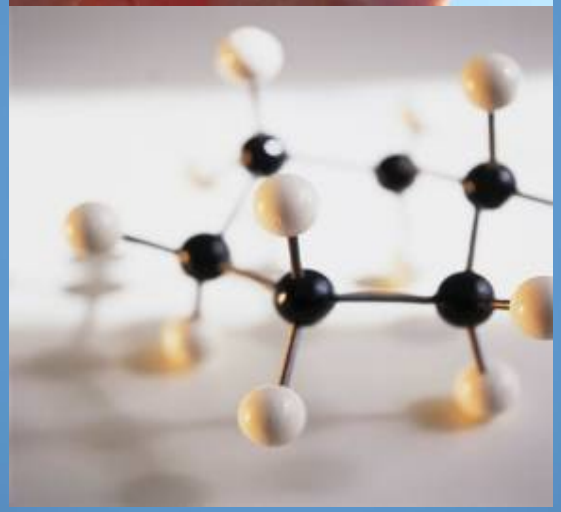


1st Brazil-U.S. Biofuels Short Course

Research Priorities on Biofuels in the USA

University of Sao Paulo
Sao Paulo, Brazil
July 27, 2009

Lawrence J. Russo, Jr.
U.S. Department of Energy Biomass Program

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
- Energy Crops
- Residue Harvesting

Biochemical Platform
- Enzymatic Hydrolysis
- Lignin Conversion

Thermochemical Platform
- Pyrolysis
- Gasification

Sugar and Lignin Intermediates

Gas and Liquid Intermediates

Products

Fuels, Chemicals, Materials, Heat And Power

Biorefineries

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	Solutions
• High cost of enzymatic conversion for cellulosic ethanol	• R&D to improve effectiveness and reduce costs of enzymatic conversion
• High cost of organisms for producing ethanol from complex sugars within cellulosic biomass	• R&D on advanced micro-organisms for fermentation of sugars
• Limitations of thermochemical conversion processes	• Re-establish thermochemical conversion as a path to success
• Demonstration/integration of technology in biorefineries	• Fund loan guarantees, commercial biorefinery demonstrations, 10% scale validation, and advanced biofuel projects
• Inadequate feedstock and distribution infrastructure	• Form interagency infrastructure and feedstock teams
• Sustainability issues	• Develop detailed LCAs, tools, and models to ensure sustainable production

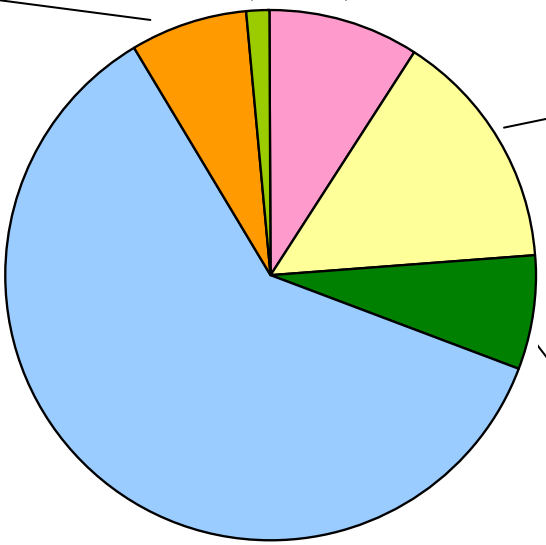
Future efforts address obstacles to biochemical and thermochemical routes to biofuels, support demonstrations, and resolve infrastructure issues.

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



Thermochemical Platform R&D
$19.9M
Syngas & Bio-oil Production
- Gasification & Gas Clean-up
- Pyrolysis & Oil Stabilization

SBIR/STTR
$2.7M

Products Development
$15.7M
- Fuels
- Other Products

Bioconversion Platform R&D
$32.1M
Low-Cost Sugars
- Pretreatment
- Enzymes
- Fermentation

Biorefinery Demonstrations
$131.5M
- Small commercial scale
- Demonstration scale
- Pilot Scale

Feedstock Infrastructure
$15.1M
Low-Cost Biomass
- Production
- Harvesting
- Collection & Storage
- Sustainability

