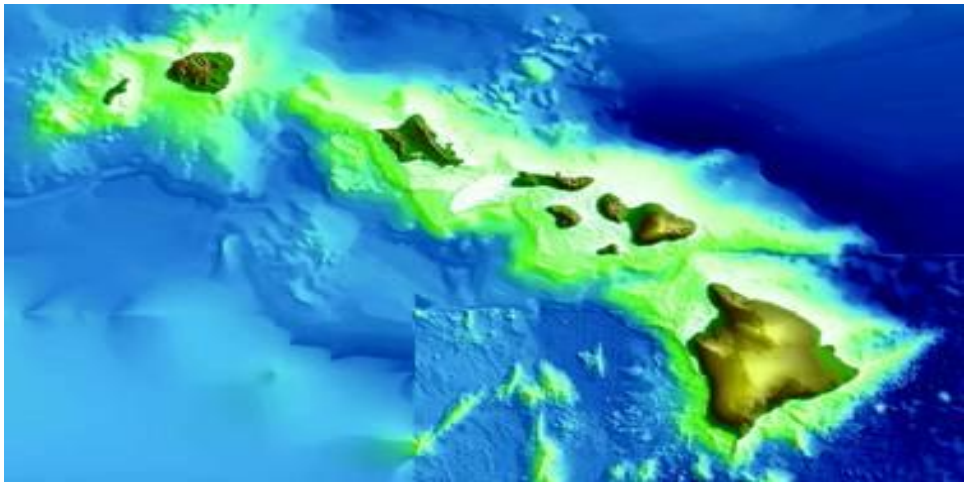
Sustainable Transportation: Overview of Bio-Fuels Systems



Terry Surles, surles@hawaii.edu

University of Hawaii and

Neil Rossmeissl

DOE/Office of Energy Efficiency and Renewable Energy

April 7, 2014

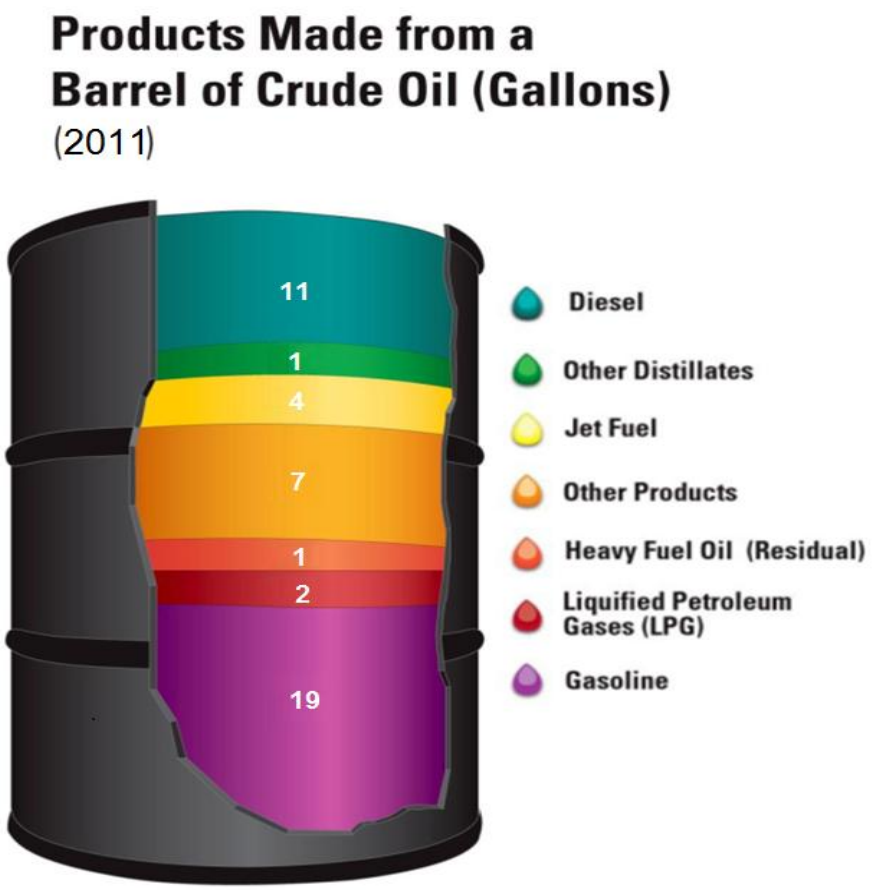
College of Social Sciences
University of Hawaii at Manoa

Bioenergy Budget History

	FY 2013 Final CR	FY 2014 OMB Request	FY 2014 Congressional Enacted
Feedstocks	**48,500**	**40,500**	**47,000**
Interface (Production)	5,000	8,500	5,000
Logistics	13,500	16,500	12,000
Algae	30,000	15,500	30,000
Conversion Technologies	**76,809**	**141,000**	**101,446**
Biochemical Conversion	35,132	51,700	35,000
Carbon Fiber Initiative	--	20,000	8,000
Waste-to-Energy	--	5,300	4,846
Incubator Program	--	--	5,800
Thermochemical Conversion	41,677	56,500	37,000
Gasification	--	7,500	5,000
Incubator Program	--	--	5,800
Integrated Biorefineries	**43,868**	**78,000**	**64,829**
IBR	43,868	33,000	19,829
Defense Production Act (DPA)	--	45,000	45,000
Analysis & Sustainability	**15,000**	**13,500**	**12,154**
Systems Analysis	9,000	5,500	6,084
Cross-cutting Sustainability	4,000	6,500	6,070
Systems Integration	2,000	1,500	--
Biopower/Cookstoves	**4,253**	**4,000**	**2,000**
NREL Site-Wide Facility Support	**--**	**5,000**	**5,000**
Total, Bioenergy Technologies	***188,430***	***282,000***	***232,429***

In thousands of dollars

Replacing the Whole Barrel



Source: Energy Information Administration (2011)

Greater focus is needed on RDD&D for a range of technologies to displace the entire barrel of petroleum crude

- *U.S. spends about $1B each day on crude oil imports.**
- *Only about 40% of a barrel of crude oil is used to produce petroleum gasoline.*
- *Reducing our dependence on oil also requires replacing diesel, jet fuel, heavy distillates, and a range of other chemicals and products that are currently derived from crude oil.*

**American Petroleum Institute*

Office of Energy Efficiency and Renewable Energy

Sustainable Transportation Technology "Offices"

Vehicles

Bioenergy

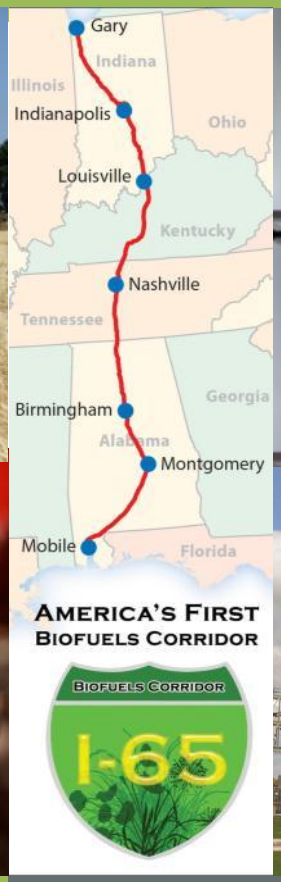
Hydrogen and Fuel Cells

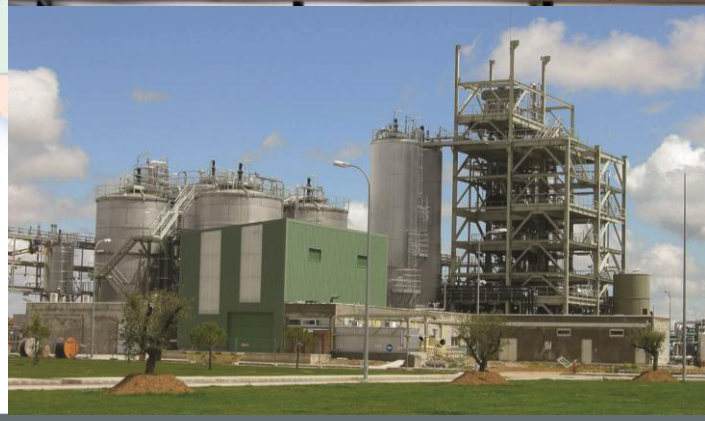
- ***Efficiency Improvement***
- ***Fuel Diversification***
- ***Domestic & Renewable Sources***
- ***Reduced GHG***

