U.S. DOE Biomass Program

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IEA Biofuels & Bioenergy: Challenges & Opportunities Conference
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Why Biomass & Biofuels

- Ethanol production and markets exist now and are growing
- Biomass is the only renewable energy source available that can displace liquid transportation fuels NOW!
- The use of biomass to produce hydrogen or as a hydrogen carrier provides long-term value to a diverse future energy supply
- Biofuels could meet up to 30 percent of our present fuel needs by 2030
- Biofuels produced from domestic resources will reduce our dependence on foreign sources of energy
- Energy supply diversity makes us less vulnerable to geopolitical uncertainties, price volatilities, and supply disruptions from natural disasters

Strong Support and Guidance

- 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.

President's Biofuels Initiative

*Keeping America competitive requires **affordable energy.** And here we have a serious problem: America is **addicted to oil,** which is often imported from unstable parts of the world.*

*The best way to break this addiction is through **technology….** and we are **on the threshold of incredible advances**…*

*So tonight I announce…push for breakthroughs in two vital areas…**change how we power our homes and offices**,…**change how we power our automobiles**.*

What the Initiative Provides for Biofuels

- Investigate the conversion of a much broader number of possible feedstocks
- Develop regional feedstocks partnerships to identify local opportunities for feedstock production and ethanol production
- Reestablish the thermo-chemical conversion technology as a second possible pathway to success
- Fermentation organism development solicitation
- Accelerated research on all major hurdles to $1.07 gallon production cost in an established industry
- Enable the 1st U.S. commercial scale cellulosic ethanol production facility (EPAct, Section 932)
- Enable larger scale demo's of a variety of feedstocks and conversion technologies.

Hurdles to Overcome

Overall Needs

- Production of ethanol from a variety of feedstocks available across the U.S.
- Lower the production costs of cellulosic ethanol
- Conversion technology options

Research Focus

- Faster fermentation times
- Improved yield of ethanol per ton of feedstock
- Continue to reduce enzyme cost
- Improve sugar recovery and conversion
- More than one conversion technology option