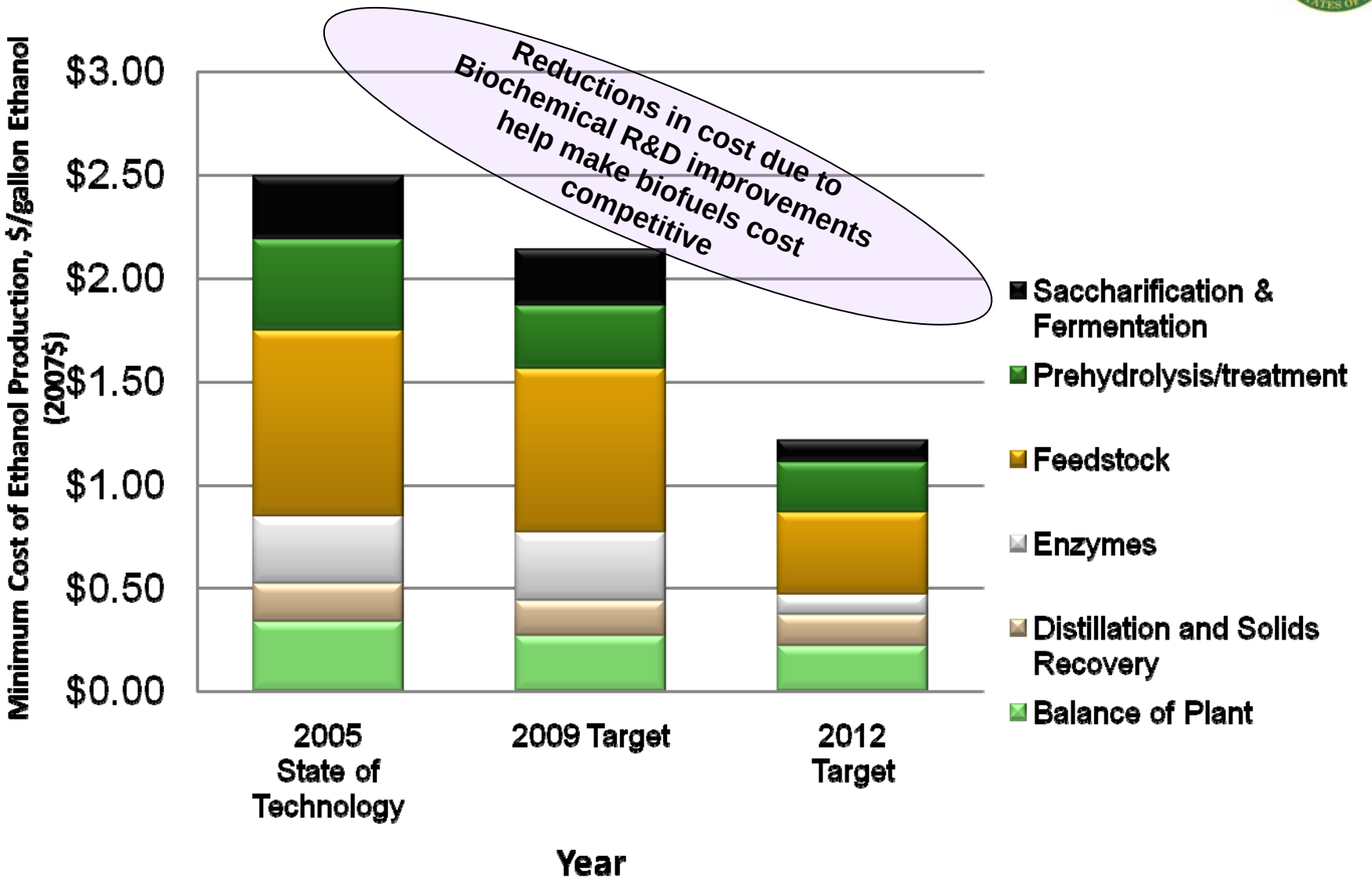
Biomass Recovery Act Funding

$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.

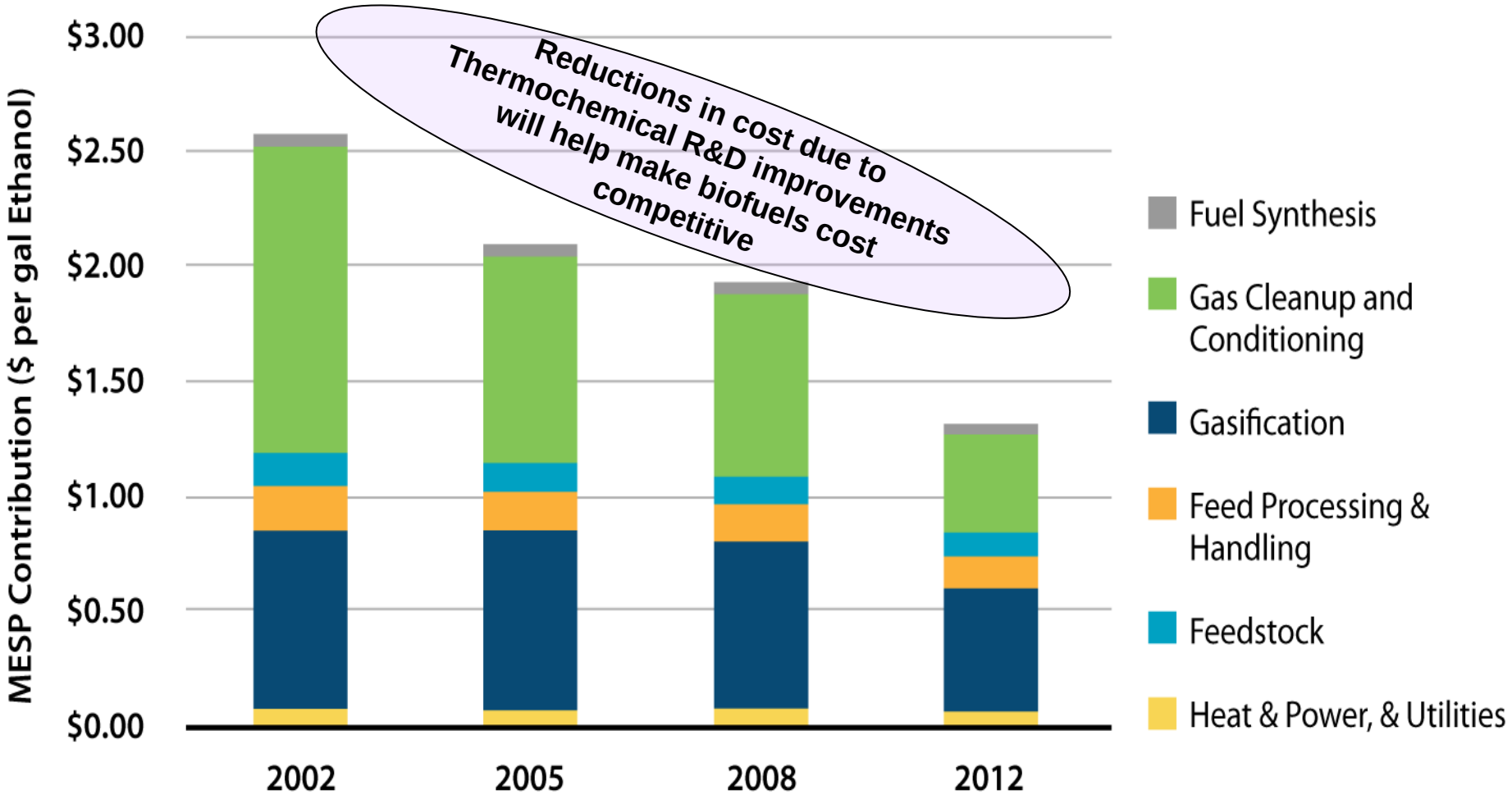
The funding will be allocated across four main areas:

