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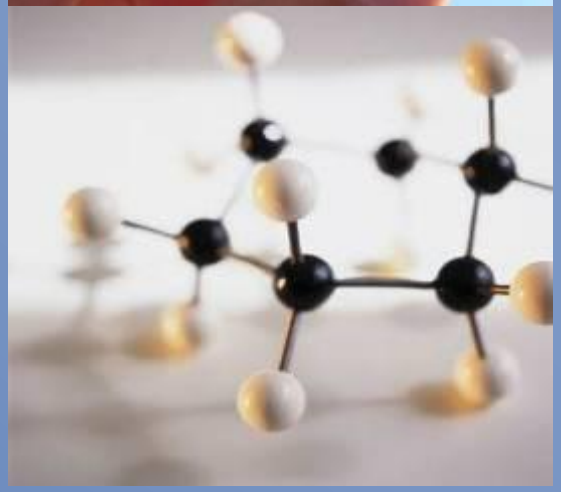
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable






The US Biomass Energy Program –Transition to the Development and Implementation of Fungible Fuel Technologies

August 24, 2009

Paul Grabowski

2009 Program Priorities

Science & Discovery

- Connecting basic and applied bioscience
- Conducting breakthrough R&D:
  - Advances in enzymes and catalysis
  - Engineering of new microorganisms
  - Novel sustainability indicators

Clean, Secure Energy

- Developing & demonstrating cellulosic and advanced biofuels to meet RFS

Economic Prosperity

- Creating 50 to 75 jobs per new biorefinery
- Creating major new energy crop markets
- Reinvigorating rural economies

Climate Change

- Reducing GHG emissions by up to 90% with advanced biofuels (relative to gasoline)

Where We Are Going

Our Goal:

136 billion liters (36 billion gallons)/year of biofuels by 2022

Our path forward:

- Integrated programs R&D to solve technical barriers
  - Applied research for short- and mid-term impact
  - Fundamental research for longer-term impact
- Cost-shared programs with industry to reduce risk

Sustainability is highly important criteria in all aspects of the DOE Program

US DOE Biomass Program

Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels End Use




Mission Statement

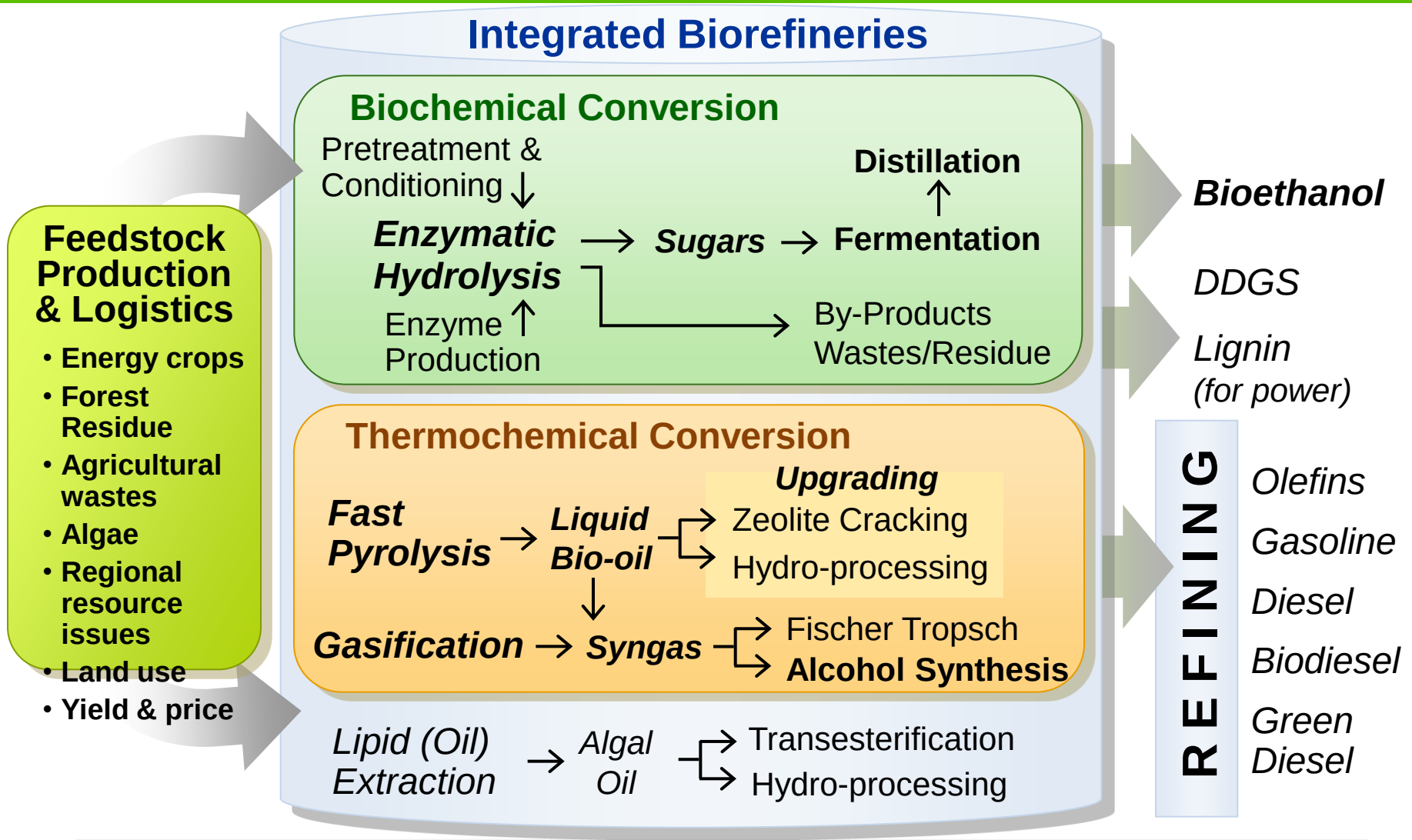
Develop and transform our renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower. Conduct targeted research, development, and demonstrations, leading to deployment in integrated biorefineries, supported through public and private partnerships.

Cellulosic Biofuels: **Transition to** biofuels that are fungible with current fuel infrastructure (infrastructure compatible). Biomass-derived (renewable) gasoline, diesel and jet.

First Need – Abundant, Low Cost Feedstock

- Dry Herbaceous – Agriculture Residues/Crops at less than 15% moisture
- Energy Crops – Wet, Dry, and Woody
- Woody – Forest resources and woody energy crops
- Increase sustainably harvested feedstock.
- Integrating feedstock production, and Conversion (TC, BC).
- Economic assessment of production costs, including logistics.

Routes to Convert Cellulosic Biomass



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

Sustainability Research Priorities

Biomass R&D Board Interagency Sustainability Working Group - Engaged in U.S. Government partnership to identify biofuels sustainability indicators

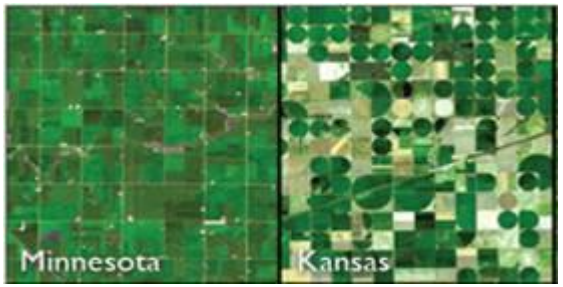
Indirect Land Use - Developing models to help study international land use impact of domestic biofuels production and mandates

Climate Change - Conduct life cycle analysis (LCA) of biofuels production and use through a wide range of existing and future production pathways

Water - Conducting LCA of water demand for biofuel production (compares corn ethanol, sugarcane ethanol, and competing petroleum fuels)

