

1st Brazil-U.S. Biofuels Short Course

Research Priorities on Biofuels in the USA

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Sao Paulo, Brazil
July 27, 2009

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2009 Program Priorities and Goals

Advancing Presidential Objectives



Science & Discovery

- Connecting basic and applied bioscience
- Conducting breakthrough R&D at universities and national labs:
 - 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

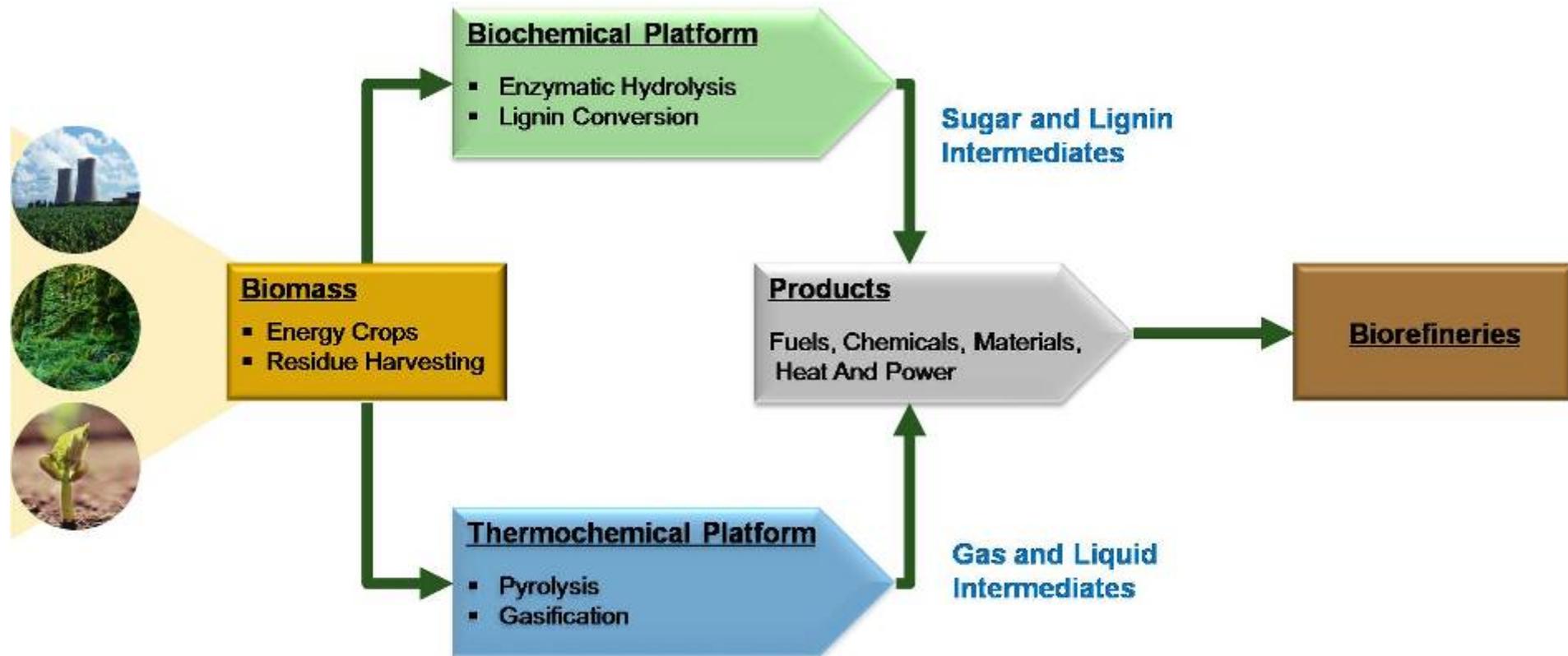
- Creating 50 to 75 jobs per new biorefinery
- Creating major new energy crop markets
- Reinvigorating rural economies

Climate Change

- Reducing GHG emissions by up to 90% with advanced biofuels (compared to gasoline)
 - LCA/climate change models still being defined



The Biomass Program Is Working On Two Major Routes To Produce Biofuels



Biomass Program Mission

Develop and transform our renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower.

Focus on targeted **research**, **development**, and **demonstration**

- Support through public and private partnerships
- **Deploy in integrated biorefineries**

- **Program's Goals**

- **Short Term:** Foster breakthrough technologies needed to make cellulosic ethanol cost competitive by 2012
- **Mid Term:** Help create an environment conducive to maximizing the sustainable production of biofuels by 2017, including cost-effective technology, sufficient infrastructure, appropriate policies, and supportive consumers
- **Long Term:** Increase the supply of renewable fuels to 36 billion gallons by 2022 (EISA, RFS)



Overcoming Barriers to Commercial Use



Barriers

- High cost of enzymatic conversion for cellulosic ethanol
- High cost of organisms for producing ethanol from complex sugars within cellulosic biomass
- Limitations of thermochemical conversion processes
- Demonstration/integration of technology in biorefineries
- Inadequate feedstock and distribution infrastructure
- Sustainability issues



Solutions

- R&D to improve effectiveness and reduce costs of enzymatic conversion
- R&D on advanced micro-organisms for fermentation of sugars
- Re-establish thermochemical conversion as a path to success
- Fund loan guarantees, commercial biorefinery demonstrations, 10% scale validation, and advanced biofuel projects
- Form interagency infrastructure and feedstock teams
- Develop detailed LCAs, tools, and models to ensure sustainable production

Future efforts address obstacles to biochemical and thermochemical routes to biofuels, support demonstrations, and resolve infrastructure issues.

