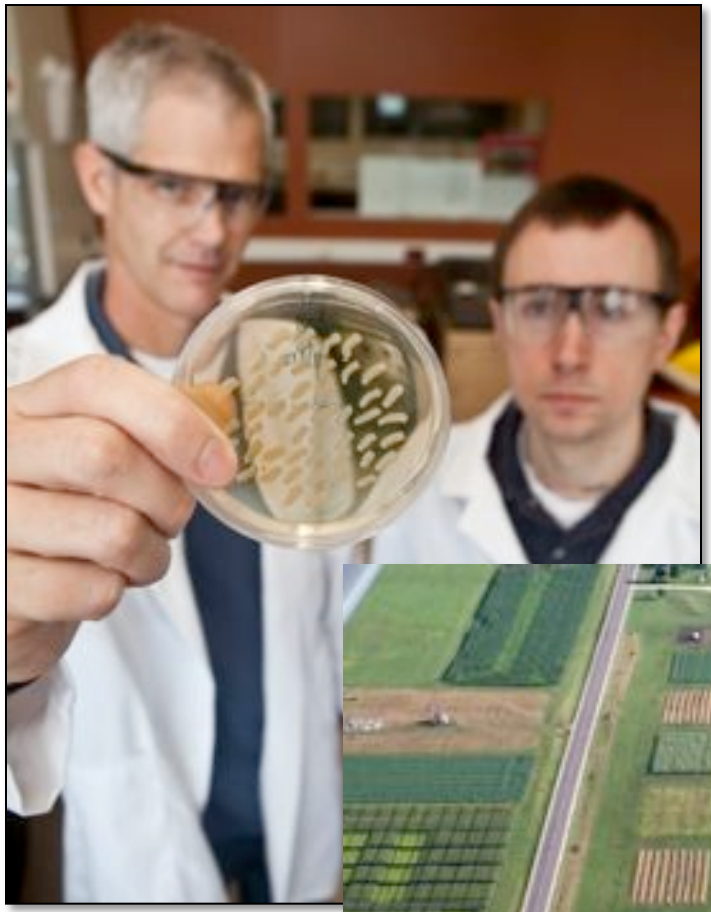
Bioenergy: Sustainability Opportunities and Challenges

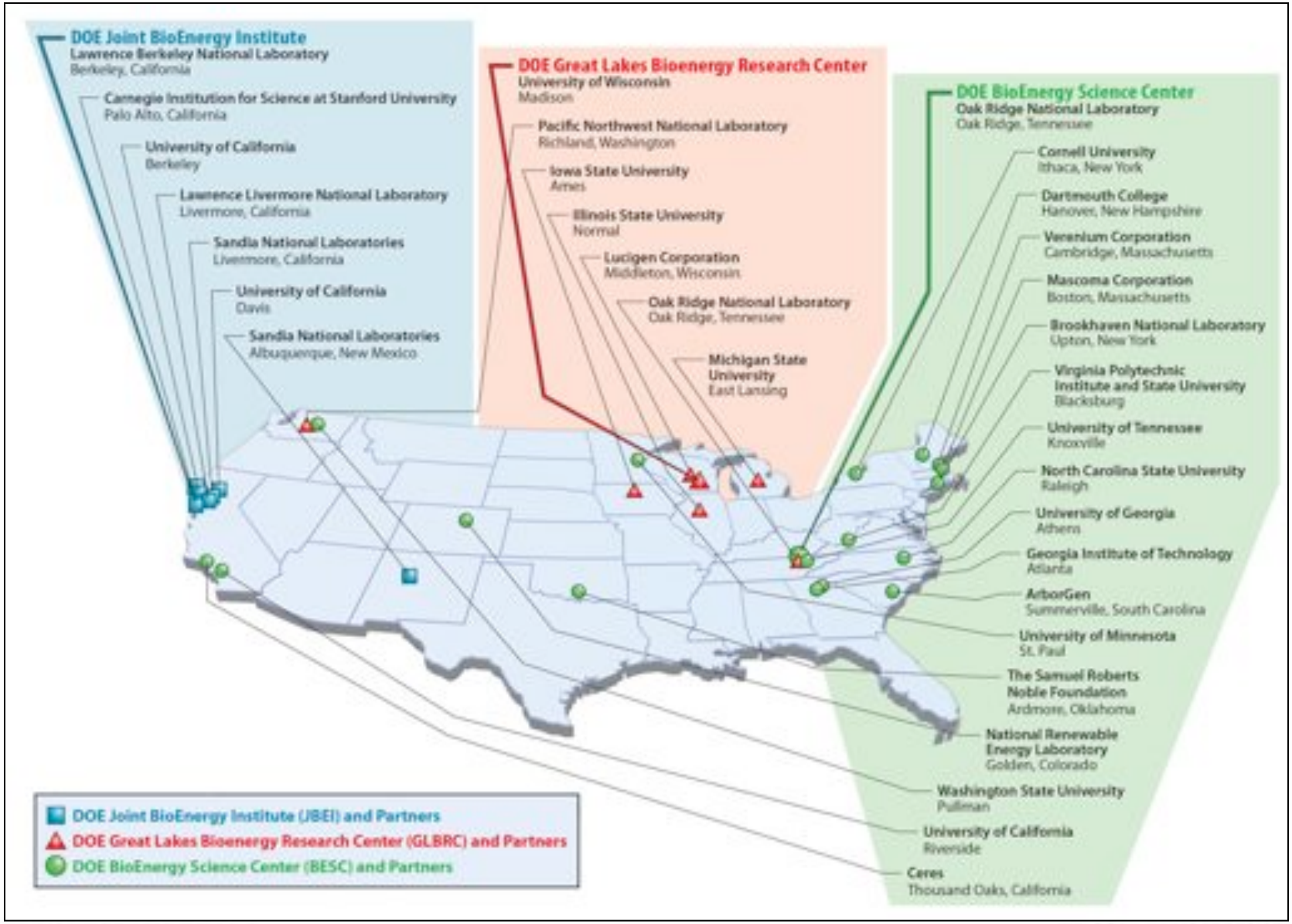
Dr. John M. Greenler
KBS K-12 Partnership
November 13, 2013

The Mission of GLBRC



To perform the basic research that generates technology to convert cellulosic biomass to sustainable biofuels.