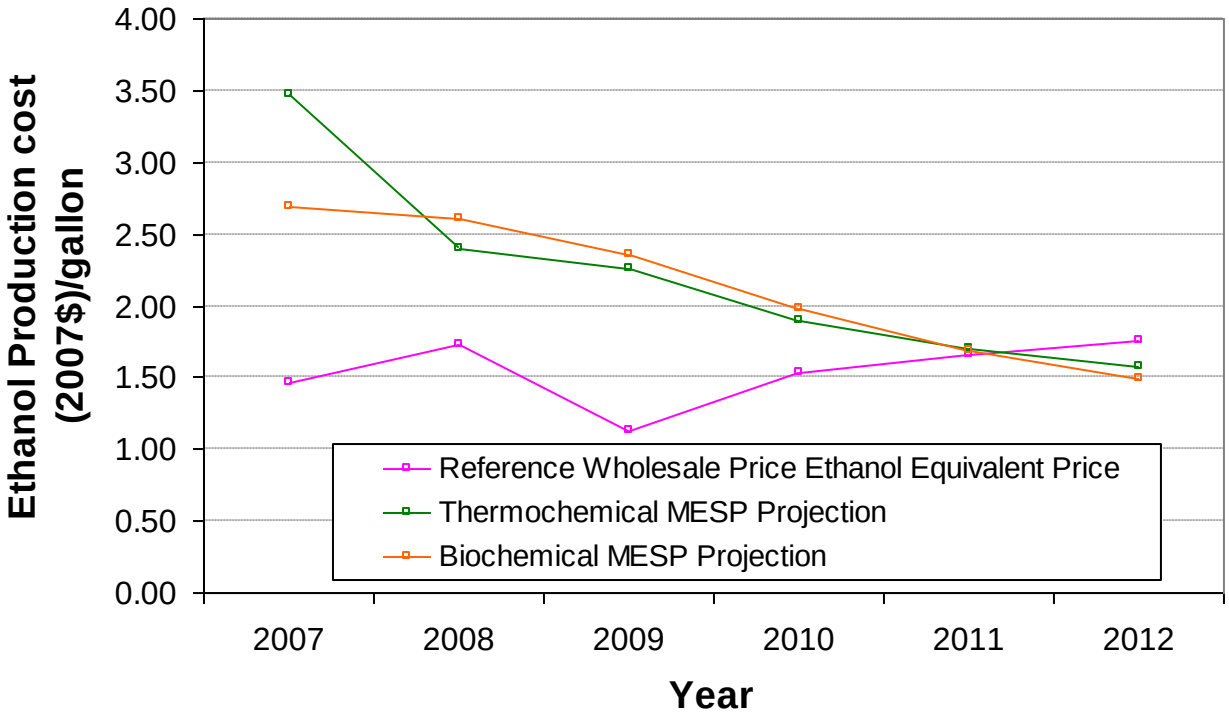
Biodiversity – Study impact of biofuels industry growth on biodiversity and sensitive ecosystems

GIS Tools - Developing GIS tools to analyze current and future U.S. feedstocks, infrastructure availability, and economic and environmental sustainability



Addressing sustainability challenges is critical to industry growth.

Program Cost Targets



2012 = $1.76/gal ethanol equivalent
•Reference wholesale price

- Based on the high and reference case of wholesale motor gasoline cost corrected for the energy density of ethanol

EIA Annual Energy Outlook 2009

Program Directions

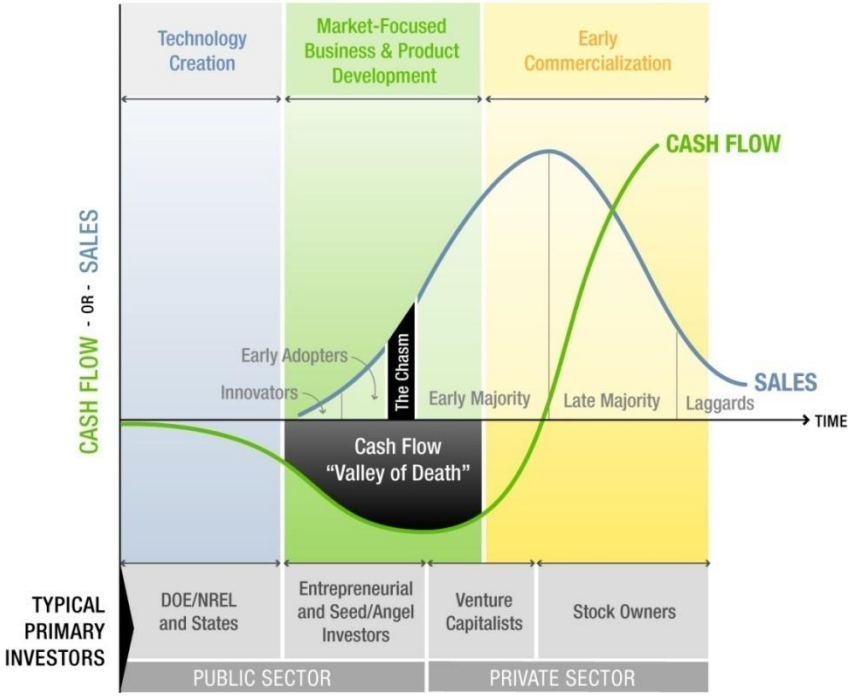
Thermochemical

- **By 2012, gasification-to-ethanol will achieve a conversion cost of $0.86/gal for ethanol…(~$1.31/gal gasoline equivalent - wholesale price)**

- **By 2015 pyrolysis and/or gasification should be achieving a conversion of around $1.45 (per gal gasoline-wholesale price)**

Commercial-Scale Biorefineries

- Validate modeled ethanol production cost and compare to targets.
- Demonstrate and validate integrated biorefineries across various pathways with at least three plants in successful operation by 2012.
  - Four cost-shared, integrated biorefinery demonstration projects to produce about 100 million gallons of cellulosic ethanol in 5 years using variety of conversion technologies and cellulosic feedstocks
  - DOE efforts are paving the way for a strong, domestic bioenergy industry



Future Program Directions

Biochemical

- **Continued focus on the technical barrier areas for cost targets.**
- **Transition to other cellulosic (fungible??)**