National Energy Goals & Climate Action Plan

Reduce oil imports by 1/3 by 2025, compared to 2008

Reduce GHG emissions 17% below 2005 levels by 2020 and 83% by 2050

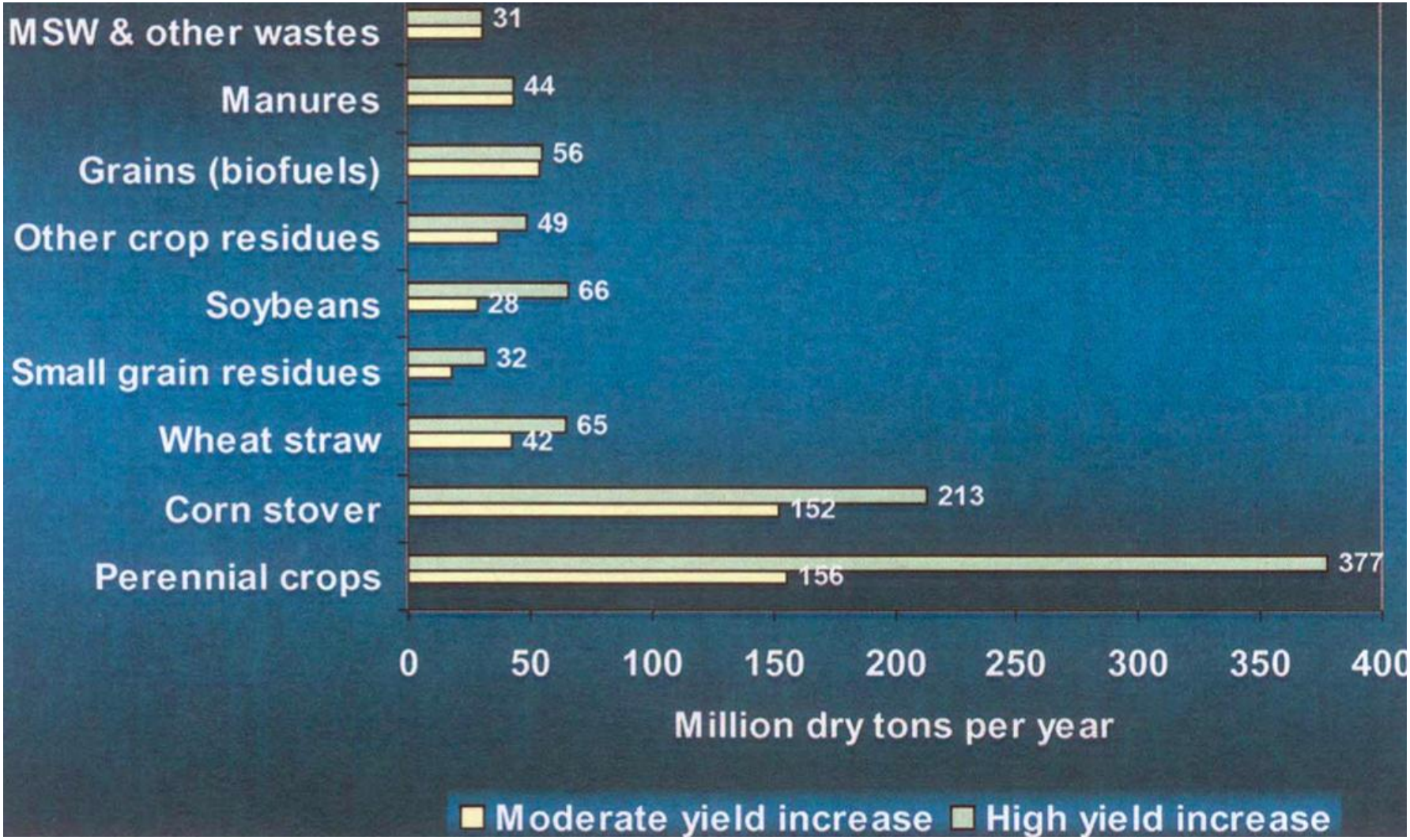

Gary
Indiana
Illinois
Indianapolis
Ohio
Louisville
Kentucky
Nashville
Tennessee
Georgia
Birmingham
Alabama
Montgomery
Mobile
Florida
AMERICA'S FIRST
BIOFUELS CORRIDOR
BIOFUELS CORRIDOR
I-65



Massive Development of Biomass Technology Has Issues (not much different from 1981 study)

- Water Use
  - Irrigation requires energy - **water/energy nexus**
  - Water rights and land use are issues in many parts of the country
  - Recent extensive droughts drive up costs of feedstocks
- Fertilizer
  - Many are produced with natural gas feedstocks
  - Run-off causes considerable pollution, ocean dead zones
- Competition for Food
- Contribution to Global Warming
  - Destruction of tropical forests
  - Limited advantages when analyzing the life-cycle of fuels
- Conversion Technologies
  - Problems with cost-effective cellulosic conversion systems
  - Transportation of low-energy density feedstocks

Availability of Non-Forest Biomass



Resource Development Activities

Switchgrass

Harvested annually

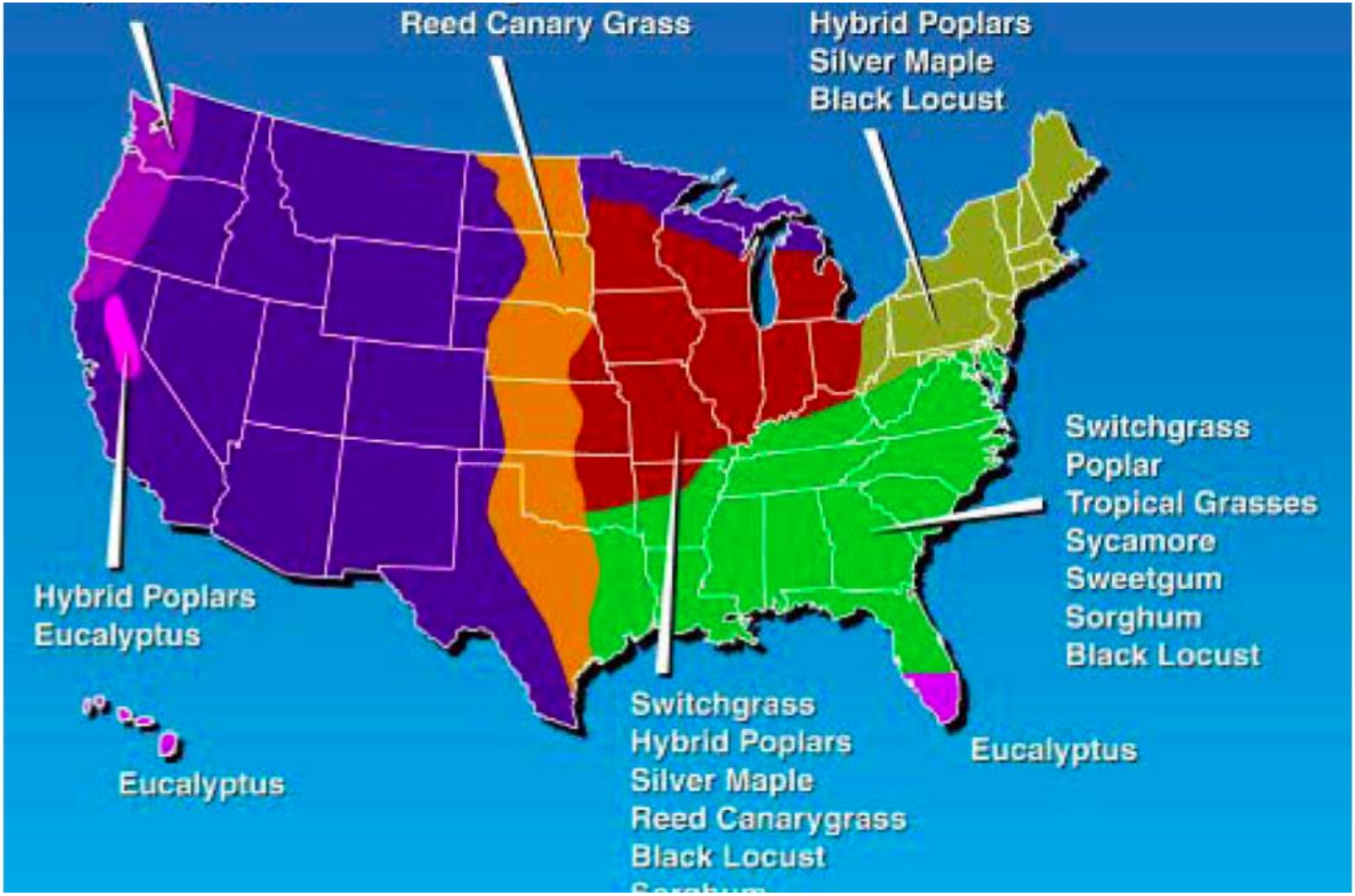
Hybrid Poplar

Harvested at age 5 to 10

Willow coppice

Harvested at age 3 or 4

Biomass Resources on a Regional Basis



The Challenge and The Opportunity

The Challenge

- More than 13 million barrels of fuel are required every day to fuel the U.S. transportation sector[1]
  - Ethanol is blended up to 10% in current gasoline
- Approximately 10% of U.S. crude oil imports are used to make chemicals and products such as plastics for industrial and consumer goods
  - Biomass derived chemicals make up 4% of current chemical sales
- Less than 2% of the oil consumed in the United States is used for power generation
  - Biopower electricity generation currently accounts for 1.4% of all electricity generated in the United States.

The Potential

- Biomass is a leading renewable resource with the potential to provide drop-in replacements for the 11 million barrels/day of petroleum fuels consumed in 245 million existing light duty and heavy duty vehicles on the road and specifically for air transportation needs (an additional 1 million barrels/day) utilizing existing infrastructure.
- The United States could produce more than 1 billion tons of sustainable biomass resources that can provide fuel for cars, trucks, and jets; make chemicals; and produce power to supply the grid.
- By 2030, there is the potential to develop terrestrial biomass resource to displace 30% of U.S. current petroleum usage. **This does NOT take into account algae.**
- Produce advanced bioenergy while maintaining food/feed/fiber production, maintaining ecosystem services, and reducing GHG emissions by at least 50% compared to the fossil fuel it displaces.

1 EIA 2012 Energy Review

Bioenergy Technologies Office

Mission

Develop and transform our renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research, development, demonstration, and deployment supported through public and private partnerships.

Strategic Goal

Develop commercially viable biomass utilization technologies to enable the sustainable, nationwide production of biofuels that are compatible with today's transportation infrastructure and can displace a share of petroleum-derived fuels to reduce U.S. dependence on oil and encourage the creation of a new domestic bioenergy industry.