United States DOE Bioenergy Research Centers



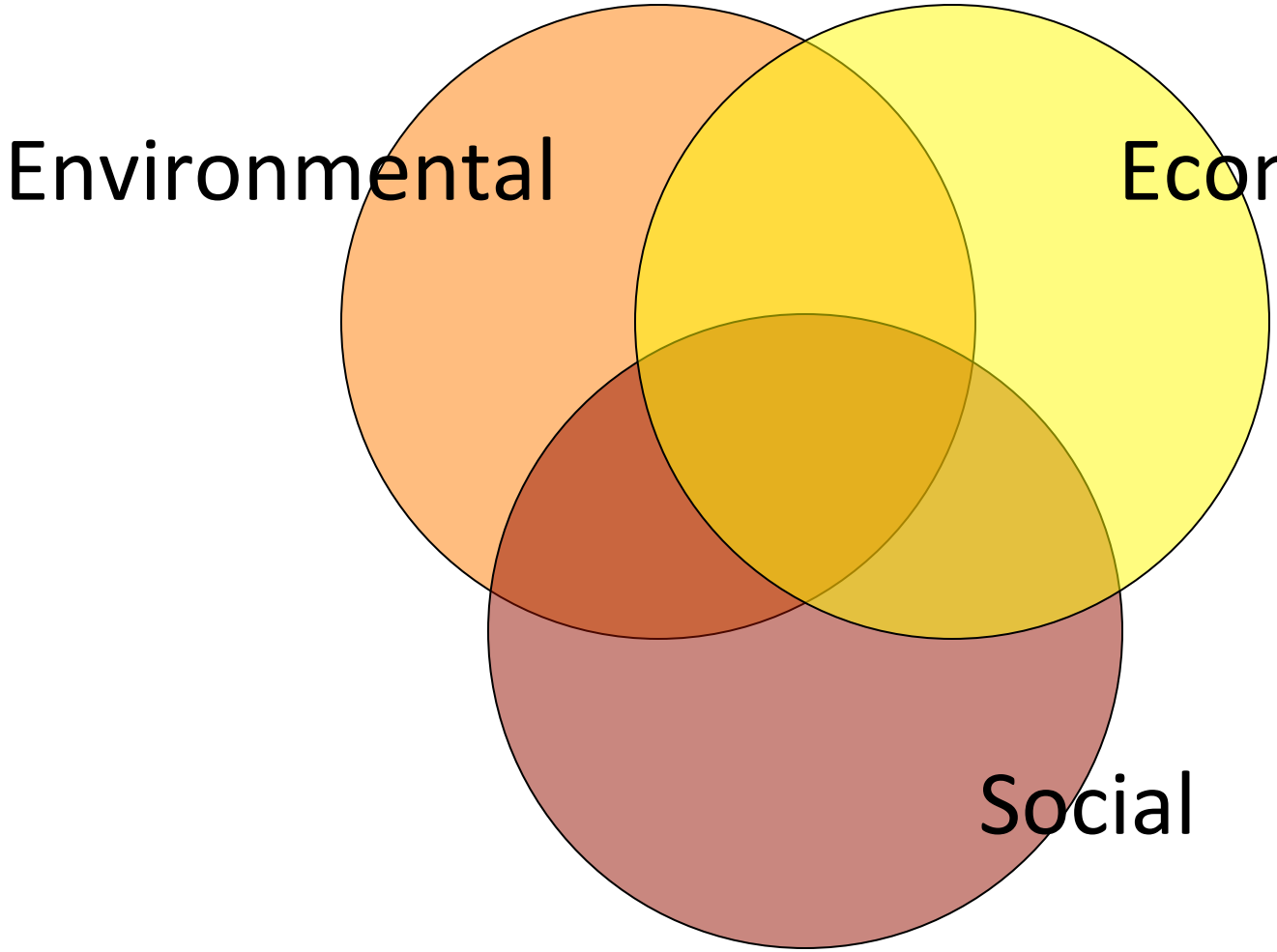
Who We Are

~400 researchers, staff & students

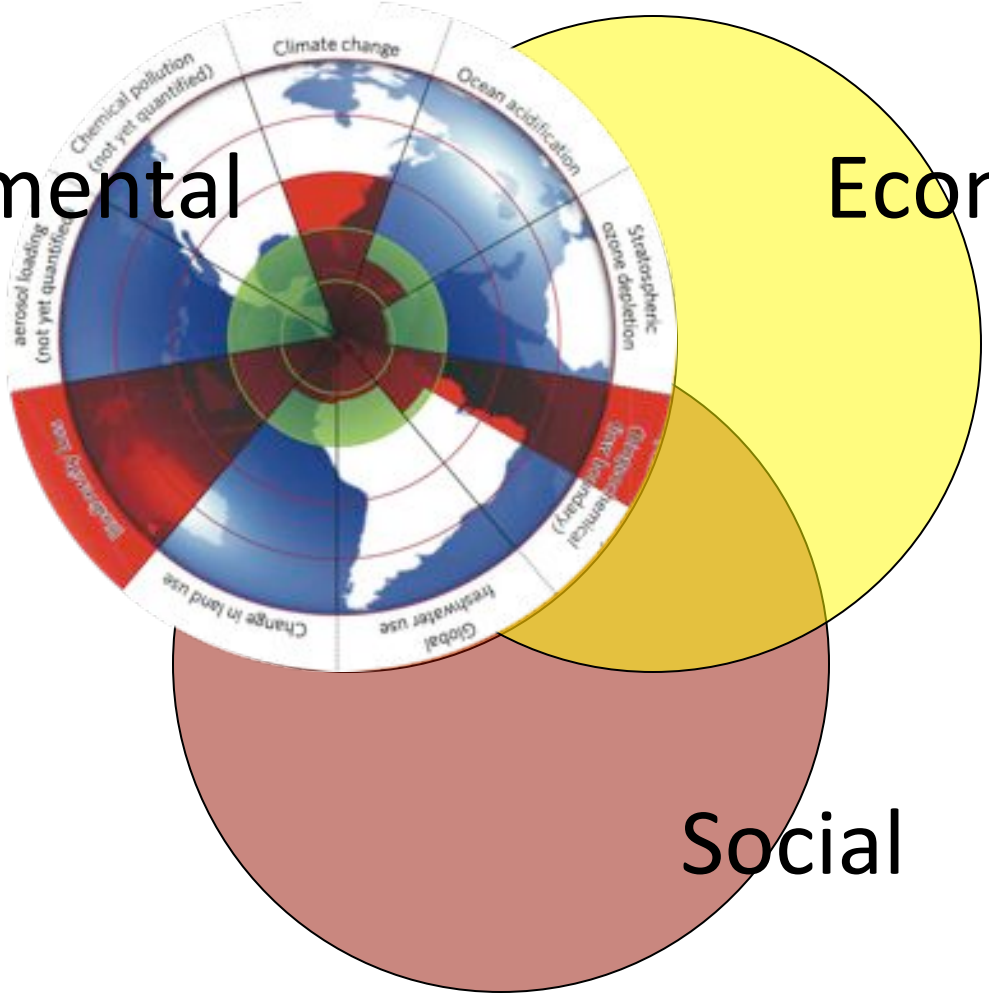
- 12 different institutions
- 70 Faculty
- 29 Scientists & engineers
- 66 Post-docs
- 52 Ph.D. students
- 55 Technicians
- 85 Undergraduates
- 42 Support staff in Operations, IIT, E&O
- ~ 60 Projects

Transdisciplinary: molecular biologists, ecologists, chemists, mechanical engineers, economists, computer modelers…

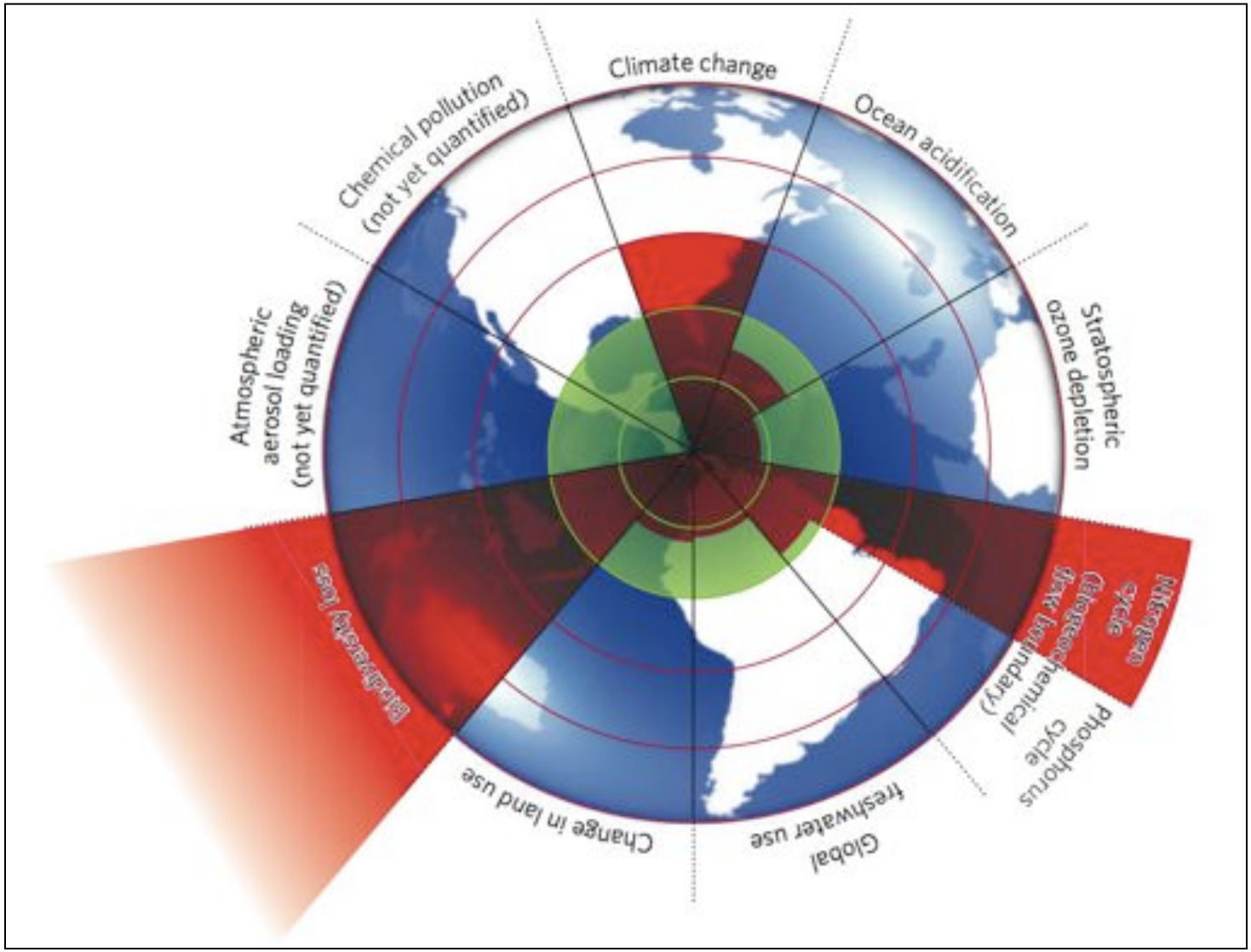
Sustainability: a Triad of Factors



Sustainability: a Triad of Factors

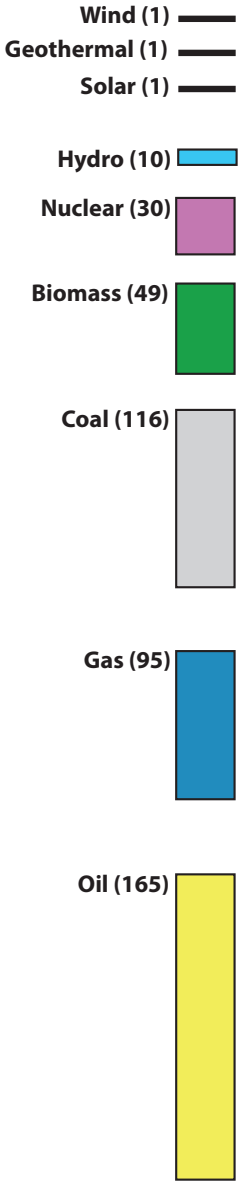


"A Safe Operating Space For Humanity"