Algal

- **Initiate RD&D for algae, lipid, and fuels production**

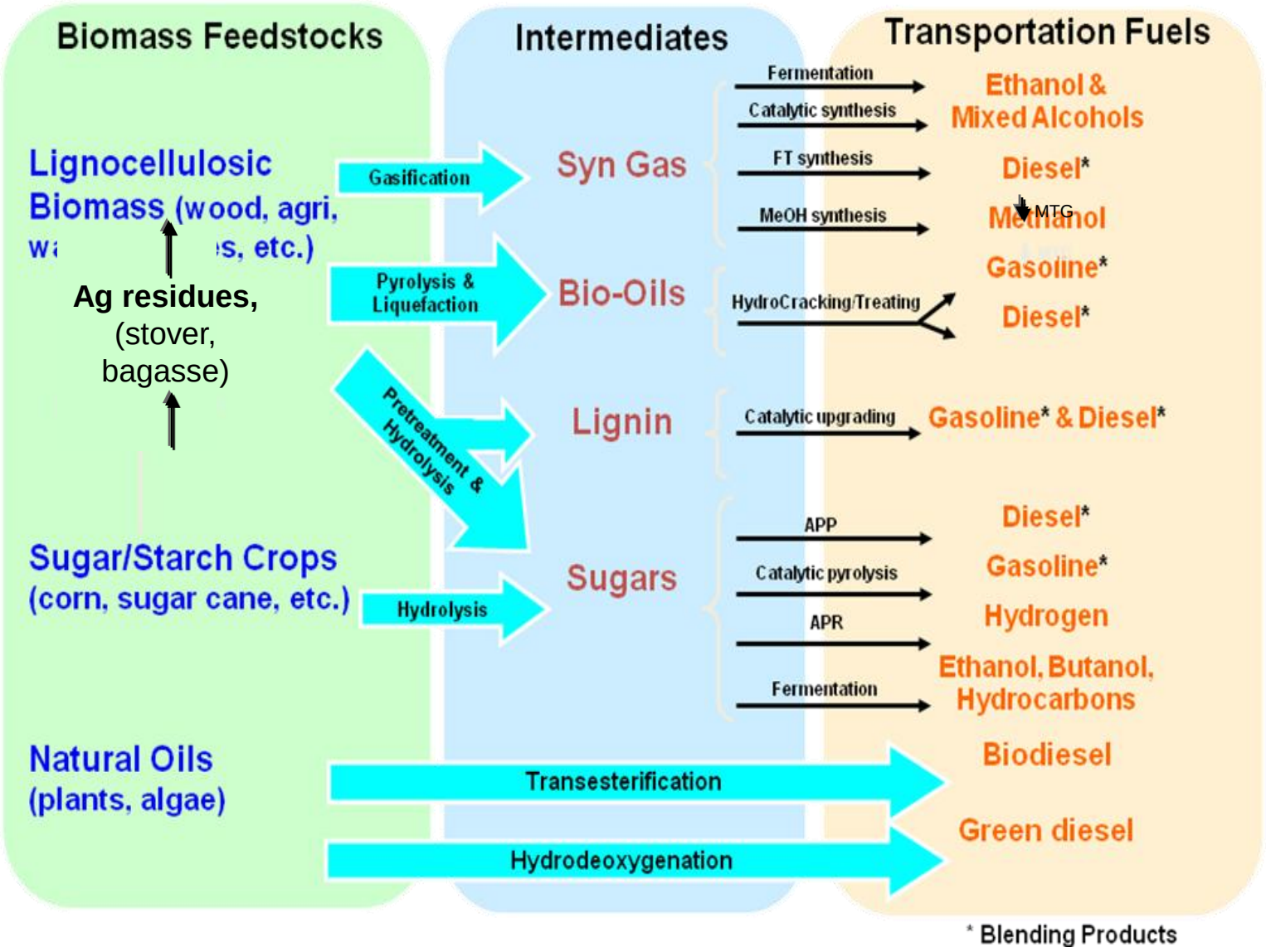
Thermochemical

- **Currently heavily focused on meeting the 2012 ethanol cost targets**
- **Transition to infrastructure compatible biofuels.**
- **Modest effort in pyrolysis and Fischer-Tropsch fules currently underway.**
- **Accelerating in FY10**

Integrated Biorefineries

- **Recently closed solicitation - Expect to see proposals that yield infrastructure compatible biofuels**

Transportation Options For Biofuels



Recovery Act Funding for Acceleration of RD&D

$480M Pilot and Demonstration-Scale Biorefineries

10 to 20 awards for refineries to be operational within 3 years

$176.5M Commercial-Scale Biorefineries

Two or more projects

Expedite construction, commissioning and start-up

$110M Fundamental Research

$5M Sustainability research with the Office of Science

$20M Integrated Process Development Unit

$85M Advanced Fungible Biofuels Technology Consortium

$20M Ethanol Infrastructure Research

Optimize flex-fuel vehicles operating on E85

Evaluate impacts of intermediate blends on conventional vehicles

Upgrade existing infrastructure for compatibility with E85

Recovery Act Funding for Acceleration of RD&D

Solicitation for Algal and Advanced Biofuels ($85M)

- New technologies for advanced biofuels
- Compatible with today's fueling infrastructure
- Partnerships of universities, private industry, and government to develop and to market new biofuels.
- Engage end users and other field experts US-lead partnerships encouraged to include foreign partners (**best-in-class**)
- Accelerate timeframe to bring new biofuels to market.
- Two to three partnerships over three years.

Two Targeted Areas

- **Algal Biofuels R&D**
  - Algae-based biofuels that are competitive with petroleum-based fuels.

- **Advanced, Infrastructure-Compatible Biofuels R&D**
  - Conversion technologies for non-ethanol biofuels
  - bio-based hydrocarbon fuels such as green gasoline, diesel, jet.

Call is currently open

Reference Number DE-FOA-0000123.

http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=210

Normal Appropriations

FY2010?

FY2011 ?

Initiatives?

Information Resources

Office of Biomass Program, John Ferrell - Program Manager

Paul Grabowski - paul.grabowski@ee.doe.gov, 202-586-0478

Web Site: http://www1.eere.energy.gov/biomass/

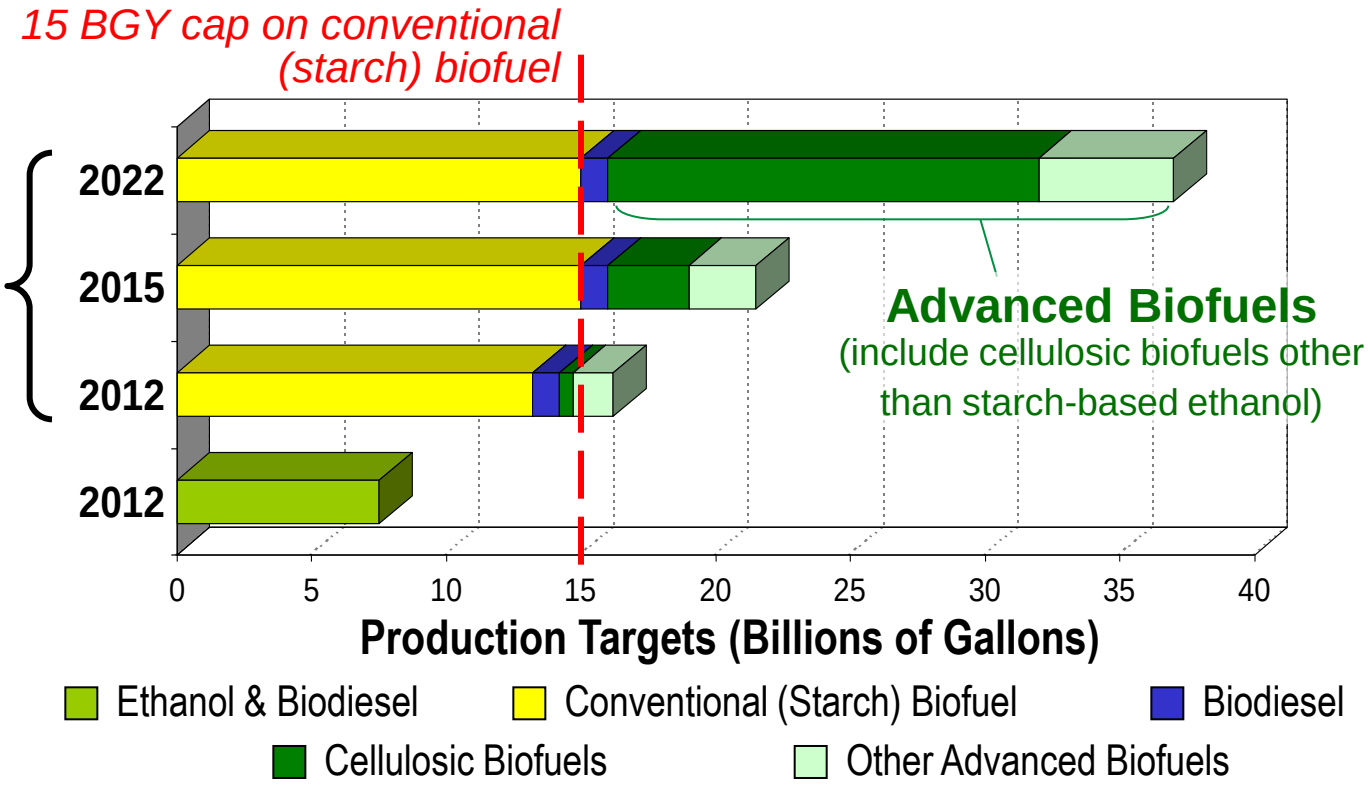
- EERE Info Center - www1.eere.energy.gov/informationcenter
- Alternative Fuels Data Center - http://www.eere.energy.gov/afdc/fuels/ethanol.html
- Bioenergy Feedstock Information Network - http://bioenergy.ornl.gov/
- Biomass R&D Initiative – www.biomass.govtools.us
- Grant Solicitations - www.grants.gov
- Office of Science - http://www.er.doe.gov/
- Loan Guarantee Program Office - http://www.lgprogram.energy.gov

Back Up Slides*

EISA Mandated Production Targets

Renewable Fuel Standard (RFS) in the Energy Independence and Security Act (EISA) of 2007