Program Goals

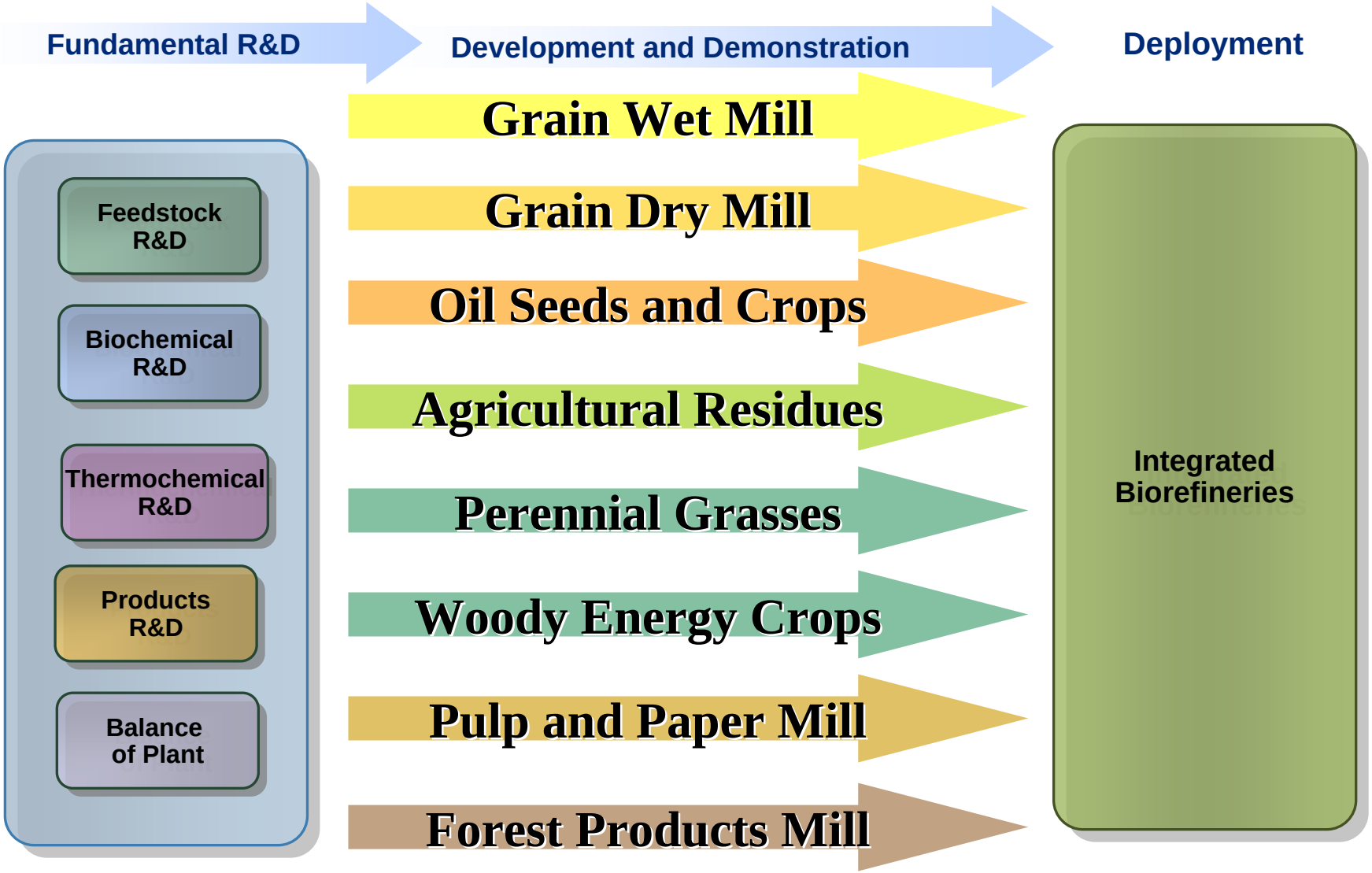
2012 Goal

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.

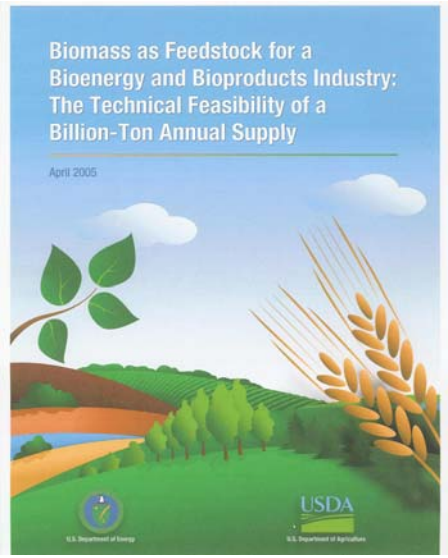
2030 Goal

Replace 30% of our current gasoline consumption with ethanol.