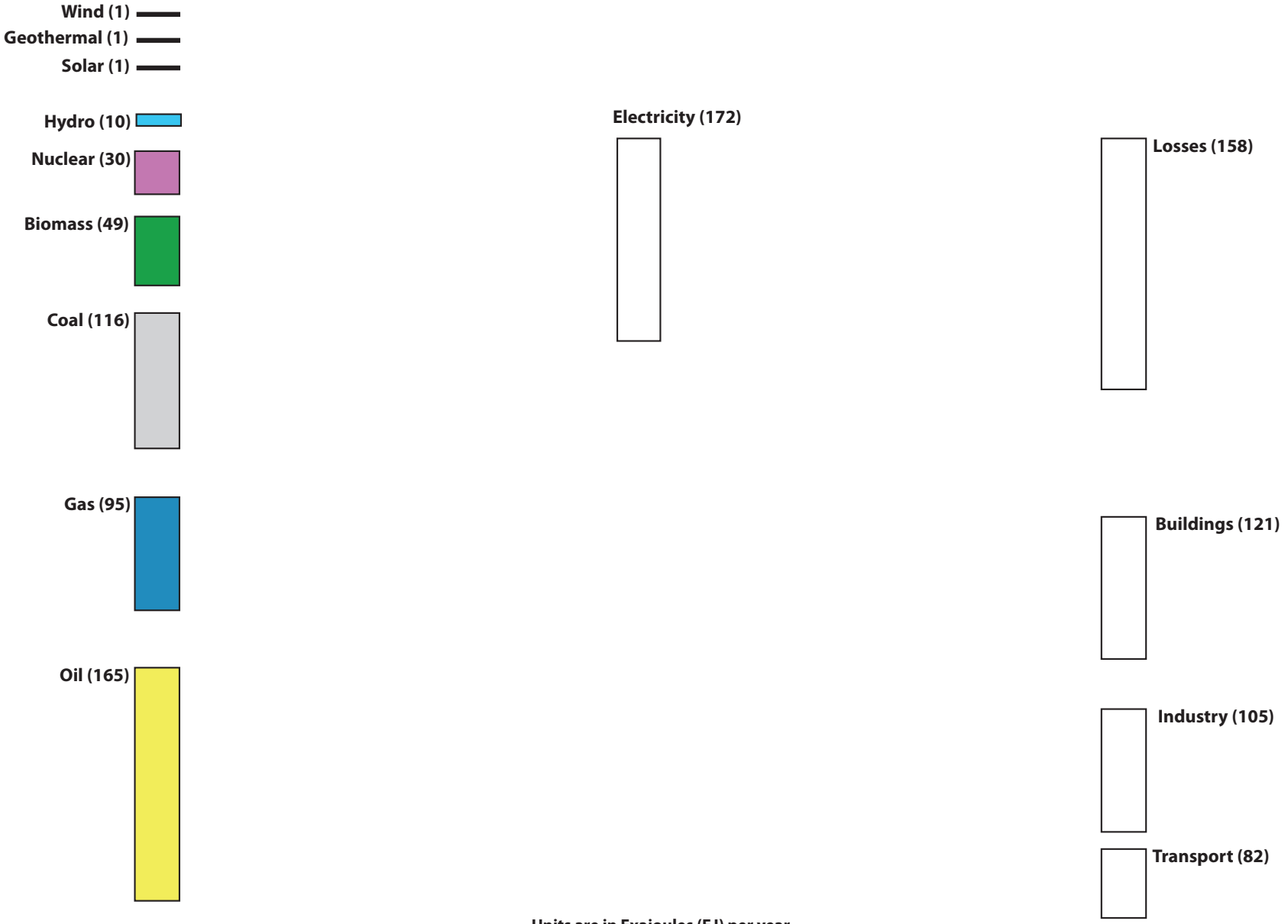


J Rockstrom et al, 2009, *Nature*, 461:472-475

Global Energy:
Sources, Uses, and Paths



Units are in Exajoules (EJ) per year


Wind (1)
Geothermal (1)
Solar (1)
Hydro (10)
Nuclear (30)
Biomass (49)
Coal (116)
Gas (95)
Oil (165)
Electricity (172)
Losses (158)
Buildings (121)
Industry (105)
Transport (82)
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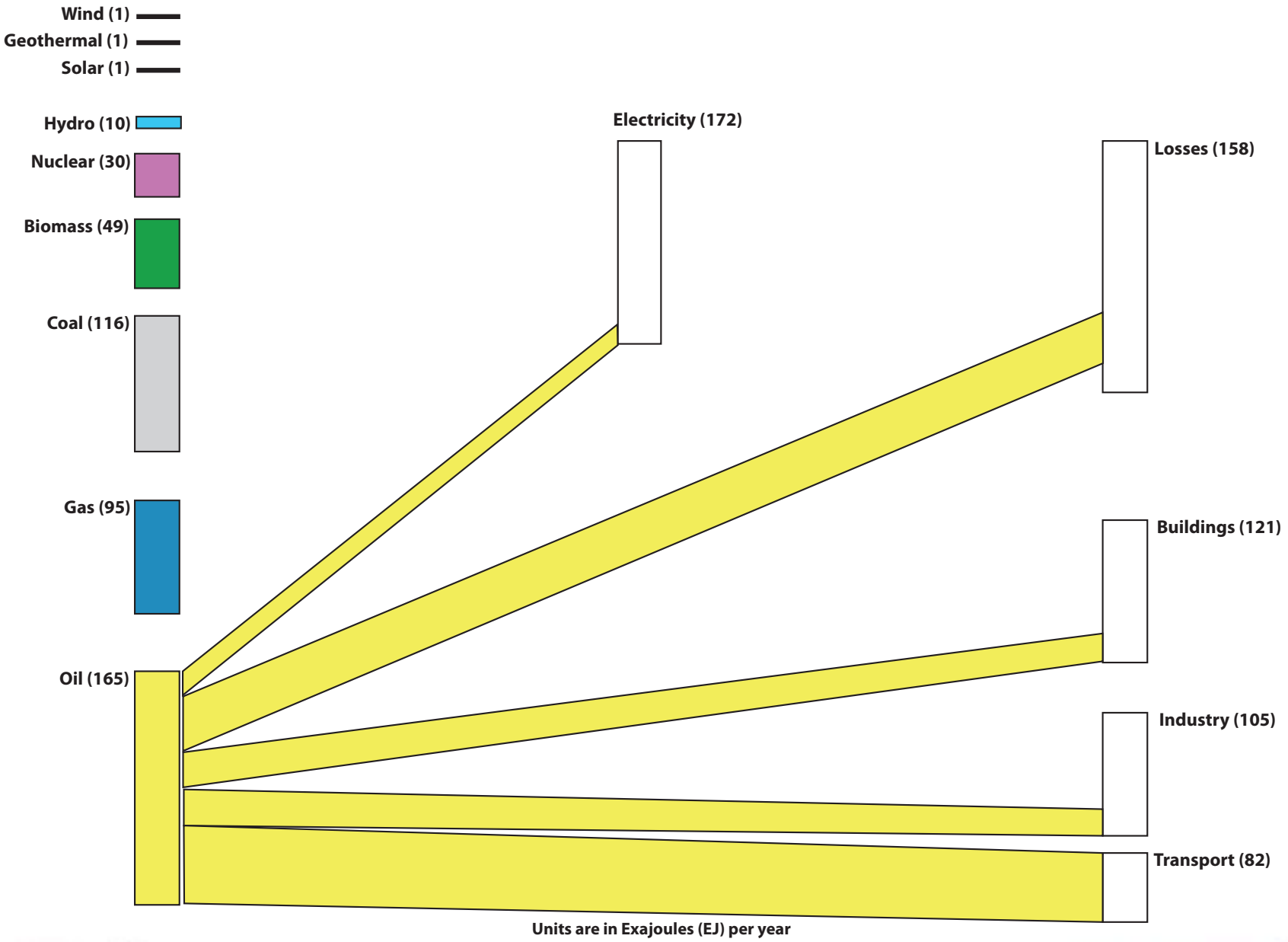
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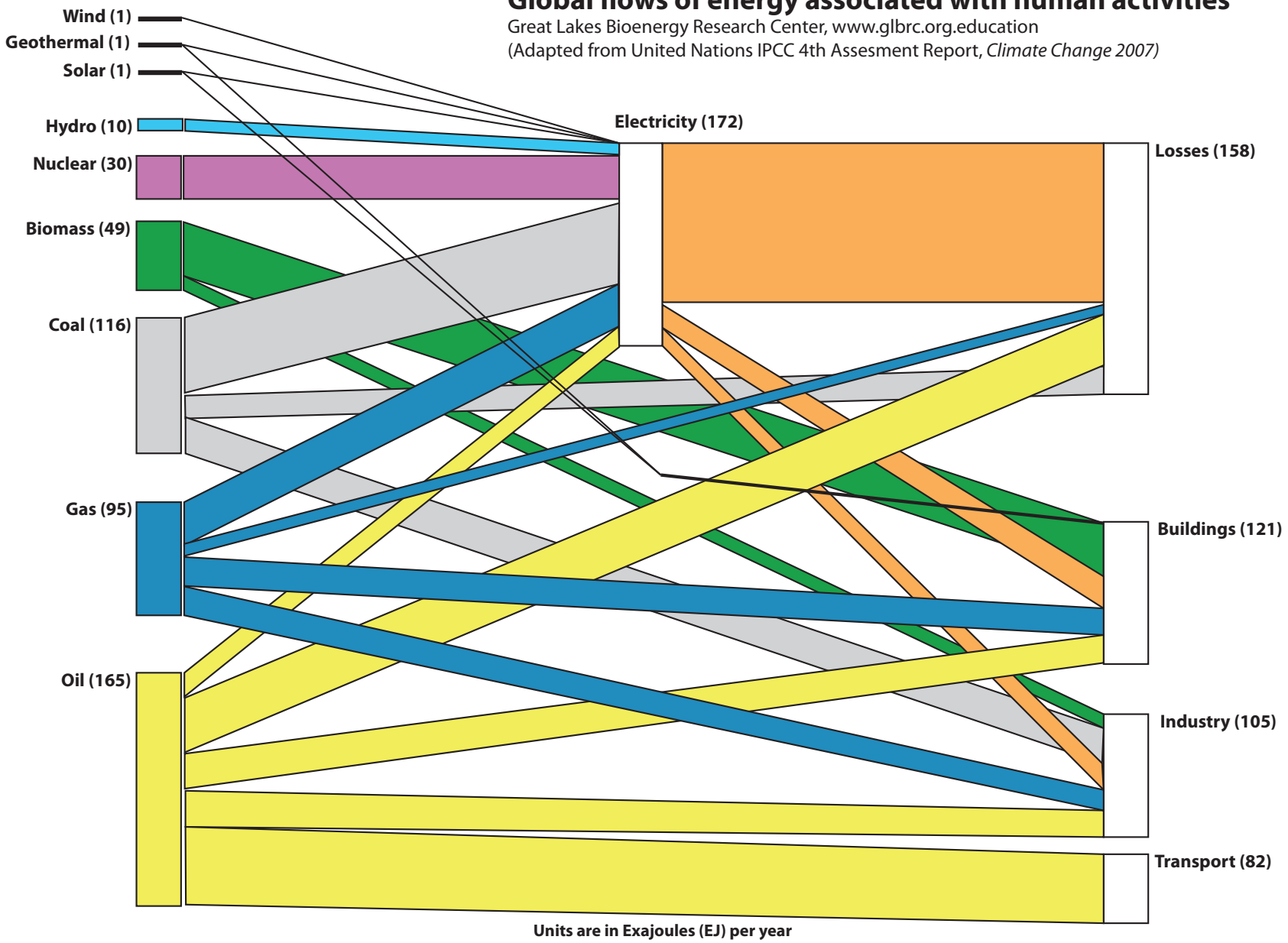
Global flows of energy associated with human activities

Great Lakes Bioenergy Research Center, www.glbrc.org.education
(Adapted from United Nations IPCC 4th Assesment Report, *Climate Change 2007)*



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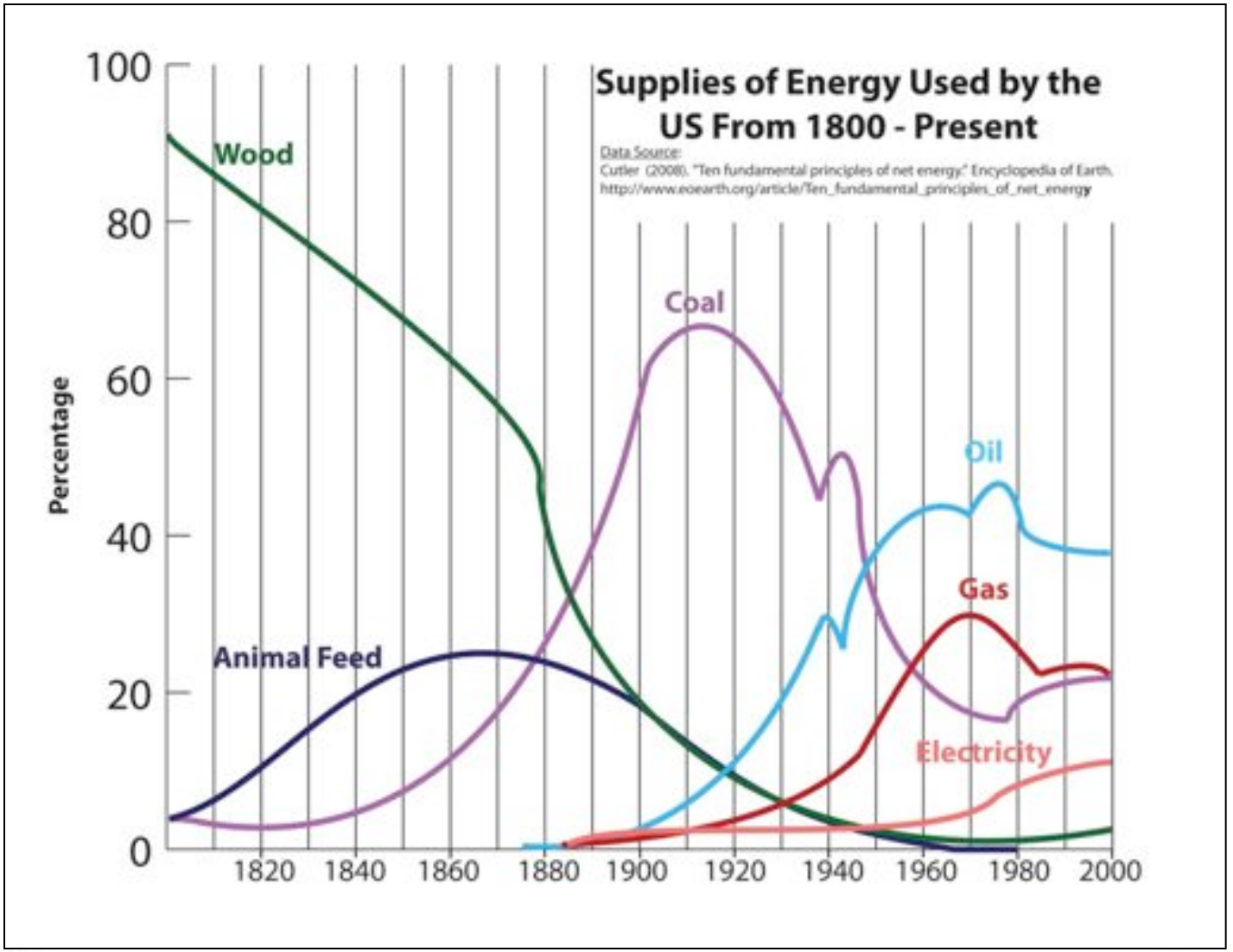
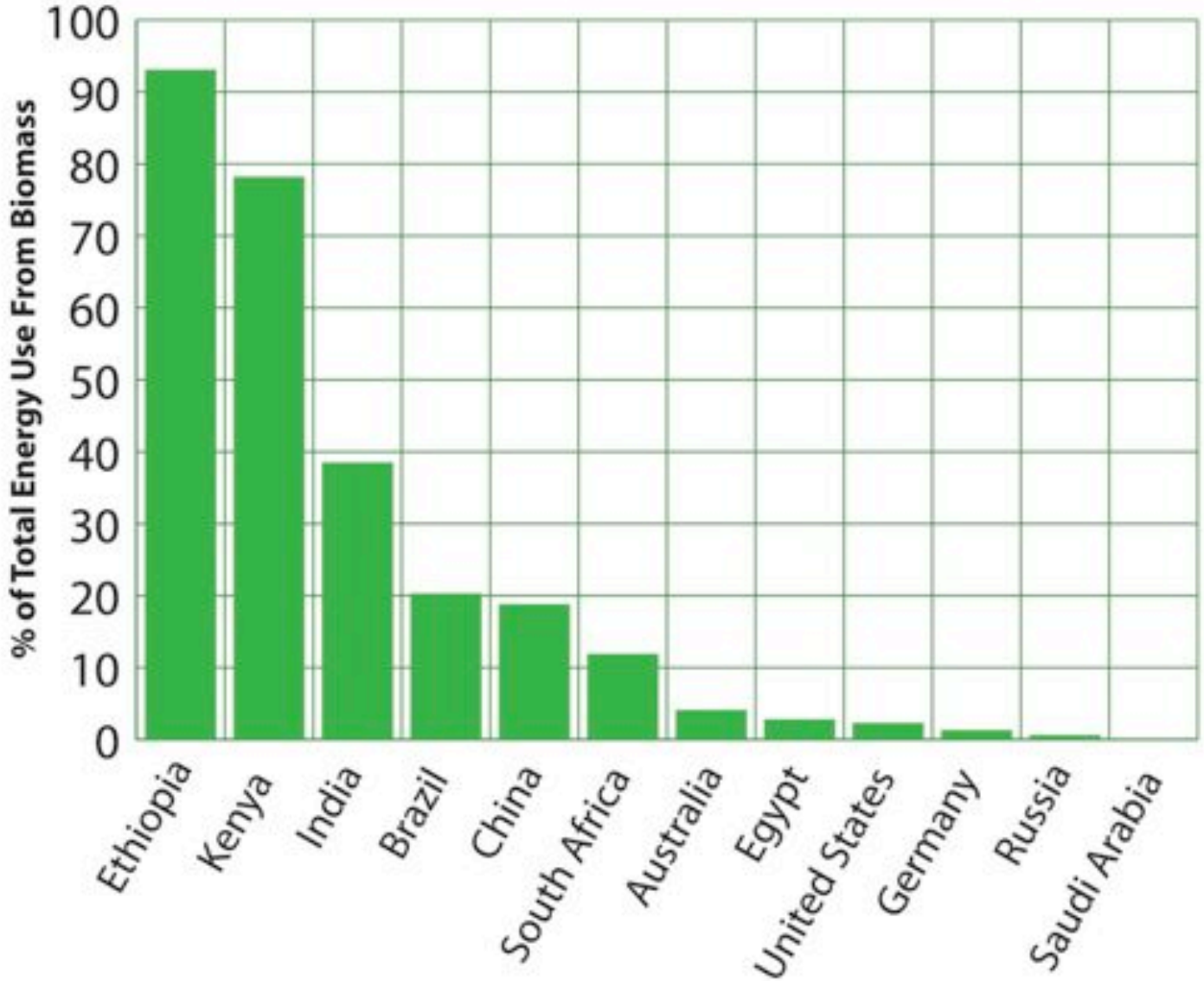
U.S. Energy Sources: Historical