What do we need research to work on

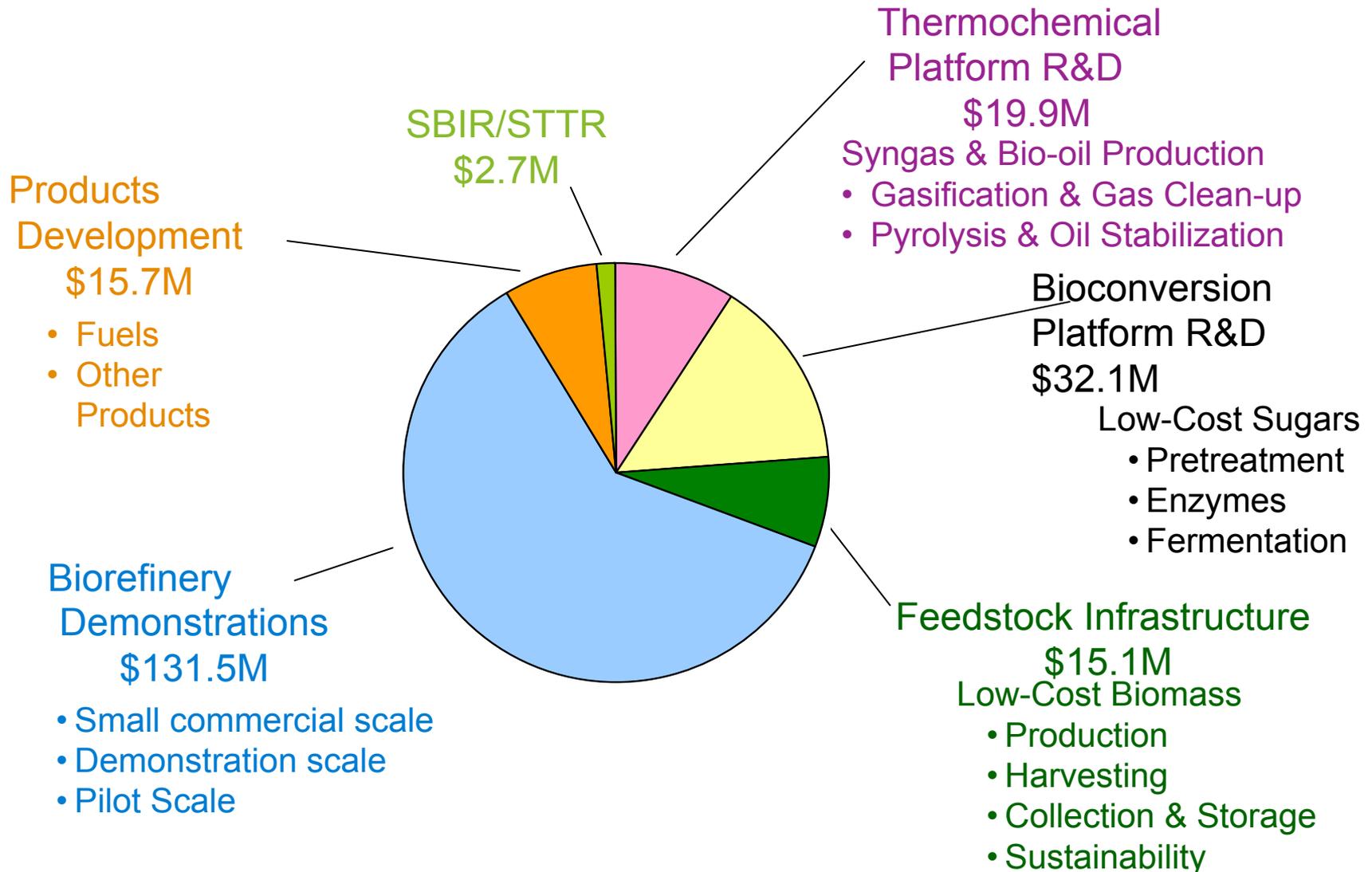


- **Feedstock**
 - Collection Systems
 - Densification
 - Uniformity
- **Conversion**
 - Cheaper
 - Higher concentrations
 - Feedstock forgiving
 - Less water
 - **CHEAPER**
- **Product**
 - Diversity
 - High market potential for fuel
 - High margin potential for co-products
- **Energy**
 - CHP – self sustaining
 - Clean
- **Sustainability**
 - Less Water
 - GHG reductions
 - NO land use changes
 - Clean
- **INTEGRATION** – DOES THE WHOLE PROCESS OPERATE BETTER THAN THE UNIT OPERATIONS

Program Plan for FY 2009



Biomass Omnibus Appropriations, by Technology Area



Biomass Recovery Act Funding



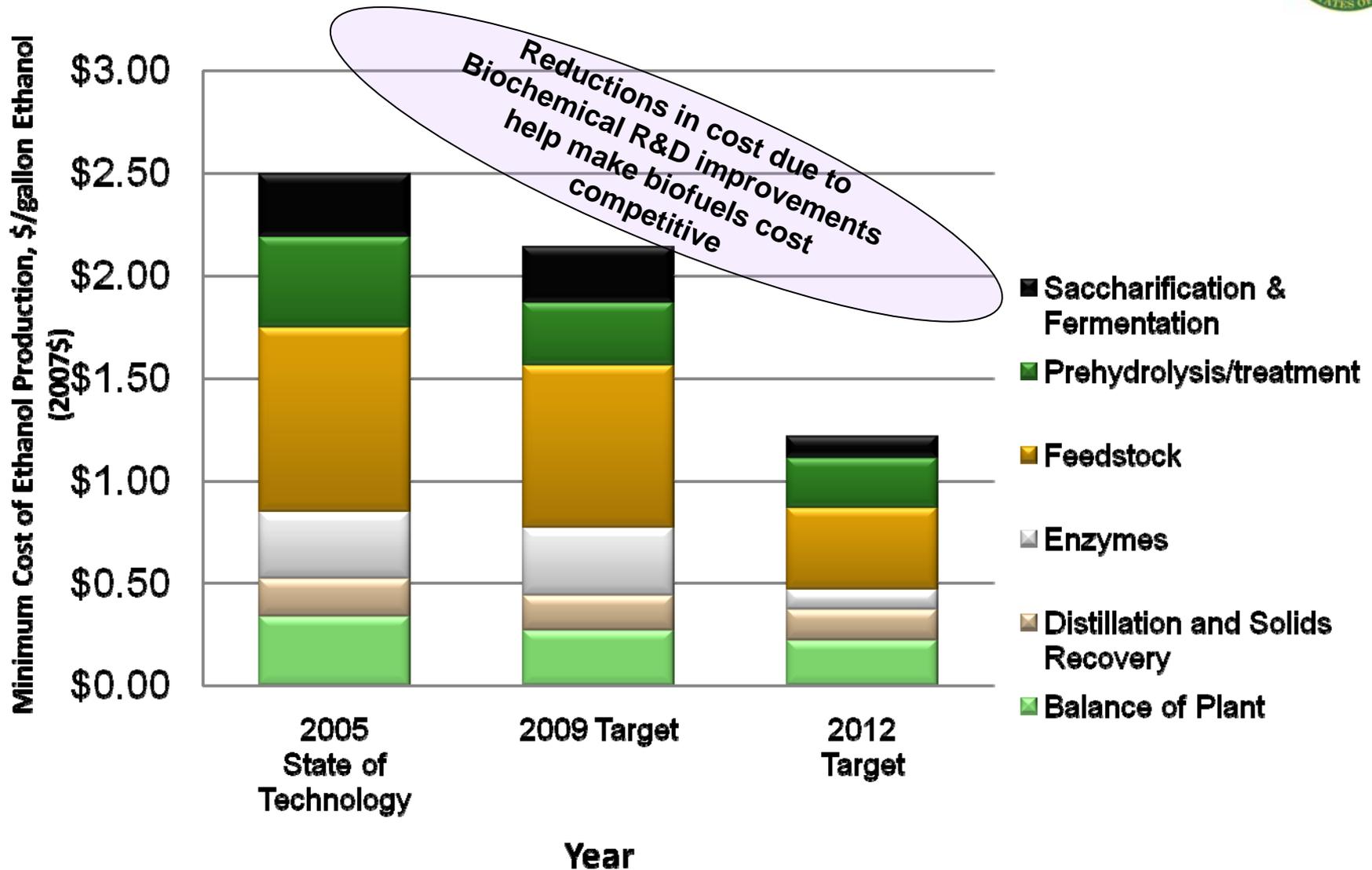
\$800 million in Recovery Act funding will be dedicated to accelerate advanced biofuels R&D and to provide additional funding for commercial-scale biorefinery demonstration projects.