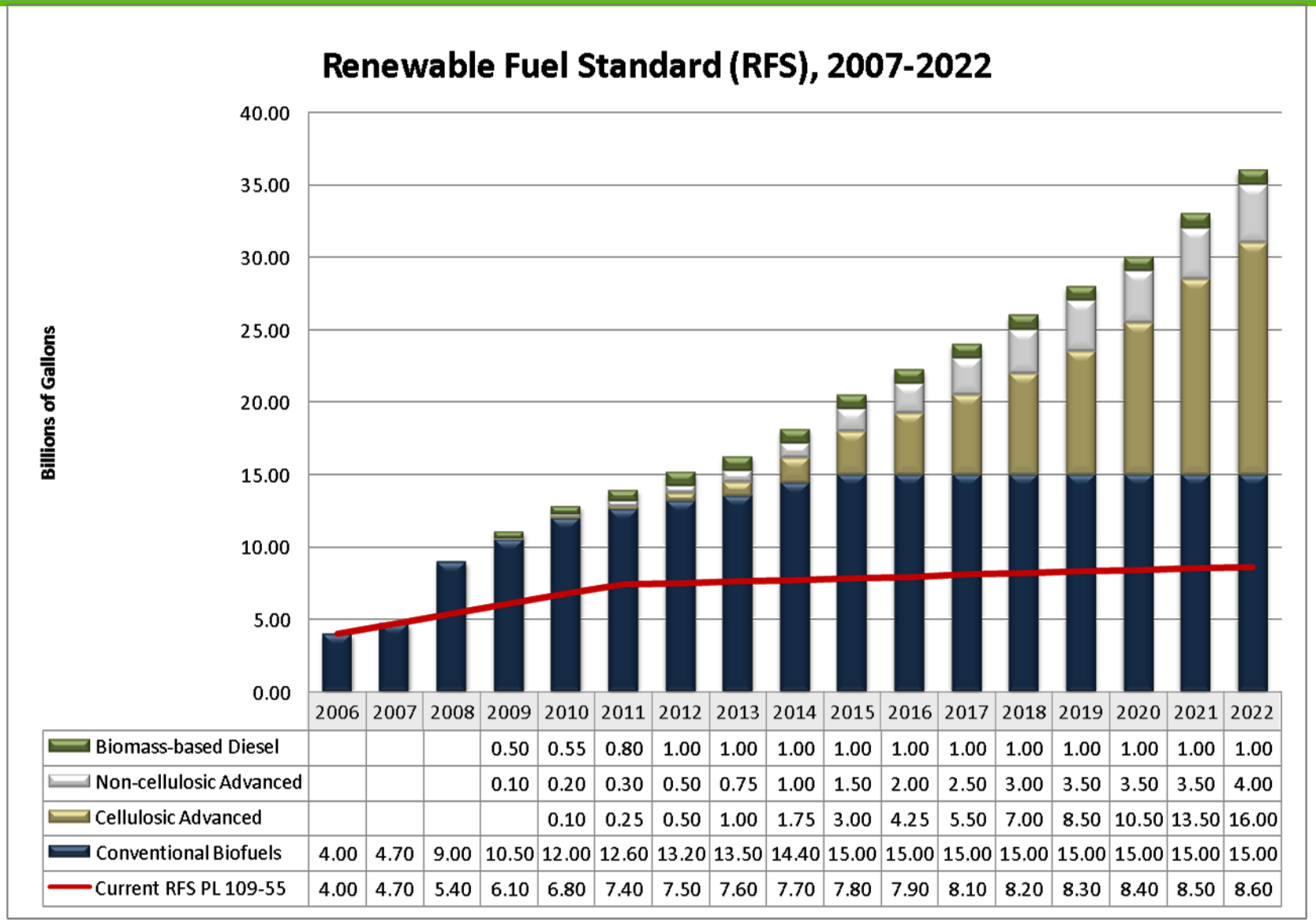
EPAct 2005



EISA defines ***Cellulosic Biofuel*** as "renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions…that are *at least 60 percent less* than baseline lifecycle greenhouse gas emissions."

EISA defines ***Advanced Biofuel*** as "renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions…that are *at least 50 percent less* than baseline lifecycle greenhouse gas emissions."

Renewable Fuel Standard – Annual Volumes



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass-based Diesel				0.50	0.55	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-cellulosic Advanced				0.10	0.20	0.30	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	3.50	3.50	4.00
Cellulosic Advanced					0.10	0.25	0.50	1.00	1.75	3.00	4.25	5.50	7.00	8.50	10.50	13.50	16.00
Conventional Biofuels	4.00	4.70	9.00	10.50	12.00	12.60	13.20	13.50	14.40	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Current RFS PL 109-55	4.00	4.70	5.40	6.10	6.80	7.40	7.50	7.60	7.70	7.80	7.90	8.10	8.20	8.30	8.40	8.50	8.60

Source: Hart Energy Consulting, Government Affairs, 2007

Renewable Fuel Definitions

From EIA's glossary

- **Renewable diesel fuel (other):** Diesel fuel and diesel fuel blending components produced from renewable sources that are coprocessed with petroleum feedstocks and meet requirements of advanced biofuels. **Note:** This category "other" pertains to the petroleum supply data system.
- **Renewable fuels (other):** Fuels and fuel blending components, except biomass-based diesel fuel, renewable diesel fuel, and fuel ethanol, produced from renewable biomass. **Note**: This category "other" pertains to the petroleum supply data system.
- **Biodiesel:** A fuel typically made from soybean, canola, or other vegetable oils; animal fats; and recycled grease. It can serve as a substitute for petroleum-derived diesel or distillate fuel. For EIA reporting, it is a fuel composed of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM (American Society for Testing & Materials) D 6751.
- **Biomass-based diesel fuel:** Biodiesel and other renewable diesel fuel or diesel fuel blending components derived from biomass, but excluding renewable diesel fuel coprocessed with petroleum feedstocks.

From the EPA

- **Biodiesel -** The Code defines biodiesel as monoalkyl esters of long chain fatty acids derived from plant or animal matter that meet (1) the registration requirements of the Environmental Protection Agency (EPA) for fuel and fuel additives and, (2) ASTM D6751.
- **Biodiesel** - defined as methyl and ethyl esters of fatty acids meeting the requirements of ASTM specification D6751. Also referred to as FAME (fatty acid methyl ester) or, in Europe, as RME (rape seed methyl ester). This definition of biodiesel comes from common usage and energy policy and tax laws of the United States.
  - According to EPAct 2005, renewable diesel is derived from biomass, using the process of thermal depolymerization that meets the following:
  - Registration requirements for fuels and chemicals established by the Environmental Protection Agency under Section 211 of the Clean Air Act (42 U.S.C. 7545)
  - Requirements of the American Society of Testing and Materials (ASTM) D975 or D396.

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Program Areas & Key Challenges

Research & Development

Feedstock Systems

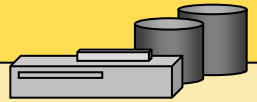
- Diverse regional biomass resources
- Yield & price
- Water & fertilizer
- Land use
- Metrics & standards

Conversion Technologies

Biochemical
- Cost & Efficiency
  - Pretreatments
  - Enzymes/yields
- Fermentation

Thermochemical
- Cost & Efficiency
- Gasification Process
- Fuel Stabilization

Demonstration & Deployment



Integrated Biorefineries

- Integrating process technologies
- Financing
- Technical expertise
- Profit potential

Infrastructure

- Transport
- Storage
- Codes & Standards (Blend wall)
- Demand/ markets
- Compatibility

Product Development

- Fuel purity & cost
- By-products/markets
- Infrastructure compatibility

Sustainability

- GHG emissions
- Water quality
- Land use
- Socioeconomics
- Predictive Modeling
- International

Three Bioenergy Research Centers

DOE Bioenergy Research Centers

- Joint BioEnergy Institute (LBNL)
- Bioenergy Science Center (ORNL)
- Great Lakes BioEnergy Research Center (Univ. of WI)

Targeting breakthroughs in biofuel technology to make abundant, affordable, low-carbon biofuels a reality

Already yielding results, such as:

- Bioengineering of yeasts that can produce gasoline-like fuels
- Developing improved ways to generate simple sugars from grasses and waste

