



Developing Products for Transportation Biorefineries

2014 APS/GERA Energy Workshop

Tim Donohue

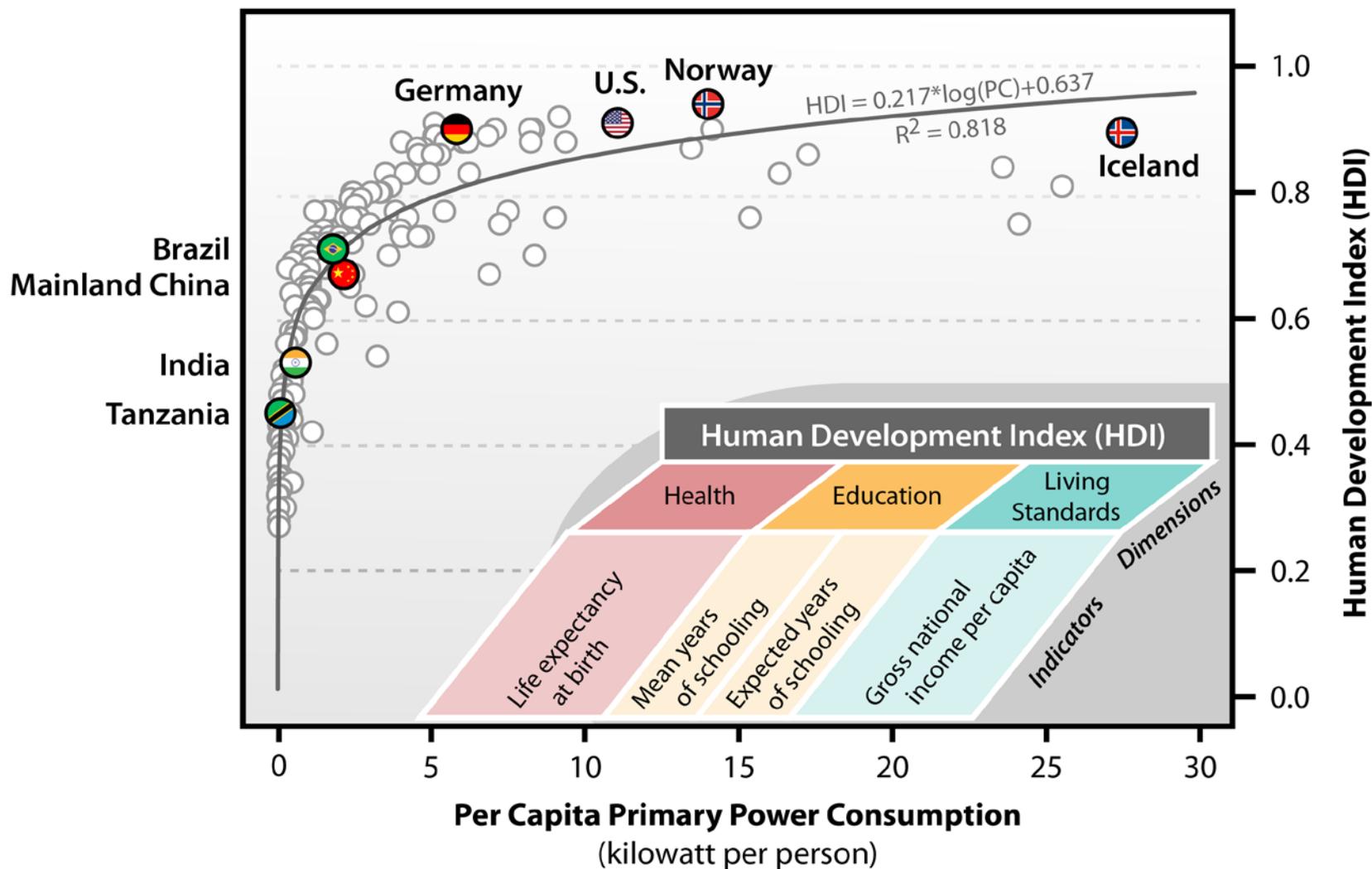
*Professor of Bacteriology, University of Wisconsin-Madison
Director, Great Lakes Bioenergy Research Center*



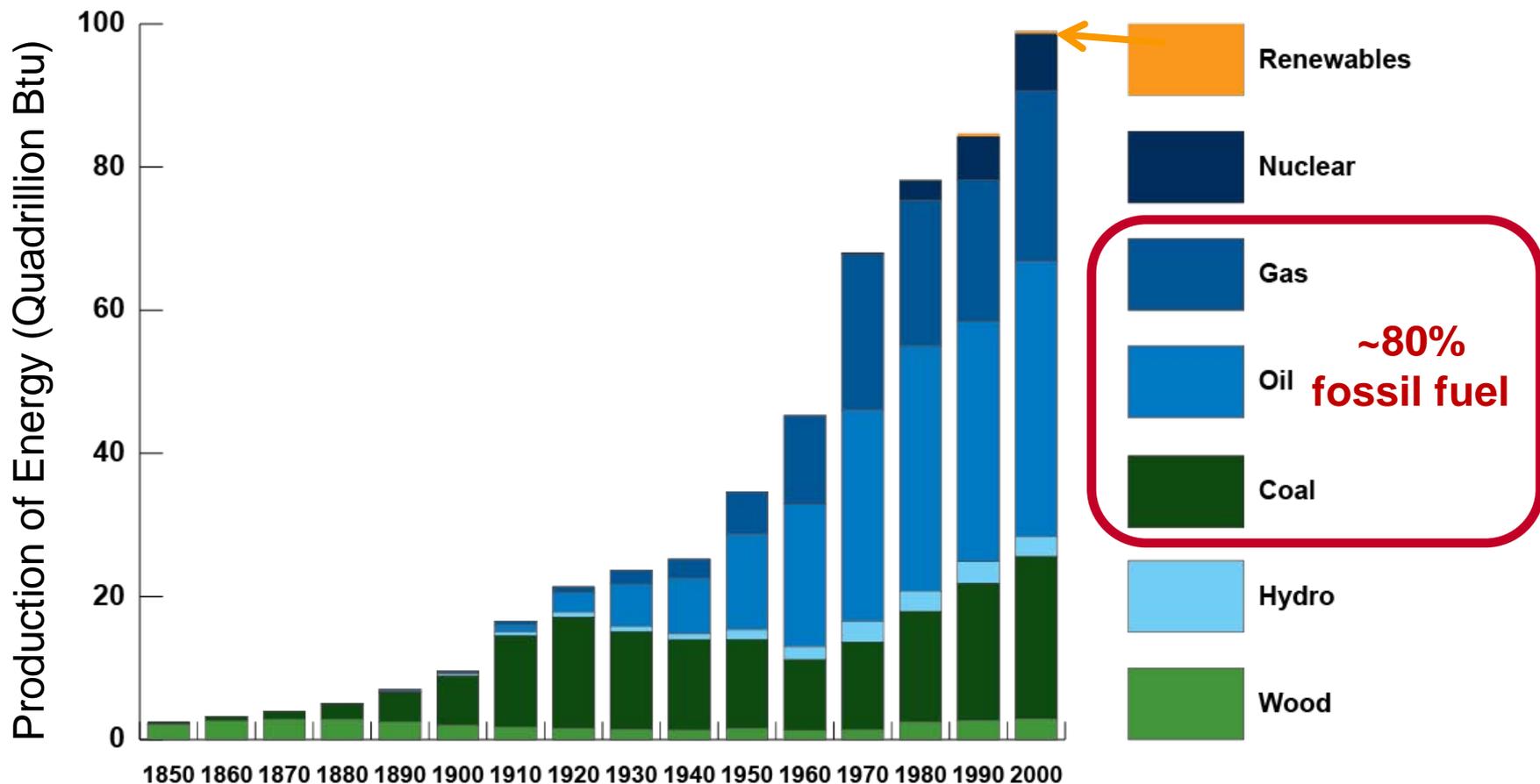
Meeting the “Energy” Needs of a Growing Population