Pathways To Success Based on Billion Ton Study



Conversion of Available Feedstocks



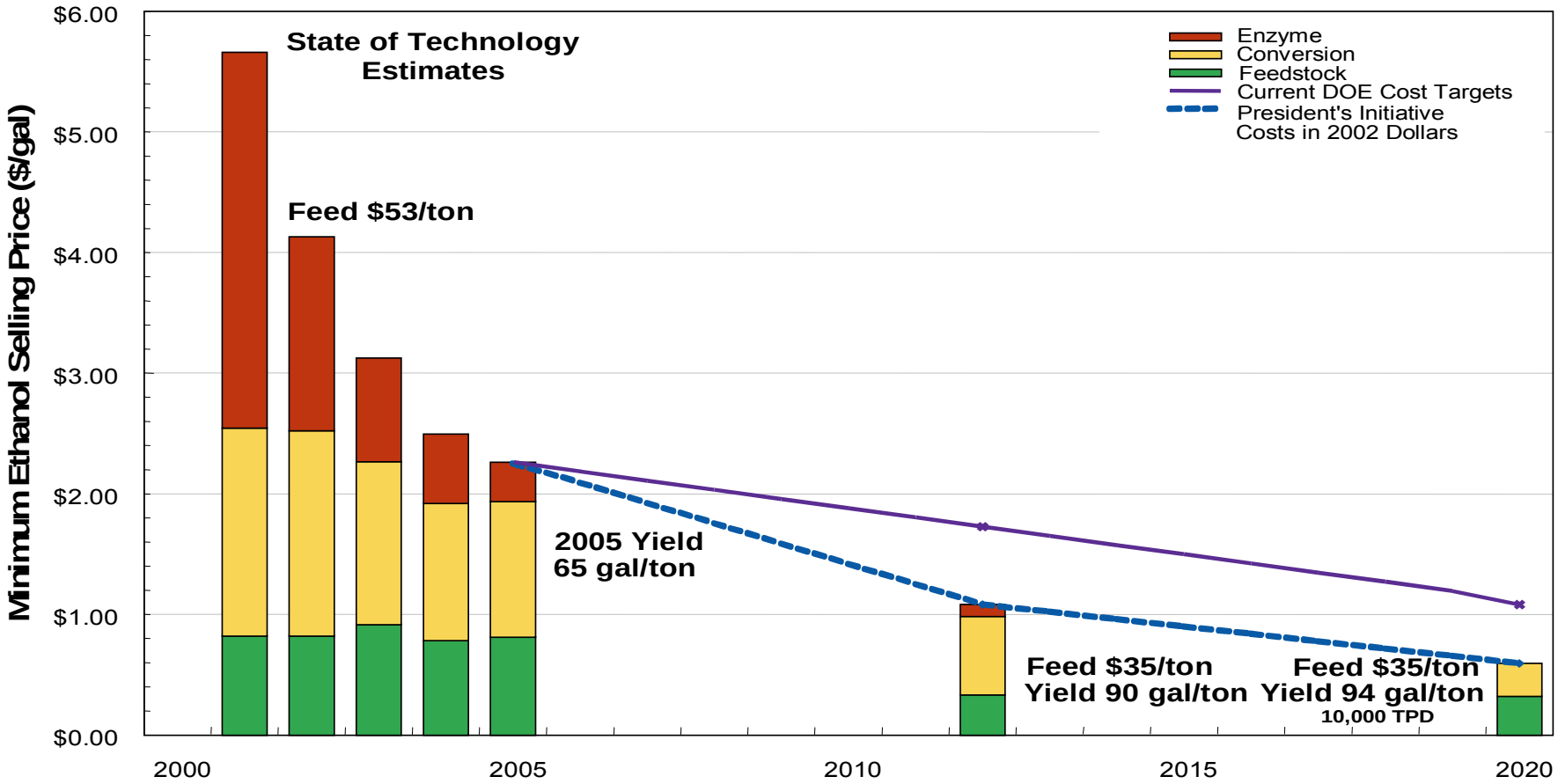
- "Billion Ton" study indicates that enough biomass is potentially available to displace > 30% of current U.S. petroleum consumption
- But it requires variety of biomass types
  - Agricultural lands
  - Corn stover, wheat straw, soybean residue, manure, switchgrass, poplar/willow energy crops, etc.
  - Forest lands
    - Forest thinnings, fuelwoods, logging residues, wood processing and paper mill residues, urban wood wastes, etc.

Feedstock Systems R&D

	2004 backcast	2005	2006	2007	2008	2009	2010	2011	2012 Market Target
Feedstock Cost Threshold ($/dry ton)	$53.00	$52.00	$50.75	$49.20	$47.30	$45.00	$42.25	$38.95	$35.00
Tonnage Available at or below Cost Threshold (millions of dry tons)***	2.8	5.5	8.2	10.8	15.9	22.2	28.9	46.2	63.3
Production									
Production Payment ($/dry ton)	$10	$10	$10	$10	$10	$10	$10	$10	$10
Harvest & Collection									
Multi-pass Capacity (% of grain only harvest capacity)	74%	85%	85%	85%	85%	85%	85%	85%	85%
Single-pass Capacity (% of grain only harvest capacity)	39%	39%	39%	39%	45%	55%	65%	75%	85%
