Bioenergy: National Goals, State of the Research, and Wave of the Future

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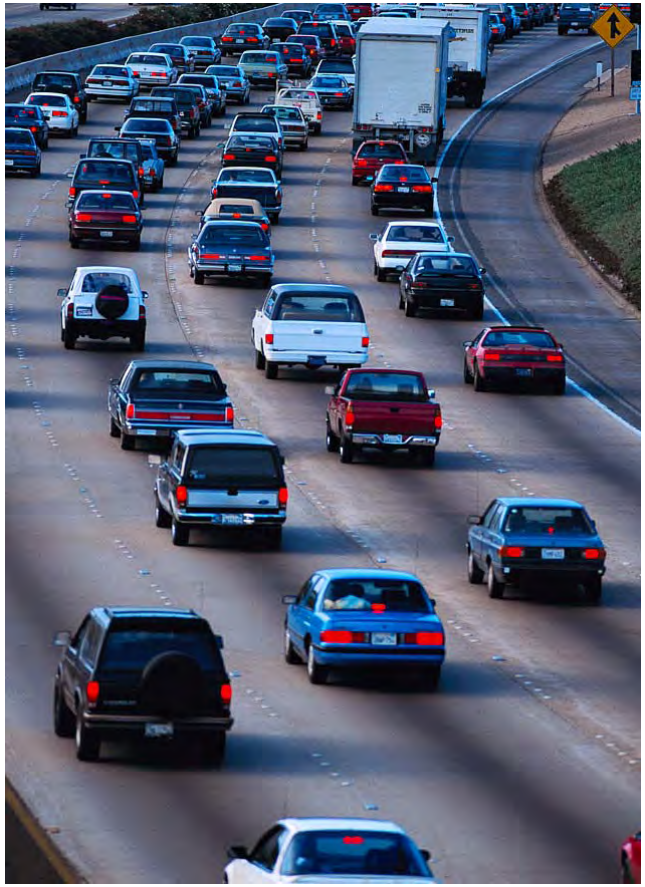
Presentation Outline

- U.S. Dependence on Foreign Oil – the need for an alternative
- Benefits of Biomass – why biomass is the best alternative
  - Existing Fuels Market
  - National and Economic Security Benefits
  - Environmental Benefits
  - Rural Development
- Biomass-related Legislation and Guidance – what is guiding Federal action
- OBP R&D – current efforts and accomplishments to date
- The President's Initiative – national goals for biomass

National and Economic Security Benefits

- Biofuels could meet the President's Goal of replacing more than 75 percent of our oil imports from the Middle East by 2025
- Energy supply diversity makes us less vulnerable to geopolitical uncertainties, price volatilities, and supply disruptions at home and abroad



Environmental Benefits

Reduction in greenhouse gas (GHG) and criteria pollutant emissions

Compared to reformulated gasoline, ethanol (E85) generates approximately[1,2,3]:

- 15% to 68% less GHG
  - 30% to 77% less carbon dioxide (CO_2)
  - Up to 58% less methane (CH_4)

Compared to fossil diesel, biodiesel (B100) generates[4]:

- 67% less unburned hydrocarbons (HC)
- 48% less carbon monoxide (CO)
- 47% less particulate matter (PM)
- ~10% more nitrogen oxides (NO_x)

[1] Low end of the range represents corn ethanol; high end represents cellulosic ethanol.
[2] These are well-to-wheel numbers.
[3] Cellulosic ethanol emissions include credits from the sale of electricity generated from biomass residues.
[4] These are tank-to-wheel numbers.

Legislative Drivers

- The President's Goals of replacing 75% of Middle East Oil imports by 2025 and for research to make cellulosic ethanol production practical and competitive by 2012
- The Energy Policy Act of 2005 provides direction on program content as well as loan guarantee authorization for commercial scale demonstrations.
- The President's National Energy Policy includes multiple recommendations that support bioenergy.
- The Biomass R&D Act of 2000 directs DOE and USDA to enhance and coordinate biomass R&D efforts.
- The Energy Title (Title IX) of the Farm Bill provides support for increased use of biomass energy and products and for R&D.