A Grand Research & Education Challenge for Land Grant Universities

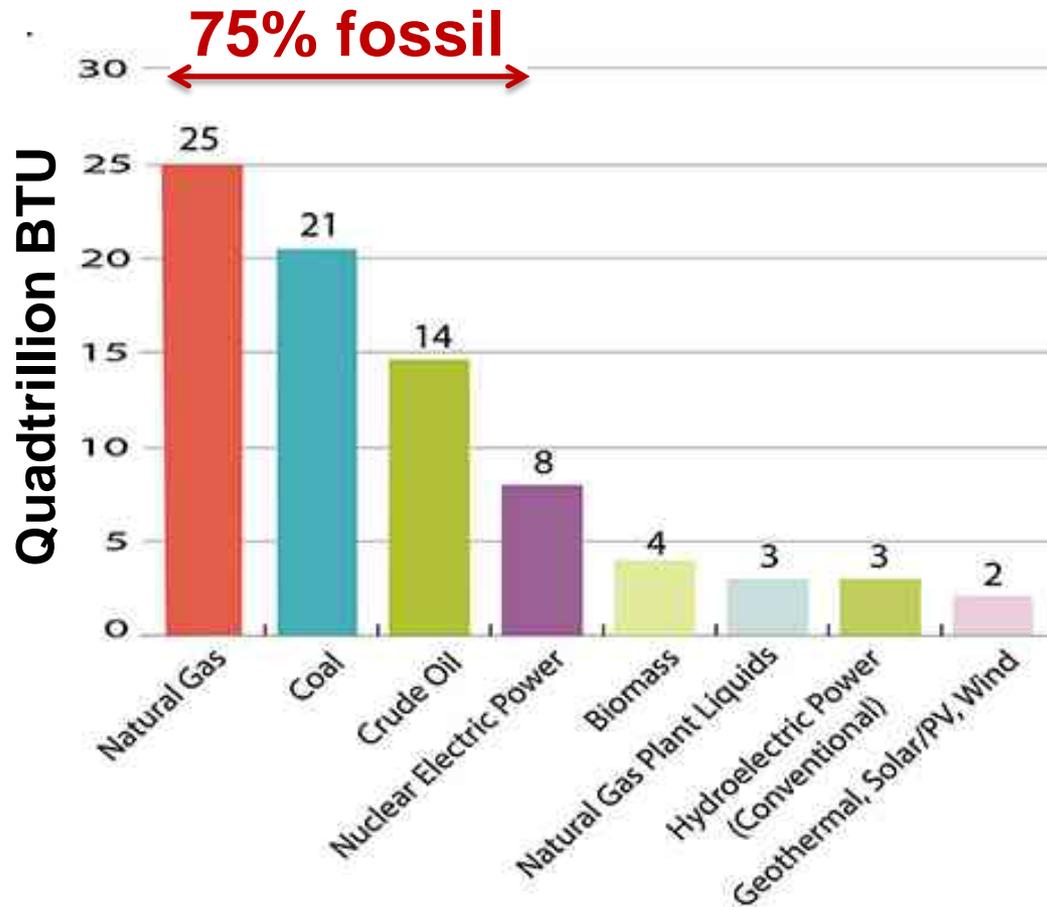
Energy Links to Global Human Development



US Energy Inputs Change Slowly

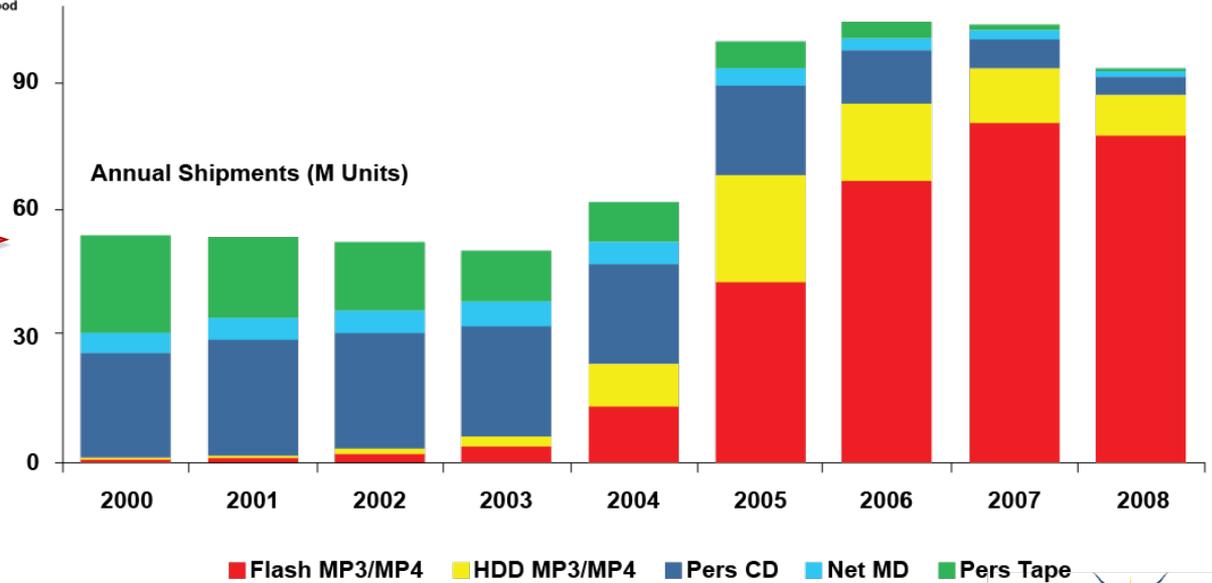
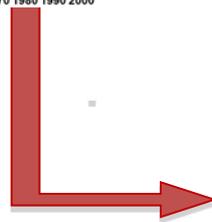
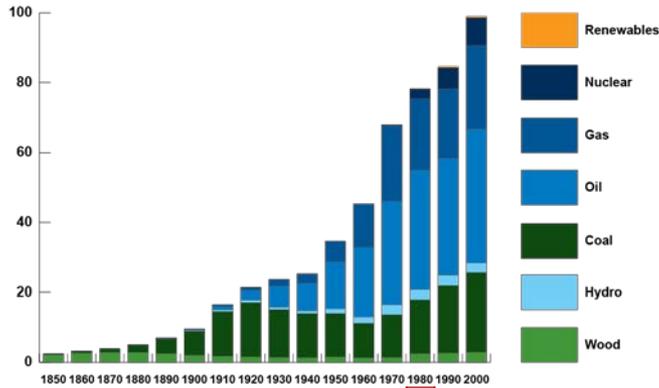


2012 US Energy Production



Source: U.S. Energy Information Administration, *Monthly Energy Review* (April 2013), Table 1.2, preliminary 2012 data.