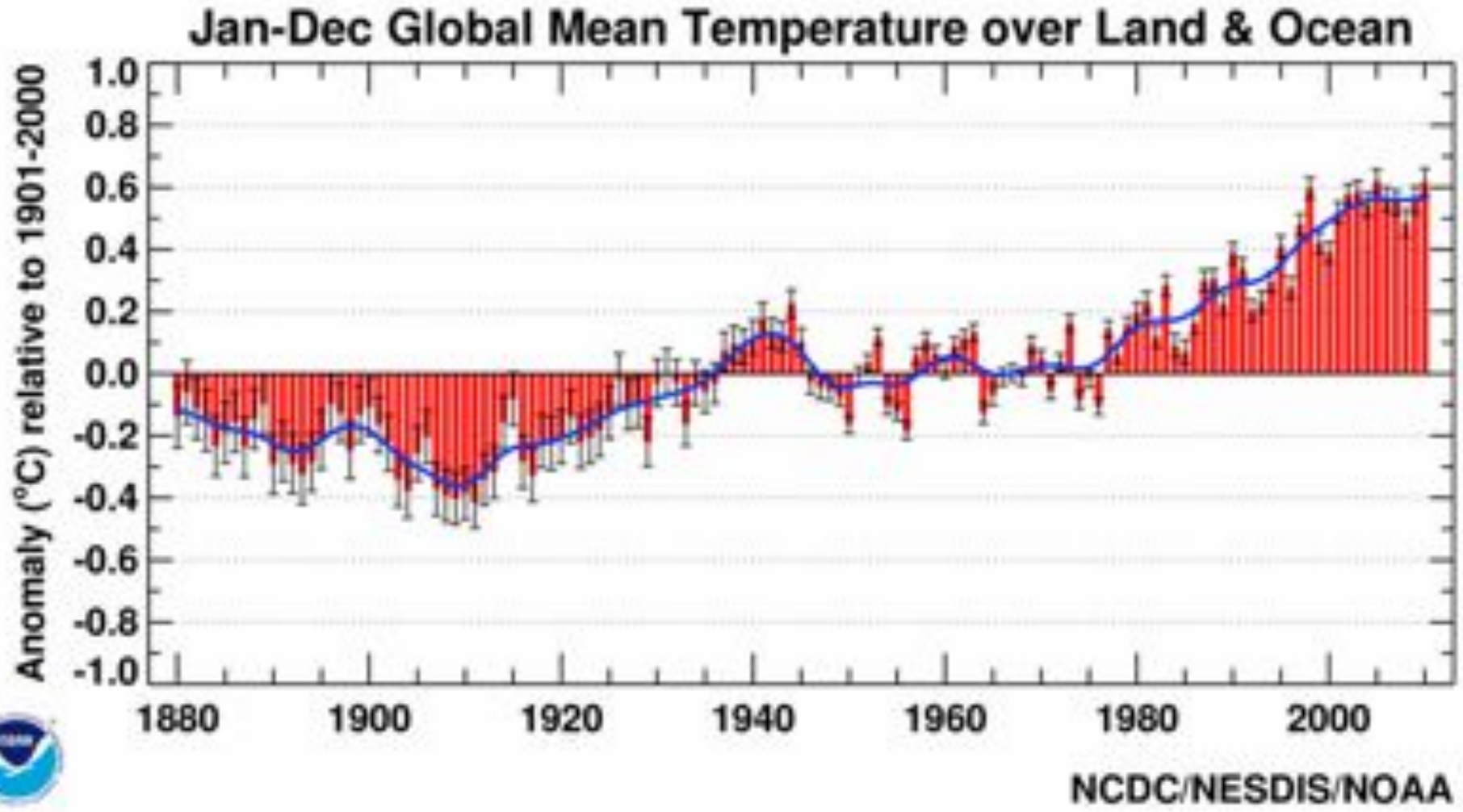


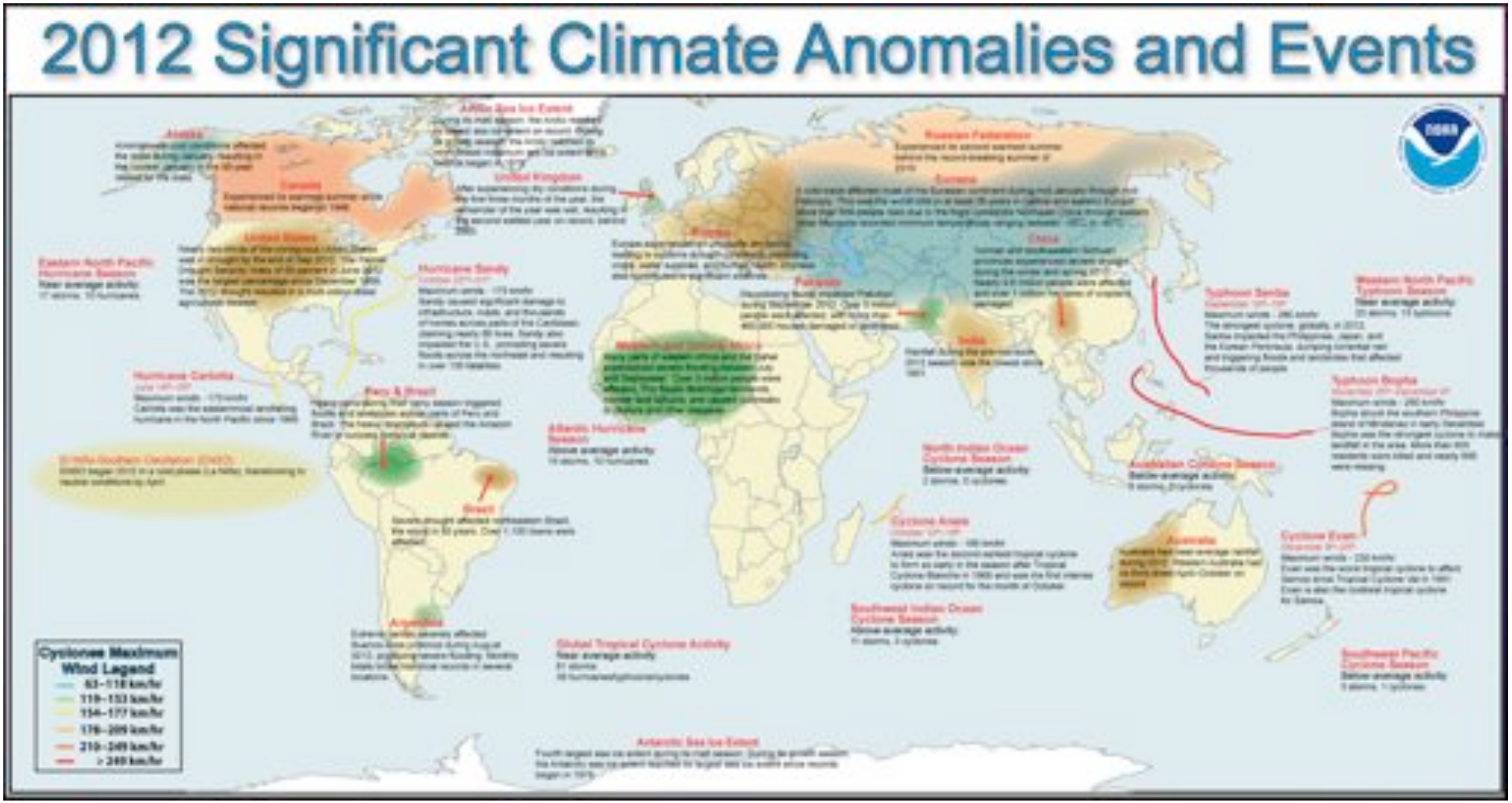
Biomass Energy Use by Country

Source Data: Earth Trends Data Tables: Energy Consumption by Source, 2005.
http://earthtrends.wri.org/datatables/index.php?theme=6