OBP Mission

"The mission of Biomass Program is to partner with U.S. industry to foster research and development on advanced technologies that will transform our abundant biomass resources into clean, affordable, and domestically-produced biofuels, biopower and high-value products. The result will be improved economic development, expanded energy supply options, and increased energy security"

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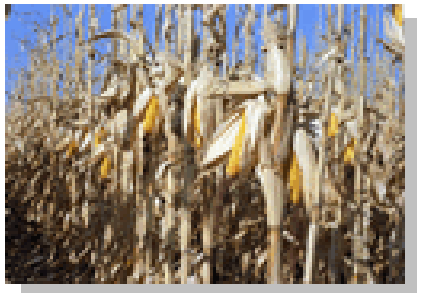
Integrated Biorefinery



Feedstock production, collection, handling & preparation

Hydrolysis
Acids, enzymes
→ **Sugars & Lignin**

Gasification
High heat, low oxygen
→ **Synthesis Gas**

Digestion
Bacteria
→ **Bio-gas**

Pyrolysis
Catalysis, heat, pressure
→ **Bio-Oil**

Extraction
Mechanical, chemical
→ **Carbon-Rich Chains**

Separation
Mechanical, chemical
→ **Plant Products**

USES

Fuels:
- Ethanol
- Renewable Diesel
- Hydrogen

Power:
- Electricity
- Heat

Chemicals:
- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty acids
- Acetic Acid
- Carbon black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food and Feed

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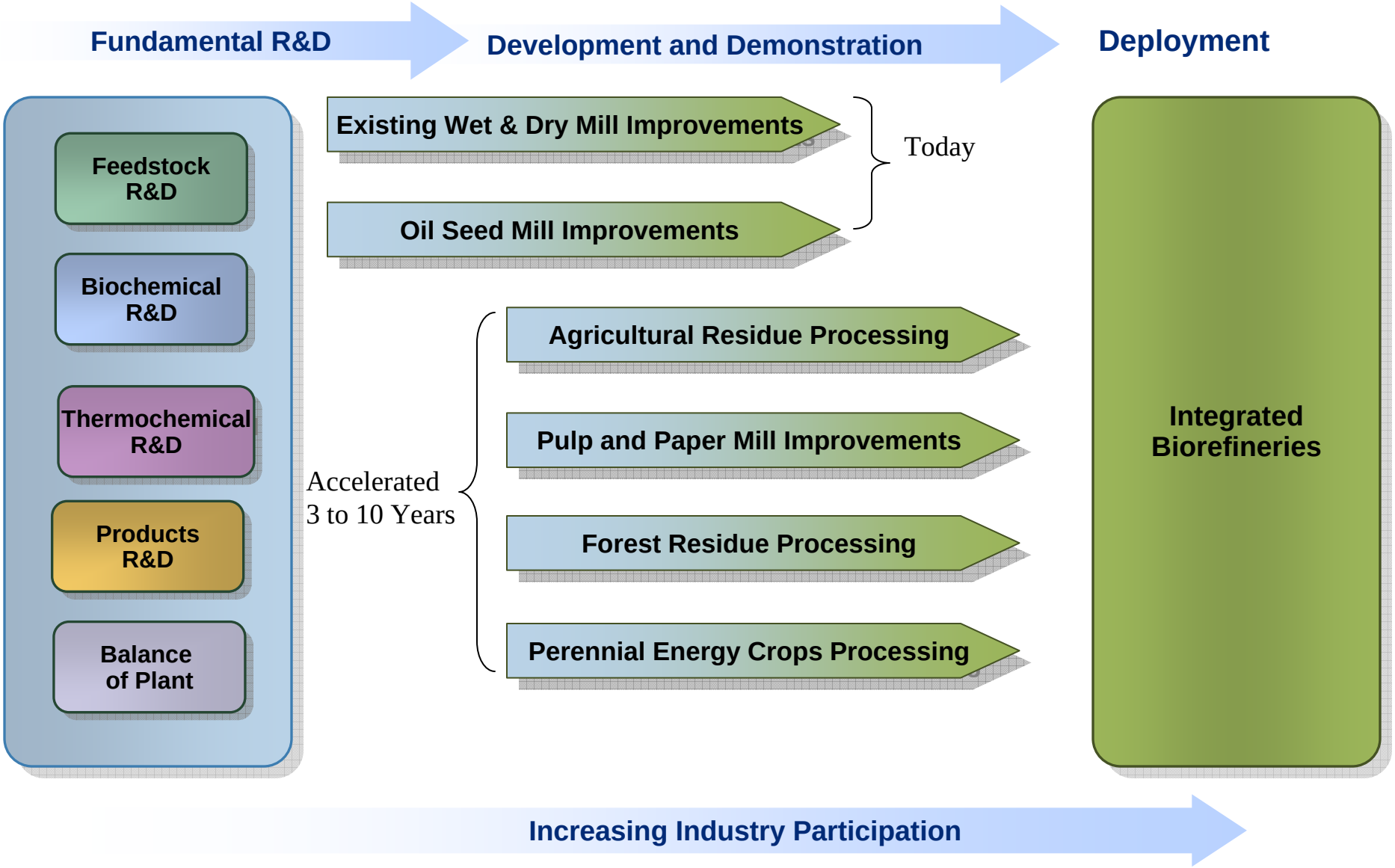
R&D Platforms and Pathways