US Energy Inputs Change Slowly



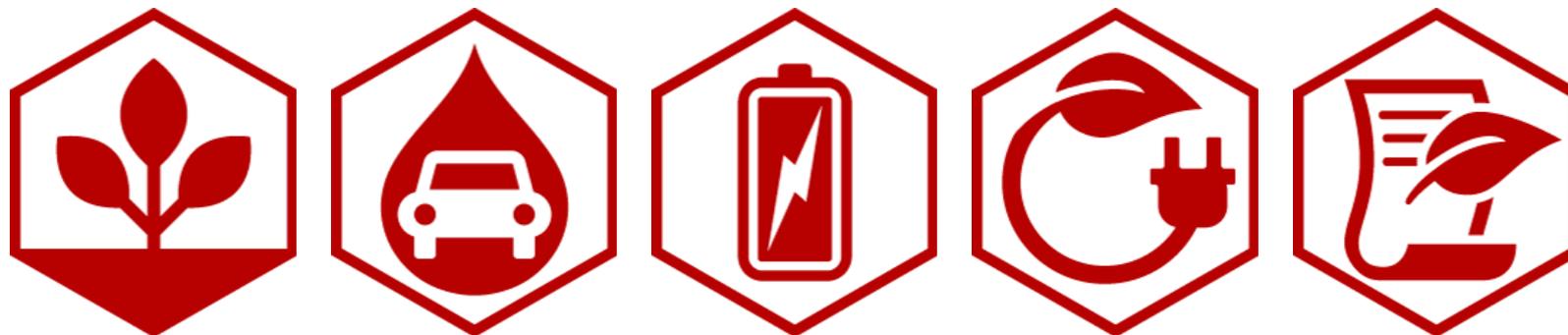
© 2009 Futuresource Consulting Ltd



Wisconsin Energy Institute

A Catalyst to Move Forward in Energy

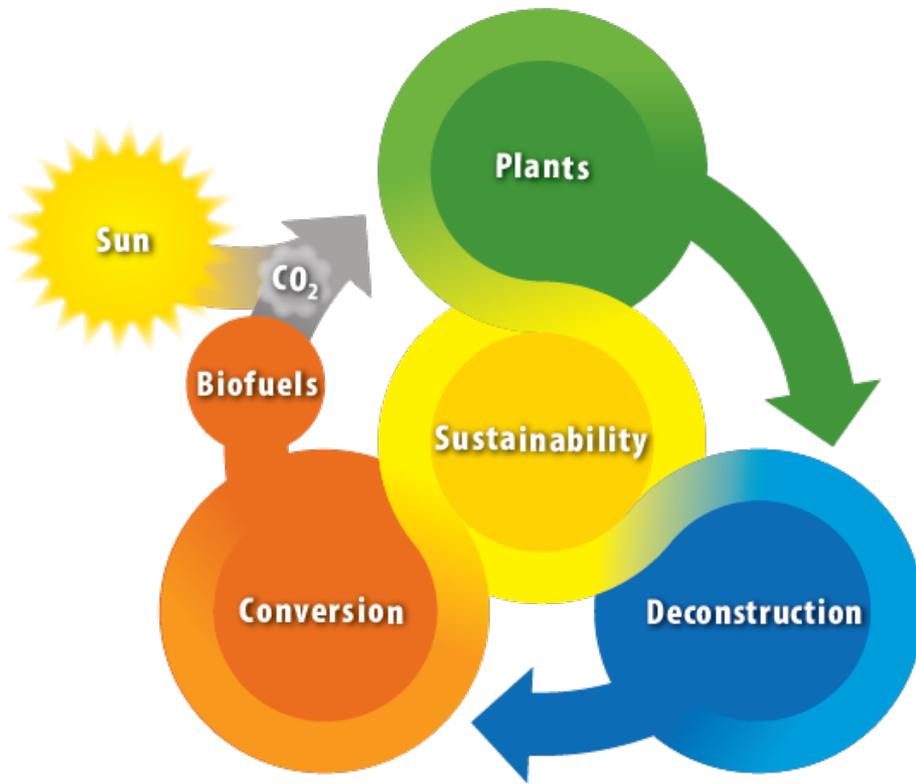
Create, integrate, & transfer knowledge in energy resources,
technology & sustainability



Breakthroughs in key areas of the energy sector:

- **Liquid fuels and transportation systems**
- Energy storage (thermal & electrical) and utilization
- Carbon neutral sources of electricity sources
- Policy, economics & societal impact of energy challenges
- Train future energy leaders

Great Lakes Bioenergy



Perform the **basic research** that generates technology to **convert cellulosic biomass to ethanol and advanced biofuels**

(GLBRC Roadmap, 2008)

- Began 2007, approved for funding through 2017 (~265M)
- 475 “**A to Z**” scientists, students & staff in US and Canada
- **DOE Office of Science, Biological & Environmental Research**

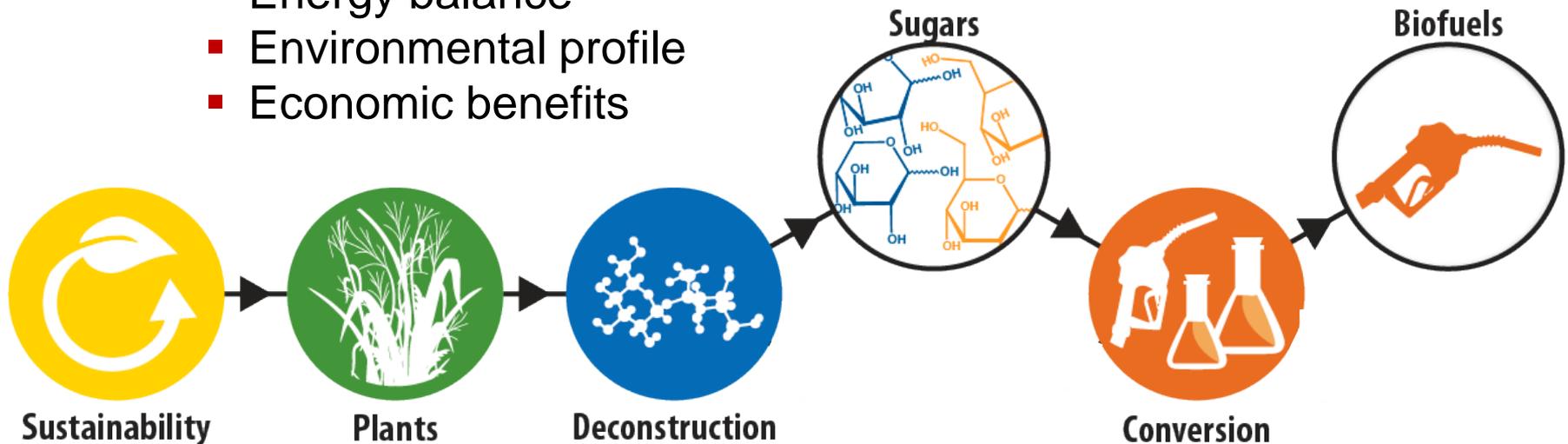
Strategies to Achieve Mission

Capitalize on resources of partners

- Researchers/Staff
- Land Grant Universities & National labs
- Technology transfer/Industry