Performance Goals

- *Through RD&D, make cellulosic biofuels competitive with petroleum-based fuels at a modeled cost for mature technology of $3 per gallon of gasoline equivalent (GGE) ($2011) based on EIA projected wholesale prices in 2017.*
- *Help create an environment conducive to maximizing the production and use of biofuels by 2022.*
- *By 2020, validate the technology and economics for the production of advanced biofuels that reduce GHG emissions by 50% or more compared to petroleum fuel at $3/gge wholesale at scale.*

Bioenergy Supply Chain

Objective: *Through targeted RD&D, enable sustainable, nationwide production of advanced biofuels that that will displace a share of petroleum-derived fuels, mitigate climate change, create American jobs, and increase U.S. energy security.*

Demonstration at Increasing

Feedstock Supply

Develop sustainable and affordable feedstock supply and efficient logistics systems.

Conversion R&D

Develop commercially viable technologies for converting feedstocks into liquid transportation fuels and products.

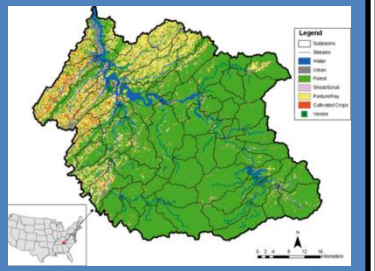
Demonstration at Increasing Scale

Validate integrated technologies at cost-shared pilot, demonstration, and pioneer scale facilities.

Cross Cutting

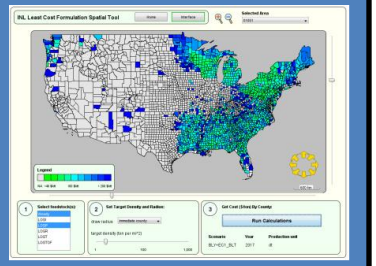
Sustainability

Promote the positive economic, social, and environmental effects of bioenergy.

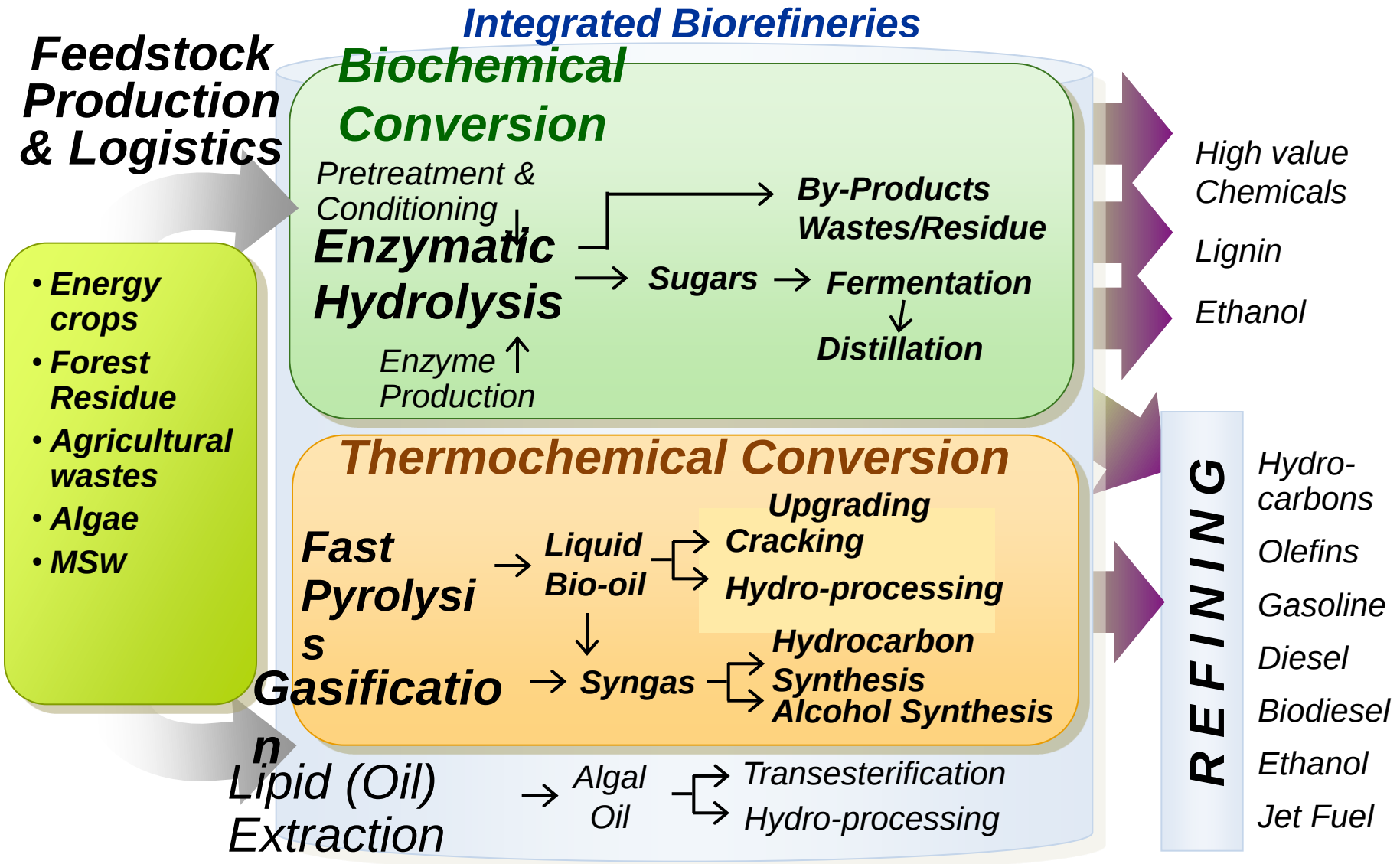


Strategic Analysis

Conduct market, policy, environmental, and other analyses to inform planning and decisions.



Routes to Convert Biomass

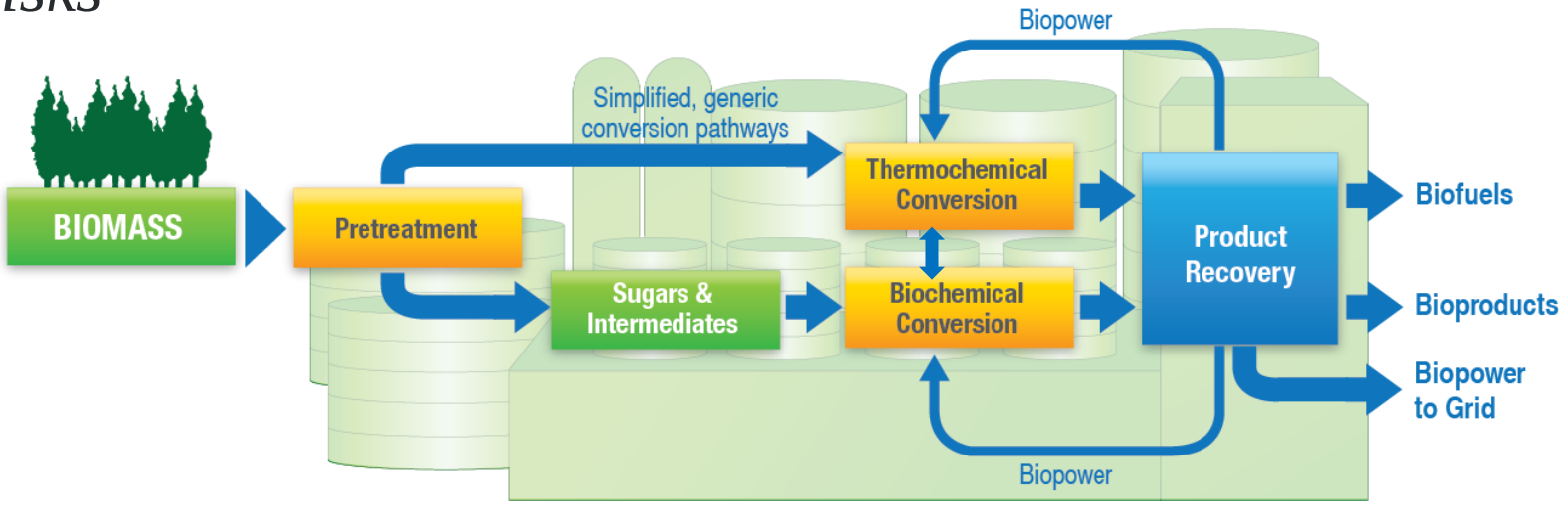


Research on multiple conversion pathways is improving the efficiency and economics of biofuels production.