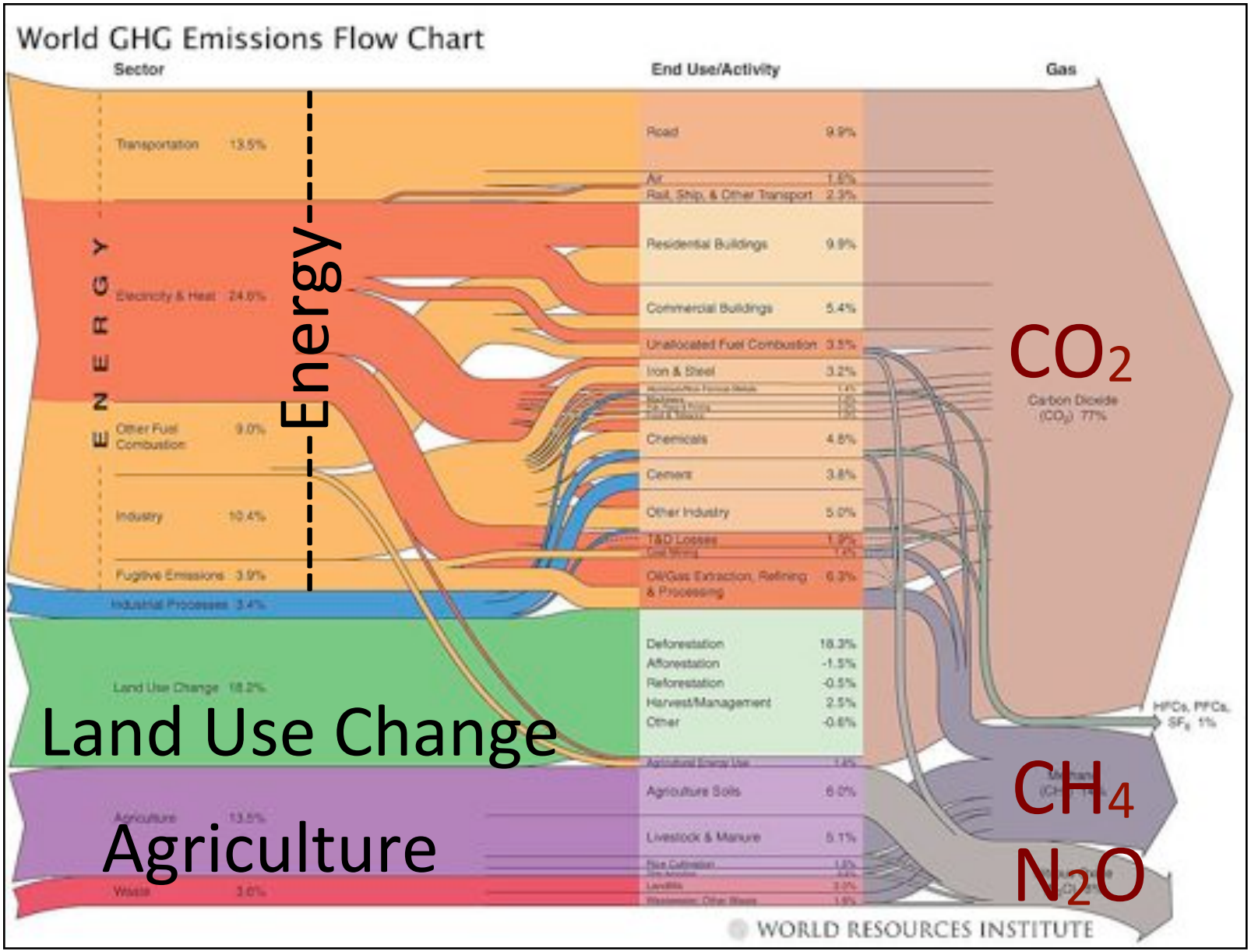


Global Warming = Climate Change



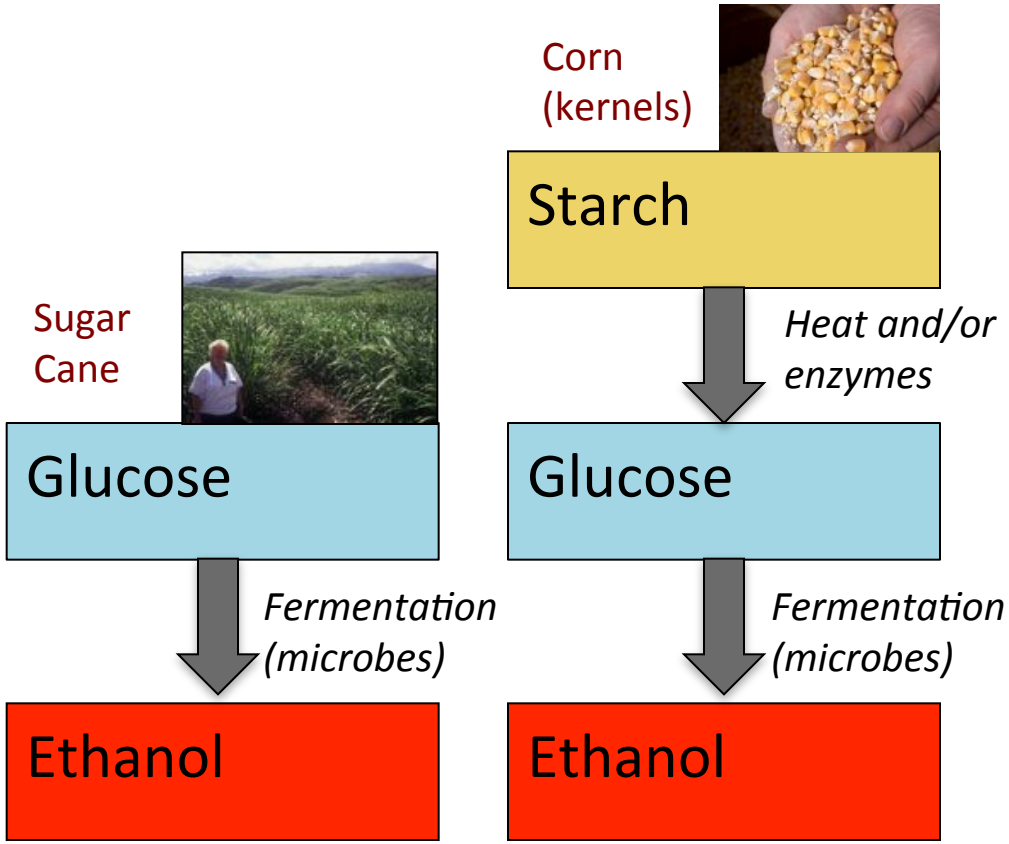


Climate Change = Increased Severe Weather


World GHG Emissions Flow Chart
Sector
End Use/Activity
Gas
ENERGY
Transportation 13.5%
Electricity & Heat 24.6%
Other Fuel Combustion 9.0%
Industry 10.4%
Fugitive Emissions 3.9%
Industrial Processes 3.4%
Land Use Change 18.2%
Agriculture 13.5%
Waste 3.0%
Road 9.9%
Air 1.5%
Rail, Ship, & Other Transport 2.3%
Residential Buildings 9.9%
Commercial Buildings 5.4%
Unallocated Fuel Combustion 3.5%
Iron & Steel 3.2%
Chemicals 4.8%
Cement 3.8%
Other Industry 5.0%
T&D Losses 1.9%
Oil/Gas Extraction, Refining & Processing 6.3%
Deforestation 18.3%
Afforestation -1.5%
Reforestation -0.5%
Harvest/Management 2.5%
Other -0.6%
Agriculture Soils 6.0%
Livestock & Manure 5.1%
Rice Cultivation 1.0%
Landfills 3.0%
Carbon Dioxide (CO2) 77%
HFCs, PFCs, SF6 1%
Energy
Land Use Change
Agriculture
CO2
CH4
N2O
WORLD RESOURCES INSTITUTE

Today's Biofuel Ethanol Technology

Conversion of sugar cane (glucose) or corn starch (glucose polymer) to ethanol



What is Cellulose?

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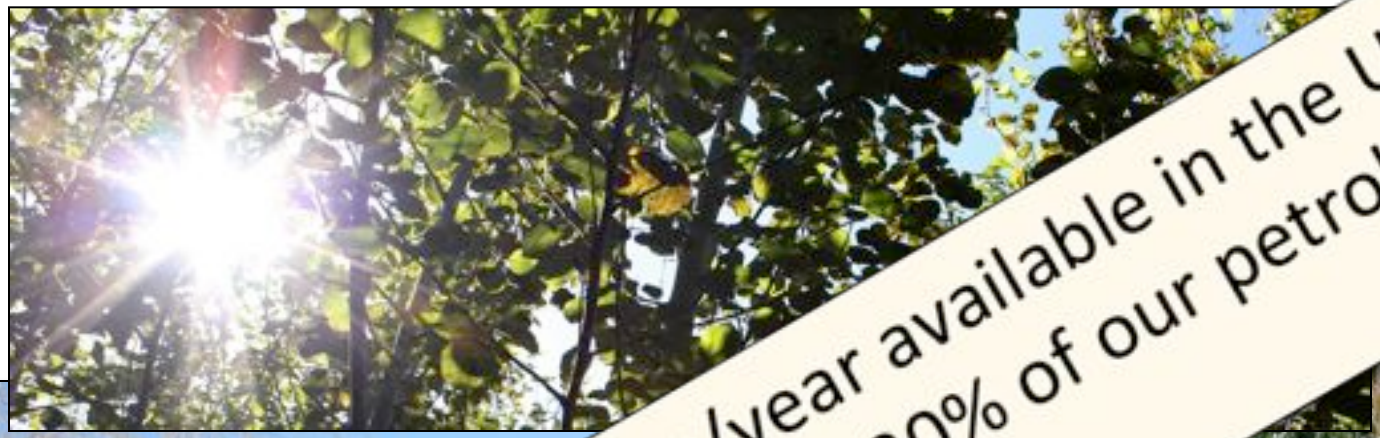
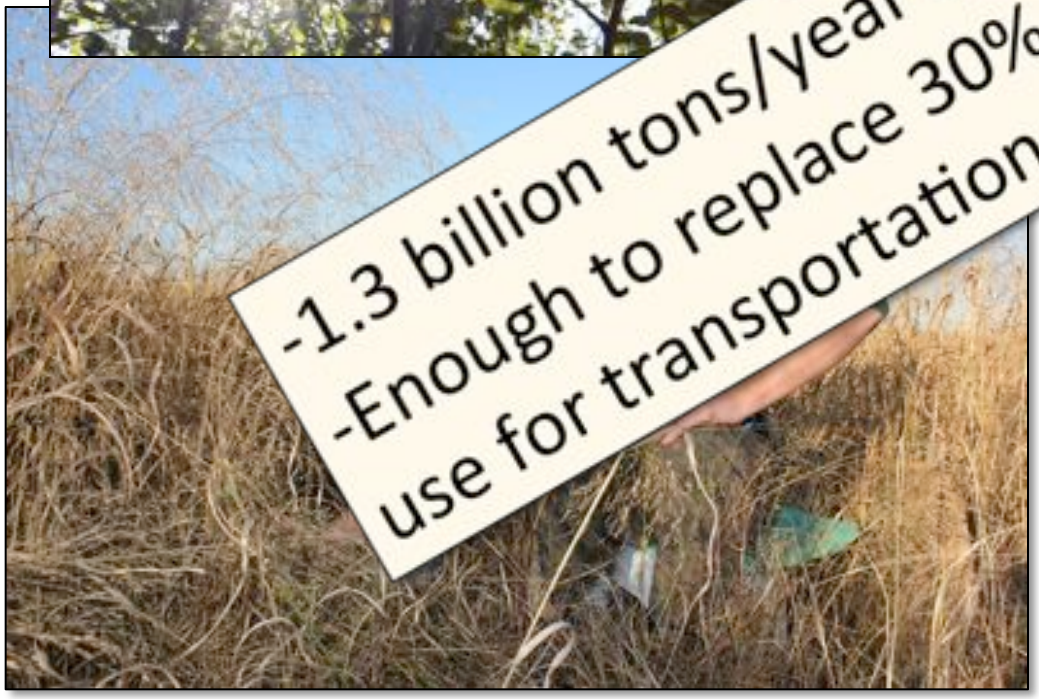
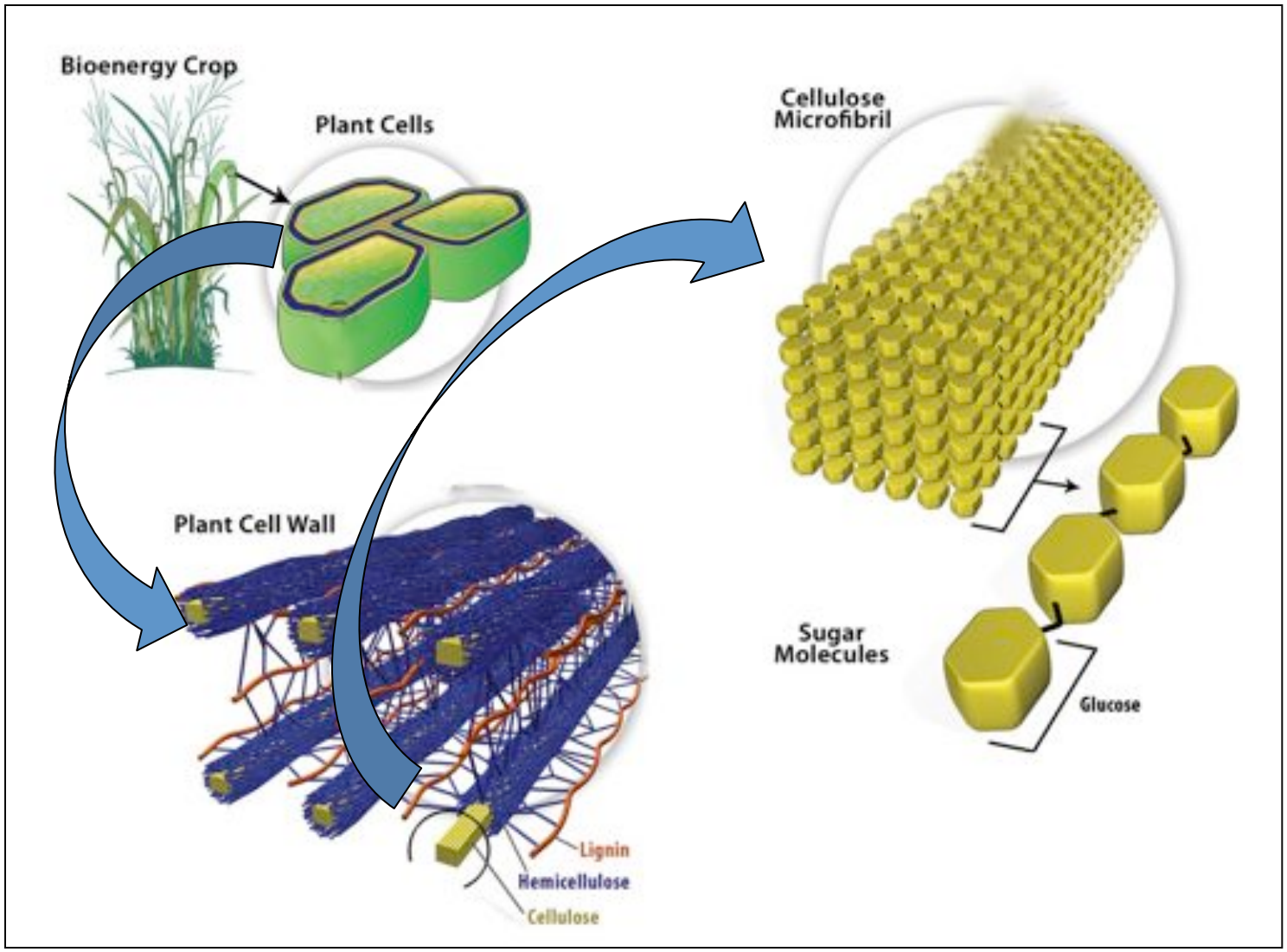