Focus on sustainable integrated solutions

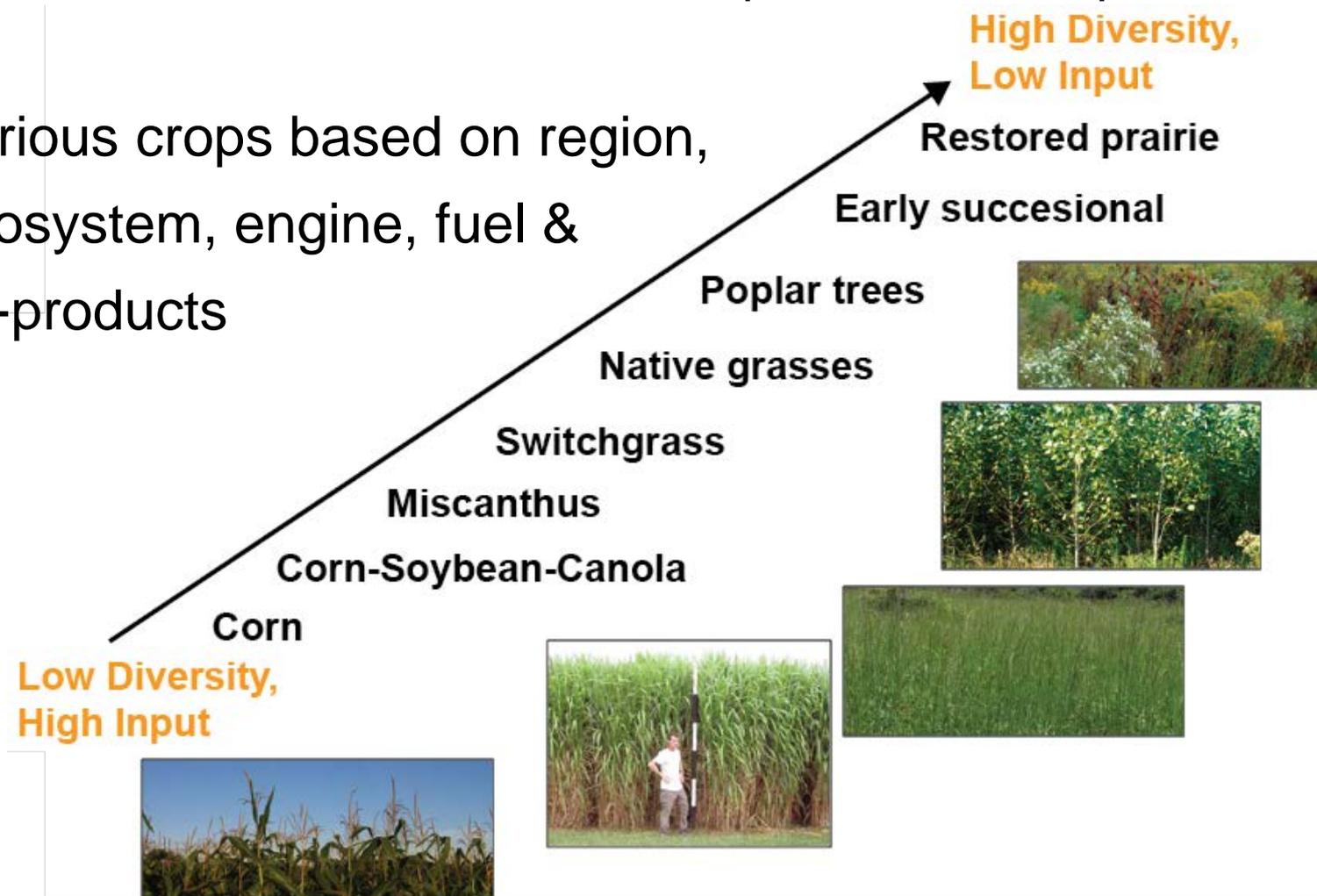
- Energy balance
- Environmental profile
- Economic benefits



Great Lakes Bioenergy Research Roadmap

Success of cellulosic biofuels depends on “multiple winners”

- Various crops based on region, ecosystem, engine, fuel & co-products



Systems Analysis of Biomass & Biofuels

Cropping Systems



Pretreated Biomass



Hydrolysate



Biofuels



Measurables

Site/Soil Type
Crop/Seed/Row
Plant/Harvest Date
Fertilizer/Herbicide
Season/Weather

Cellulose
Hemicelluloses
Lignin
Plant Cell Residue

Total CHO
C-5 & C-6 Sugars
Amino Acids
Organic Acids/Amides
Ammonia/Phosphate
~30 Metals/Inorganic Ions

Hydrolysate Inputs
Transcripts
Targeted Metabolites
Excreted Products
Fuel
Input/Output COD
Microbial Growth

Data Management

Scientific Discoveries

Collaboration Enables Discoveries

Host Institutions (farm to bench to combustion)



External (DOE, USDA, NSF, Others)