The funding will be allocated across four main areas:

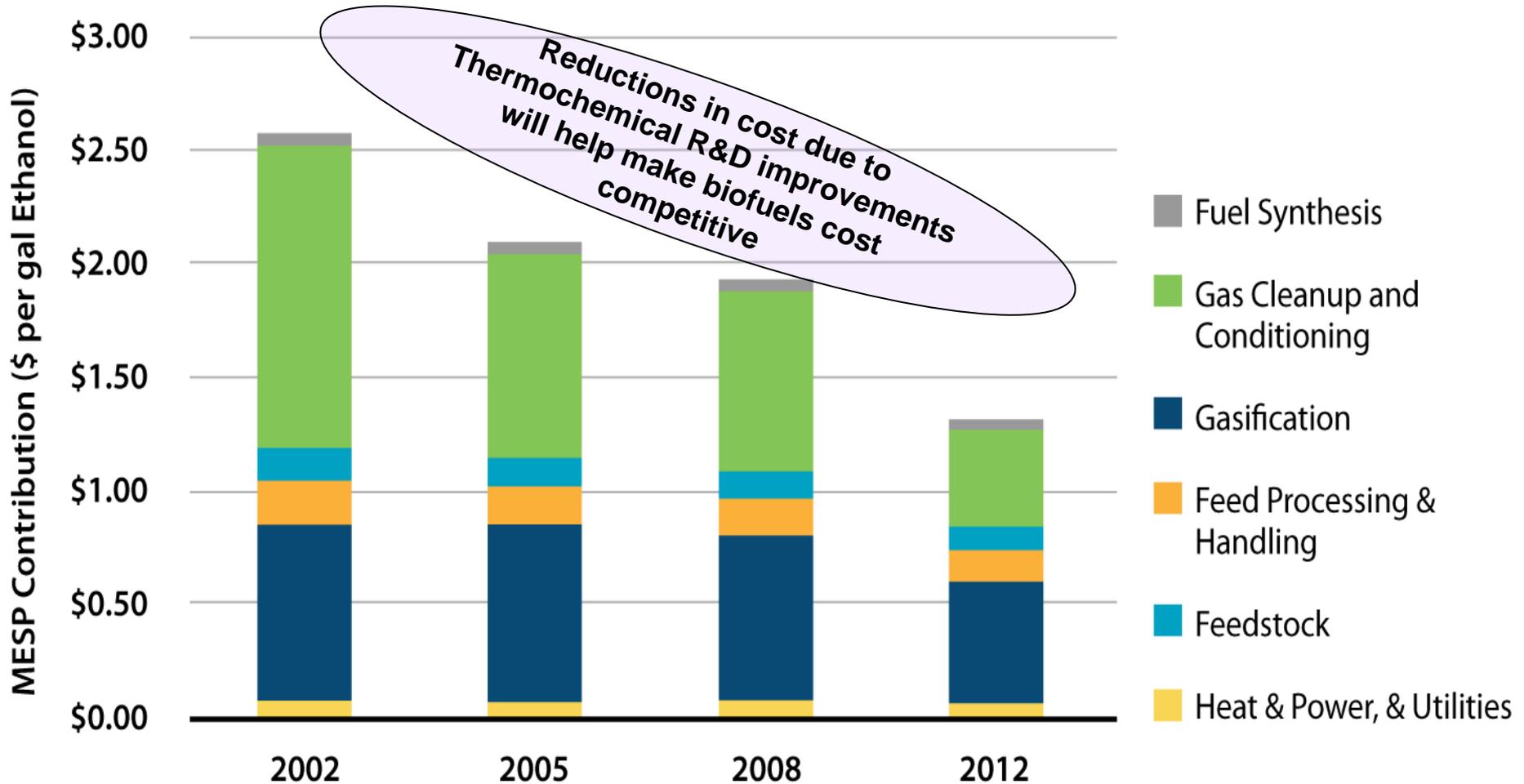
- \$480 Million Solicitation for Integrated Pilot- and Demonstration-Scale Biorefineries
- \$176.5 Million for Commercial-Scale Biorefinery Projects
- \$110 Million for Fundamental Research in Key Program Areas
- \$20 Million for Ethanol Research