Innovation is Challenging and Involves Risks

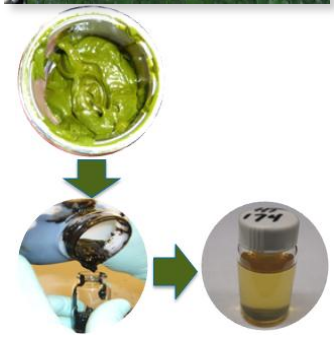
De-risking of technologies is central to R&D into and through demonstration, addressing greater integration and scale:

- *BETO is focusing on advancing more technologies, including renewable gasoline, diesel, and jet fuels*
- *Technical, construction, operational and financial/market risks*



Biomass Key Challenges	Pretreatment Key Challenges	Conversion Key Challenges	Product Key Challenges
•Reliable supply •Consistent quality •Affordable delivery	•Biomass feeding •Biomass sizing and moisture •Solids handling •Construction materials	•Products Yields •Construction materials •Catalysts •Fermentation organisms	•Separations •Catalytic upgrading •Recycle loops

FY14 Algae Activities



Manage Applied R&D in Commercially Relevant Scales:

- Algae Testbed Public-Private Partnership (led by Arizona State University) and Regional Algal Feedstock Testbed Partnership (led by University of Arizona) (FY12 $15M, FY13 $8M) – Year 2 activities
- Advancements in Algal Biomass Yield (ABY) Projects (FY13 16.5M) – Year 1 activities
- Hawaii Bioenergy, Sapphire Energy (NM), California Polytechnic State University, and New Mexico State University
- Projects have successfully completed validation and are beginning work on integrating R&D on increased biological productivity, efficient harvest and preprocessing, and decreased capital & operating costs

Conduct Data Validation to improve Office Analyses:

- Validate Office techno-economic models using algae biorefinery data (Sapphire Energy and Algenol) in order to inform DOE baseline metrics and better evaluate performer successes (FY14 $435k)
- Use data at scale to develop techno-economic analyses of promising new technologies – Algal Lipid Extraction and Upgrading, and Whole Algae Hydrothermal Liquefaction (included in National Lab FY14 budget)

Increase Portfolio Diversity:

- Select Algal Biomass Yield (ABY) alternates (FY14 $7M) and co-manage with Conversion an algal- Carbon, Hydrogen, and Separations Efficiencies (CHASE) alternate (FY14 $1.5M) to increase probability of successful solutions.

Support R&D Breakthroughs: (FY14 $9M)

- Continue directing R&D at DOE national labs
- Accelerate innovation pipeline with incubator/seed projects to capture potential of currently off-roadmap technologies

Garner Stakeholder Input to Refine MYPP Planning:

- Convened the Algal Biofuels Strategy Workshop Nov 19-20 in Mesa, Arizona, attended by 29 university, 17 national laboratory, 25 industry, 4 advocacy, and 13 government stakeholders
- A second workshop will be held March 26-27 in Charleston, SC
- Plan for refinement of Multi-Year Program Plan based on input from workshops and the 2013 peer review.

Defense Production Act (DPA) Initiative

In July 2011, the Secretaries of Agriculture, Energy, and Navy signed an Memorandum of Understanding to commit $510 M ($170 M from each agency) to produce hydrocarbon jet and diesel biofuels in the near term. This initiative sought to achieve:

- *Multiple, commercial-scale integrated biorefineries*
- *Cost-competitive biofuel with conventional petroleum (w/o subsidies)*
- *Domestically produced fuels from non-food feedstocks*
- *Drop-in, fully compatible, MILSPEC fuels (F-76, JP-5, JP8)*
- *Help meet the Navy's demand for 1.26 billion gallons of fuel per year*
- *Contribute to the Navy's goal of launching the "Great Green Fleet" in 2016*

DOE has a $45M appropriation for DPA in FY14

The first projects selected under DPA are:

Company	Location	Feedstock	Conversion Pathway	Capacity (MMgpy)
Emerald Biofuels	Gulf Coast	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	94.0
Natures BioReserve	South Sioux City, NE	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	65.8
Fulcrum Bioenergy	Western United States	Municipal Solid Waste	Gasification – Fischer Tröpsch (FT)	17.0
Red Rock Biofuels	Lakeview, OR	Woody Biomass	Gasification – Fischer Tröpsch (FT)	16.0

Inter- and Intra-agency Collaboration

The DOE Bioenergy Technologies Office partners with other government agencies and other offices within DOE to advanced the development of an advanced biofuels industry.

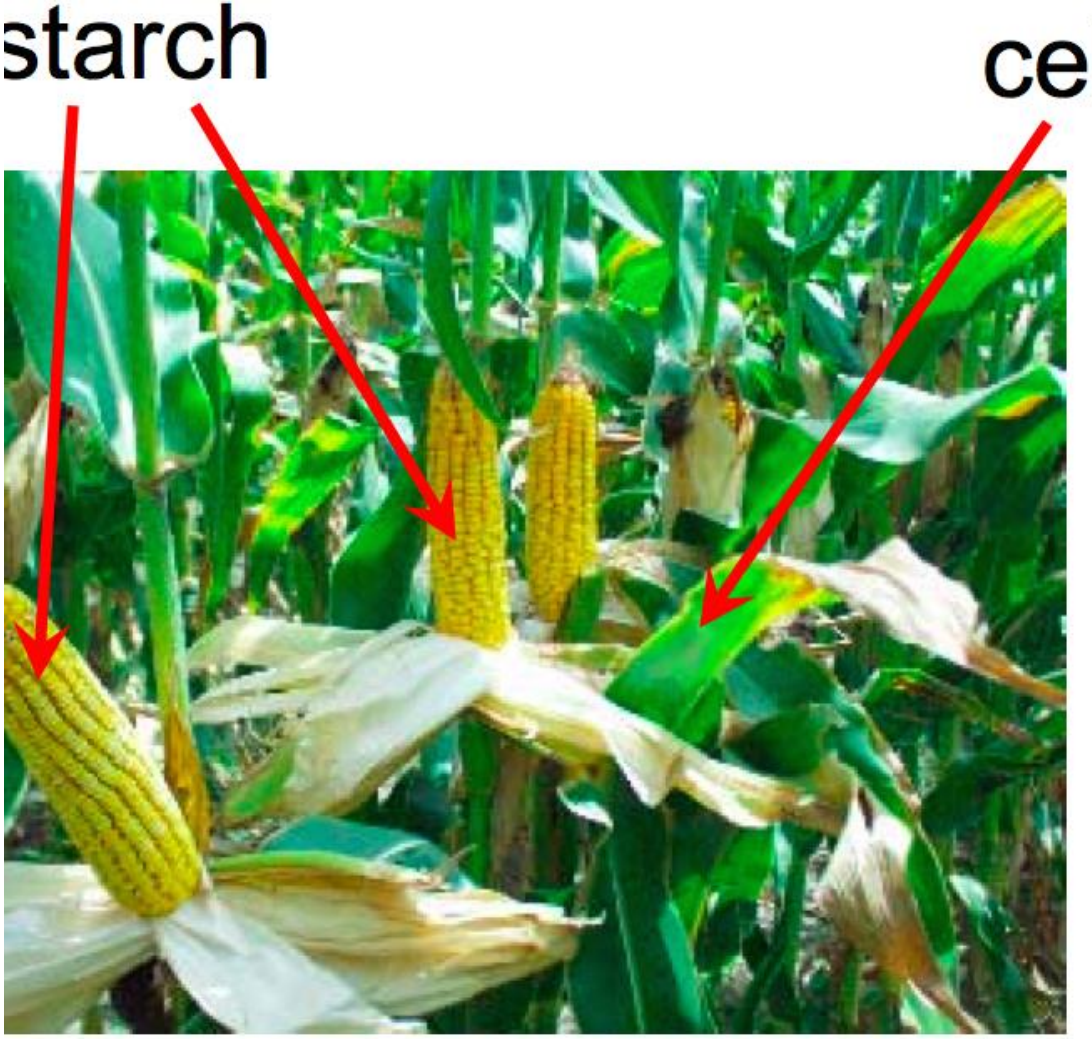
Federal Collaboration

- *Biomass Research & Development Board*
- *Offices and programs within the following:*
  - *Department of Agriculture*
  - *Department of Defense*
  - *Department of the Interior*
  - *Department of Transportation*
  - *Environmental Protection Agency*
  - *National Aeronautics and Space Administration*
  - *National Science Foundation*
  - *Office of Science and Technology Policy*