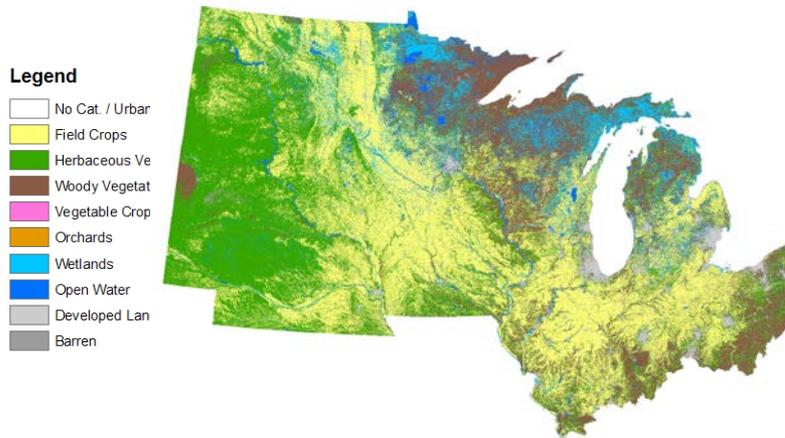


Education & Outreach

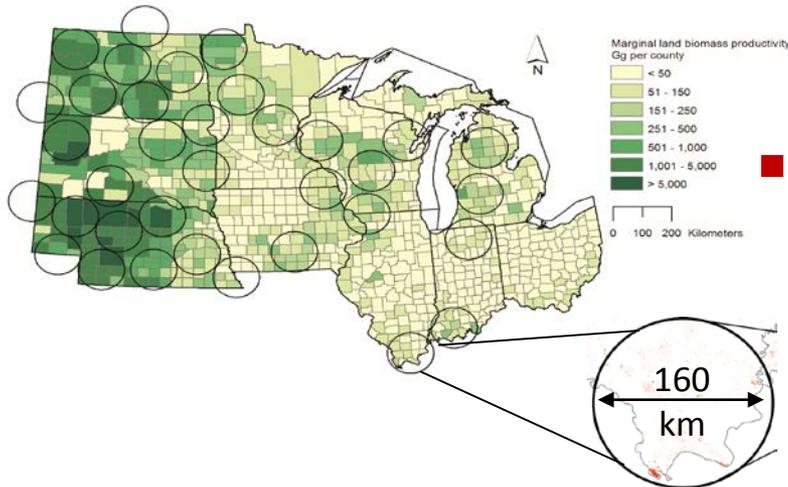


Early Efforts

Sustainable production of crops with desirable biofuel traits



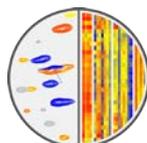
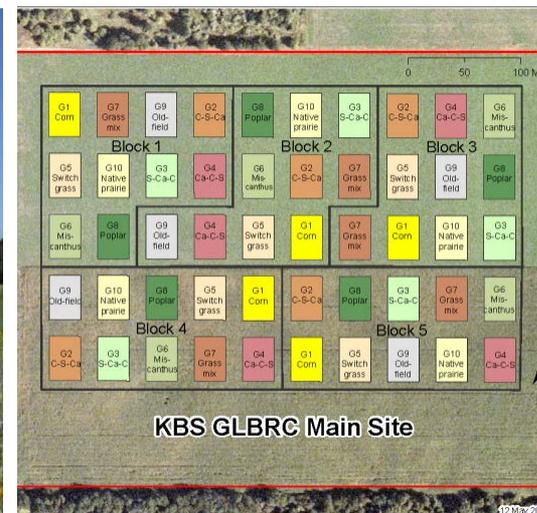
- Enable deployment of improved biofuels crops (inputs, productivity, processing, yields)



- Multi-scale models of sustainable biofuels production (local, regional & national)

Recent Advances

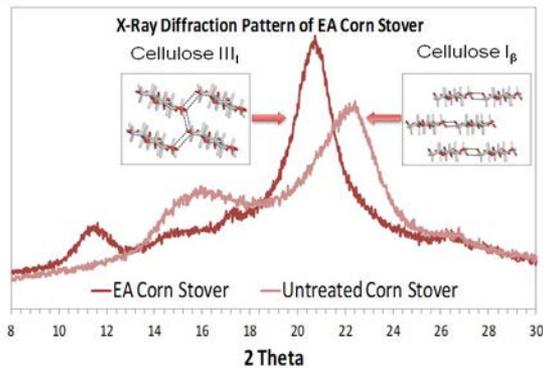
- Improve yield & traits of biofuel crops
- Role of marginal & fertile lands in cellulosic biofuels production



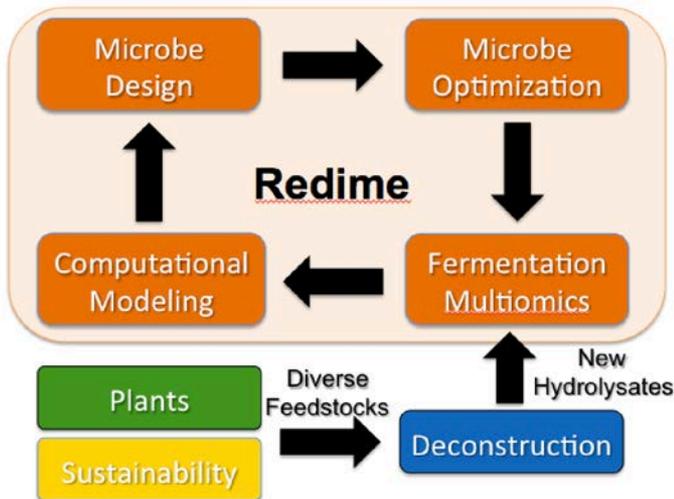
Farmers
Landowners
Universities

Early Efforts

Energy efficient conversion of biomass into fuels & chemicals



- Improved sugar & lignin streams

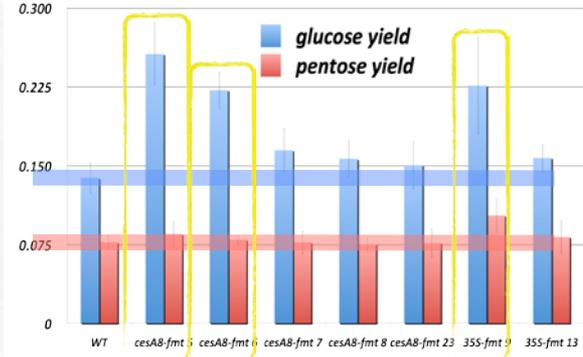


- Identify steps that cost energy & limit product yield

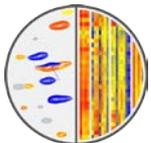
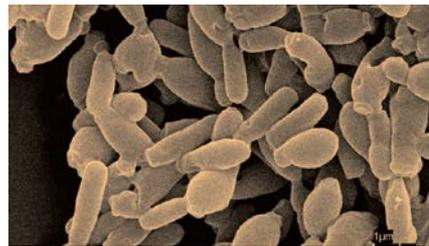
Recent Advances