Biochemical R&D

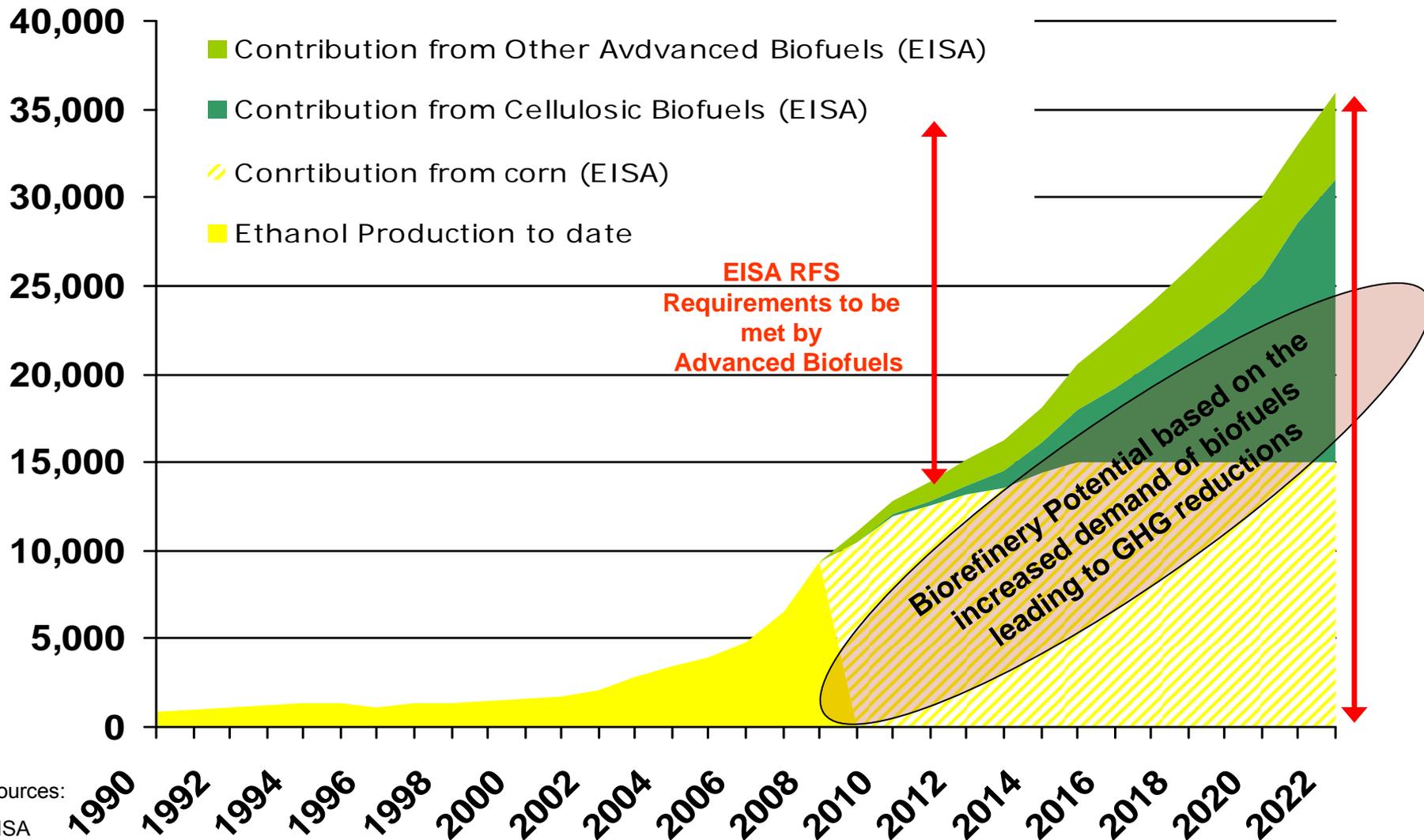


Thermochemical R&D



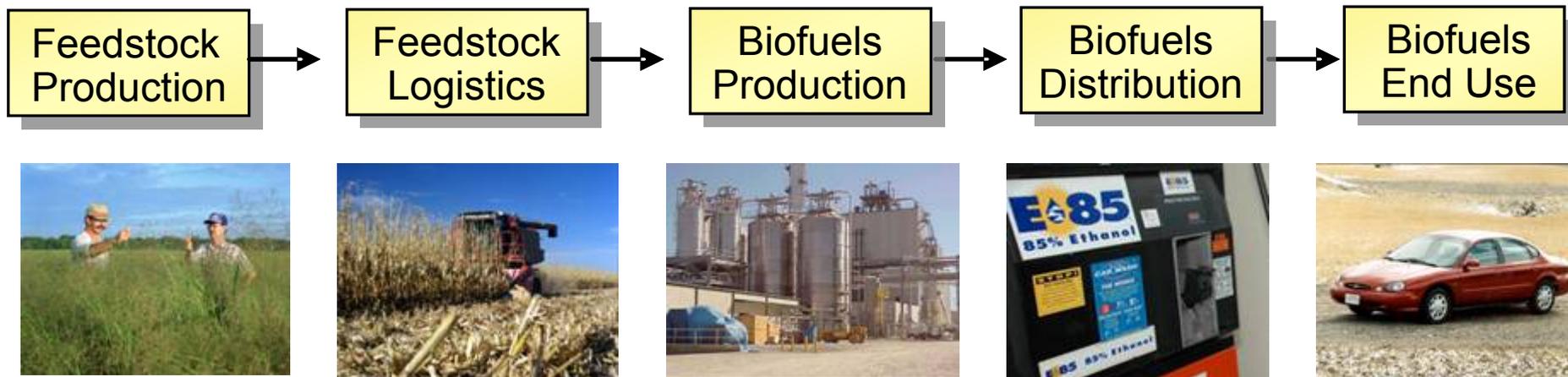
Biofuels Production, EISA Requirements

(Million Gallons/Year)



Sources:
EISA
Renewable Fuels Association (As of July 14, 2008)

Strategic Focus: Sustainable Biofuels



- **Cellulosic Ethanol:** Historical focus of program.
- **Alternative Light-Duty and Diesel Replacement Fuels:** Expanded strategy includes advanced biofuels that require governmental support and can significantly contribute to meeting the RFS2. Update to *Multi-Year Plan* by December 2009.

Our Commitment to Sustainability



The Biomass Program is committed to developing the resources, technologies, and systems needed for biofuels to grow in a way that enhances the health of our environment and protects our planet. To that end, we are working to...

- Develop diverse, non-food feedstocks that require little water, fertilizer, or new land
- Foster sustainable forestry practices
- Harvest biomass components selectively, leaving adequate soil nutrients
- Assess life-cycle impacts of major scale-up in biofuels production, from feedstocks to vehicles, addressing:
 - land use and soil health
 - water use
 - air quality issues
 - impacts on greenhouse gas (GHG) emissions



Future Needs for Biofuels and Bioenergy



Technology Advances

- Diverse feedstocks in all regions
- Flexible, bio-powered conversion
 - Mix of biochemical (advanced enzymes), thermochemical (pyrolysis, gasification, etc.), and other conversion technologies
- Increased yields and efficiency
- Lower production costs
- Efficient logistics and deployment
- Modular systems to reduce capital costs



Other National Benefits

- Sustainable domestic energy
- Strong economic growth (new technology markets and jobs)
- Positive impact on climate and air quality



New & High-Yield Feedstocks

- Energy crops
- Wastes
- Algae



Advanced Biofuels

- Algal Based Biofuels
- Higher Alcohols
- Green Gasoline
- Renewable Diesel
- Renewable Jet Fuel Formulations



Value-added Bioproducts/Coproducts



Carbon Mitigation

- Potential role in future carbon legislation



Stimulate/Leverage Scientific Progress

Regional Feedstock Partnership Feedstock Trial Sites



SunGrant INITIATIVE Regional Feedstock Partnership
Current Field Site Locations



Feedstock	
	Corn Stover
	Sorghum
	Cereal Crops
	Energycane
	Switchgrass
	Poplar
	Poplar (proposed sites)
	Willow
	Miscanthus
	CRP
Sustainability Sites	
	Corn Stover
	Sorghum
	Switchgrass
	Miscanthus
Regions	
	Western
	North Central
	South Central
	Northeast
	Southeast



Successive Generations of Biofuels



Current Demonstration and Piloting Focus



Corn Ethanol

- Commercially available (no DOE research ongoing)
- Reduced GHG emissions
- Capped by RFS



Cellulosic Ethanol

- Focus of current DOE research
- Potential to lower GHG emissions 86%
- Uses biomass from waste and non-agricultural land



Advanced Biofuels

- DOE scoping studies in progress for algae; green oil
- Could minimize environmental footprint
- Energy content and fuel economy similar to petroleum-based fuels

Advanced Biofuel Options – Fungible Fuels

(from other than starch or sugar)



Recent studies highlight the potential of advanced biofuels other than cellulosic ethanol.

Compared to ethanol, this next generation of biofuels would be more similar in chemical makeup to gasoline and diesel fuels.

Their compatibility with the existing infrastructure may expedite rapid displacement of petroleum (hydrocarbon-based fuels) in the market.



- Green gasoline/renewable diesel
- Advanced cellulosic biofuels
- **Algal-based fuels**

} Hydrocarbon-Compatible
(Infrastructure-Compatible)
Advanced Biofuels

DOE Algal Biofuels Program



Biomass Program

Alternative Fuels Development Under the Advanced Biofuels Initiative

Background

The Energy Independence and Security Act of 2007 (EISA) establishes a new renewable fuels standard (RFS) that calls for 21 billion gallons of advanced biofuels to be used as part of U.S. transportation fuels by 2022. The legislation defines advanced biofuel as renewable fuels (other than corn-based ethanol) that offer life-cycle greenhouse gas (GHG) emissions at least 50 percent below baseline life-cycle GHG emissions. Biofuels eligible for meeting the EISA RFS are shown in the box inset below.

While cellulosic ethanol will likely play a significant role in meeting EISA goals, a number of other advanced... The size of... replacement fuel... biomass, mixed al... series fuels, diesel... biodiesel, dimethyl... and alternatives to... (FT) liquid fuels... of development... private sector... advantages as well.

Scoping Studies

To identify fuels with the greatest potential to meet the new RFS, the program is evaluating the commercial viability of different catalytic bio fuels technologies. The National Renewable Energy Laboratory (NREL) is collaborating with Iowa State University (ISU) to assess technology opportunities for the near term (5 to 8 years). The immediate goal is to compare a broad range of



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Algal Biofuels

Biofuels made from microalgae hold the potential to solve many of the sustainability challenges facing other biofuels today.

Eligible Advan

- Ethanol derived from lignin, sugar or corn stover
- Ethanol derived from distillers grains with added water
- Biomass-based ethanol
- Biojet production from wood
- Biodiesel or other... through the conversion of... matter from non... feedstocks, such as... into transportation...