DOE Loan Guarantee Program

Program Objectives

Issue loan guarantees to eligible projects that:

- Avoid, reduce, or sequester anthropogenic emissions of greenhouse gases or air pollutants
- Employ new or significantly improved technologies as compared to commercial technologies in service
- Can be deployed commercially
  - Beyond the R&D, development, pilot, and demonstration stages
- Provide a reasonable prospect for repayment

Leveraging Partnerships to Achieve Goals

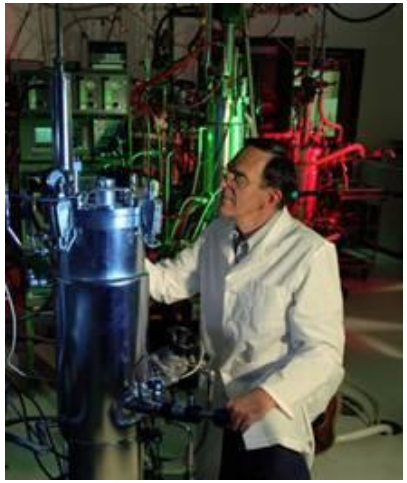
R&D OPPORTUNITIES

- *Thermochemical Conversion (up to $7.75 million)*
  - Integration of gasification and catalyst development
  - Create a syngas that meets the cleanliness specifications of existing synthesis processes from widely available biomass
- *Pyrolysis Oil Stabilization (up to $7.5 million)*
  - Stabilizing bio-oil prior to upgrading
  - Removing char, lowering the oxygen content, and reducing the acidity of pyrolysis oil
- *Joint DOE-USDA Solicitation ($18.4 million)*
  - Biomass R&D Initiative: 21 awards announced March 2008
- *Advanced Biofuels University Solicitation ($4 million)*
  - Novel nutrition and oil production from algae
  - Novel enzyme pellet scheme for fermentation of sugars
  - Micro-channel reforming of pyrolysis oil

Key Conversion Platform Accomplishments

RESEARCH AND DEVELOPMENT OPPORTUNITIES

- **Ethanologen Solicitation (up to $23 million)**
  - Five selected research teams working on microorganisms
  - Drive to more robust to temperature and ethanol concentration organisms
  - Goal to increase microorganism productivity and use of pentose sugars



- **Enzyme Solicitation (up to $33.8 million)**
  - Creating highly effective, inexpensive enzyme systems for commercial biomass hydrolysis; second phase: cellulase development with cost-sharing industry partners
  - Utilize pretreated corn stover and switch grass to maximize production of glucose and xylose yields
  - Develop a more robust enzyme

Leveraging Partnerships to Achieve Goals

Removing barriers to large-scale production of cellulosic biofuels

Pilot & Demonstration Facilities

- ***Commercial-Scale Biorefineries*** (up to $272 million)
  - Four cost-shared, integrated biorefinery demonstration projects to produce 130 million gallons of cellulosic ethanol in 5 years using a variety of conversion technologies and cellulosic feedstocks
- ***10%-Scale Biorefinery Validation*** (up to $240 million)
  - Cost-shared, integrated biorefinery demonstrations using cellulosic feedstocks to produce renewable fuels; one-tenth of commercial scale
  - Nine selectees announced
- ***1 ton/day Pilot or 50 ton/day Demo of Advanced Biofuels***
  - Cost-shared integrated pilots/demos of emerging technologies
  - Solicitation closed June 30, 2009

Policy Factors (through 2007)

DOE Strategic Plan (2006)

Theme 1: Energy Security – Promoting America's energy security through reliable, clean, and affordable energy

Theme 3: Scientific Discovery and Innovation – Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology

EERE Strategic Plan (2002)

Dramatically reduce dependence on foreign oil
Create the new domestic bioindustry

OBP Strategic Goal ('08 Budget)

Develop biorefinery related technologies associated with the different biomass resource pathways to the point that they can compete in terms of cost and performance and are used by the Nation's transportation, chemical, agriculture, forestry, and power industries to meet their respective market objectives.

President's Advanced Energy Initiative (AEI) (2006)

Change the way we fuel our vehicles

Make cellulosic ethanol cost competitive with corn ethanol by 2012

BioFuels Initiative (BFI) (2006)

Make cellulosic ethanol cost competitive by 2012

Replace 30% of transportation fuel supply with biofuels by 2030

President's "20 in 10" Goal (2007 SOU)

Reduce U.S. Gasoline Usage By 20 Percent In The Next Ten Years (by 2017)

Renewable Fuel Standard

35 billion gallons (ethanol basis) of renewable and alternative fuels in 2017.

Biofuel Contribution

Corn Ethanol

Imported Ethanol

Cellulosic Ethanol

Biodiesel

Renewable Diesel

EPAct 2005 Sec. 932. BIOENERGY PROGRAM.

The Secretary shall conduct a program of research, development, demonstration, and commercial application for bioenergy, including-

(1) biopower energy systems;
(2) biofuels;
(3) bioproducts;
(4) integrated biorefineries that may produce biopower, biofuels, and bioproducts;
(5) cross-cutting research and development in feedstocks; and
(6) economic analysis

Includes 'Integrated Biorefinery Demonstration ' (932-d)

Select Other EPAct 2005 Provisions

Sec. 942: Incentives to ensure 1 billion gallons of cellulosic biofuel annual production by 2015 (reverse auction)
Title 17: Loan Guarantees

OBP Vision, Mission and Performance Goals

OBP Performance Goals

Biomass Program

•Make cellulosic ethanol cost competitive, at a modeled cost for mature technology of $1.76/gallon by 2012 *

•Help create an environment conducive to maximizing the production and use of biofuels by 2017 and displacing 30 percent of 2004 gasoline use by 2030

Feedstocks

Supply:

2012: 130 M TPY

2017: 250 M TPY

Logistics:

2012:$0.39/gal EtOH

2017:$0.33/gal EtOH

Thermochemical Conversion R&D

Reduce the processing cost of converting woody feedstocks to ethanol to $0.86/gal by 2012

Integrated Biorefineries

Demonstrate and validate integrated biorefineries across various pathways with the successful operation of at least 3 plants by 2012. Validate modeled ethanol production cost and compare to target of $1.76/gal in 2017.

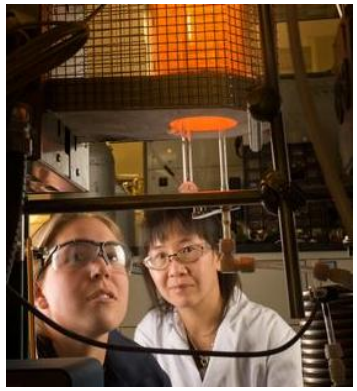
Biofuels Infrastructure

•Complete standards development and testing of E15 and E20 distribution systems and vehicles.

•Support E85 on regional basis.

*All dollar are 2007$, Based on EIA Annual Energy Outlook 2009 corrected for energy density of ethanol

Advanced Biofuels Activities



Analyses to identify fuels with greatest potential:

- Technical and economic maturity in 5-8 years
- Hydrocarbon compatibility
- Greater than 80% GHG reduction
- Complete Fall, 2008

Determination of core capabilities relevant to advanced biofuel technologies

- Mixed Alcohols and Fischer Tropsch: Reducing cost via commercial-scale demonstration projects
- Green Gasoline and Diesel: Solicitation on pyrolysis to produce bio-oils and continuing work to address LCA, technical challenges, and scale-up issues
- Algal Diesel: Developing fast-growing, high-yield lipid strains

Algae Biofuels Road mapping to identify barriers and research priorities to overcome these barriers (December 2008)

Beyond Ethanol: Advanced Biofuels

- Recent studies highlight the potential of advanced biofuels other than cellulosic ethanol.
- This next generation of biofuels would be more similar in chemical makeup to gasoline and diesel fuels.
- Compatibility with the existing infrastructure may expedite penetration of these next-generation biofuels in the market.