Deployment of improved biofuels crops

- Low-energy “Zip-lignin” improves sugar release in *Populus*



- Produce “drop-in” biofuel (AcTAG) in crops & microbes

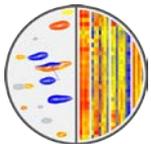
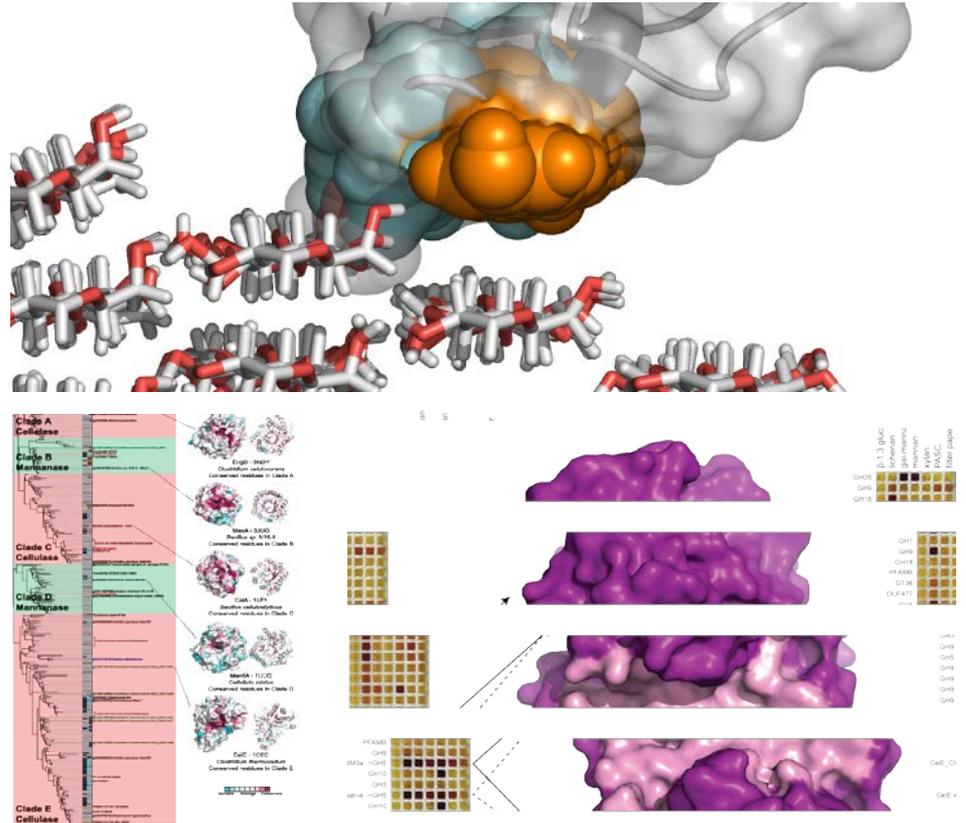


Universities

Recent Advances

Genome-enabled improvements to biomass processing

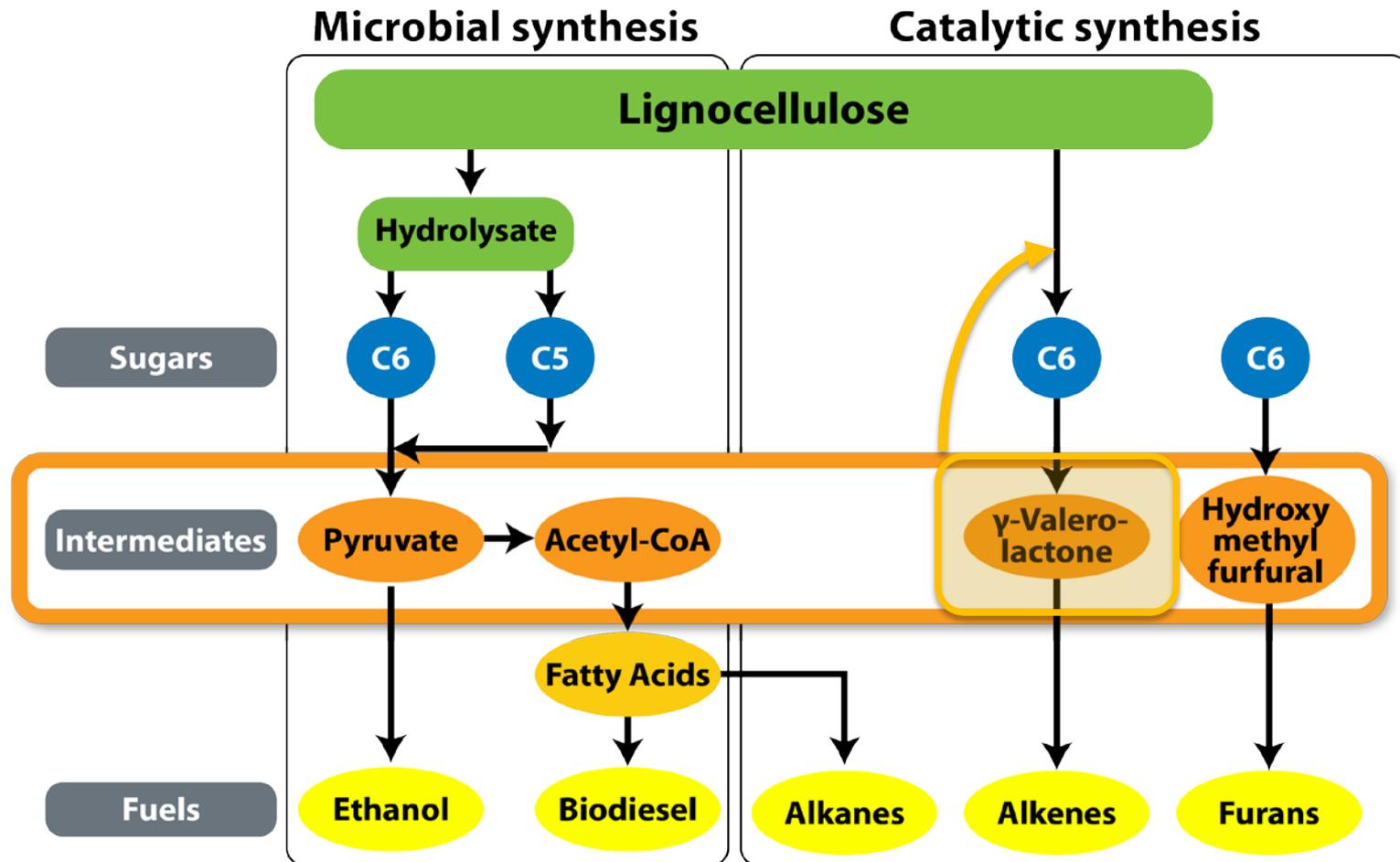
- Easier to digest cell wall sugar polymers
- Enzymes with broad substrate specificity



Universities

Early Efforts

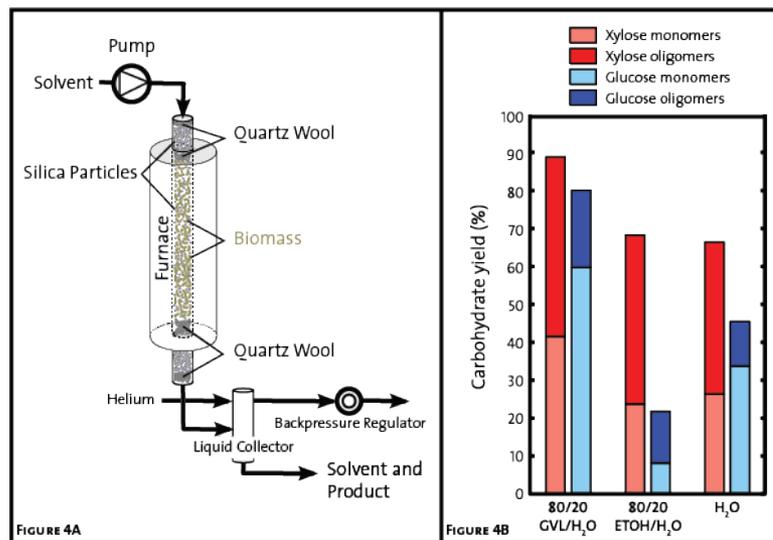
Strategic Intermediates Enable Biofuels Production