Renewed Interest and Funding

Higher oil prices and increased interest in energy security have stimulated new public and private investment in algal biofuels research. The Biomass Program is reviewing the Aquatic Species Program at the National Renewable Energy Laboratory (NREL) to build on past success and drive down the cost of large-scale algal biofuel production. NREL, Sandia, and other laboratories are also launching research into algal biofuels for private investors and programs within the Defense Advanced Research Projects Agency (DARPA) and Air Force Office of Scientific Research (AFOSR).

Benefits of Algal Biofuels

Improvised Productivity: Microalgae, as distinct from seaweed or macroalgae, can potentially produce 200 times as much oil per acre than soybeans—or any other terrestrial oil-producing crop.

Non-Competitive with Agriculture: Algae can be cultivated in large open ponds or in closed photobioreactors located on non-arable land in a variety of climates (including deserts).

Flexible on Water Quality: Many species of algae thrive in seawater, water from saline aquifers, or even wastewater from treatment plants.

Mitigation of CO₂: During photosynthesis, algae use solar energy to fix carbon dioxide (CO₂) into biomass, so the water used to cultivate algae must be enriched with CO₂. This requirement offers an opportunity to make productive use of the CO₂ from power plants, biofuel facilities, and other sources.

Broad Product Portfolio: The lipids produced by algae can be used to produce a range of biofuels, and the remaining biomass residue has a variety of useful applications:

- convert to generate heat
- use in anaerobic digesters to produce methane
- use as a fermentation feedstock in the production of ethanol
- use in value-added byproducts, such as animal feed



- DOE Office of Biomass Program is establishing an “Advanced Biofuels Initiative”
- An element will be the “Algal Biofuels Program”
 - Stakeholder workshop held Dec 08
- Provide input to DOE for an “Algal Biofuels Roadmap”
 - Anticipate 4 major R&D and analysis areas:
 - Basic algal biology
 - Process research
 - Production/integrated scale up
 - Economic analysis

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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

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Biofuels From Algae



Petroleum Refinery



Biodiesel



Green Diesel



Jet Fuel (Jet A or JP-8)



Cellulosic Biorefinery

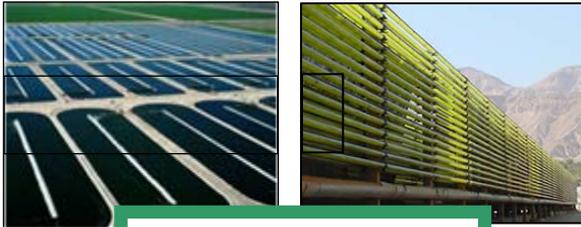


Ethanol

Lipids

Carbohydrates and Protein

Algal Biofuels - Technical Barriers

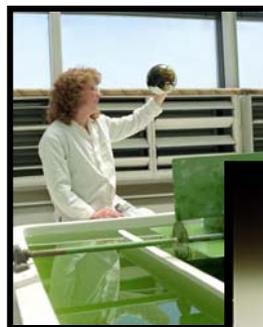


Algal Cultivation

- Bioreactor design
 - Temperature control
 - Invasion and fouling
- Starting species
 - Growth rate
 - Oil content & FA profile
- Nutrient requirements
 - CO₂ and H₂O sources

- De-watering methods
- Lipid extraction
- Purification

Oil (Lipid) Recovery

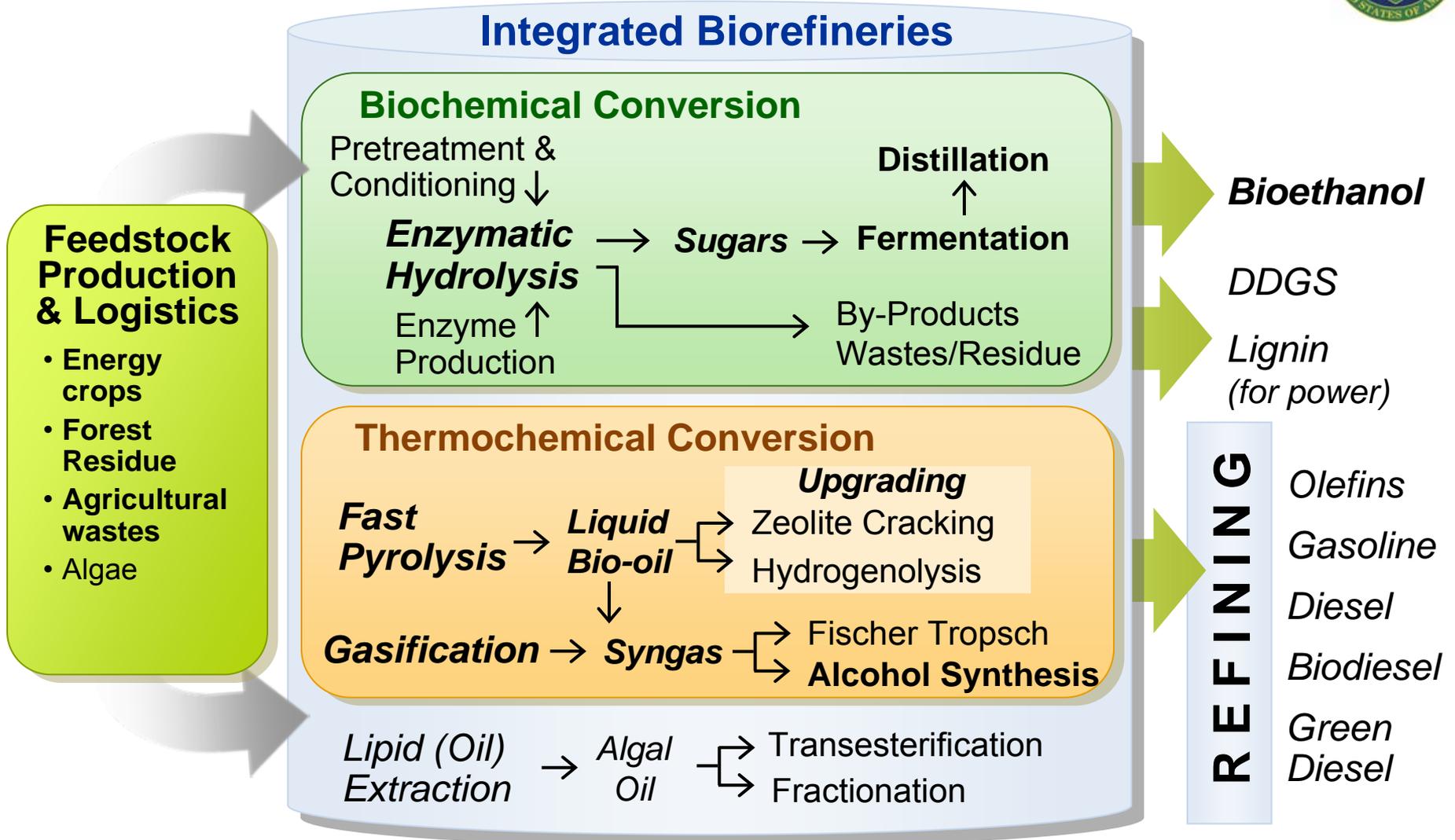


- Process optimization
- Fuel characteristics
- Engine testing (ASTM)

