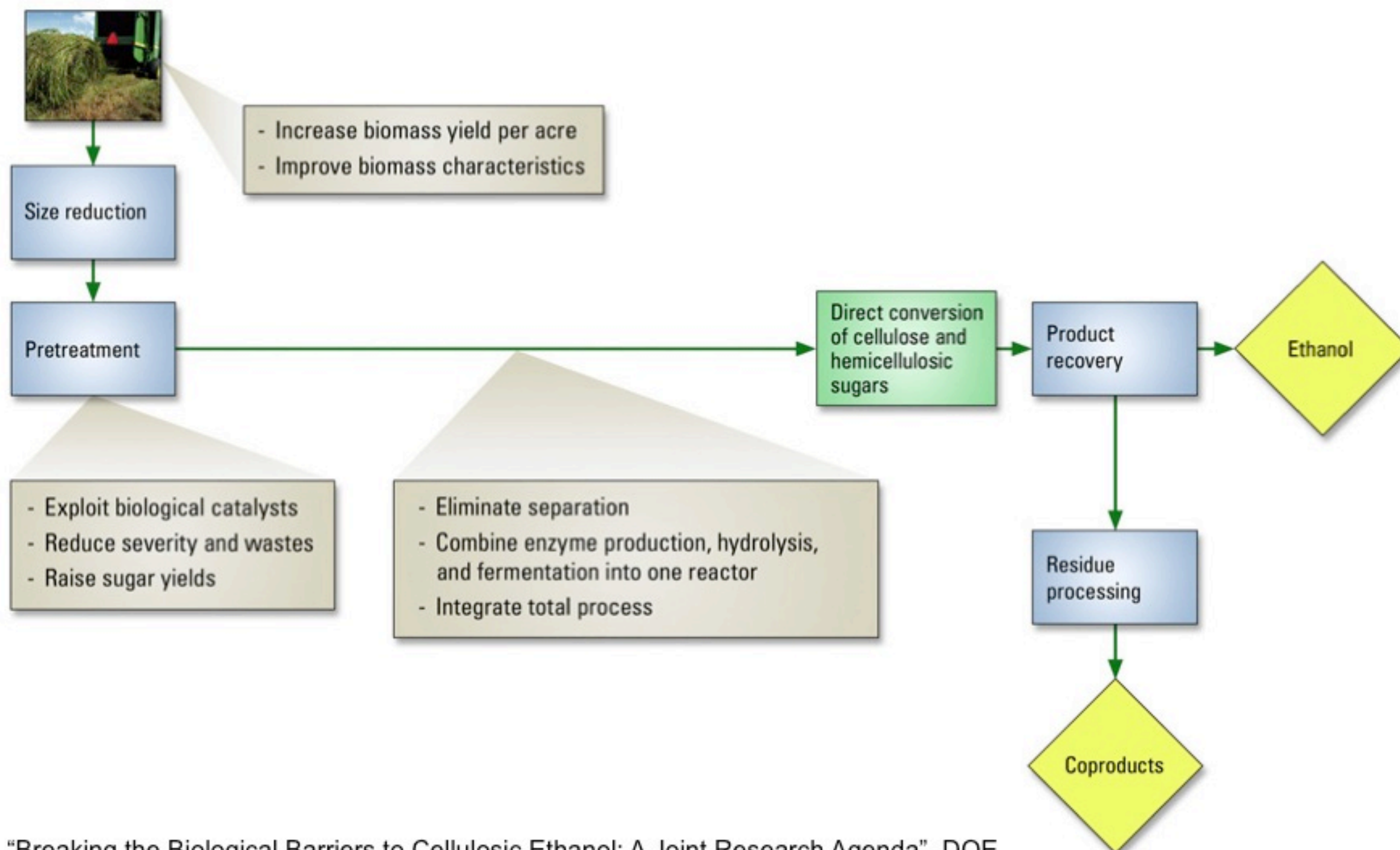
Not all plants are built the same way, so biomass processing steps may differ



Pauly and Keegstra 2008 The Plant Journal

Figure 2. Cell-wall polymer composition (cellulose, hemicellulose and lignin) and hemicellulose composition for a variety of plant materials that are currently under discussion for use as biofuel feedstocks (based on the data shown in Table 3 and references therein).