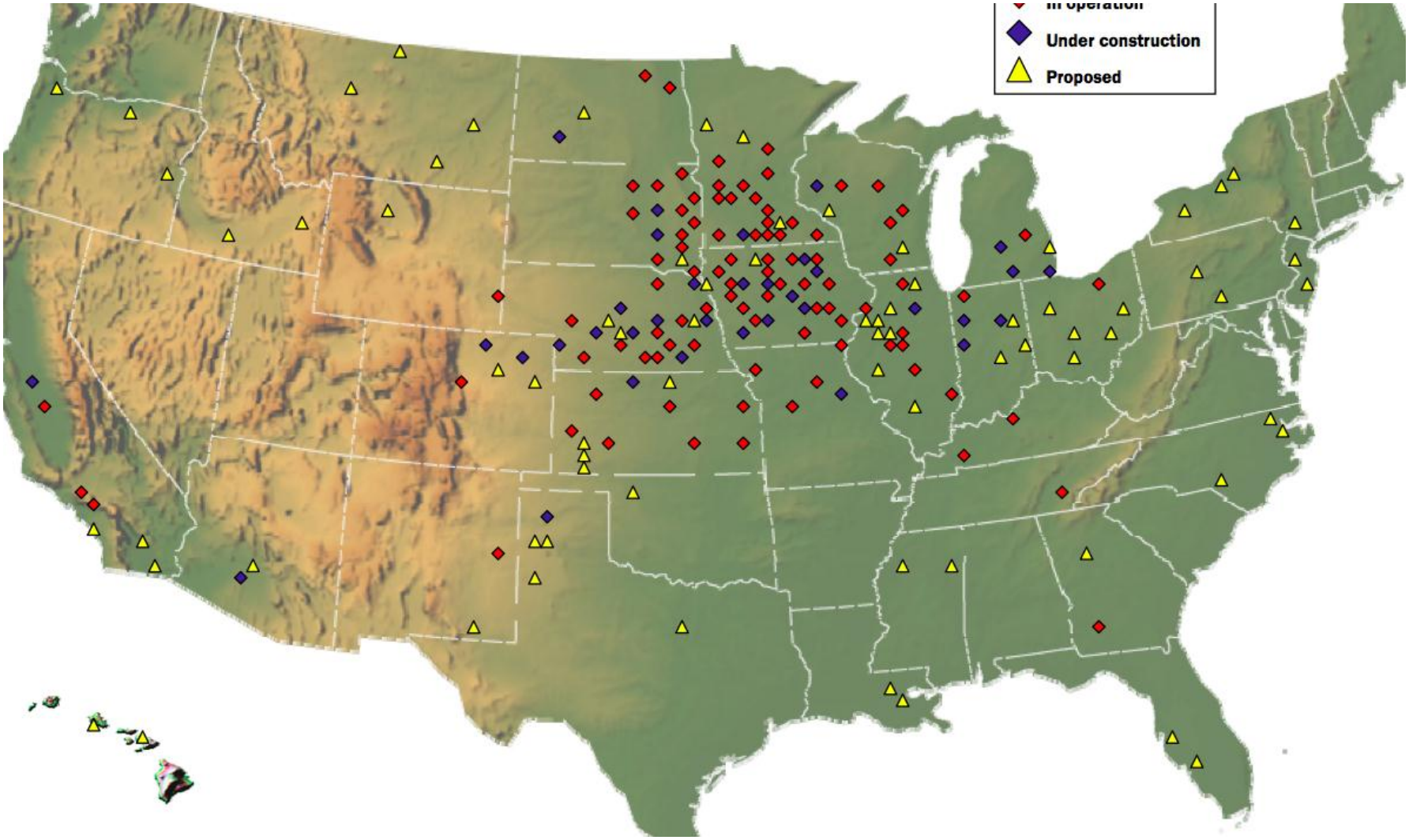
DOE Internal Collaboration

- *Energy Efficiency and Renewable Energy*
- *Bioenergy Technologies Office*
- *Vehicle Technologies Office*
- *Advanced Manufacturing Office*
- *Fuel Cell Technologies Office*
- *Fossil Energy*
- *Office of Science*
- *ARPA-E*
- *Energy Information Administration*

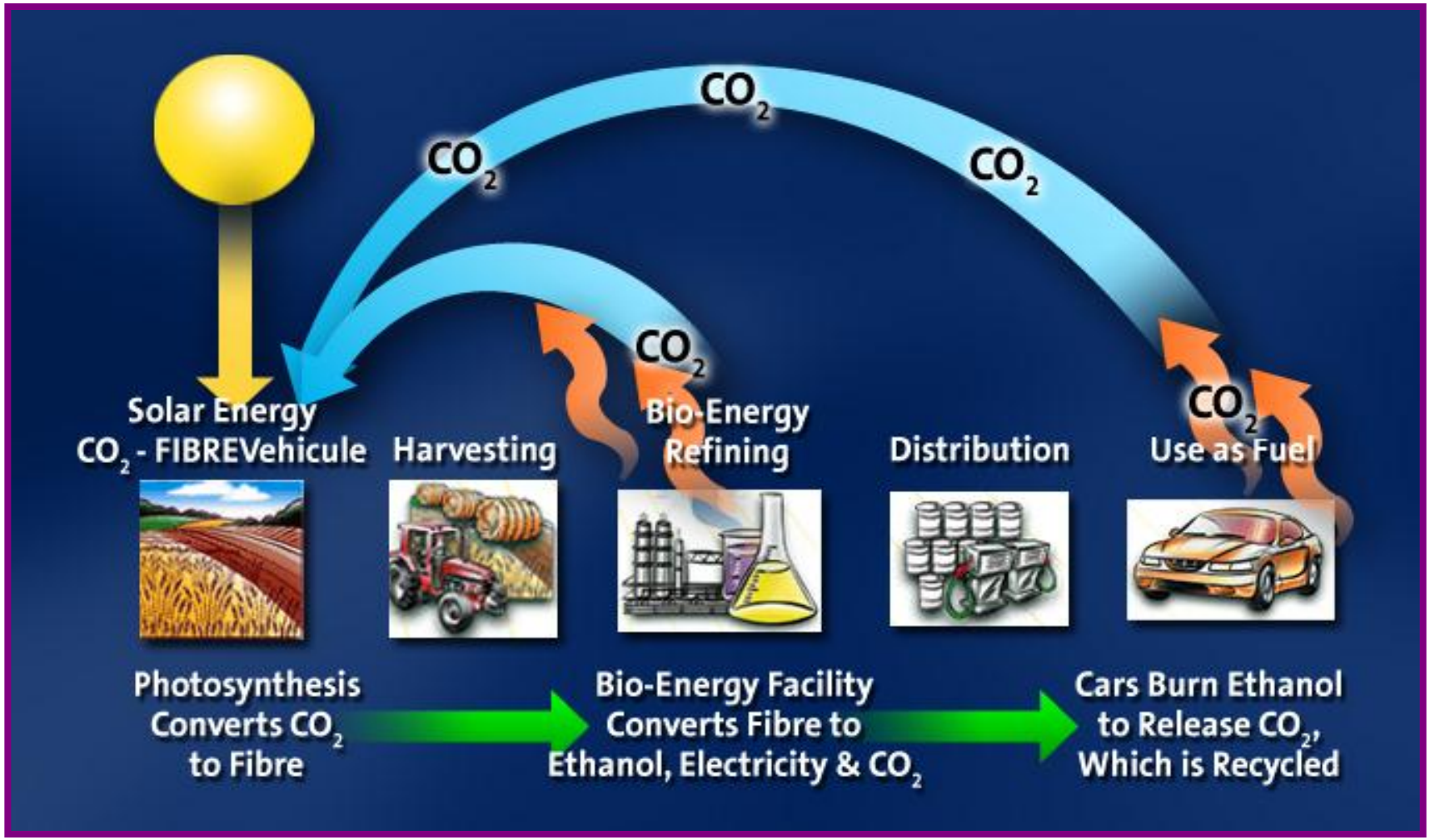
Only Economic Approach is Currently Use of Starch