Fuel Production

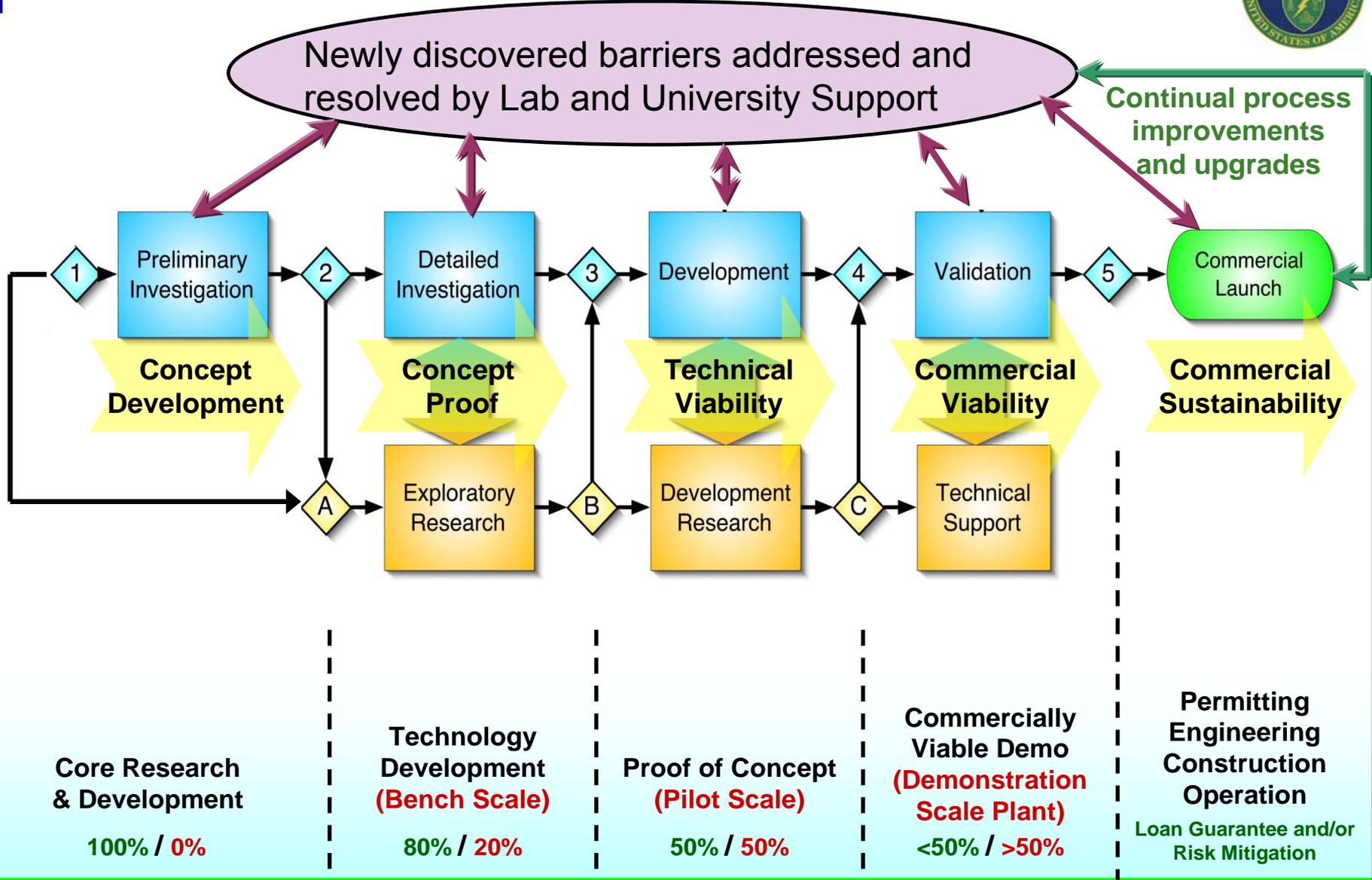


Exploring Routes to Convert Cellulosic Biomass



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

Current Deployment Progression Plan



Solicitations: Leveraging Partnerships to Achieve Goals



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 variety of conversion technologies and cellulosic feedstocks

10%-Scale Biorefinery Validation (up to \$210 million)

- Cost-shared, integrated biorefinery demonstrations using cellulosic feedstocks to produce renewable fuels; one-tenth of commercial scale
- Eight selectees announced for a total investment of \$210 million

Ethanologen Solicitation (up to \$23 million)

- Five selected research teams working on microorganisms

Enzyme Solicitation (up to \$33.8 million)

- Four selected research teams working on inexpensive enzyme systems for commercial biomass hydrolysis

Thermochemical Solicitation (up to \$16.7 million)

- Integration of gasification and catalyst development
- Pyrolysis oil stabilization

Joint DOE-USDA Solicitation (\$5.2 million of \$18 million funded by DOE)