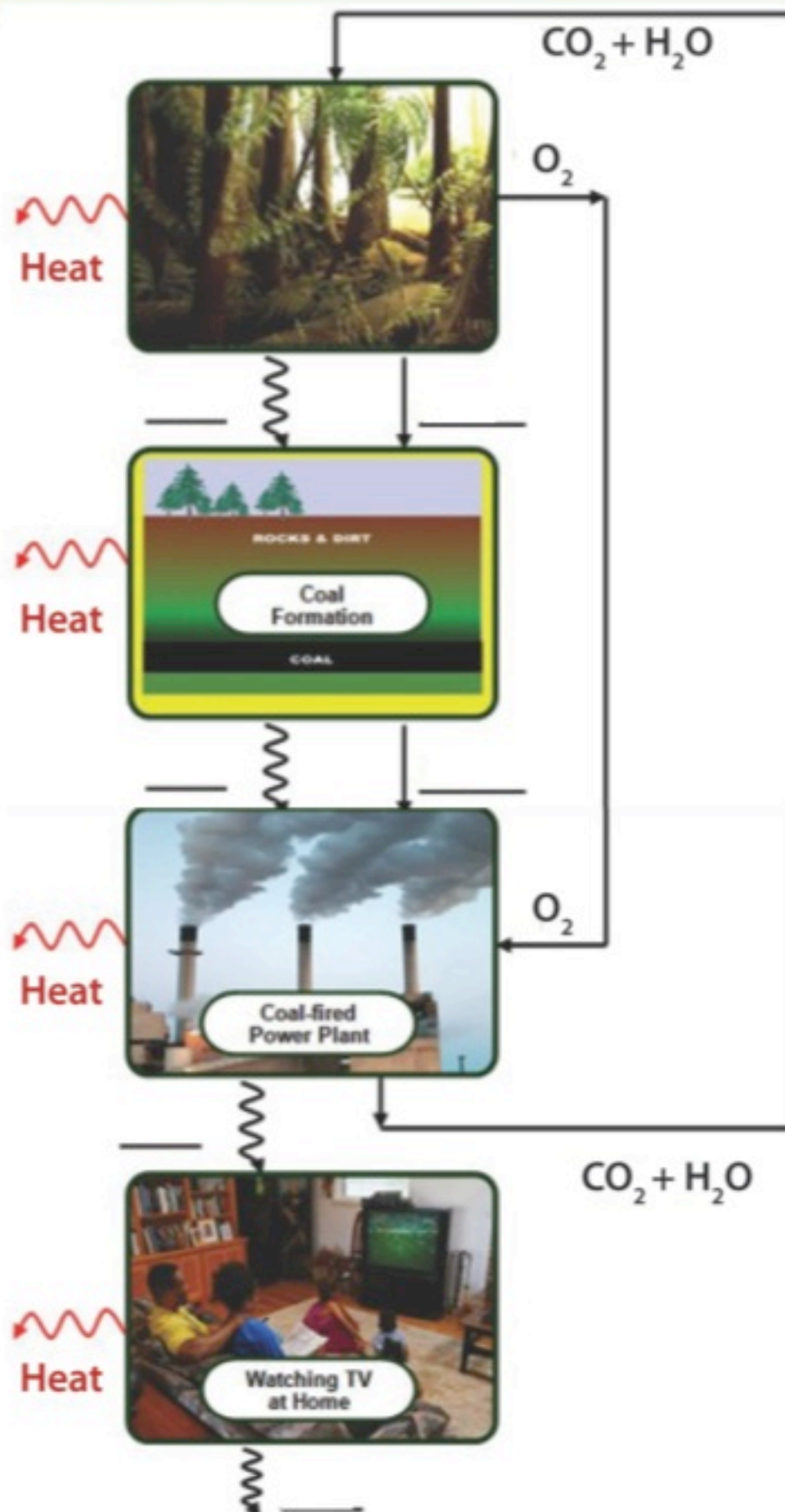
The Future of Cellulosic Ethanol?



"Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda", DOE

How are coal and biomass, like switchgrass, related?

If coal and switchgrass both release carbon dioxide when burned, why do we care which one we use as a fuel to power a refinery?





carbon dioxide



Rapidly
recycled
carbon dioxide



Combustion for
energy



Ancient fossil fuel

Millions of years to form



Biomass

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

*For more information write us:
education@glbrc.wisc.edu or
visit www.glbrc.org/education*