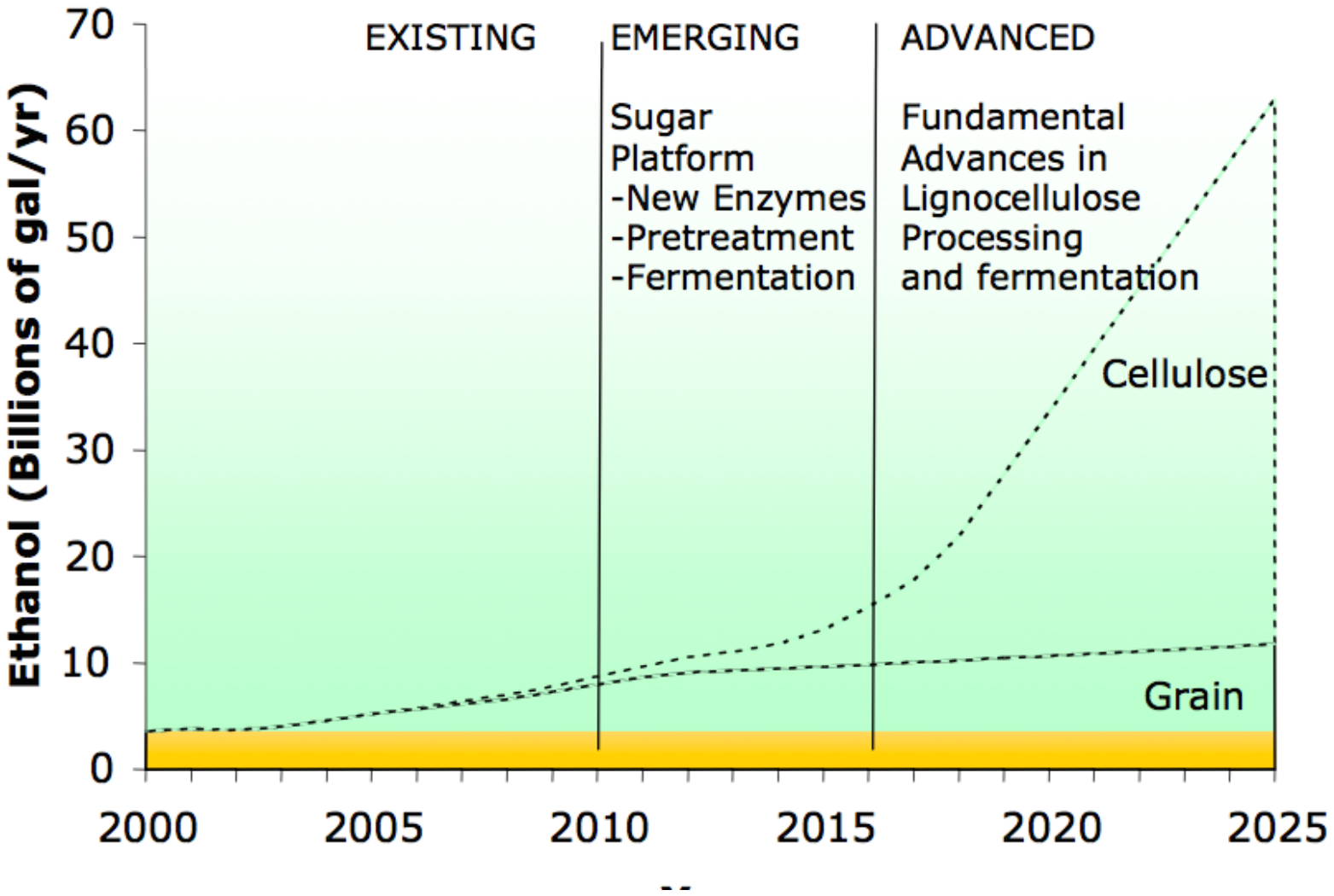
Corn to Ethanol Facilities



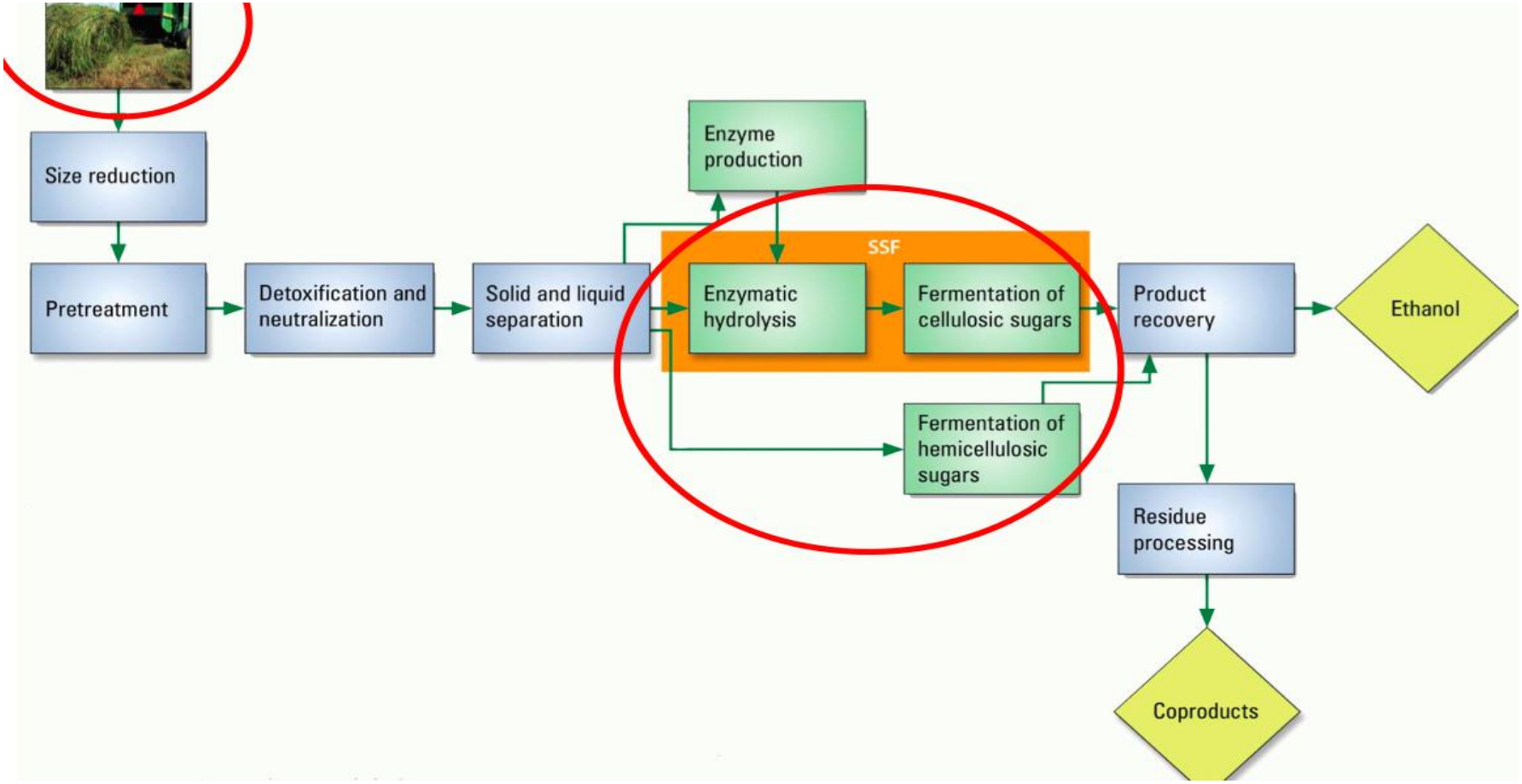
Well-to-Wheels Analysis – Ethanol System



DOE Vision

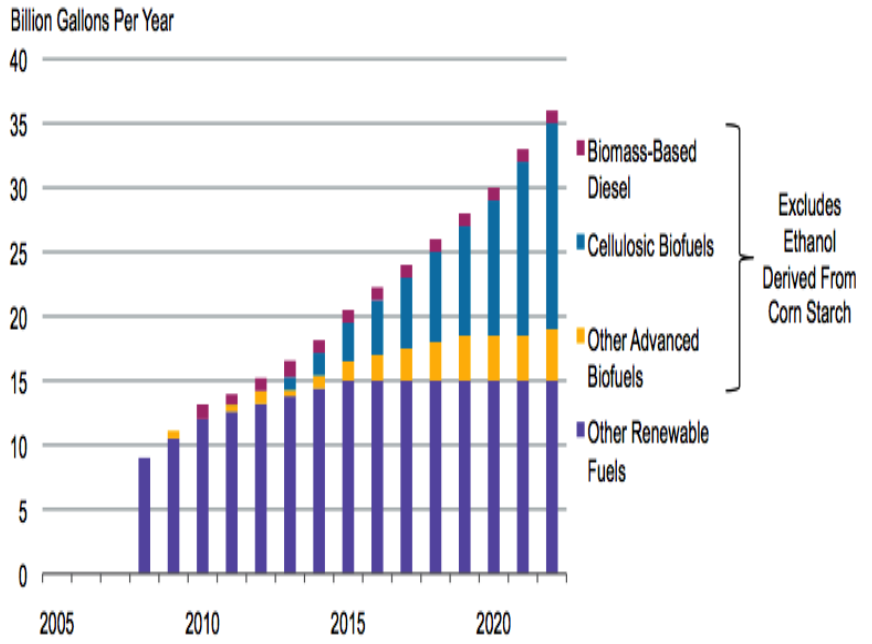

EXISTING
EMERGING
ADVANCED
Sugar Platform
-New Enzymes
-Pretreatment
-Fermentation
Fundamental Advances in Lignocellulose Processing and fermentation
Cellulose
Grain
Ethanol (Billions of gal/yr)
70
60
50
40
30
20
10
0
2000
2005
2010
2015
2020
2025

Process for Conversion on Cellulosic Materials

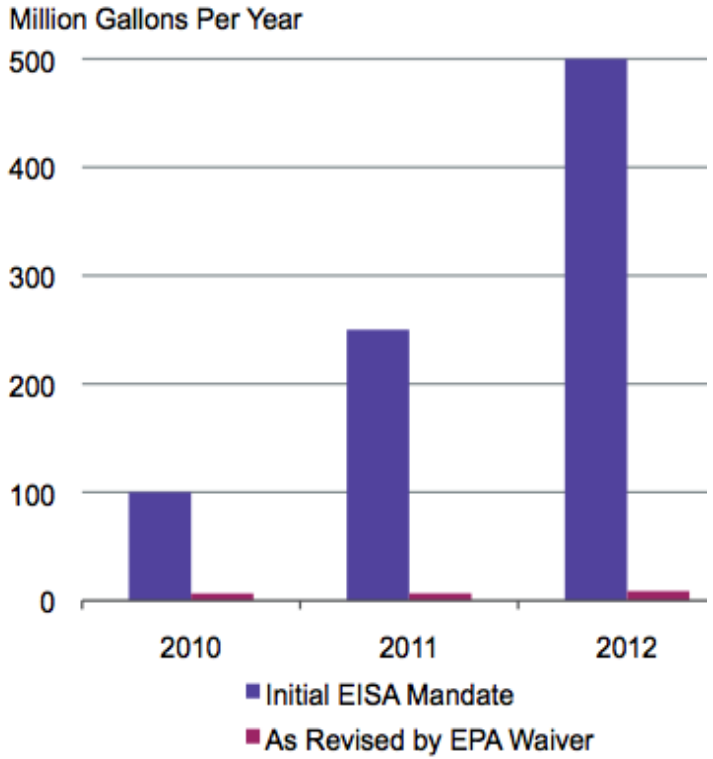


Serious Shortfall in Cellulosic Production for Liquid Fuels Vs. Mandates, BUT Dupont Starting Up Facility

Figure 2-21: Renewable Fuel Standard (RFS2) Volume Requirements



Source: Randy Schnepf and Brent D. Yacobucci, Congressional Research Service, *Renewable Fuel Standard (RFS): Overview and Issues*, January 2012, R40155, 3, http://www.fas.org/sgp/crs/misc/R40155.pdf.



Source: Randy Schnepf and Brent D. Yacobucci, Congressional Research Service, *Renewable Fuel Standard (RFS): Overview and Issues*, January 2012, R40155, 3, http://www.fas.org/sgp/crs/misc/R40155.pdf.