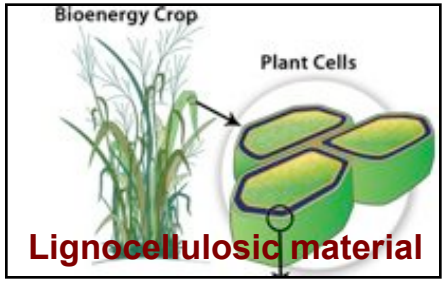


-1.3 billion tons/year available in the U.S.
-Enough to replace 30% of our petroleum use for transportation

What is Cellulose?



Conversion of Cellulosic Plant Biomass to Fuels



Today's technology

Corn (kernels)

Starch

Heat and/or enzymes

Glucose

Sugar Cane

Glucose

Fermentation (microbes)

Fermentation (microbes)

Ethanol

Ethanol

Tomorrow's technology (GLBRC)

Plant biomass

? *Pretreat (grind, heat, chemicals, pressure)*

"Loosened" cell wall material (cellulose hemicellulose, lignin)

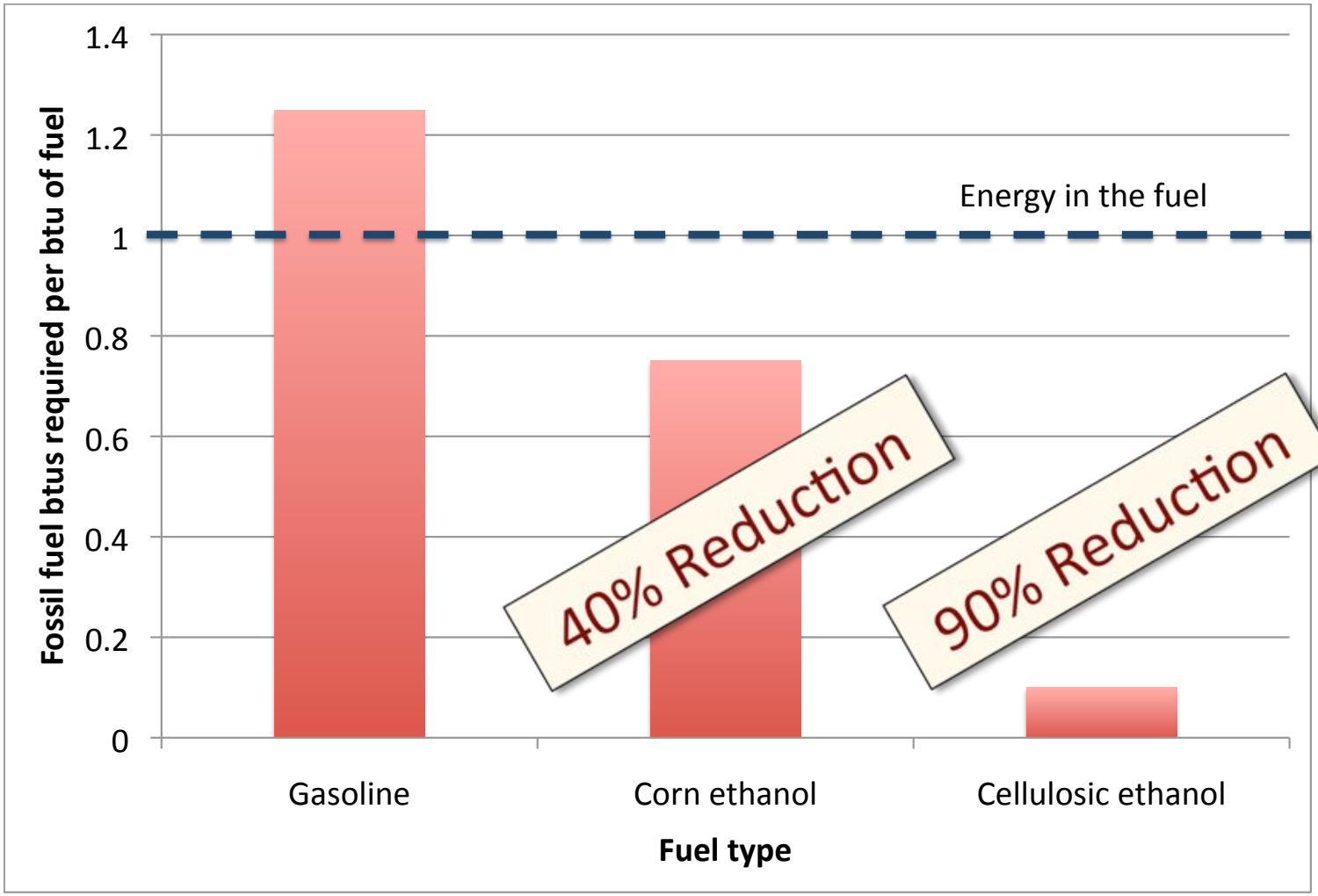
? *Enzymes (cellulases, etc) or microbes*

Mixed sugars, etc. (glucose, arabinose, xylose, phenolics, etc.)

? *Fermentation (microbes) or catalysts*

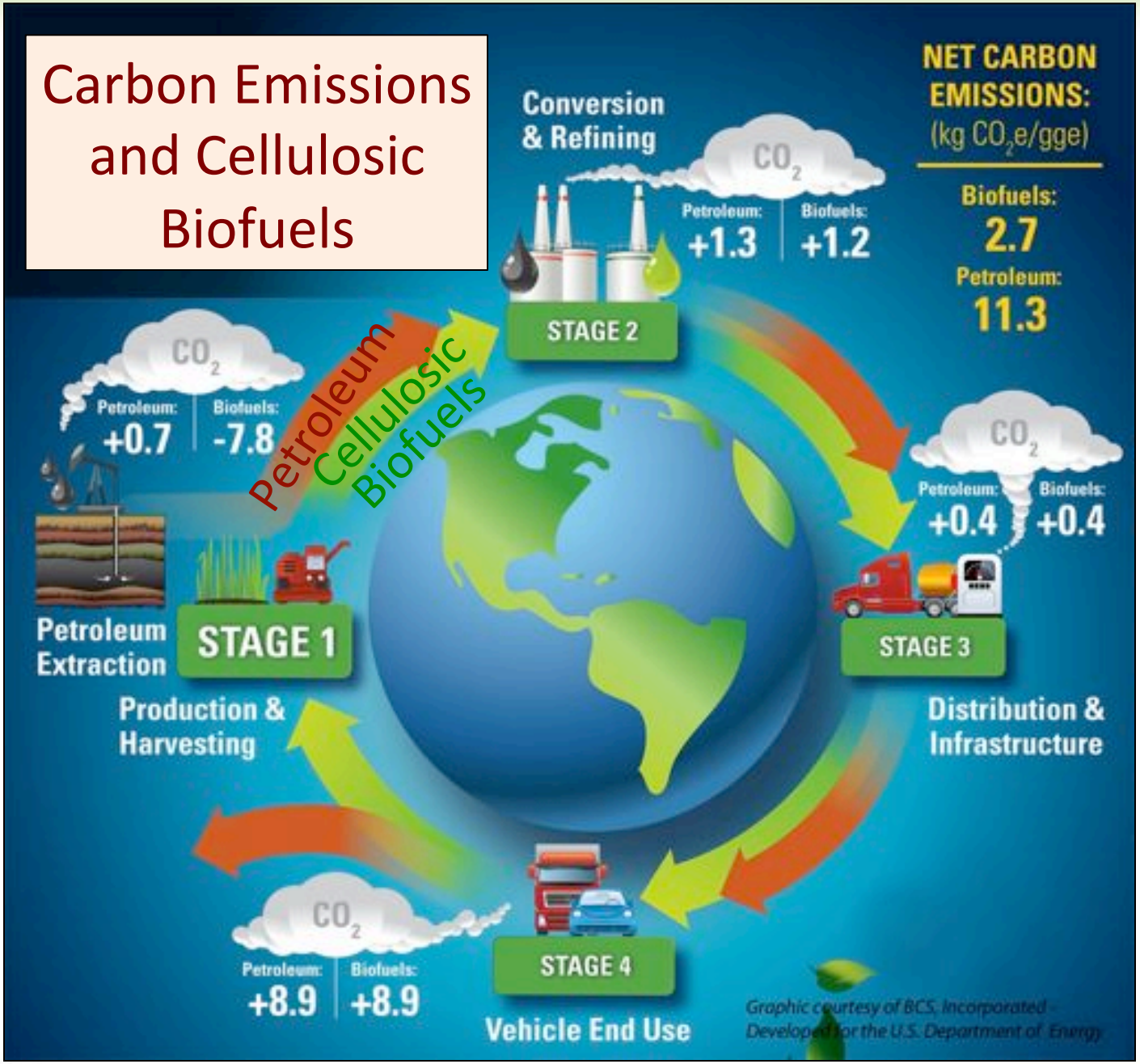
Ethanol (next generation fuel)