Renewable gasoline
Renewable Diesel
Cellulosic biobutanol
  – Other higher alcohols
Algal-based hydrocarbons

} Infrastructure-Compatible Advanced Biofuels

Biofuels Beyond Ethanol

Today

Ethanol – As a blending agent from either grain or cellulosic material from Ag and/or Forestry industry

Biodiesel – Transesterified vegetable oils blended with diesel

Green Diesel – Fats, algal oils, waste oils, or virgin oils converted to low sulfur diesel in petroleum refinery

Higher alcohols – Examples include: butanol, mixed alcohols, higher carbon alcohols (C5 - and greater)

Fischer-Tropsch Liquids – And other products from syngas including methanol, dimethyl ether, etc

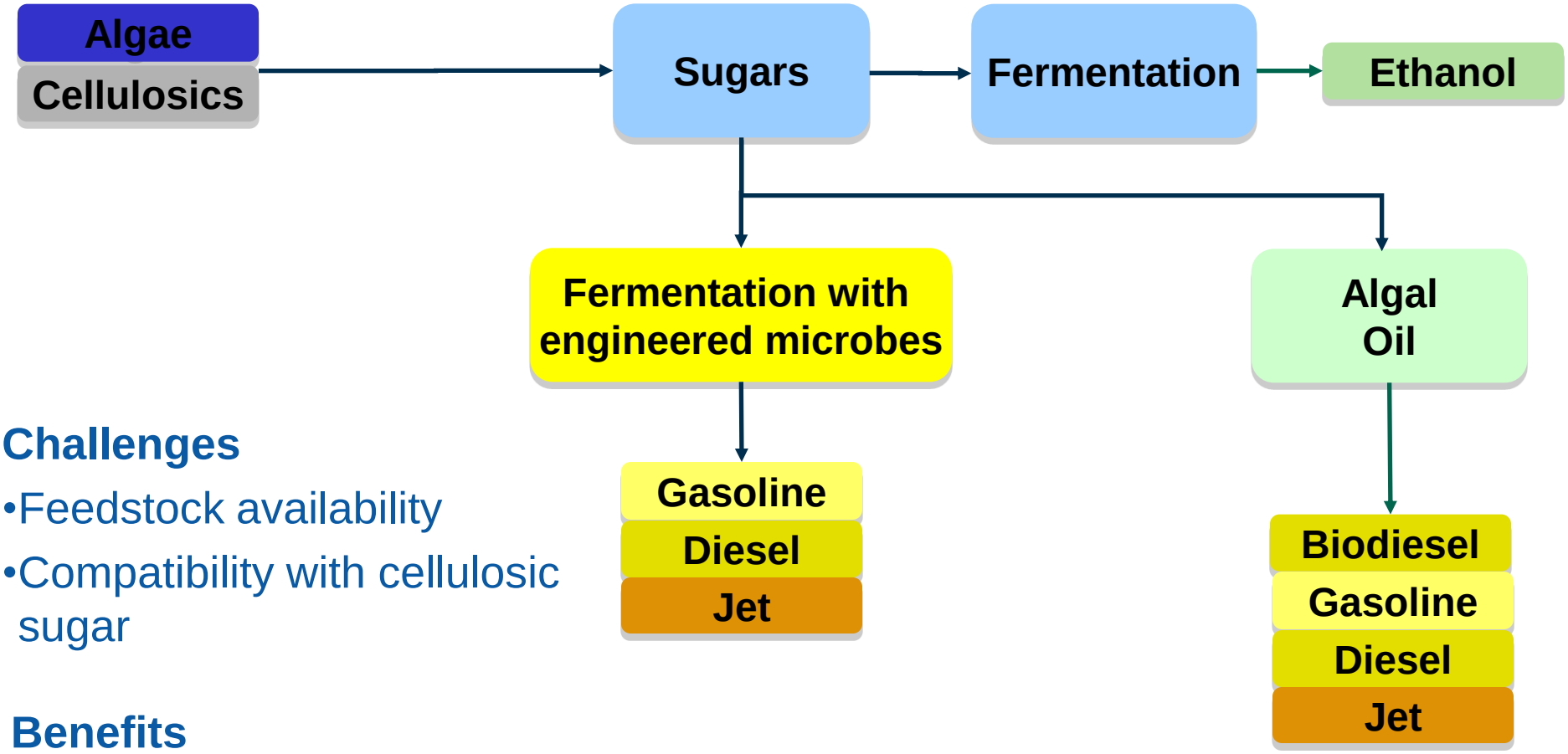
Pyrolysis Liquids – Alternative feedstock to petroleum refinery or gasification facility to produce petroleum/diesel

Methanol derived fuels – Methanol to gasoline technology, dimethyl ether and other products

Other fuels – Liquid transportation fuels from sugars/oils refinery not discussed or yet envisioned

Future

Alternative Pathways to Advanced Biofuels Beyond Thermochemistry



Challenges

- Feedstock availability
- Compatibility with cellulosic sugar

Benefits

- Infrastructure-compatible
- Highly controlled fuel properties

Fundamental Research in Key Program Areas

Objective:

Establish two new Biofuels Applied R&D Consortia to accelerate the development of algal and advanced biofuels. Collaborate with the Office of Science (SC) and the Bioenergy Research Centers (BRCs).

Procurement Strategy:

New solicitation for Biofuels Applied R&D Consortia open to National Labs, academia and industry. 1 Algal Biofuels Consortium and 1 Advanced Fungible Biofuels Technology Consortium will be selected for up to $85M DOE share over three years. Collaboration with SC and their BRCs for $25M over five years through existing M&O contracts and agreements.

Funding:

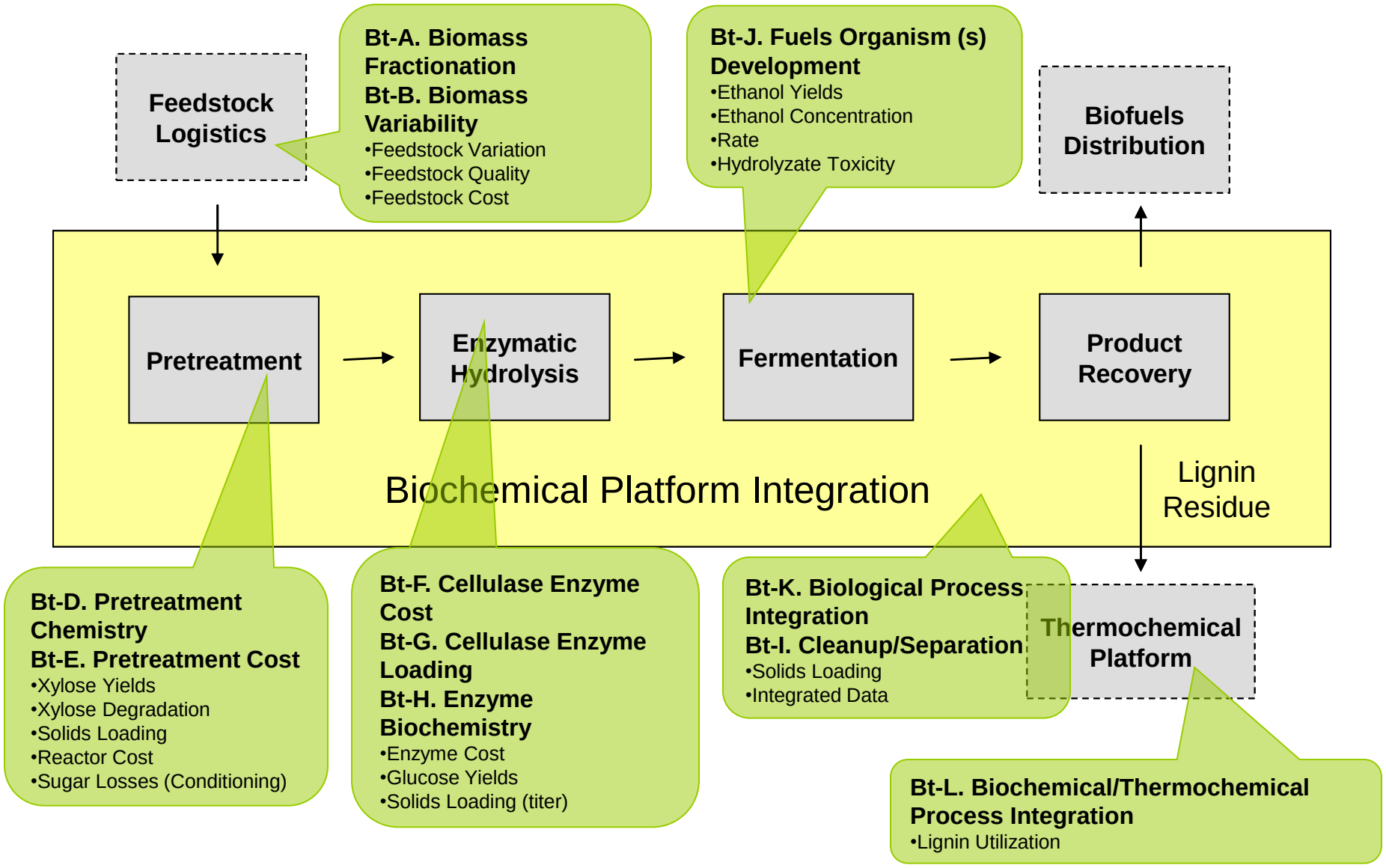
Recovery Act (FY2009-13): $110M

Timeline:

Release of FOA for consortia – Jul. 2009
Public release of algae roadmap – Aug. 2009
Fund sustainability effort – Sept. 2009
Make selection for consortia – Nov. 2009
Award consortia – Dec. 2009
Fund pilot facility (LBNL) – Jan. 2010
Complete costing RA$ – Sept. 2013

Accelerate transformational science to create a sustainable biofuels industry.

Biochemical Platform Approach



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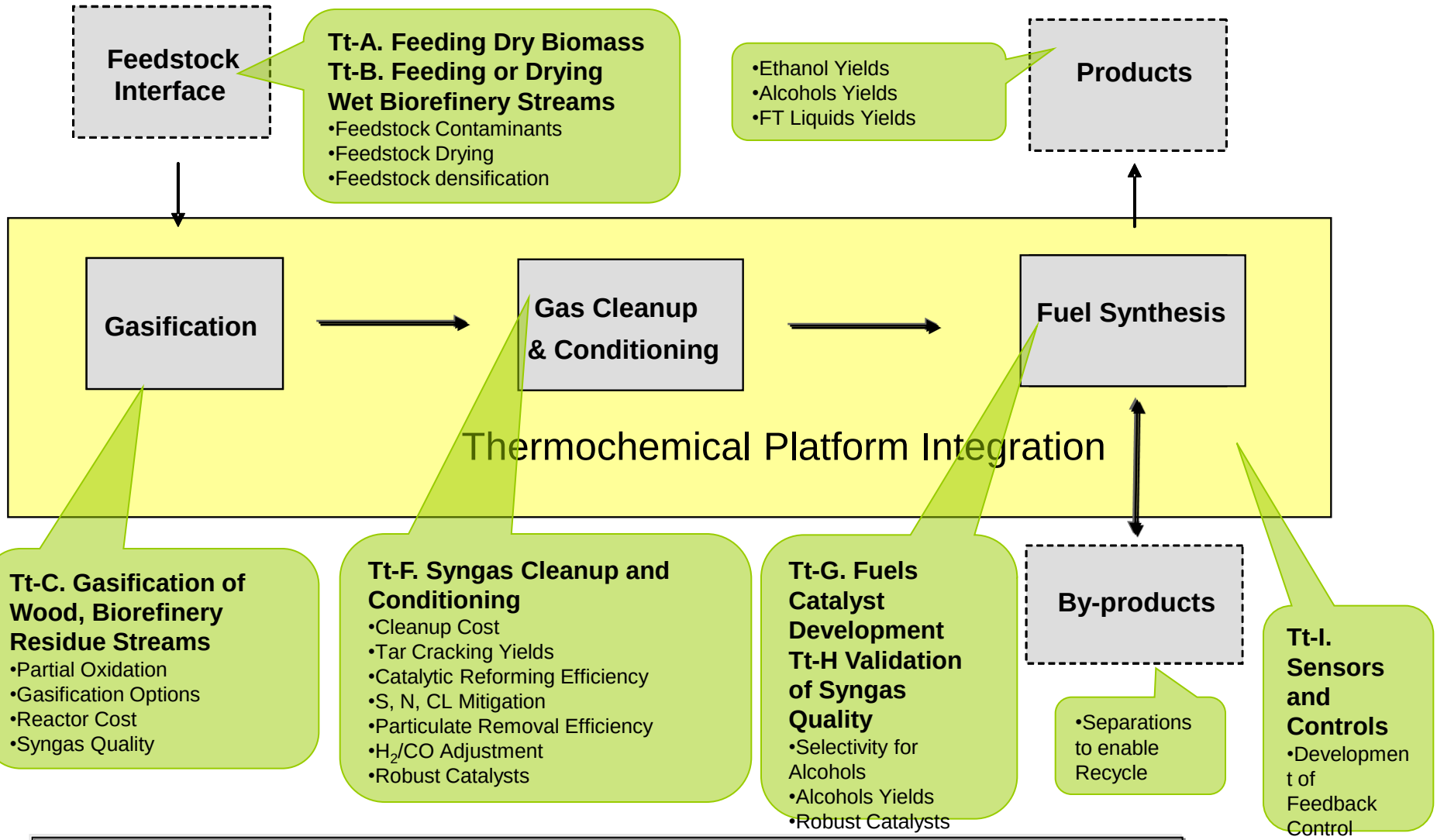
Thermochemical Platform Approach
to Gasification for Biofuels



Gas Clean-up & Fuel Synthesis primary focus of research to drive down cost of producing fuel from gasification route

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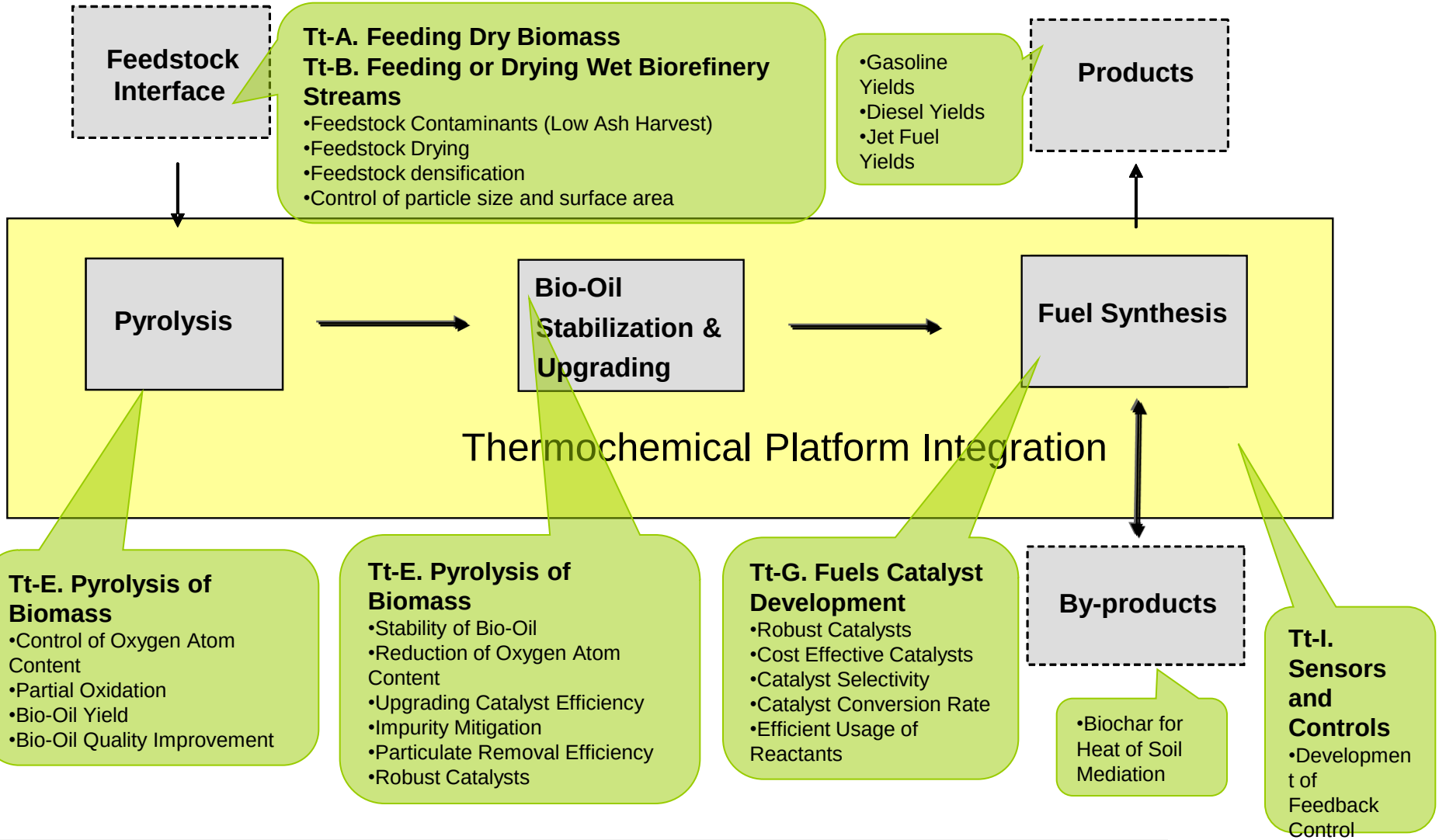
Thermochemical Platform Approach
to Pyrolysis for Biofuels