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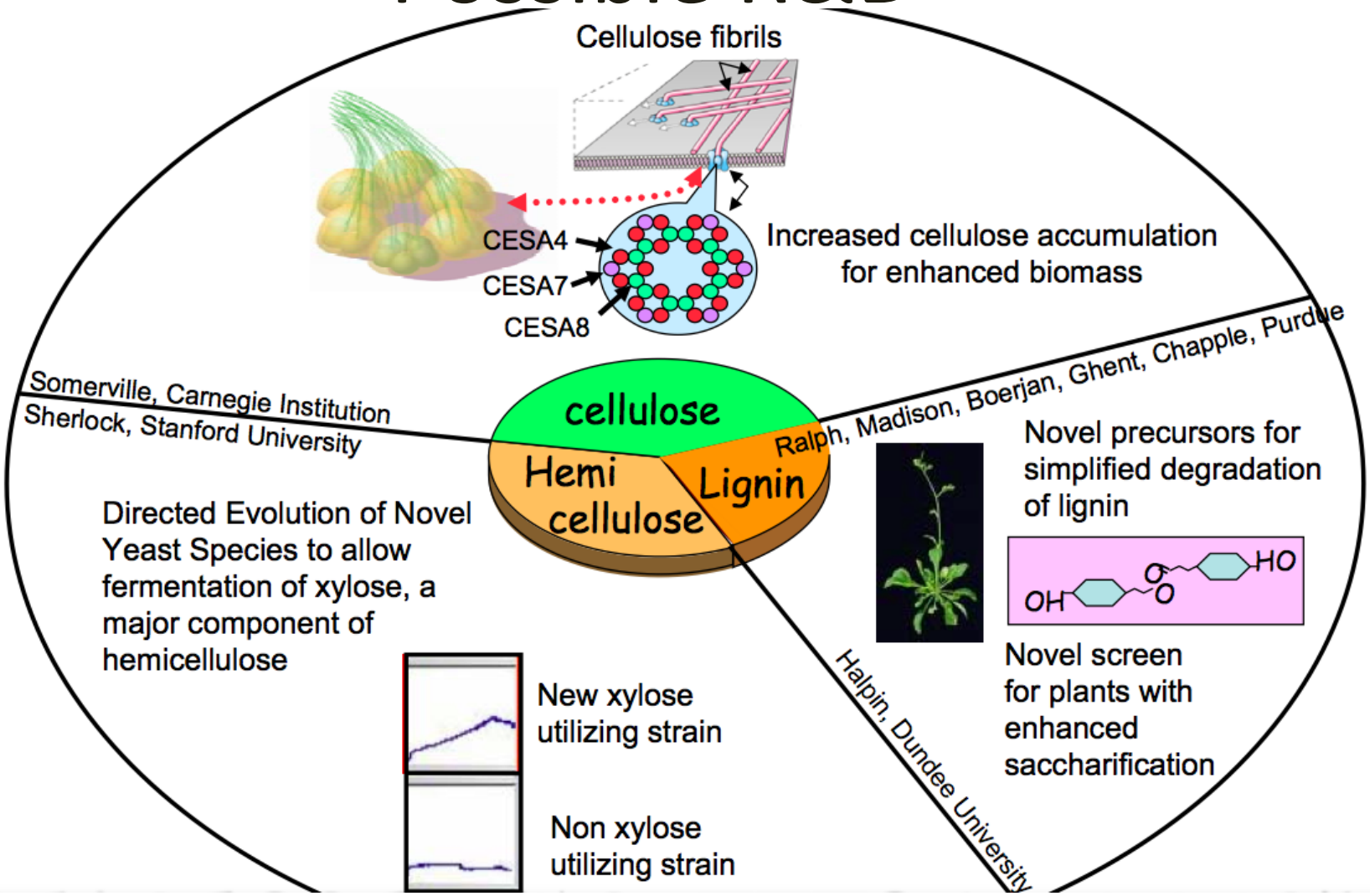
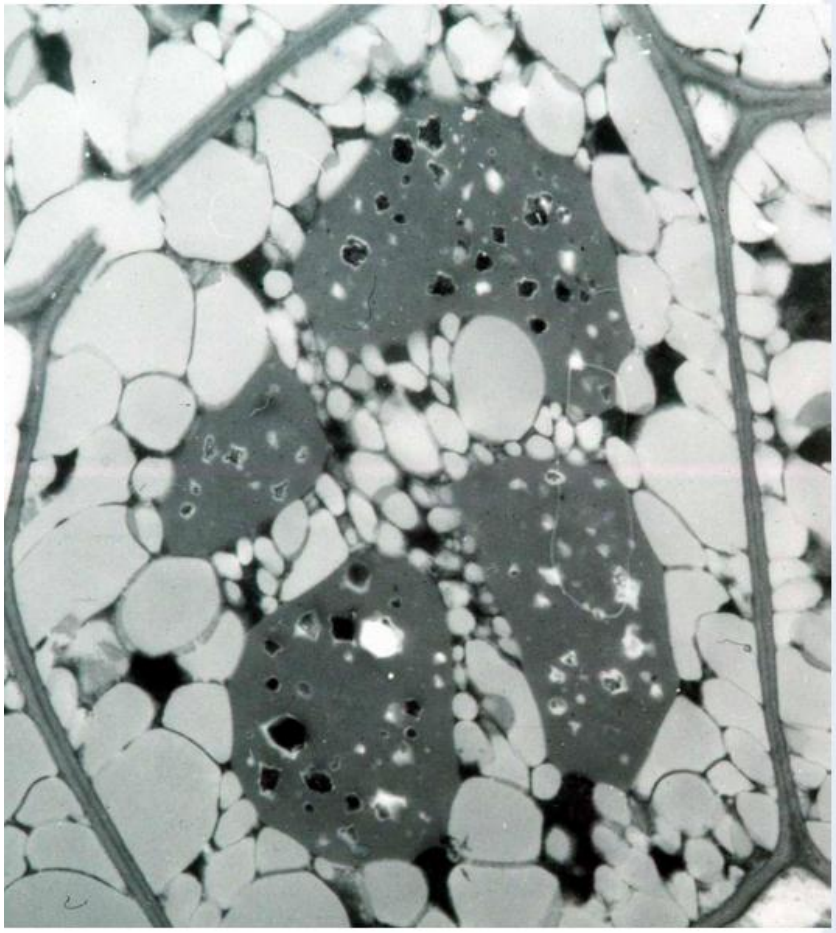
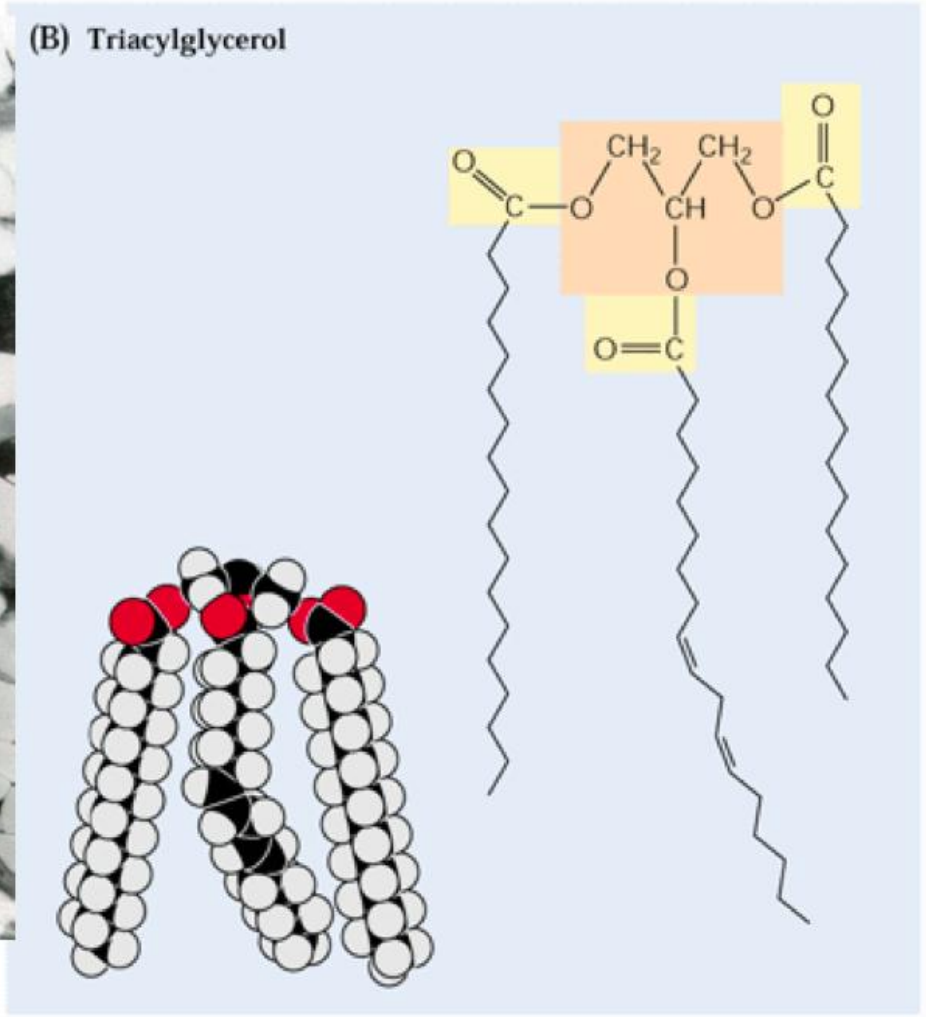
Possible R&D