- $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

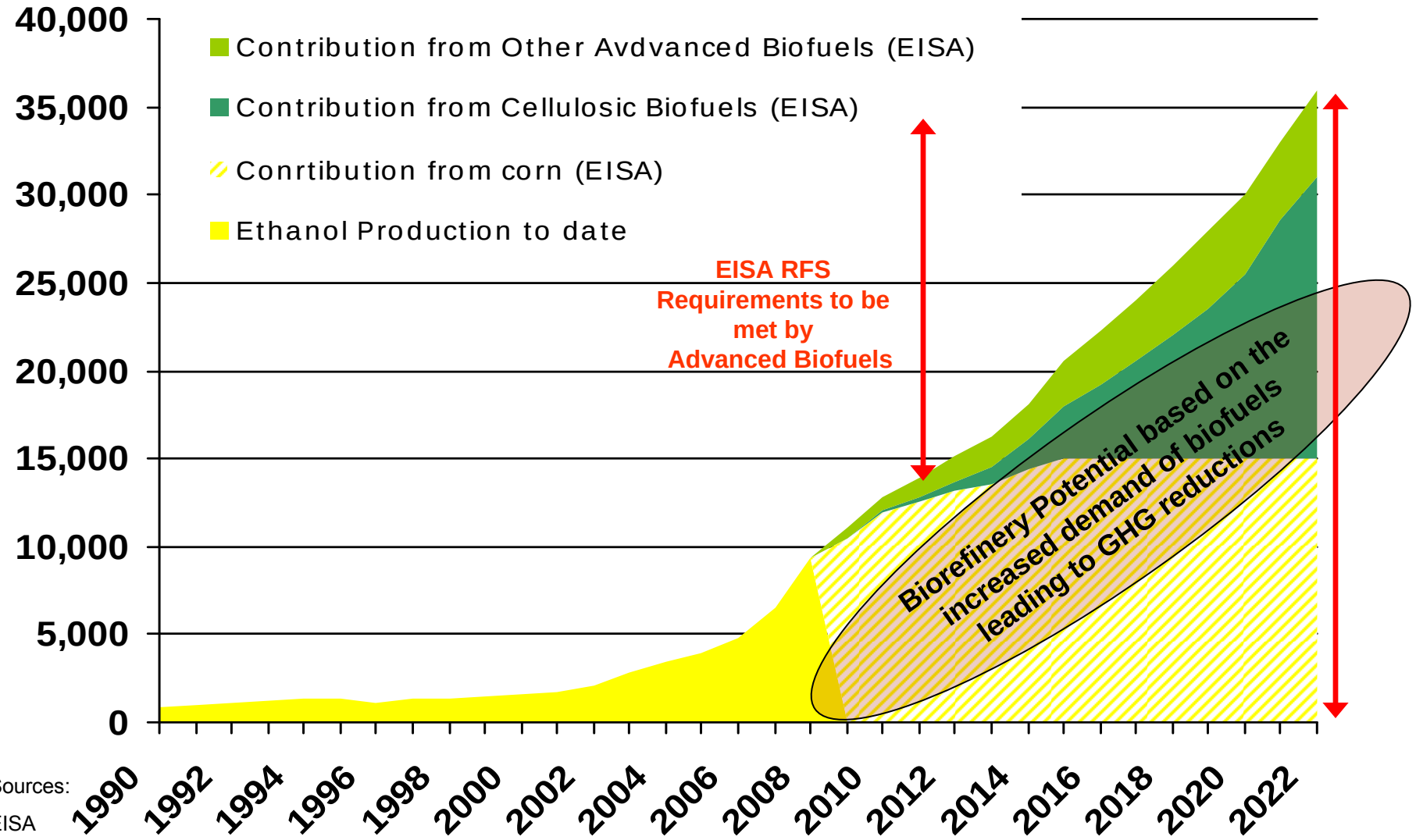


Thermochemical R&D



Biofuels Production, EISA Requirements

(Million Gallons/Year)



Sources:

EISA

Renewable Fuels Association (As of July 14, 2008)