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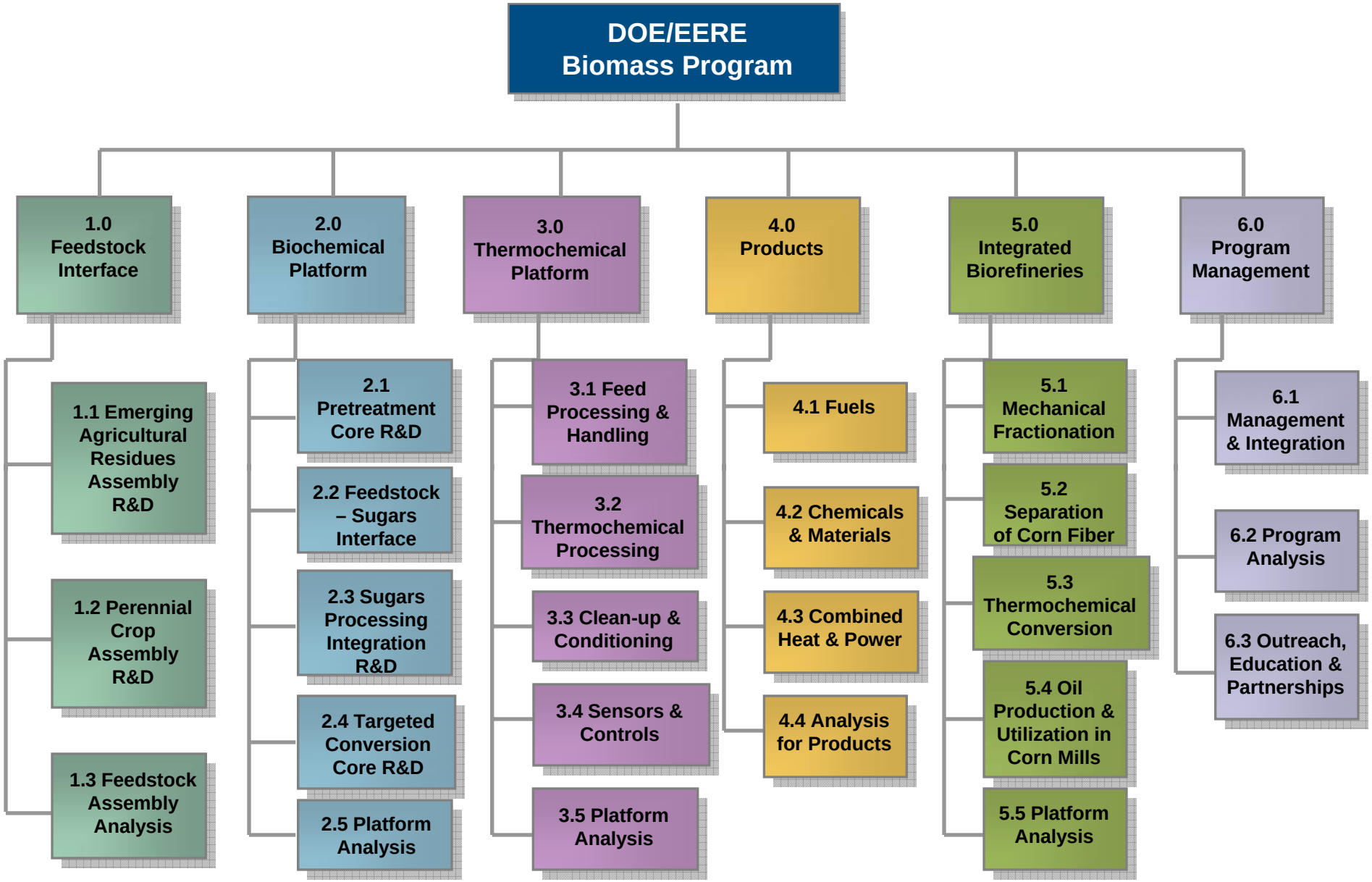
Work Breakdown Structure