- Biomass R&D Initiative: 20 awards announced March 2008

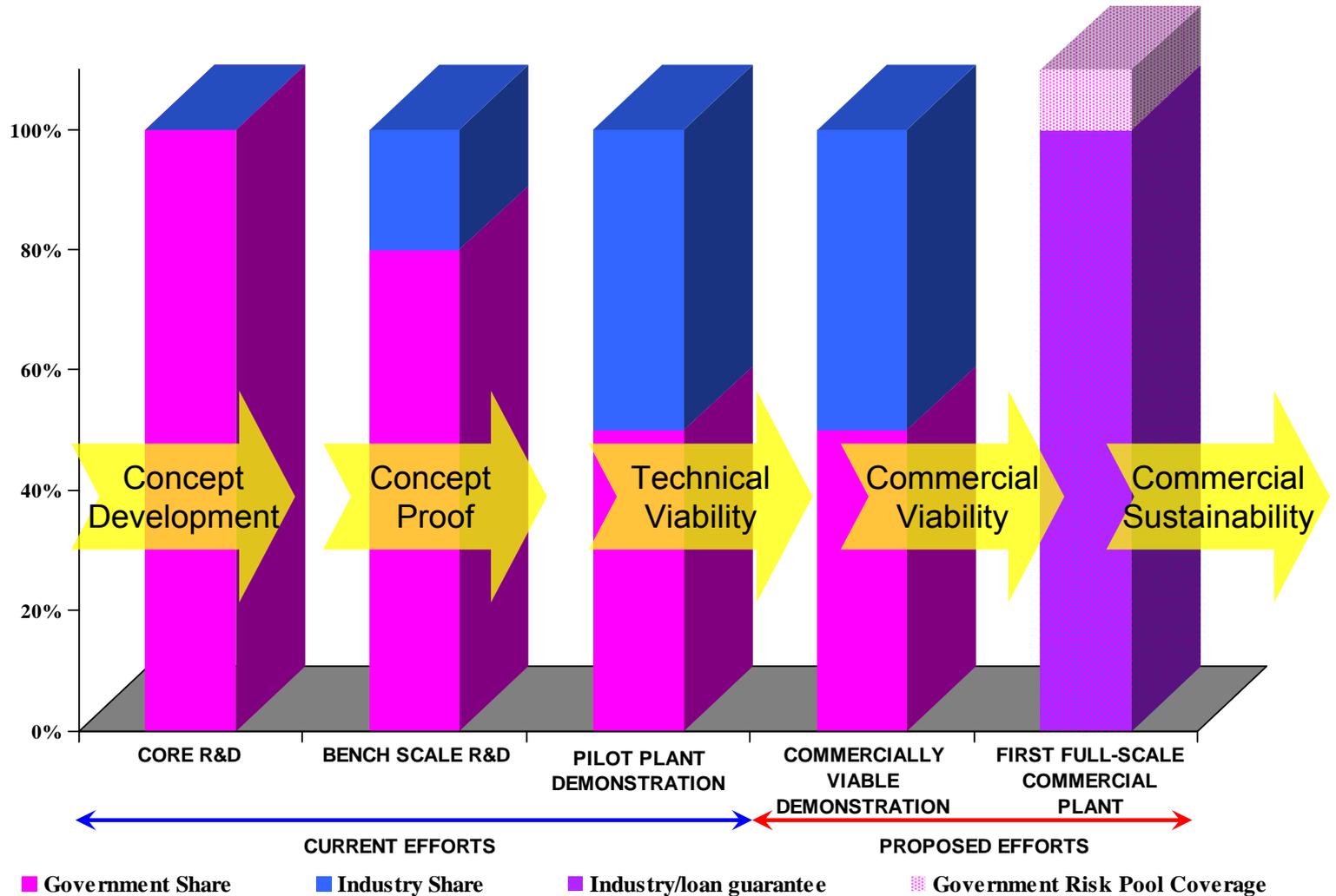
Current Solicitations

- **Integrated Demonstration / Pilot Scale Biorefinery**
- Annual USDA/DOE Joint Solicitation
- Feedstock Logistics Solicitation



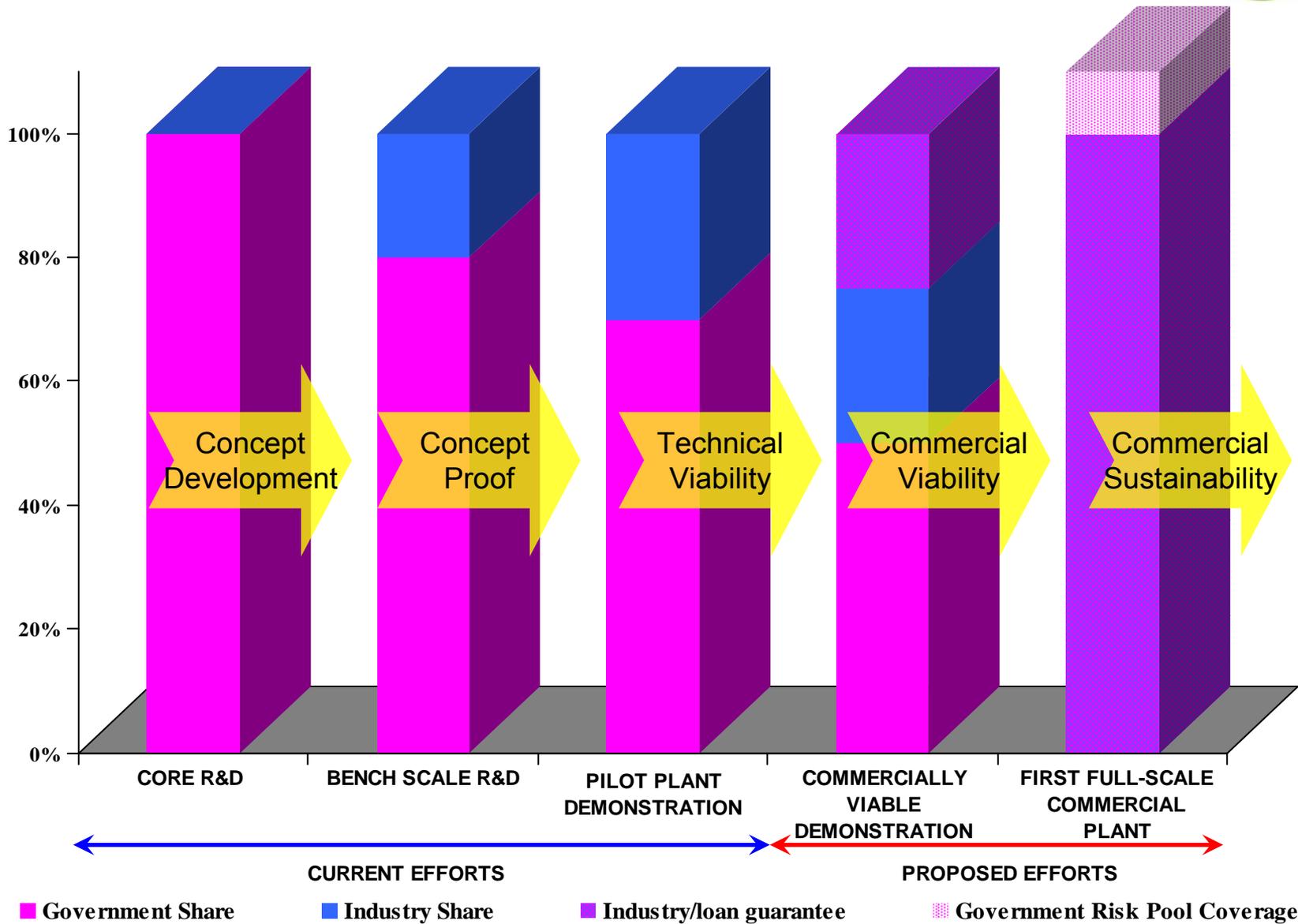
Current Deployment Funding Plan

Government Grants / Industry Cost-Share/ Loan Guarantees



Another Take on Deployment Funding

Government Grants / Industry Cost-Share/ Loan Guarantees



Biomass Program Deployment Highlights



The response to the executive and legislative mandates includes

2005:
EPACT

- Awarded \$385 million via competitive solicitations for six full scale Integrated Biorefineries. **(4 currently in development)**

2007:
EISA

Awarded \$240 million via competitive solicitations for a total of nine small-scale biorefineries using range of feedstocks to test conversion technologies for the production of cellulosic biofuels **(8 currently in development)**