Fossil Fuel Energy In, Verses Biofuel Energy Out



Based on "Well to wheel analysis of advanced fuel/vehicle systems", by Wang et al., NREL 2005

Carbon Emissions and Cellulosic Biofuels



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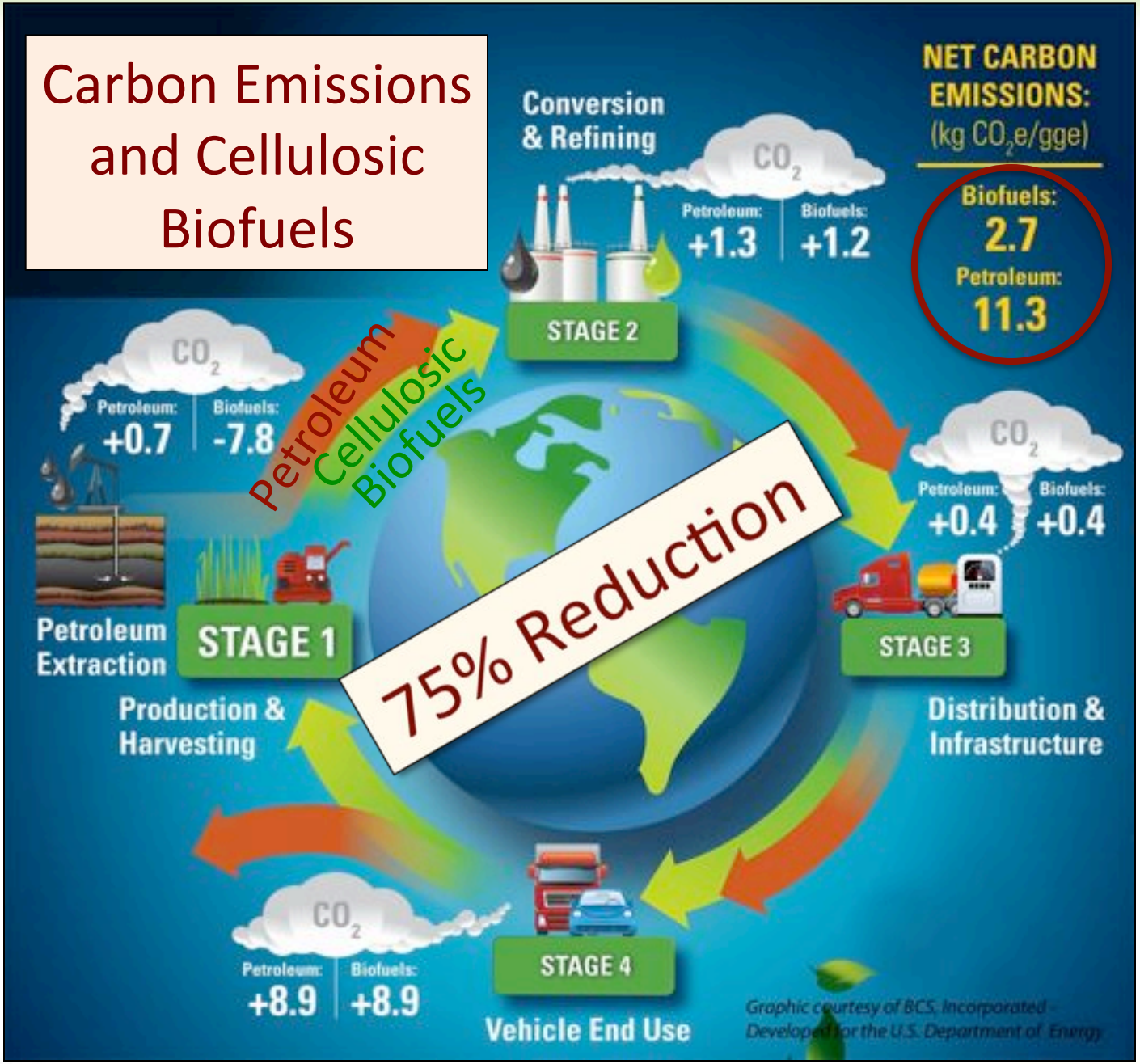
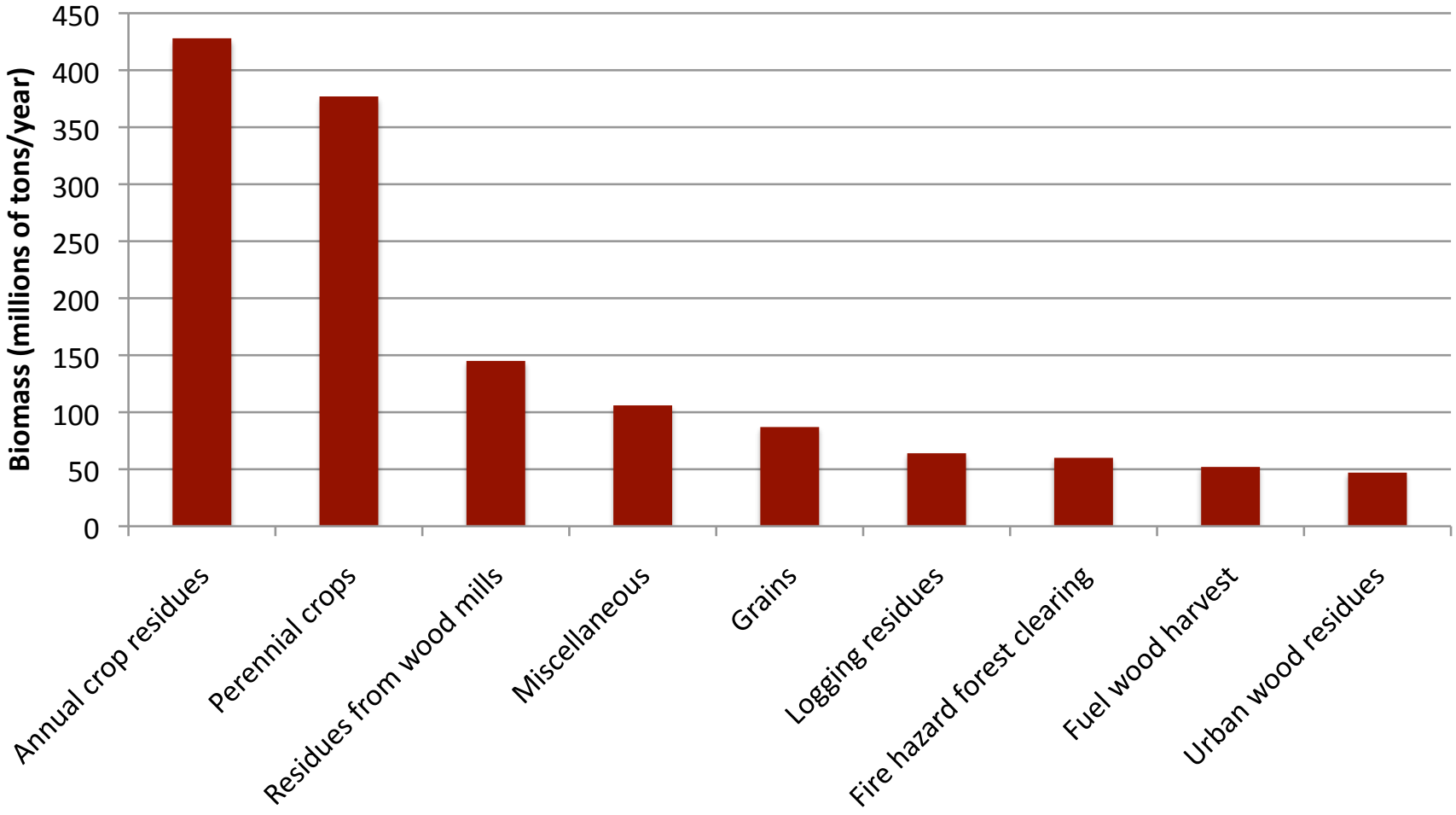
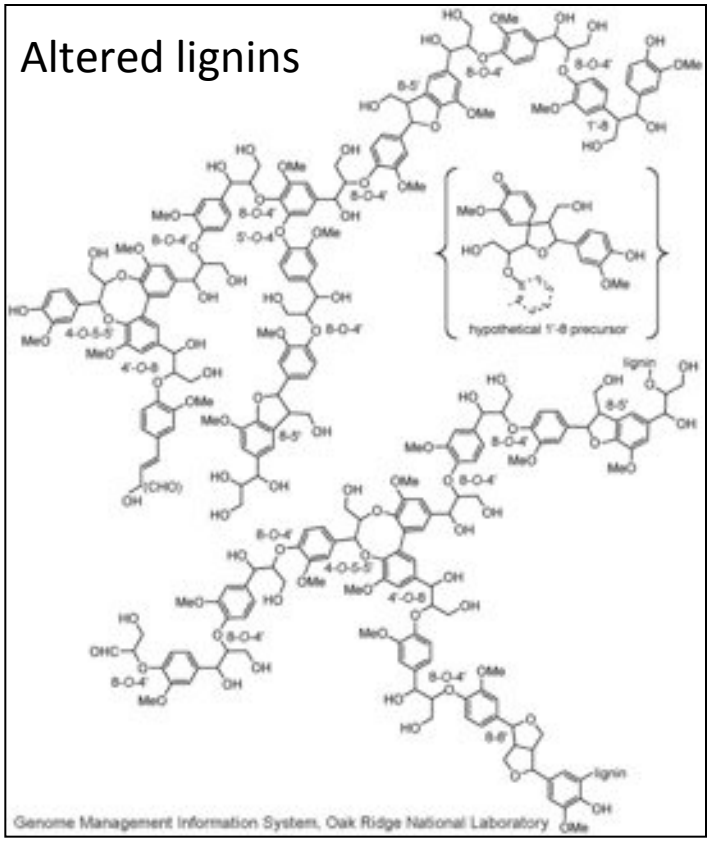


Biomass Feedstocks Available for Billion Ton/Year Harvest in the U.S.