Platform Area Targets

Technology Platform	Cost Target
Feedstocks	Delivered feedstock cost of $35/dry ton by 2010
Biochemical	Sugars cost of $0.064/pound by 2010
Thermochemical	Syngas cost of $7.15/MMBtu by 2007
Products	ID at least one sugar - or oil – derived biobased chemical or material to enter the scaled-up development phase
Integrated Biorefinery	Complete preliminary engineering design package, market analysis, & financial projections for at least 2 industrial-scale projects for near term agricultural pathways to produce a minimum of 5 million gallons of biofuels/year.

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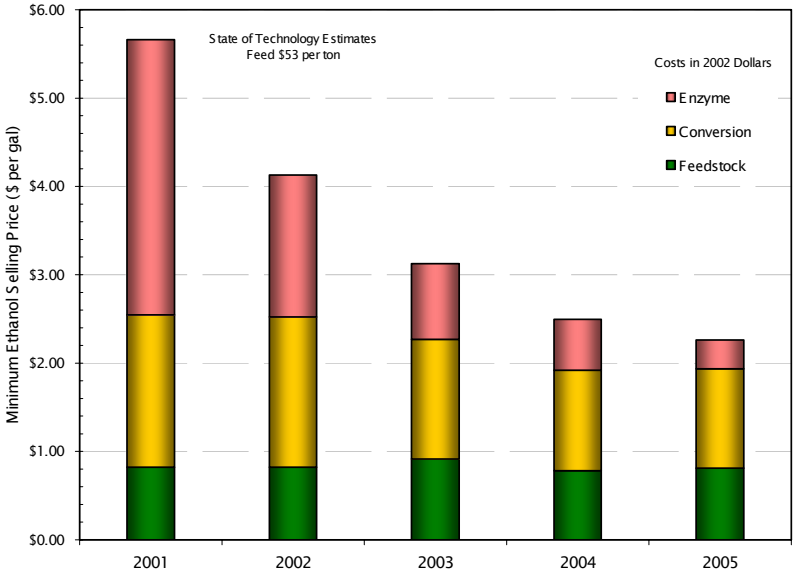
Fermentation Technology Platform