Strategic Focus: Sustainable Biofuels

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




- **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

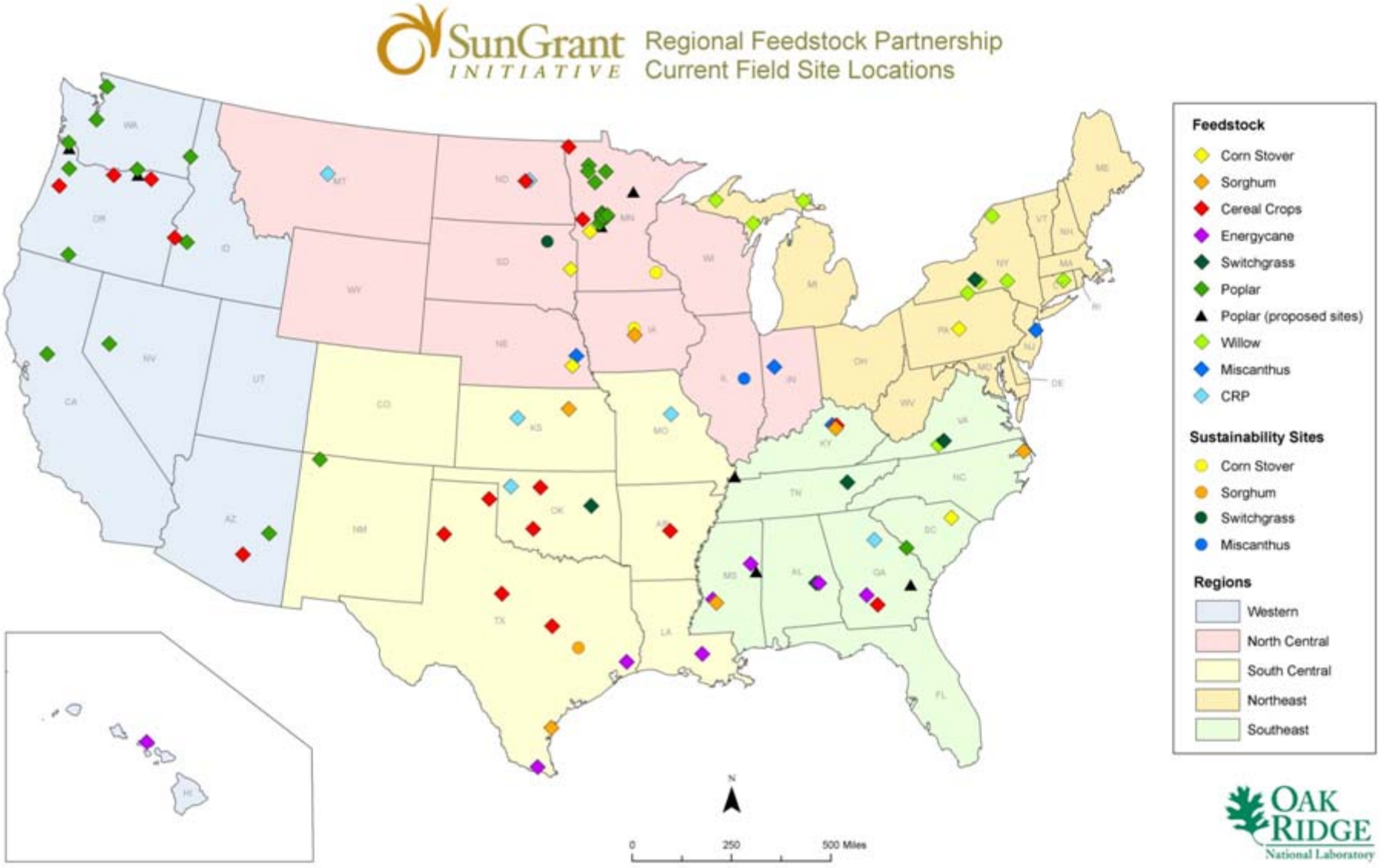
Advanced Biofuels
- Algal Based Biofuels
- Higher Alcohols
- Green Gasoline
- Renewable Diesel
- Renewable Jet Fuel Formulations

Value-added Bioproducts/Coproducts

Carbon Mitigation
- Potential role in future carbon legislation

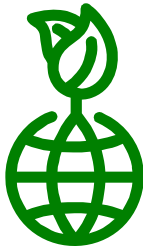
Stimulate/Leverage Scientific Progress

Regional Feedstock Partnership Feedstock Trial Sites



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.

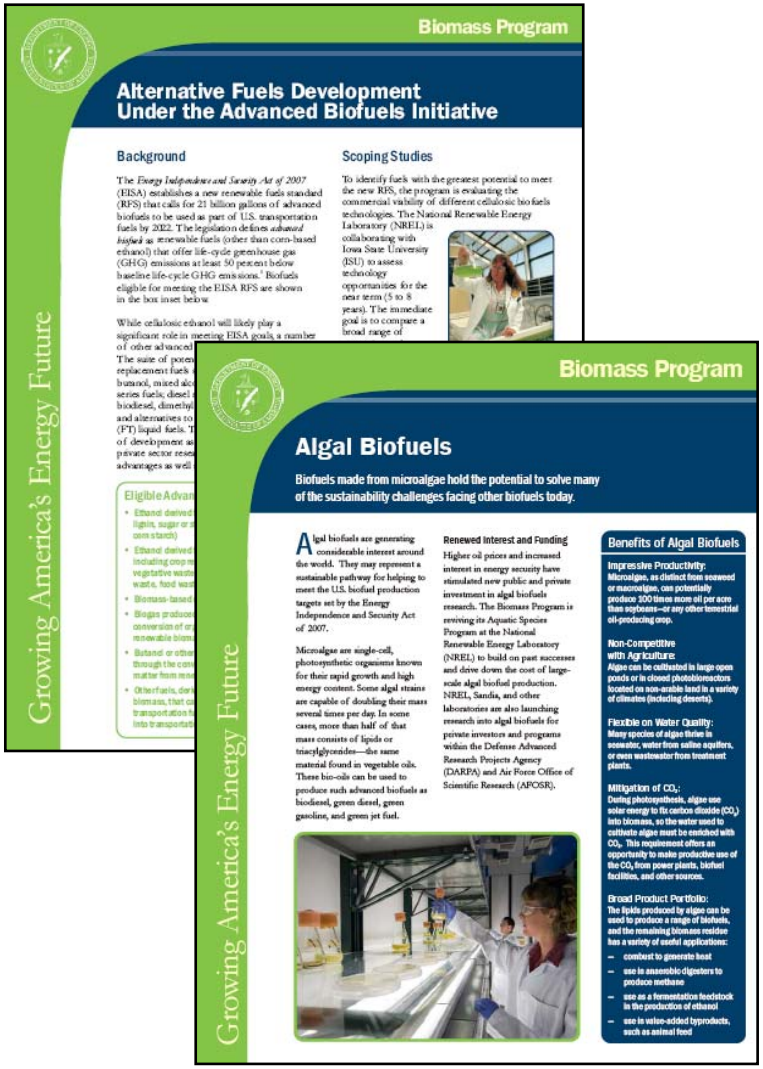
Compared to ethanol, this next generation of biofuels would be more similar in chemical makeup to gasoline and diesel fuels.