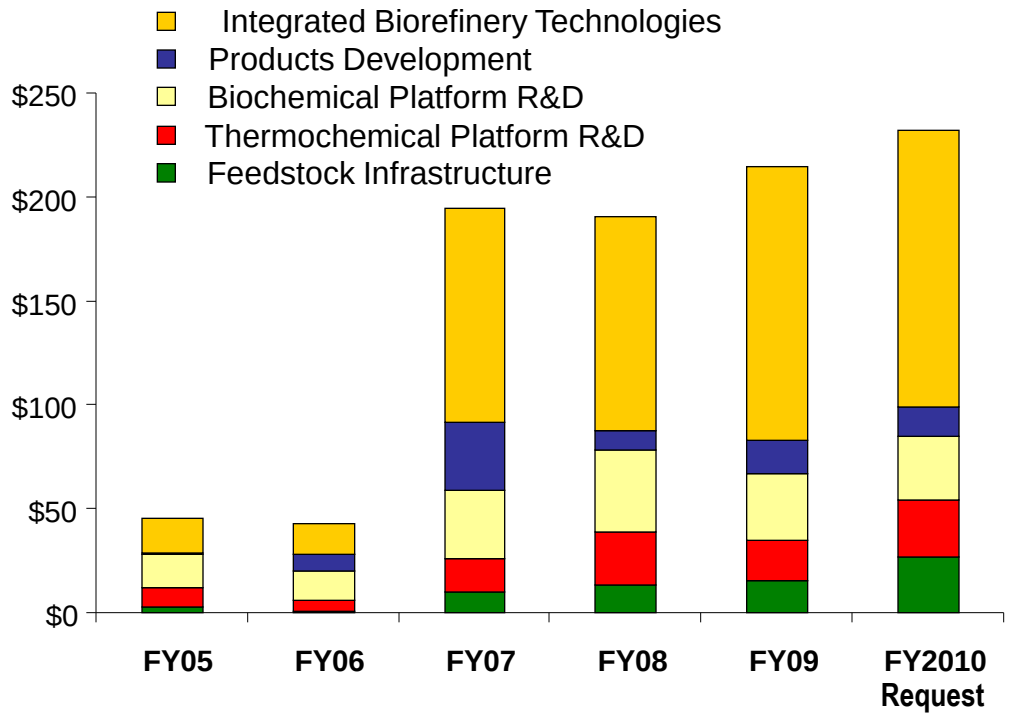


Bio-oil stabilization key to improving pyrolysis-to-fuel pathway

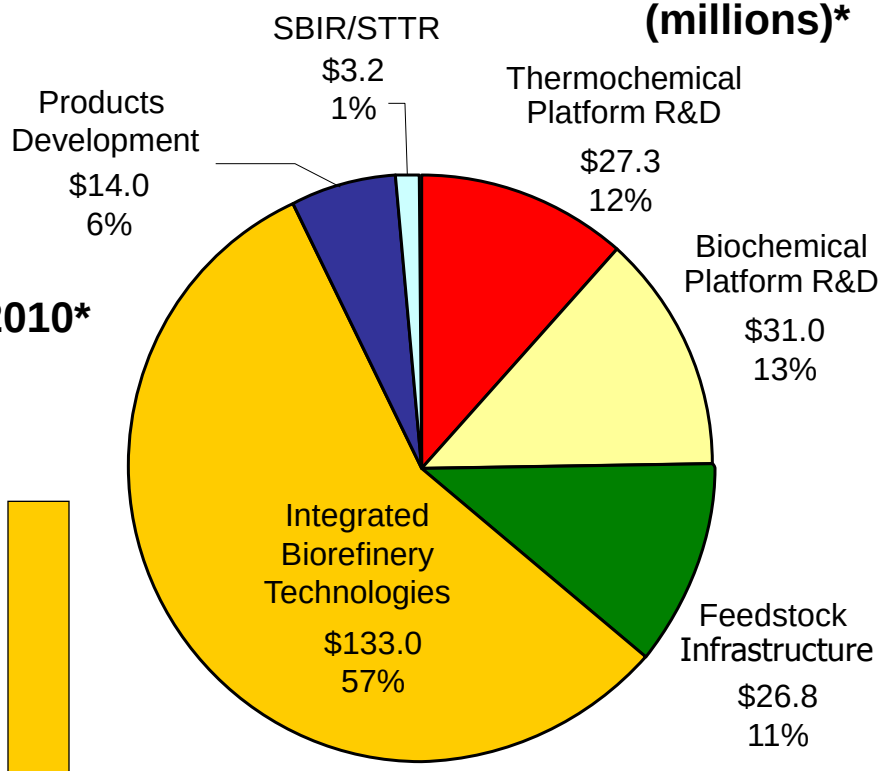
Biomass Program Budgets

FY2010 budget request reflects increased focus on *Thermochemical Conversion* technology and *Feedstock Infrastructure*.

Biomass Program Budget History, FY2005-2010*



Biomass Program Budget Request, FY2010 (millions)*



*** Excludes earmarks**

Conversion Critical Barriers

Barriers	Solutions
• High enzymatic conversion costs	• R&D to improve effectiveness and reduce costs of enzymatic conversion
• Low C5 sugars conversion	• R&D on advanced micro-organisms for fermentation of sugars
• Low syngas-to-fuel yields	• R&D to improve syngas clean-up and catalyst for alcohol/fuel synthesis
• Low pyrolysis oil quality	• R&D to improve py-oil stabilization and compatibility with current infrastructure
• Infancy of commercial-scale integration of process components	• Fund loan guarantees, commercial biorefinery demonstrations, and 10% scale validation projects

Future efforts address obstacles to conversion routes to biofuels, support demonstrations, and resolve infrastructure issues

Biofuels Beyond Ethanol

Today

Ethanol – As a blending agent from either grain or cellulosic material from Ag and/or Forestry industry

Biodiesel – Transesterified vegetable oils blended with diesel

Green Gasoline, Green Diesel and Jet fuels – Fats, algal oils, waste oils, or virgin oils converted to low sulfur diesel in petroleum refinery

Higher Alcohols – Examples include: butanol, mixed alcohols, higher carbon alcohols (C5 – and greater)

Fischer-Tropsch Liquids – And other products from syngas including methanol, dimethyl ether, etc.

Pyrolysis Liquids – Alternative feedstock to petroleum refinery or gasification facility to produce petroleum/diesel

Methanol Derived Fuels – Methanol to gasoline technology, dimethyl ether and other products

Blendstocks – Renewable additives that benefit combustion and emissions properties of conventional fuels

Other Fuels – Liquid transportation fuels from sugars/oils refinery not discussed or yet envisioned

Future