	2001 Early Enzyme-Subcontract	2005 Post Enzyme-Subcontract	2010	2012 Market Target
Minimum Ethanol Selling Price	$5.66	$2.26		$1.07
Installed Capital per Annual Gallon		$3.04		1.85
Yield (Gallon/dry ton)		65		90
Feedstock				
Feedstock Cost ($/dry ton)	$53	$53		*$30/35
Pretreatment				
Solids Loading (wt%)	19%	30%	30%	30%
Xylan to Xylose	68%	63%	81%	90%
Xylan to Degradation Products	16%	13%	8%	5%
Conditioning				
Xylose Sugar Loss	13%	13%	4%	0%
Glucose Sugar Loss	12%	12%	4%	0%
Enzymes				
**Enzyme Contribution ($/gal EtOH)	$3.11	$0.32	$0.16	$0.10
Saccharification & Fermentation				
Total Solids Loading (wt%)	13%	20%	20%	20%
Combined Saccharification & Fermentation Time (d)	10	7	5	3
Overall Cellulose to Ethanol	86%	86%	86%	86%
Xylose to Ethanol	76%	76%	80%	85%
Minor Sugars to Ethanol	0%	0%	80%	85%
*$35 per dry ton loose feedstock is equivalent to $30 per dry ton baled feedstock				
**Model value, slightly lower than metric value				

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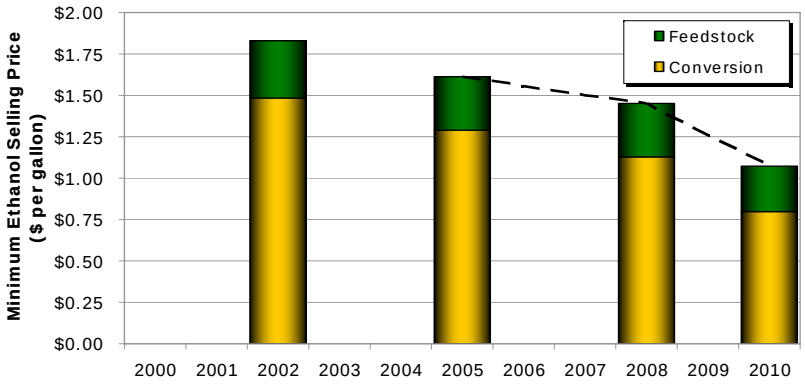
Gasification Technology Platform



	2002	2005	2008	2010 (FY06 Budget Target)
Process Description	Tar Removal & Disposal	Sequential Tar & Light Hydrocarbon Reforming	Sequential Tar & Light Hydrocarbon Reforming — Increased Hydrocarbon Conversion	Consolidated Tar & Light Hydrocarbon Reforming
Minimum Ethanol Selling Price ($/gal ethanol)	$1.83	$1.61	$1.45	$1.07
Higher Alcohol Co-Product Value (% market value)	85%	85%	85%	85%
Installed capital cost ($/annual gal MA)	$3.01	$2.71	$2.69	$2.36
Operating cost ($/annual gal MA)	$0.87	$0.81	$0.75	$0.50
Ethanol Yield (gal/dry ton)	55	56	56	55
Mixed Alcohol Yield (gal/dry ton)	75	77	77	76
Feedstock				
Feedstock Type	Woods Chips	Woods Chips	Biorefinery residues	Biorefinery residues
Feedstock cost ($/dry ton)	$30	$30	$30	$30
Thermochemical conversion				
Process type	Low Pressure Indirect Gasification	Low Pressure Indirect Gasification	Low Pressure Indirect Gasification	Low Pressure Indirect Gasification
Syngas yield (lb/lb dry feed)	0.78	0.78	0.78	0.78
Benzene & Tar yield (lb/lb dry feed)	0.014	0.014	0.014	0.014
Raw syngas methane (mol% - dry basis)	15.36	15.36	15.36	15.36
Cleanup and Conditioning				
Methane out of tar reformer (mol% - dry basis)	N/A	8.25	4.6	1.73
Tar reformer performance:				
Light HC reforming - % CH4 conversion	N/A	20%	50%	80%
Heavy HC reforming - % benzene	N/A	70%	90%	99%
Heavy HC reforming - %tar conversion	N/A	95%	97%	99.9%
Light HC reforming - % CH4 conversion	79%	79%	79%	NA
Sulfur removal	1 ppmv (SMR)	1 ppmv (SMR)	1 ppmv (SMR)	50 ppmv (MA)
H2/CO ratio for fuel synthesis	1.2	1.2	1.2	1.2
CO2 recycle (lb/lb dry feed)	1.99	1.72	1.69	0.51
Compression for fuel synthesis (psia)	2,000	2,000	2,000	2,000
Catalytic Fuel Synthesis				
Single pass CO conversion	38.5	38.5	38.5	38.5
Overall CO conversion	96.9	96.9	96.9	96.9
CO selectivity to alcohols	80	80	80	80