Selective Harvest Dockage/Quality Credits* (% cost threshold)	0%	0%	0%	0%	1%	3%	4.5%	4.5%	4.5%
Mechanical Preprocessing									
(Dry) Capacity (dry tons/kW-hr)	0.011	0.028	0.028	0.031	0.033	0.033	0.033	0.033	0.033
(Dry) Bulk Density (dry lbs/cu-ft)	8.0	10.0	12.8	12.8	12.8	13.0	13.2	13.5	14.0
(Dry) Fractionation Quality Credits* (% cost threshold)	0%	0%	0%	0.5%	1%	2%	3%	5%	7%
(Wet) Capacity (dry tons/kW-hr)	0.004	0.012	0.012	0.016	0.020	0.025	0.025	0.025	0.025
(Wet) Fractionation Quality Credits* (% cost threshold)	0%	0%	0%	1%	2.5%	3.75%	4.5%	4.75%	5%
Storage									
(Dry) Shrinkage (% net fermentable sugar loss)	>10%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%
(Wet) Shrinkage (% net fermentable sugar loss)	>15%	>15%	>15%	>15%	>15%	10%	8%	6%	5%
(Wet) Stored Product Credit** (% Ethanol in Feedstock wt/wt)	0%	0%	0%	1.5%	2.5%	3.25%	3.5%	3.75%	4%
Transportation & Handling									
Field Handling Efficiencies (dry tons/labor-hr)	5.0	6.3	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Plant Handling Efficiencies (dry tons/labor-hr)	10.6	10.6	20.8	26.6	26.6	26.6	26.6	26.6	26.6