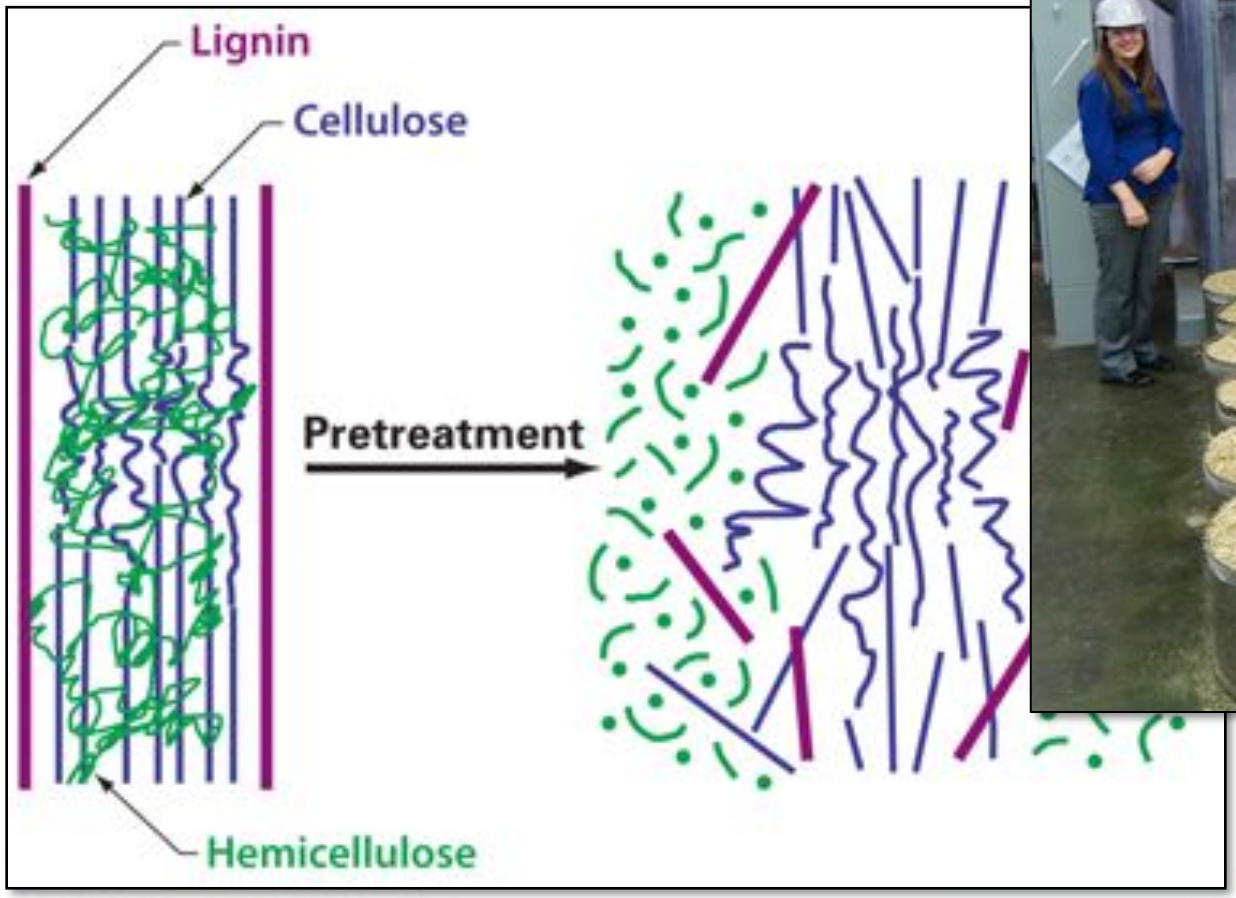
R.D. Perlack, et al, 2005, Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply (DOE/GO-102005-2135). Oak Ridge, TN: US DOE



Plant Breeding for Greater Biofuels Potential



Pretreatment: Ammonia Fiber Expansion (AFEX)

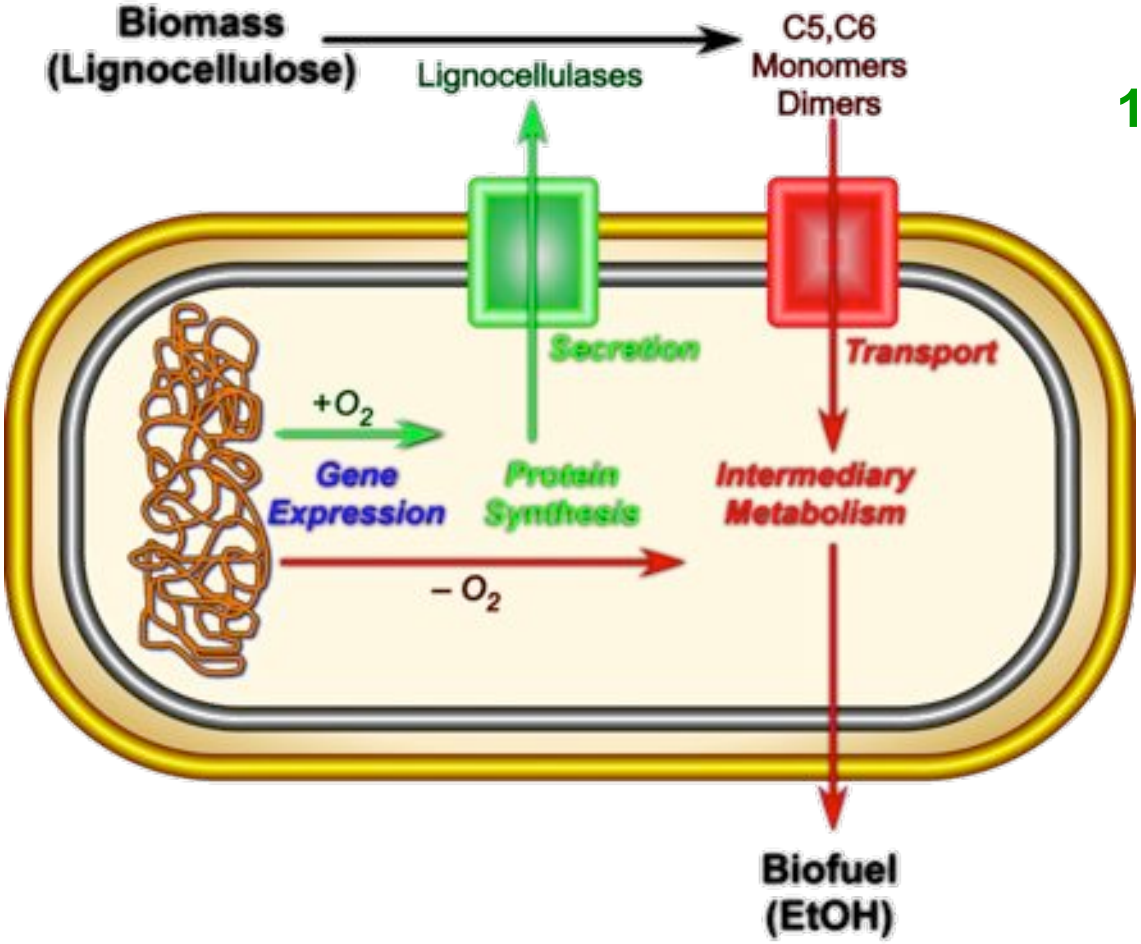


GREAT LAKES BIOENERGY

Bioprospecting - Thermophiles at Yellowstone

Improved Biomass Conversion

Long-Term Strategy for Improved Fuel/Ethanol Yields



1) <u>Aerobic growth</u>: optimize production of extracellular enzymes (lignocellulases)

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

Biofuel Crops and Sustainability

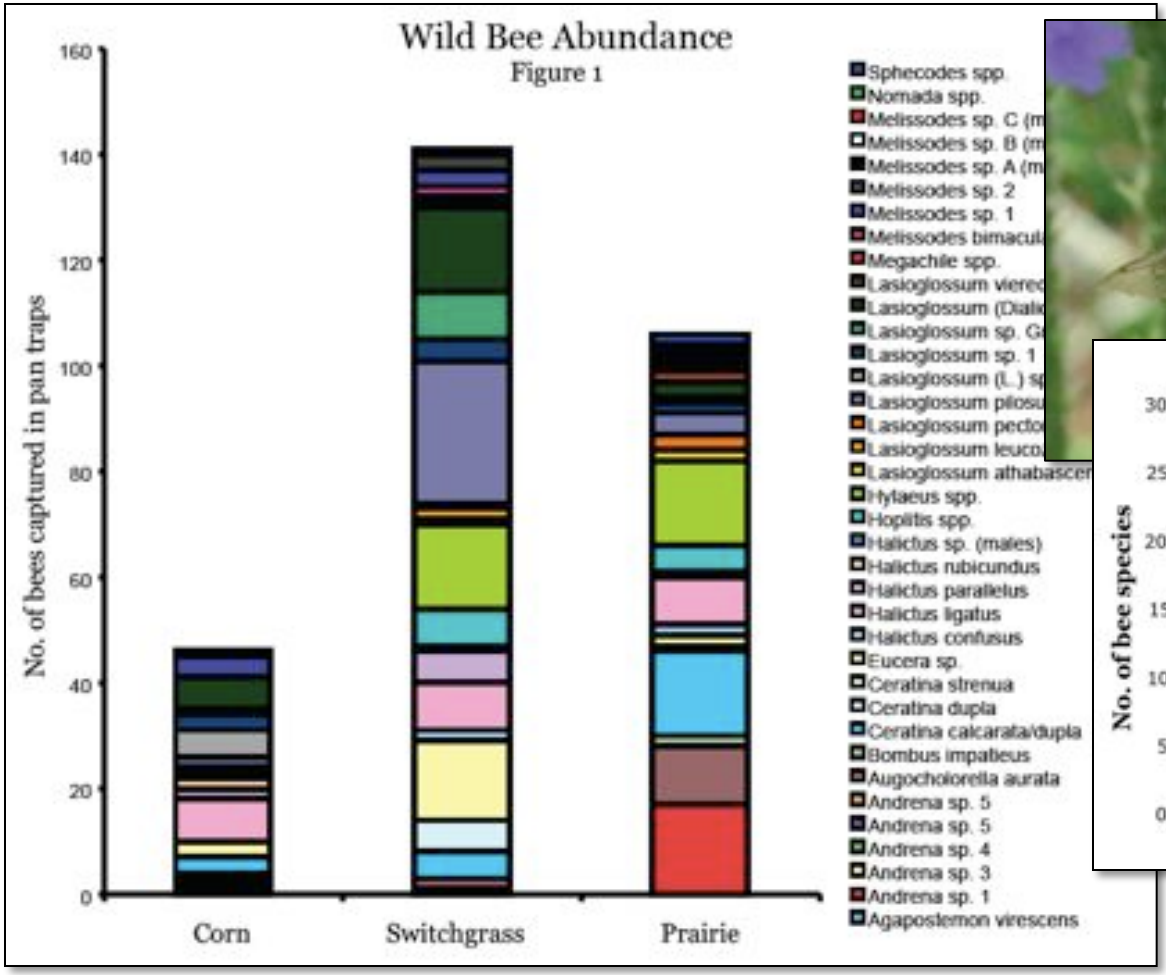
Lower Biodiversity	Higher Biodiversity
• Annual	• Perennial
• Monoculture	• Polyculture
• Exotic	• Native
• High input	• Low input

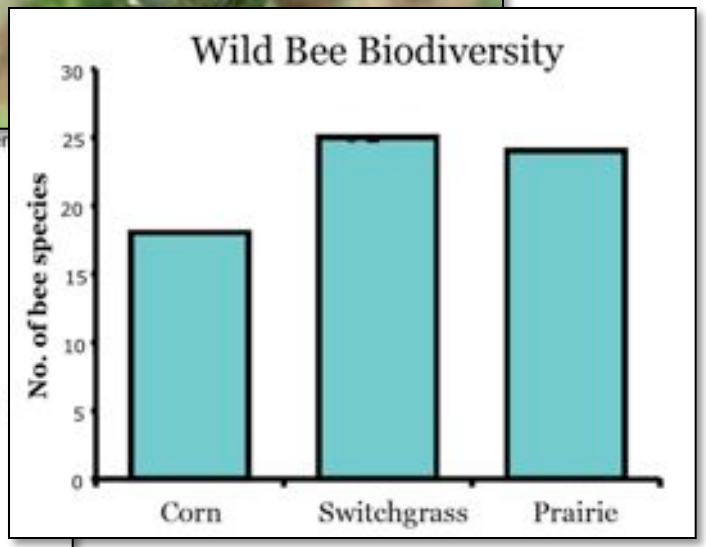
Corn

Switchgrass

Mixed prairie
"Low-Input High-Diversity"

The Effect of Biofuel Crops on Wild Bee Abundance and Biodiversity





GLBRC - Kellogg Biological Station, H Gordon et al

Monitoring Greenhouse Gases

GLBRC - Kellogg Biological Station, 2009