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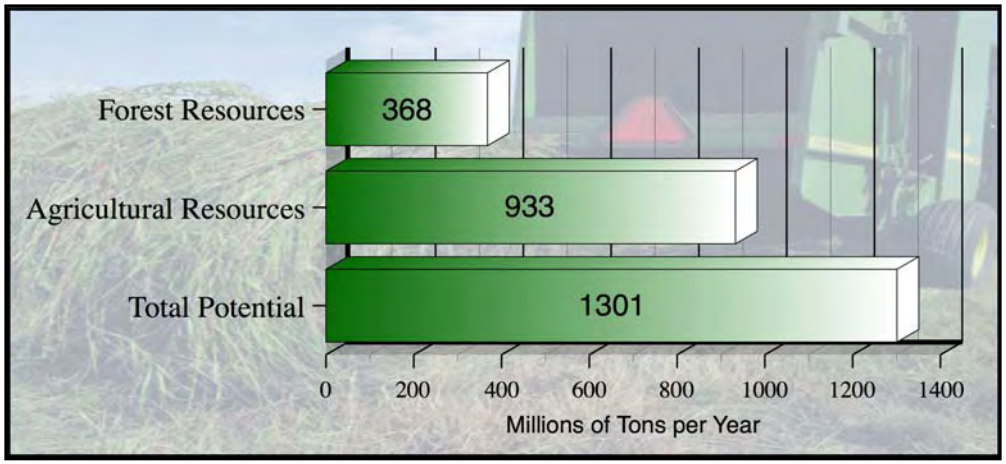
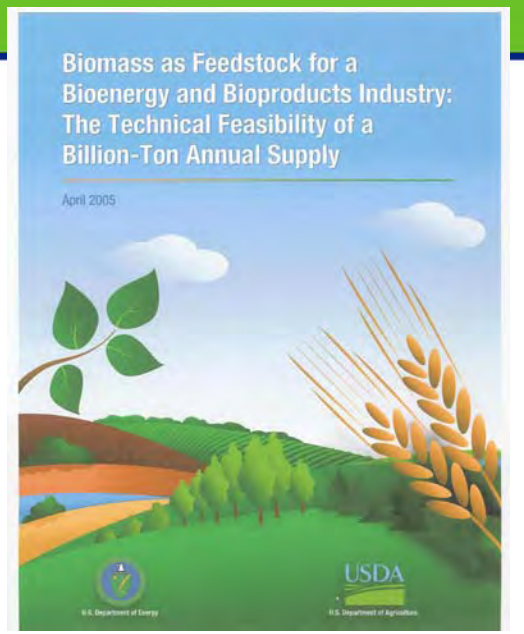
Conversion of Available Feedstocks





"Billion Ton" study indicates that enough biomass is potentially available to displace > 30% of current U.S. petroleum consumption

But it requires variety of biomass types

- Agricultural lands
  - Corn stover, wheat straw, soybean residue, manure, switchgrass, poplar/willow energy crops, etc.
- Forest lands
  - Forest thinnings, fuelwoods, logging residues, wood processing and paper mill residues, urban wood wastes, etc.

President's Biofuels Initiative

Replace more than 75 percent of our oil imports from the Middle East by 2025

2012 Goal: Fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switch grass. Our goal is to make this new kind of ethanol practical and competitive within six years.