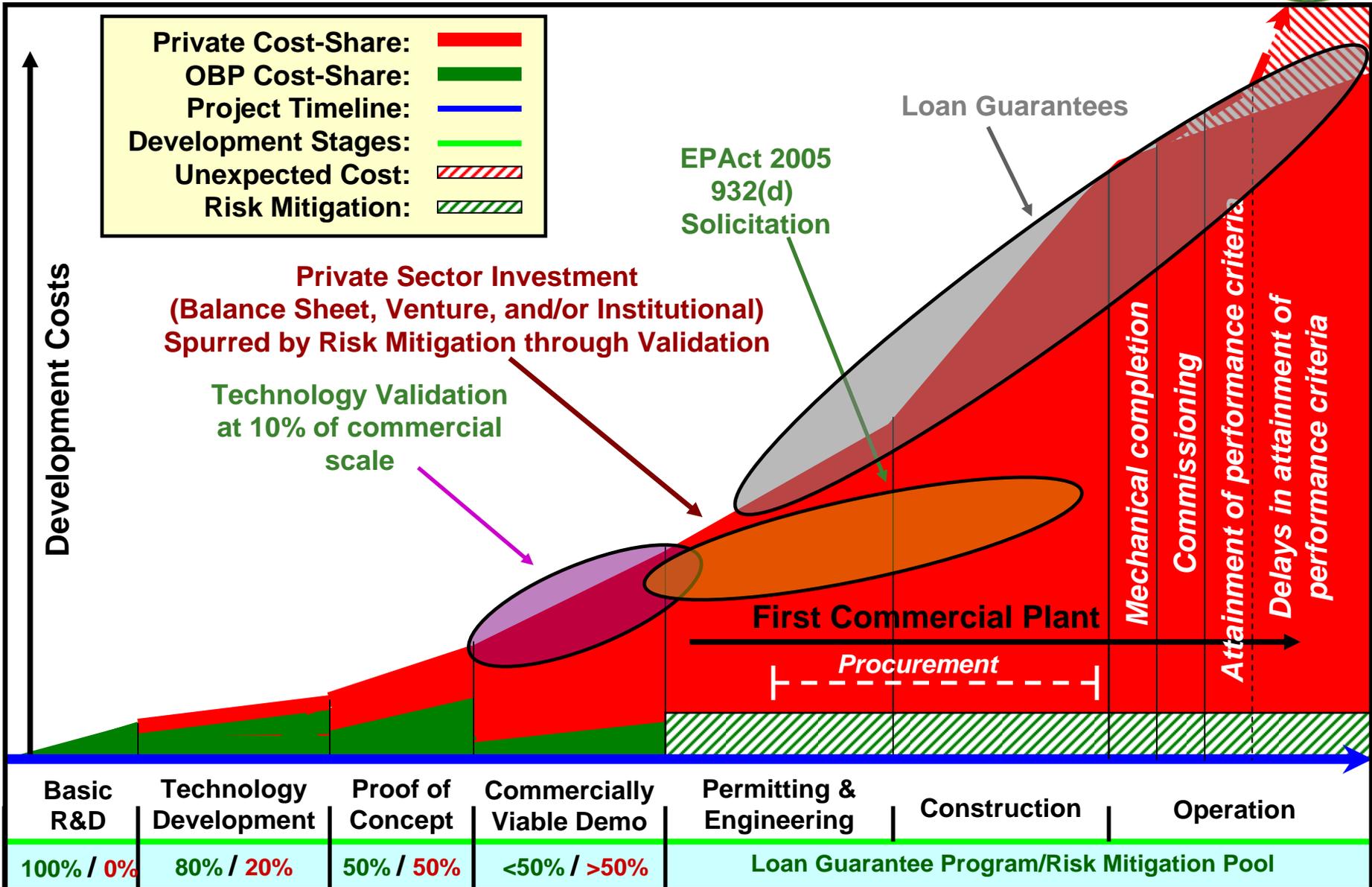
2008:
FCEA

- Offering \$200 million via competitive solicitations for pilot and demonstration-scale biorefineries to produce biofuels
 - including algal feedstocks and the production of advanced biofuels such as bio-butanol and green gasoline. **(FOA revamped for recovery funds)**

2009:
ARRA

- \$480 Million Solicitation for Integrated Pilot- and Demonstration-Scale Biorefineries **(\$200 million FOA reissued)**
- \$176.5 Million for Commercial-Scale Biorefinery Projects **(Enhancing Projects Awarded under EPAct 932(d))**

Deployment Barriers and Solutions

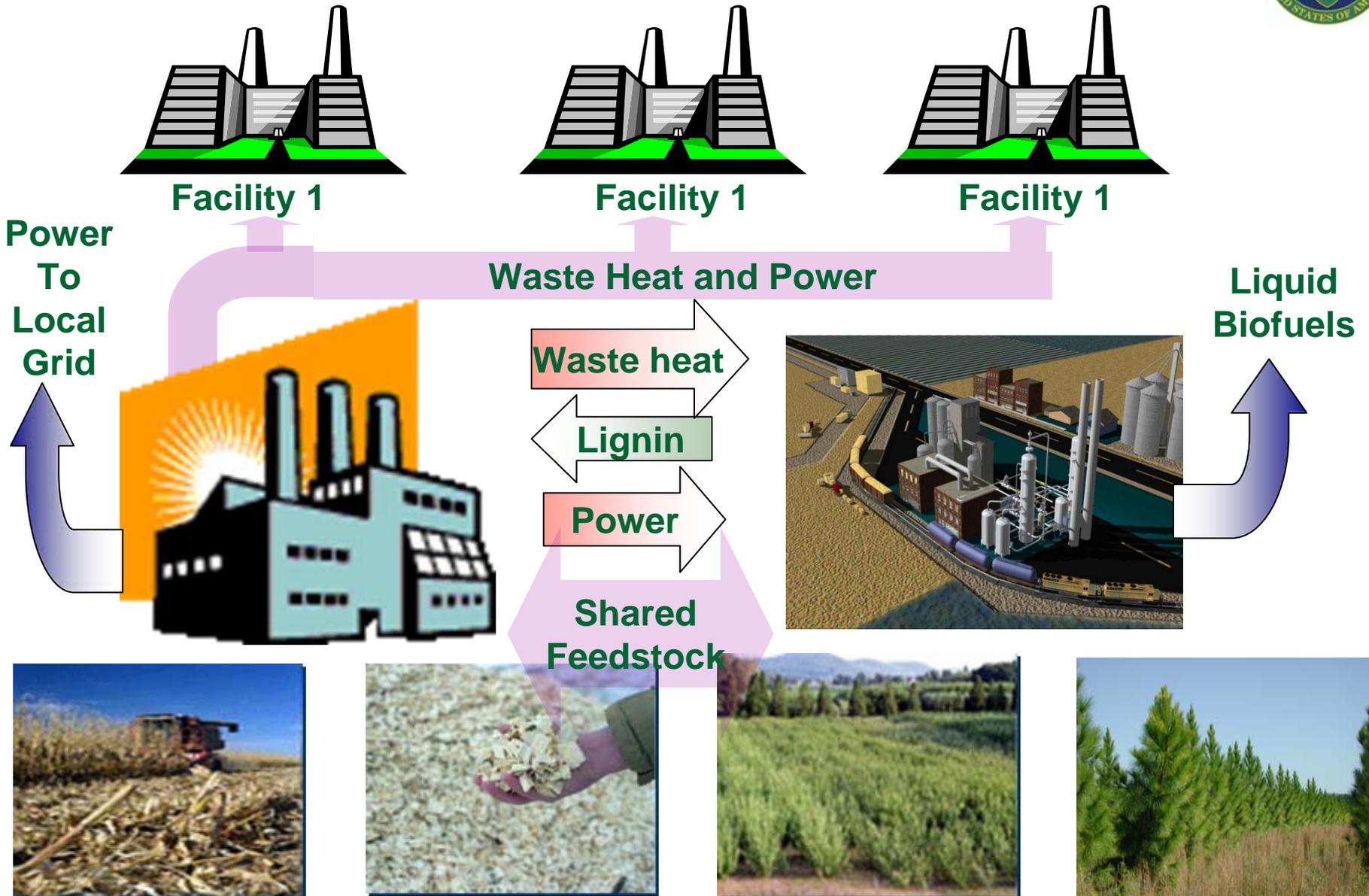


What to Look for in Commercialization Projects



- Can it be partially supported by existing infrastructure and skill sets
 - Pulp and Paper industry (propensity toward Thermochemical)
 - Existing grain to ethanol industry (propensity toward Biochemical)
- Is it also solving a problem
 - Disposing of a waste
 - Mitigating a potential hazard
 - Wild fire potential
 - Diseased trees
- Is there another niche
 - Captive feedstock
 - High market potential
- **IS IT SUSTAINABLE**

A Community Based "Green" Industrial Complex ??



Information Resources



- Office of Biomass Program - <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/>
- Grant Solicitations - www.grants.gov
- Office of Science - <http://www.er.doe.gov/>
- Loan Guarantee Program Office - <http://www.lgprogram.energy.gov>