*Improved composition for greater product yield, optimized particle size, and optimized digestibility characteristics
**Ethanol production in storage from sugars otherwise lost in treatment
***Tonnage estimates only include feedstock types not associated with red highlighted parameters.

Fermentation Platform Cost Reduction

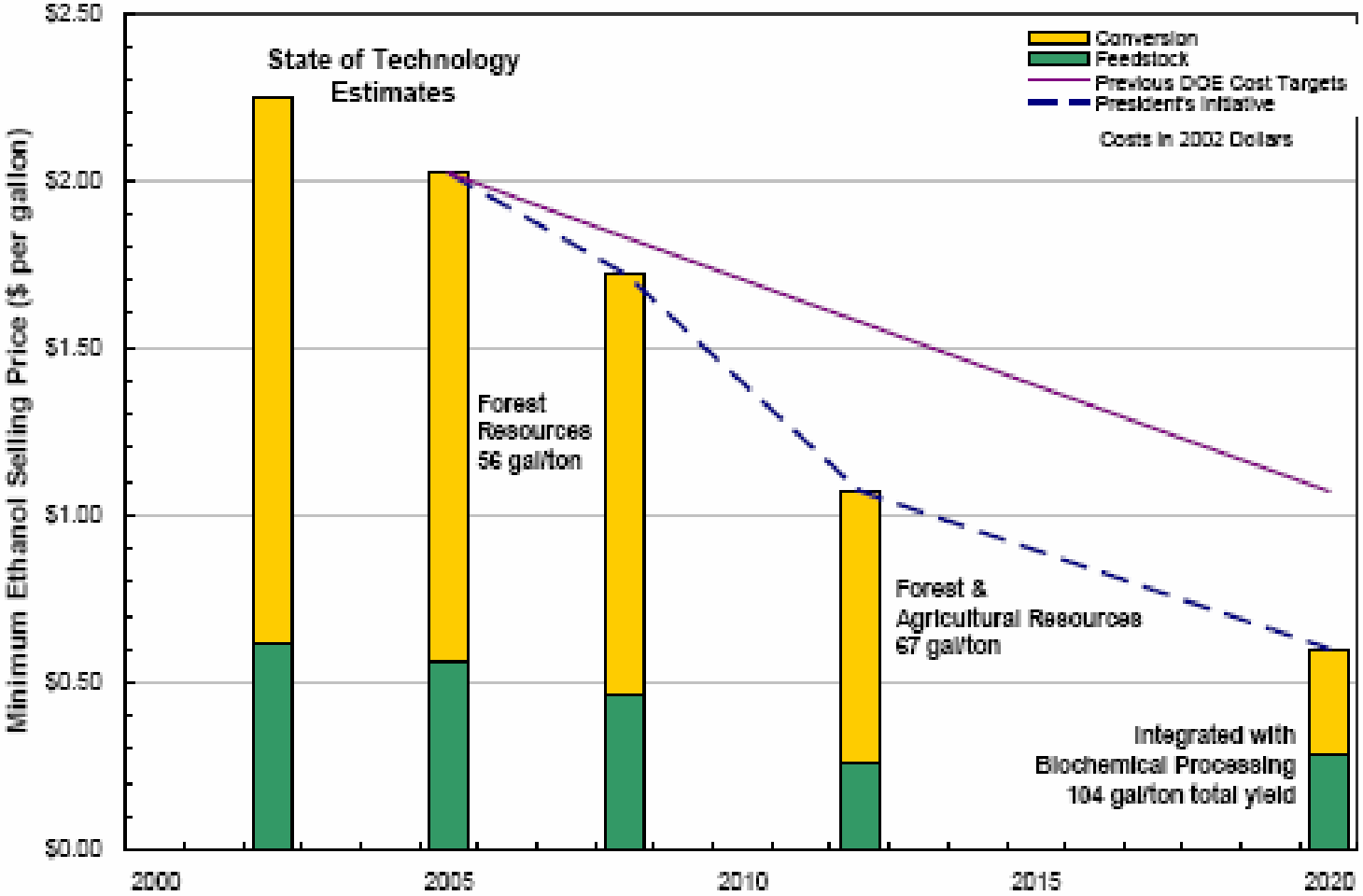


Fermentation Technology Platform

	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		$35
Pretreatment				
Solids Loading (wt%)	19%	30%	30%	30%
Xylan to Xylose	68%	63%	81%	90%
Xylan to Degradation Products	16%	13%	8%	5%
Conditioning				
Xylose Sugar Loss	13%	13%	4%	0%
Glucose Sugar Loss	12%	12%	4%	0%
Enzymes				
**Enzyme Contribution ($/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%