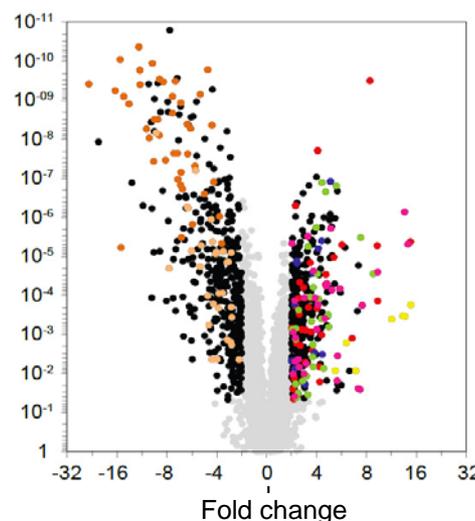
Recent Advances

Energy efficient conversion of biomass into fuels & chemicals

- Lower input biological & chemical pretreatments

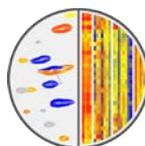


- Systems analysis of toxins that lower product yield across crops



Multiomic analyses

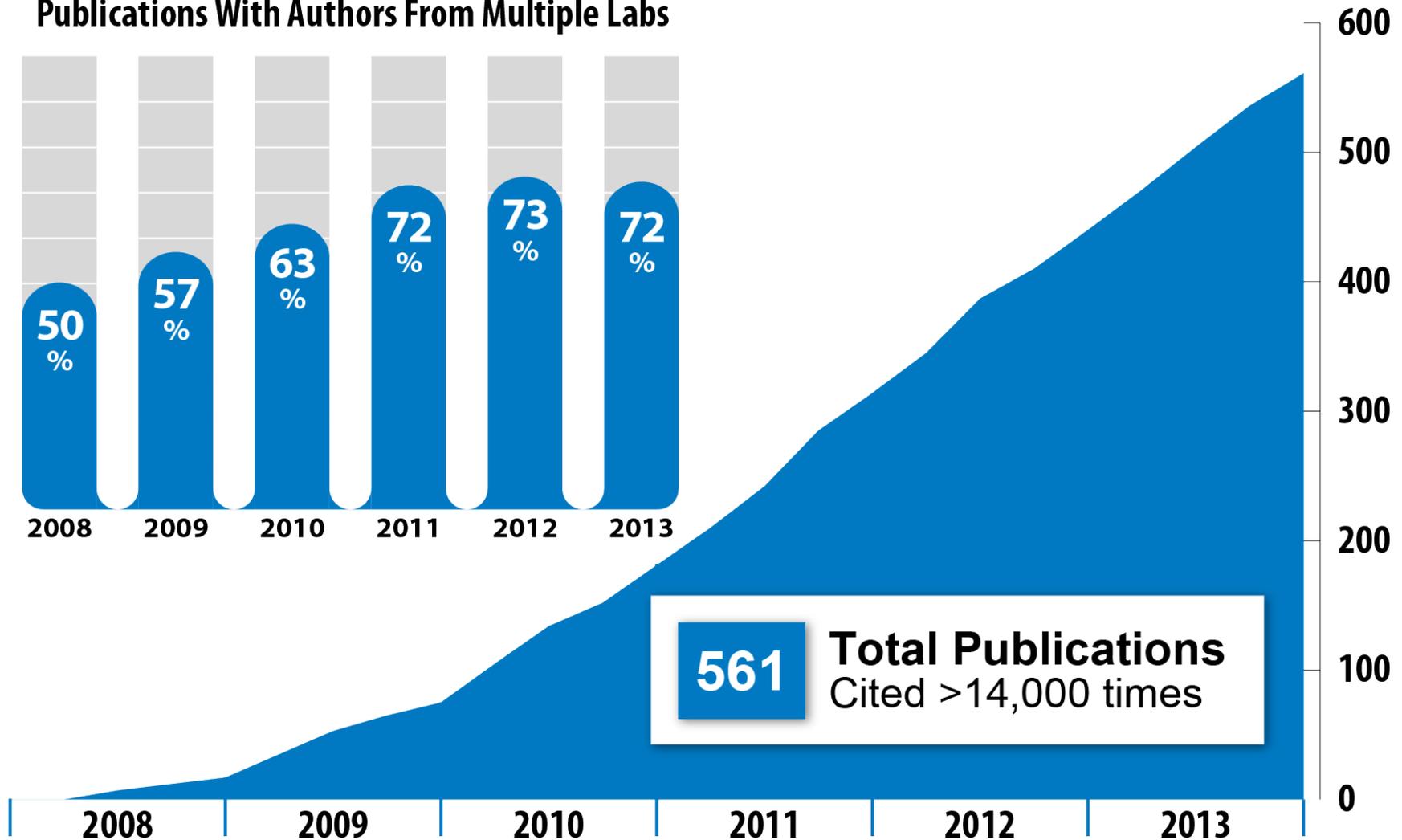
- Stress related
- Efflux pumps
- Anaerobic respiration
- Carbohydrate usage (non-glucose)
- Amino acid synthesis
- Flagella/Chemotaxis
- Thiamine biosynthesis
- Iron metabolism
- Citrate lyase
- Osmotic tolerance