How Do We Get There?

- "We'll also fund additional research in cutting-edge methods of producing ethanol"
- Provide the fundamental R&D and capability needed for future developments
- Use public policy directives and incentives to drive development and markets
- Implement strategy during 2007 – 2012
  - Help industry build the first unit
  - Cost share industrial-scale validation of multiple pathways to the integrated biorefinery
  - Expand feedstock development efforts

The Biofuels Initiative Strategy

- Investigate the Conversion of a much broader number of possible feedstocks
- Accelerate the present efforts to extract and ferment the sugars in corn stover to ethanol at a cost competitive price
- Reestablish the Thermo-Chemical conversion technology as a second possible pathway to success
- Develop regional feedstock partnerships to identify local opportunities for feedstock production and ethanol production

BACK-UP SLIDES

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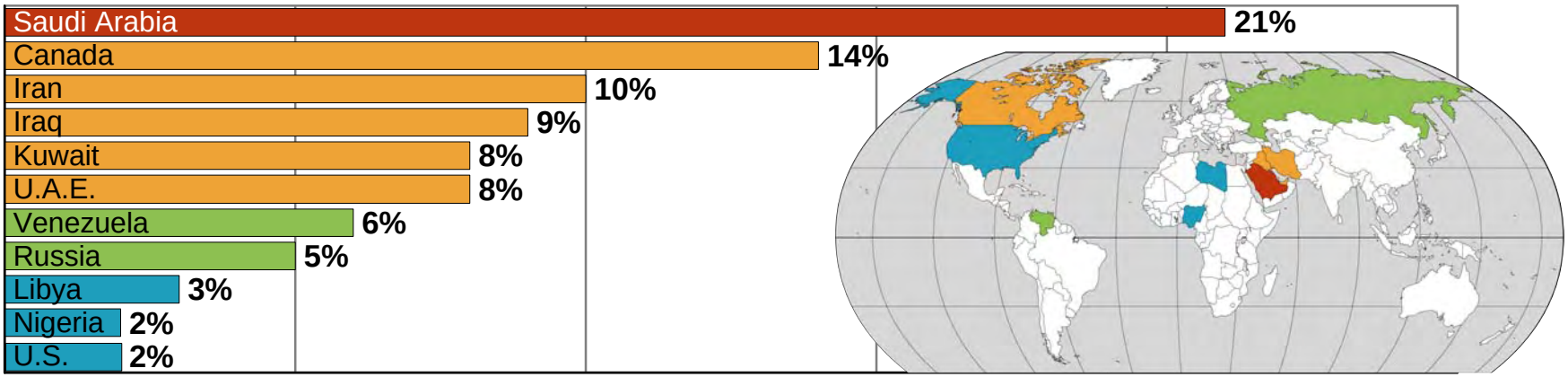
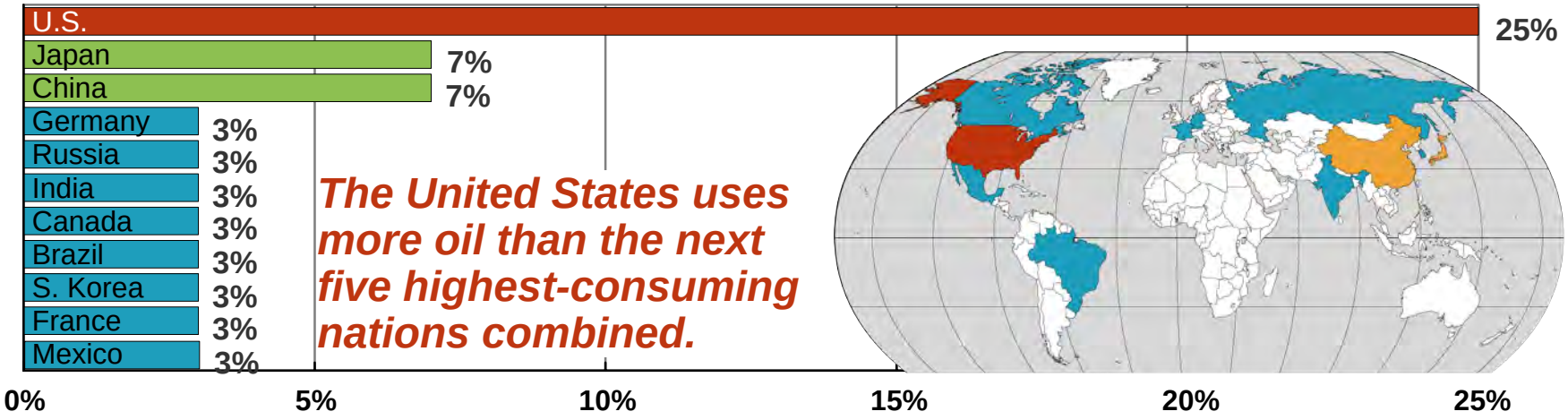
U.S. Dependence on Foreign Oil