**Model value, slightly lower than metric value

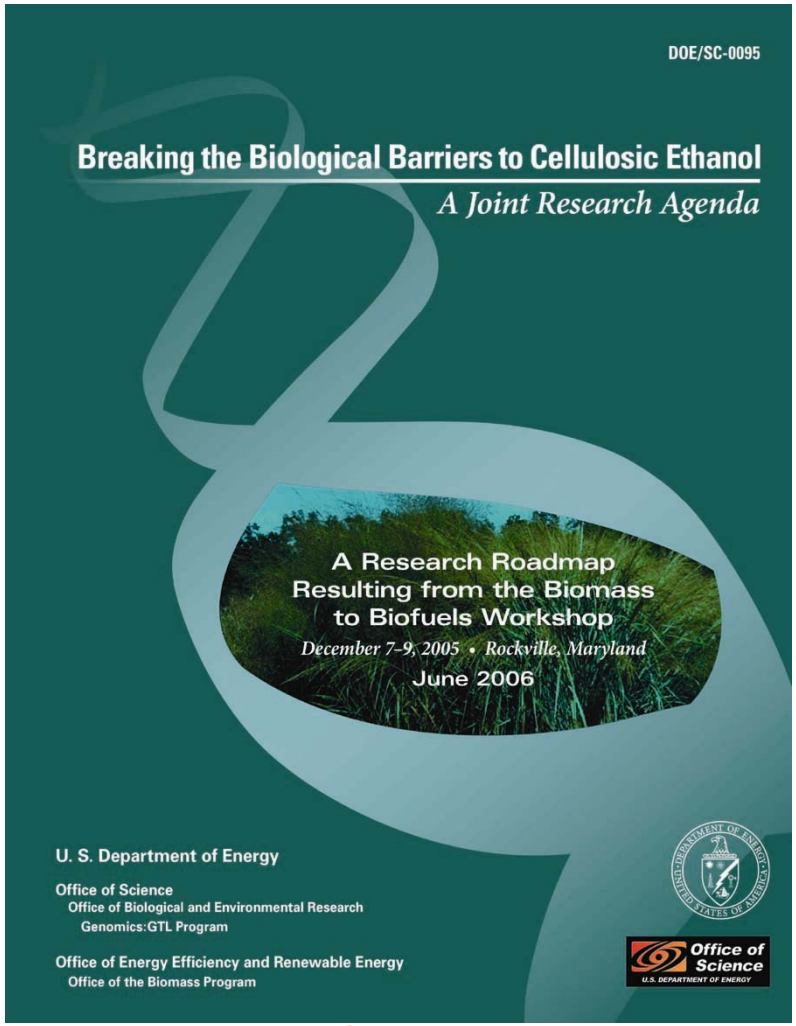
Thermochemical Platform Cost Reduction



Gasification Technology Platform

	2002	2005	2008	2010 (FY06 Budget Target)	2012
Process Description	Tar Removal & Disposal	Sequential Tar & Light Hydrocarbon Reforming	Sequential Tar & Light Hydrocarbon Reforming — Increased Hydrocarbon Conversion	Consolidated Tar & Light Hydrocarbon Reforming	Improved Alcohol Catalysis & Synthesis
Minimum Ethanol Selling Price ($/gal ethanol)	$1.83	$1.61	$1.45	$1.07	$1.07
Higher Alcohol Co-Product Value (% market value)	85%	85%	85%	85%	69%
Minimum Mixed Alcohol Selling Price ($/gal ethanol equivalent)	$1.96	$1.80	$1.71	$1.42	$1.25
Installed capital cost ($/annual gal MA)	$3.01	$2.71	$2.69	$2.36	$2.00
Operating cost ($/annual gal MA)	$0.87	$0.81	$0.75	$0.50	$0.49
Ethanol Yield (gal/dry ton)	55	56	56	55	67
Mixed Alcohol Yield (gal/dry ton)	75	77	77	76	89
Feedstock					
Feedstock Type	Woods Chips	Woods Chips	Biorefinery residues	Biorefinery residues	Biorefinery residues
Feedstock cost ($/dry ton)	$30	$30	$30	$30	$30
Thermochemical conversion					
Syngas yield (lb/lb dry feed)	0.78	0.78	0.78	0.78	0.78
Raw syngas methane (mol% - dry basis)	15.36	15.36	15.36	15.36	15.36
Cleanup and Conditioning					
Tar reformer exit methane (mol% - dry basis)	N/A	8.25	4.6	1.73	1.73
Tar reformer light HC reforming - % CH4 conversion	N/A	20%	50%	80%	80%
Tar reformer heavy HC reforming - % benzene	N/A	70%	90%	99%	99%
Tar reformer heavy HC reforming - %tar conversion	N/A	95%	97%	99.9%	99.9%
SMR Light HC reforming - % CH4 conversion	79%	79%	79%	NA	NA
Sulfur removal	1 ppmv (SMR)	1 ppmv (SMR)	1 ppmv (SMR)	50 ppmv (MA)	50 ppmv (MA)
CO2 recycle (lb/lb dry feed)	1.99	1.72	1.69	0.51	0.66
Catalytic Fuel Synthesis					
Compression for fuel synthesis (psia)	2,000	2,000	2,000	2,000	1,000
Single pass CO conversion	38.5	38.5	38.5	38.5	50
Overall CO conversion	96.9	96.9	96.9	96.9	98.1
CO selectivity to alcohols	80	80	80	80	90

Biomass to Biofuels Research Needs



A Joint DOE Planning Workshop

Office of Science

Office of Biological & Environmental Research

Office of Energy Efficiency & Renewable Energy

Office of the Biomass Program

www.doegenomestolife.org/biofuels/

Biomass to Biofuels Research Timeline

Within 5 Years

Research Phase

- Devise sustainable, effective, and economical methods for cellulosic feedstock harvest, deconstruction, and conversion to ethanol
- Enzymatic breakdown to 5- & 6- carbon sugars & lignin
- Use of Thermo and Biochemical Conversion
- Cofermentation of sugars to specified end products (i.e. ethanol)

Within 10 Years

Technology Deployment Phase

- Creation of new generation of energy crops with enhanced sustainability, yield, & composition
- Simultaneous breakdown of biomass to sugars & cofermentation of sugars via new biological systems
- Enhanced substrate range, temperature & inhibitor tolerance, & capability to function in complex biorefining environments
- Time scales that are economically viable

Within 15 Years

Systems - Integration Phase

- Incorporate concurrently engineered energy crops & biorefineries tailored for specific agroecosystems
- New & improved enzymes for breaking down biomass into sugars
- Robust fermentation processes
- Accelerate & simplify the end-to-end production of fuel ethanol
- Approach theoretical conversion limits
- Spur flexible biorefineries