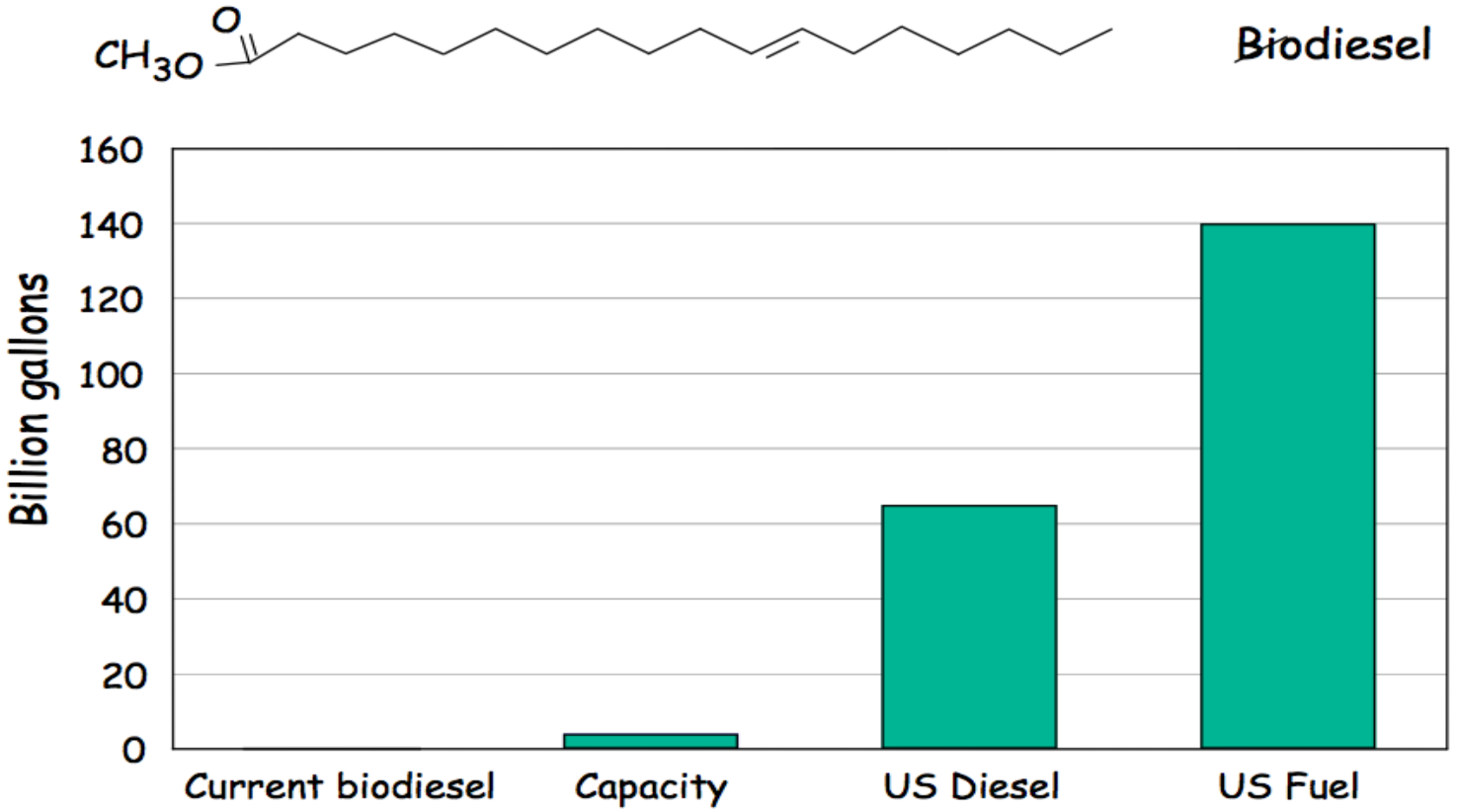

Cellulose fibrils
CESA4
CESA7
CESA8
Increased cellulose accumulation for enhanced biomass
Somerville, Carnegie Institution
Sherlock, Stanford University
cellulose
Hemi cellulose
Lignin
Ralph, Madison, Boerjan, Ghent, Chapple, Purdue
Directed Evolution of Novel Yeast Species to allow fermentation of xylose, a major component of hemicellulose
New xylose utilizing strain
Non xylose utilizing strain
Novel precursors for simplified degradation of lignin
HO
OH
O
O
Novel screen for plants with enhanced saccharification
Halpin, Dundee University

Biodiesel





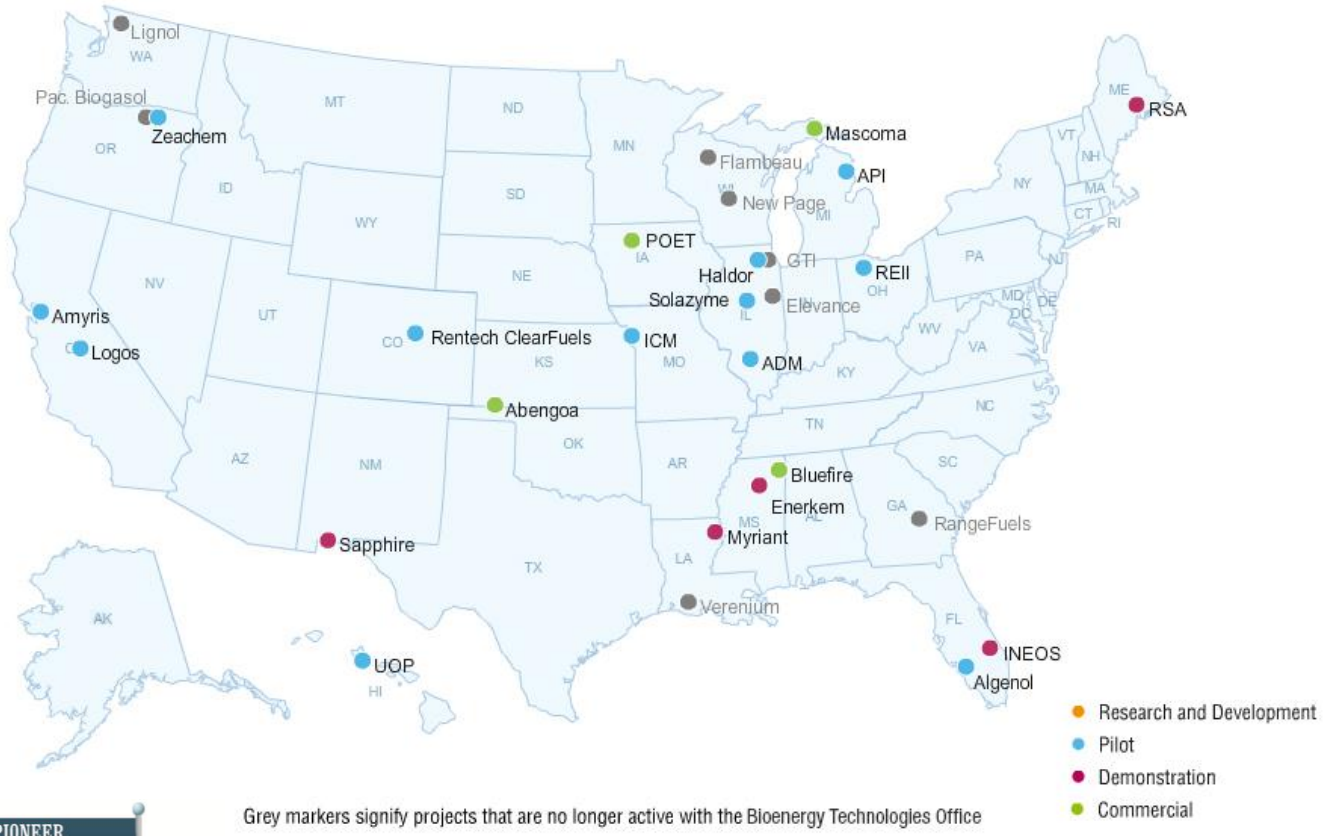
Shortage of Domestic Biodiesel from Either Natural Resources or Industrial Use



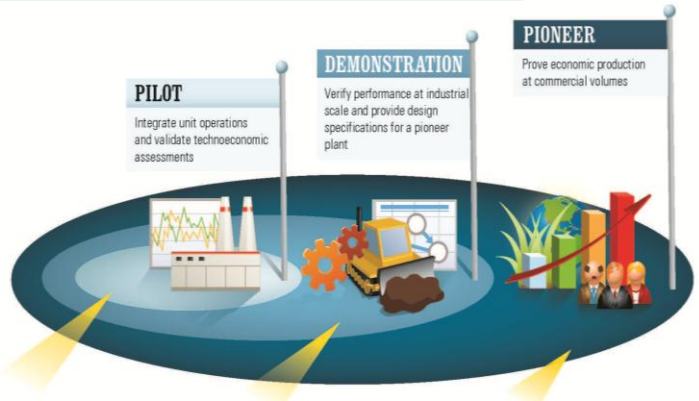
BETO-Funded Demonstration Portfolio

- *The Integrated Biorefineries (IBR) program manages a diverse portfolio of demonstration projects focused on the scale-up of biofuels production technologies from pilot- to demonstration- to pioneer-scale.*
- *Of the total 33 biorefineries that have received funding through BETO, 3 have been completed, 5 are in close-out, and 5 have either been terminated or withdrawn.*
- *The remaining 20 IBRs are considered active and utilize a broad spectrum of feedstocks and conversion techniques.*

Map of BETO-funded Demonstration Projects



Grey markers signify projects that are no longer active with the Bioenergy Technologies Office



For more information visit:
http://www.eere.energy.gov/biomass/integrated_biorefineries.html

Note: 4 iPilot Projects do not appear on this map

New BETO Initiatives

Renewable Carbon Fiber

•*DOE is working to produce innovative new materials from biomass, by utilizing sugars, lignin, and other biorefinery products, to enhance industry economics*

Incubator Program

•*DOE is creating a dedicated, annual funding mechanism to support innovative technologies that are not represented in DOE's existing technology portfolio*

Waste-to-Energy (WTE)

•*DOE is focusing on near-term market entry opportunities to WTE technologies in the U.S., specifically with regard to anaerobic digestion at landfills to recycle organic waste biomass into renewable energy*

Natural Gas-Biomass to Liquids

•DOE is exploring opportunities to combine biomass with low-cost natural gas for the production of liquid fuels

Replenishing the Demonstration at Scale Portfolio

•Driving the R&D successes on the pyrolysis of biomass to bio-oils to market through a new Funding Opportunity Announcement on scaling up and integrating advanced biomass technologies

Renewable Aviation Fuels

•DOE is working with the Federal Aviation Administration, and the Commercial Aviation Alternative Fuels Initiative to support the development of bio-based jet fuels