Oil Reserves



Rate of Use



Updated July 2005. Source: International Energy Annual 2003 (EIA), Tables 1.2 and 8.1-O&GJ. Canada's reserves include tar sands.

Federal Agency Collaboration

- Healthy Forest Restoration Act of 2003, Title II
- Memorandum of Understanding (MOU) for Woody Biomass Utilization (DOE/USDA/DOI)
- MOU for Biomass to Hydrogen (DOE/USDA)
- Biomass Research and Development Act of 2000
  - Biomass R&D Technical Advisory Committee
    - Vision for Bioenergy & Biobased Products in the US
    - Roadmap for Bioenergy & Biobased Products in the US
  - Biomass R&D Board (DOE/USDA/DOI/EPA/NSF/OFEE)
- Farm Bill 2002, Title IX
  - Federal Procurement of Biobased Products (Section 9002)
  - Renewable Energy Systems and Energy Efficiency Improvements (Section 9006)
  - Biomass Research and Development (Section 9008)
    - Joint DOE/USDA Solicitation for FY 02, FY 03, & FY04
  - Continuation of the Bioenergy Program (Section 9010)
- Joint Projects
  - Joint USDA/DOE Feedstock Stage Gate Review
  - Billion Ton Feedstock Study (USDA/DOE)

Existing Fuels Market

Current Transportation Fuels Demand

- 2005 gasoline consumption: 139.9 B gal per year
- 2005 On-Highway Diesel consumption: 36.5 B gal per year

Key Drivers Behind Future Biofuel Demand

- 2005 EPAct mandates the use of 7.5 B gal of renewable fuels per year in U.S. gasoline by 2012
- State MTBE Bans
  - 17 currently in effect, 1 begins in 2007, 2 pending Federal action this accounts for approximately 45 percent of the Nation's MTBE Consumption
  - 2002 MTBE demand was 3.2 B gal per year
  - Flexible fuel vehicles (FFVs)
    - Approximately 4.5 million FFVs are on the road that are capable of consuming more than 3.5 B gal per year of ethanol[1]

[1] Assumes use of E85 as the primary fuel.

Rural Development

- **In 2004, the ethanol industry[1]:**
  - Supported creation of more than 147,000 jobs in all economic sectors
  - Boosted U.S. household income by $4.4 billion through increased economic activity and new jobs
  - Added $1.3 billion and $1.2 billion of tax revenue for federal and state/local governments, respectively
- **A 40 million gallon per year dry mill ethanol plant can[1]:**
  - Expand the local economic base by $110 million annually
  - Create approximately 41 new jobs at the plant
  - Add nearly $20 million to annual household income in the surrounding community
  - Contribute approximately $1.2 million annually to state and local tax revenue
- According to the USDA, ethanol production increases the price a farmer receives for corn by 25-50 cents per bushel

1 Estimated by applying RIMS II multipliers (U.S. Department of Commerce, Bureau of Economic Analysis) to plant expenditures.