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



- 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

Biofuels From Algae

Petroleum Refinery

Biodiesel

Green Diesel

Lipids

Carbohydrates and Protein

Cellulosic Biorefinery

Ethanol

Jet Fuel (Jet A or JP-8)

Algal Biofuels - Technical Barriers

Algal Cultivation

- Bioreactor design
  - Temperature control
  - Invasion and fouling
- Starting species
  - Growth rate
  - Oil content & FA profile
- Nutrient requirements
  - CO_2 and H_2O sources

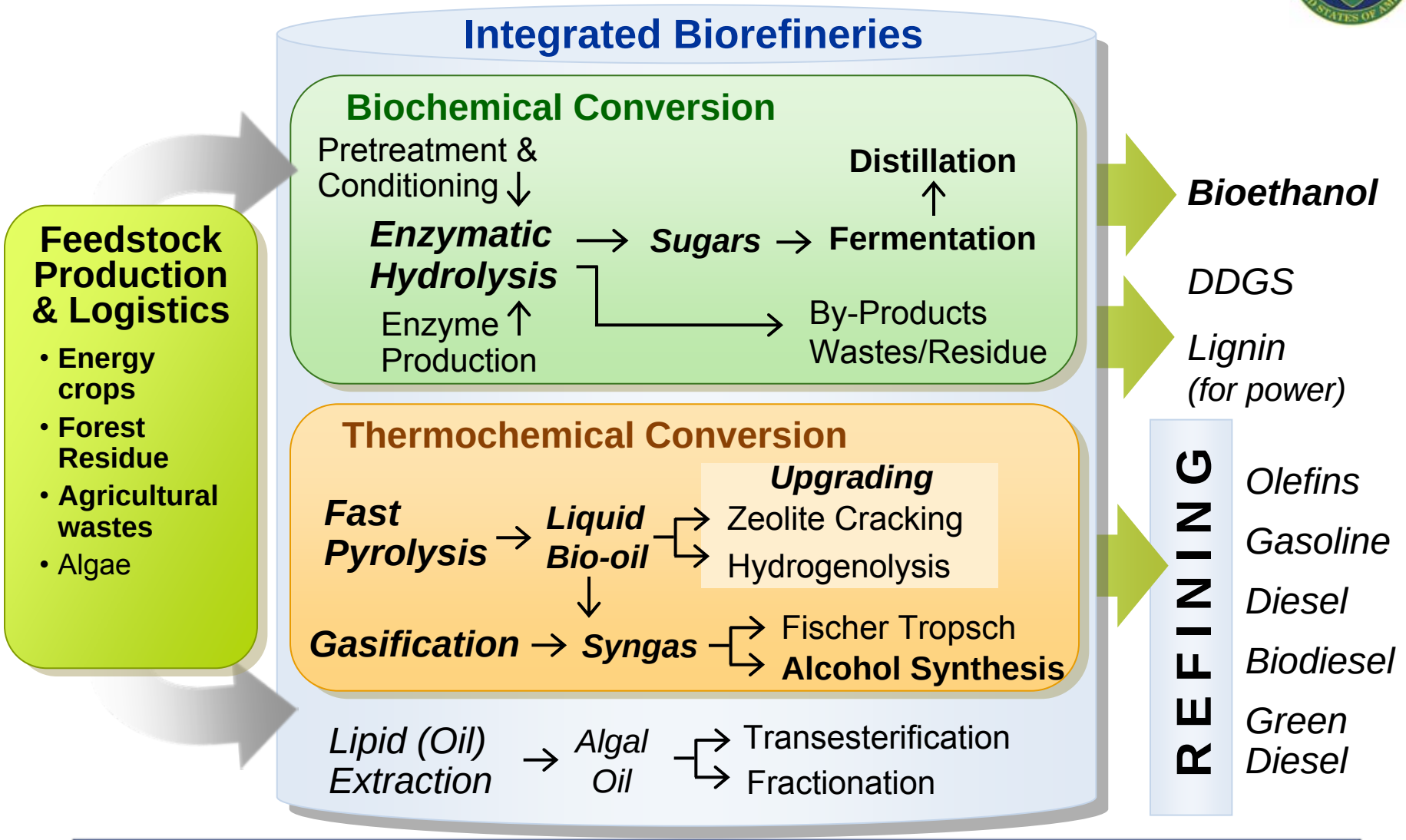
Oil (Lipid) Recovery

- De-watering methods
- Lipid extraction
- Purification

Fuel Production

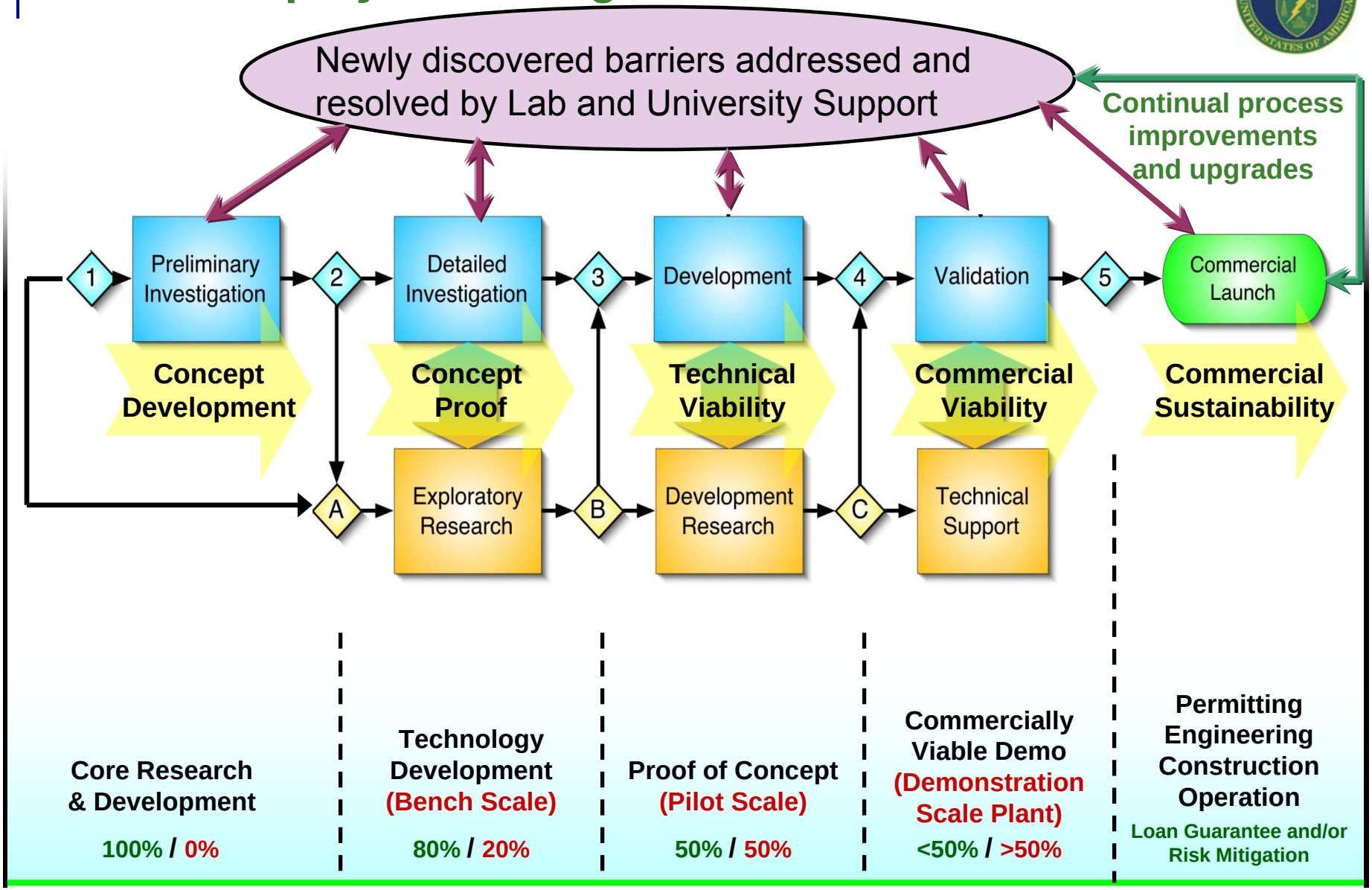
- Process optimization
- Fuel characteristics
- Engine testing (ASTM)

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)

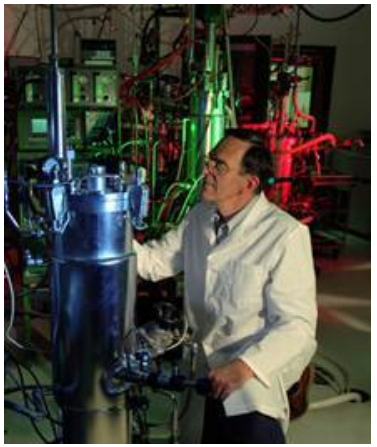
- Integration of gasification and catalyst development
- Pyrolysis oil stabilization