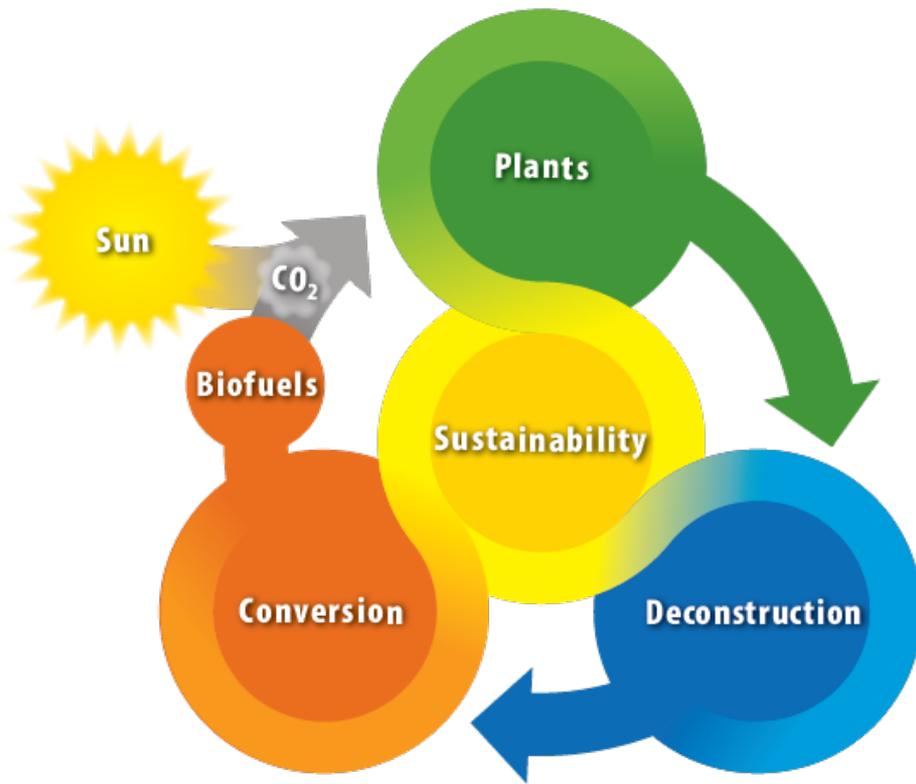
Universities

Products of Research Integration

Publications With Authors From Multiple Labs



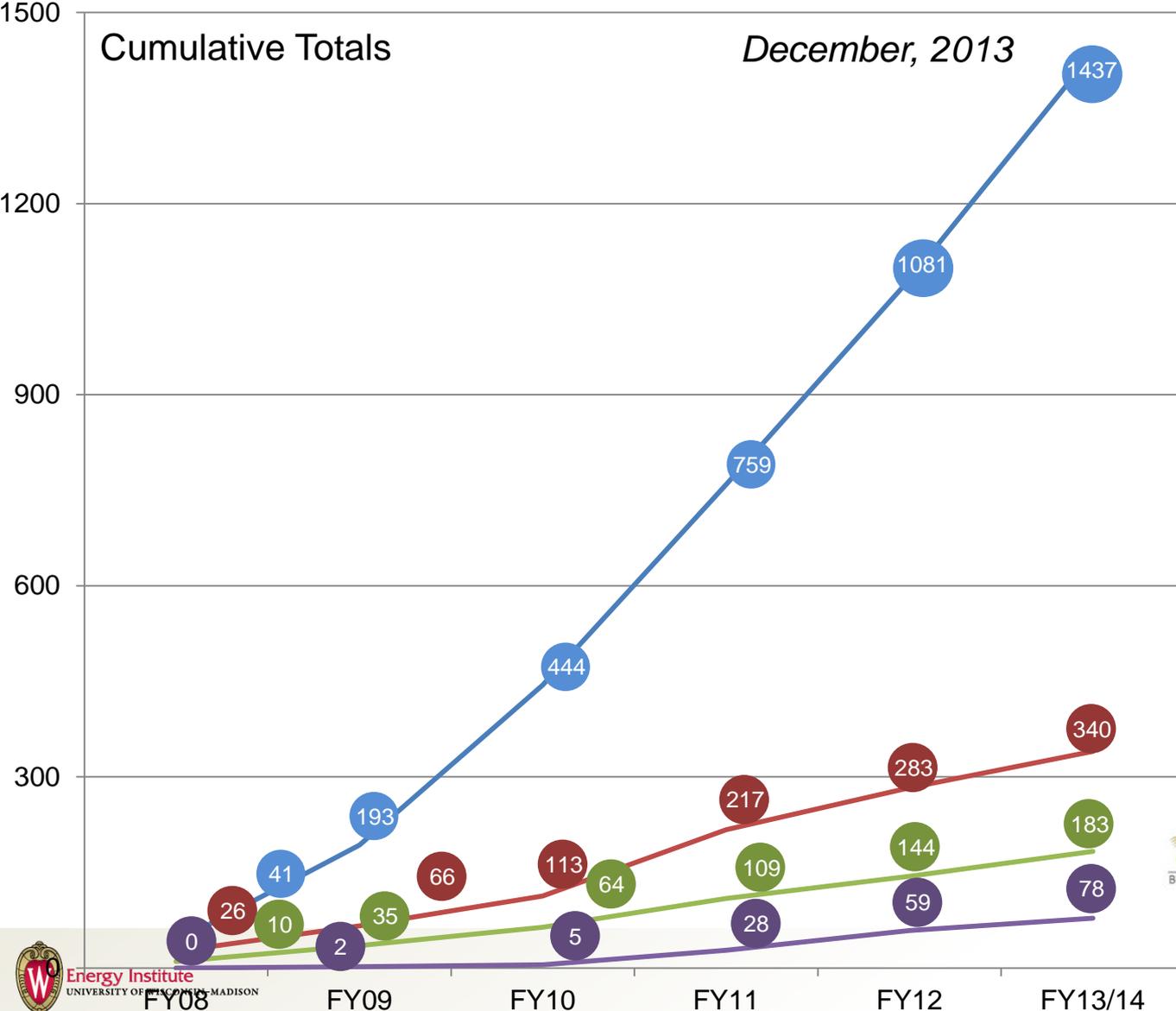
Moving Advances to Market



Perform the basic research that **generates technology** to convert cellulosic biomass to ethanol and advanced biofuels

(GLBRC Roadmap, 2008)

DOE BIOENERGY RESEARCH CENTERS: ACCELERATING DEPLOYMENT OF SCIENCE & COMMERCIALIZATION



Total Publications¹
1437

Total Invention Disclosures
340

Total Patent Applications
183

Total Licenses/Options²
78



Moving Advances to Market



MONSANTO



novozymes

Rethink Tomorrow

Pacific Ethanol, Inc.

ceres

POET
biorefining

SCION
forests • products • innovation



Borregaard
LignoTech



Lignol



IOGEN
CORPORATION



evolva

Cargill



firstgreen
PARTNERS



DSM

BRIGHT SCIENCE. BRIGHTER LIVING.



FuturaGene

Yielding the Future™

GlucanBio

allopartis

tesetagen
BIOTECHNOLOGY

MillerCoors™

GINKGOBIOWORKS™



LS9, INC.

genomatica

ZeaChem

LYGOS

Nextval



FDC Enterprises
Grasslands
Services

Creating Superior Quality Grasslands

opxbio
good chemistry.



SAFFRON EAGLE
BIOFUELS

Nextval

ABENGOA



MASCOMA



NIDUS

bp
Mendel
BIOTECHNOLOGY

ExxonMobil

ADM

Elanco



SuGanit



BASF
The Chemical Company



Oakbio

Clean Technology, Clean Products

Statoil

Hyrax
ENERGY



Caliper
a PerkinElmer company



Show Me Energy Cooperative
empowering the next generation...

...through a flexible model that allows plant matter to be turned into fuel and power

BESC
BioEnergy Science Center

jbei
Joint BioEnergy In...
GREAT LAKES BIOENERGY
RESEARCH CENTER



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Transforming the Future



Breaking barriers and meeting challenges:

- Improving biofuel crops and producing fuel & chemicals
- Speeding transfer of validated technologies to industry
- Sustainable production of biofuels crops
 - ❖ Not *food vs. fuel* but both