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

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

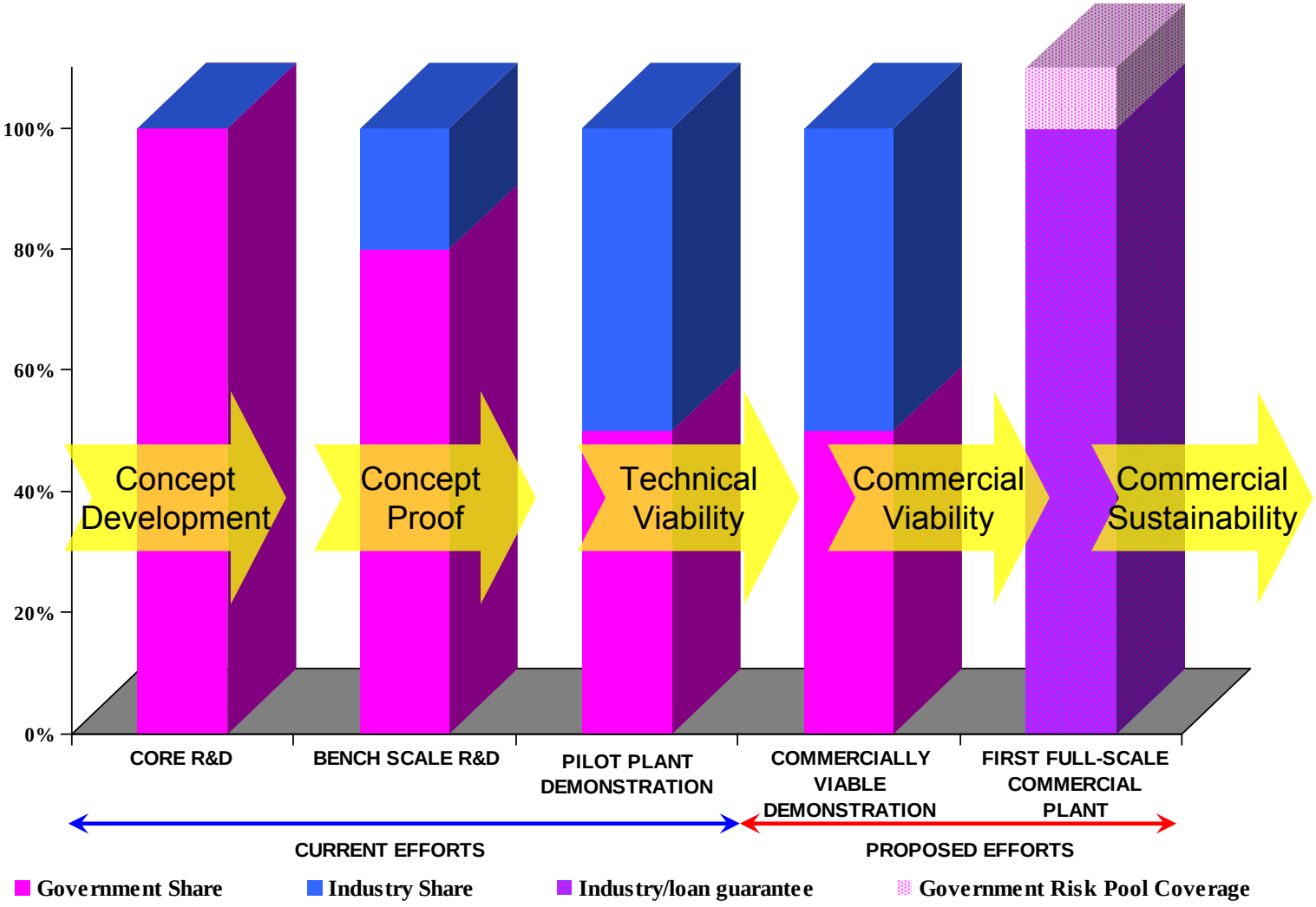
Current Solicitations

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



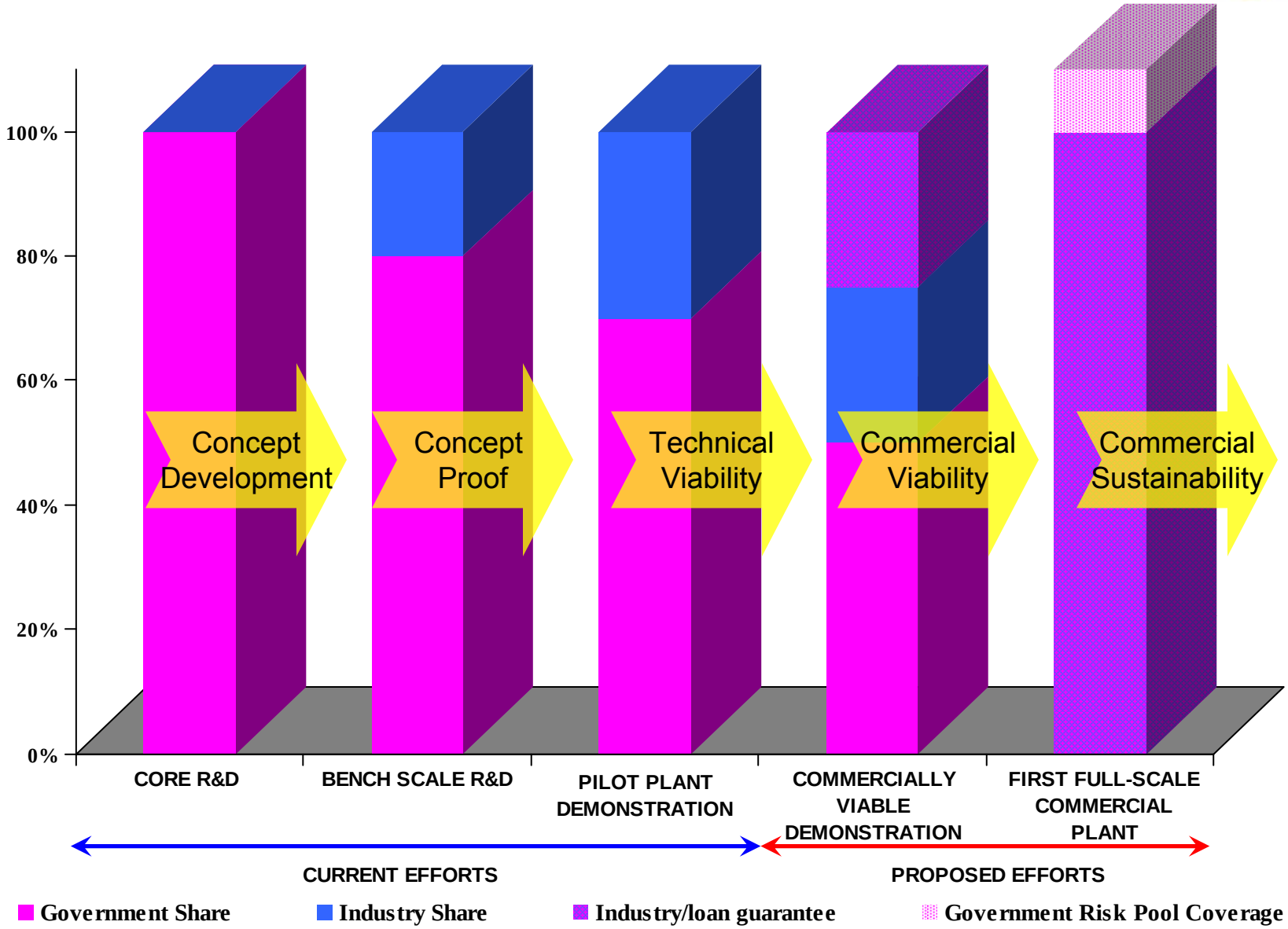
Current Deployment Funding Plan

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

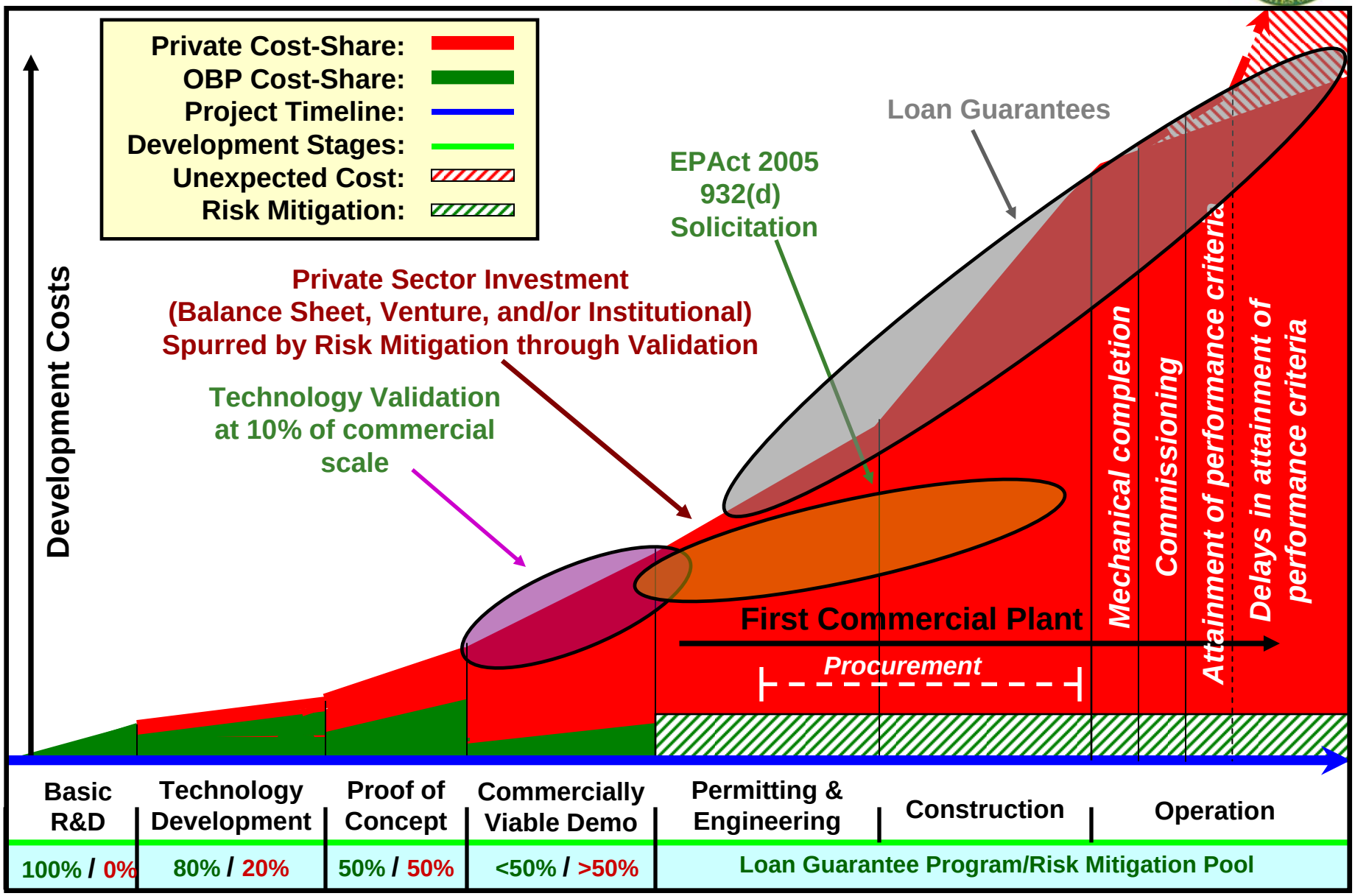
- including algal feedstocks and the production of advanced biofuels such as bio-butanol and green gasoline. **(FOA revamped for recovery funds)**

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))**

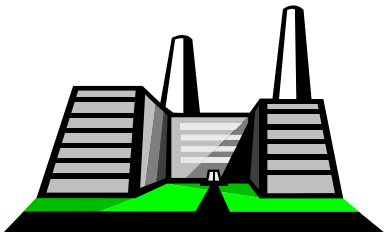
Deployment Barriers and Solutions



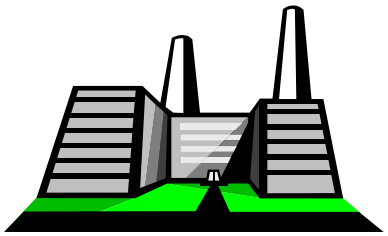
What to Look for in Commercialization Projects

- 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

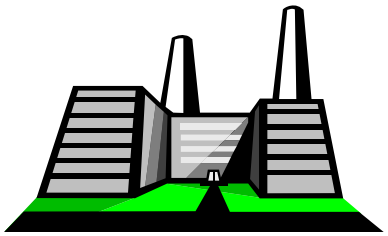
A Community Based "Green" Industrial Complex ??



Facility 1



Facility 1



Facility 1

Power To Local Grid

Waste Heat and Power

Liquid Biofuels

Waste heat

Lignin

Power

Shared Feedstock

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