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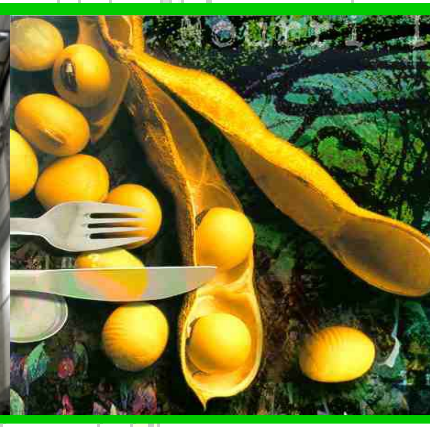
Energy Efficiency and Renewable Energy

The President's Biofuels Initiative

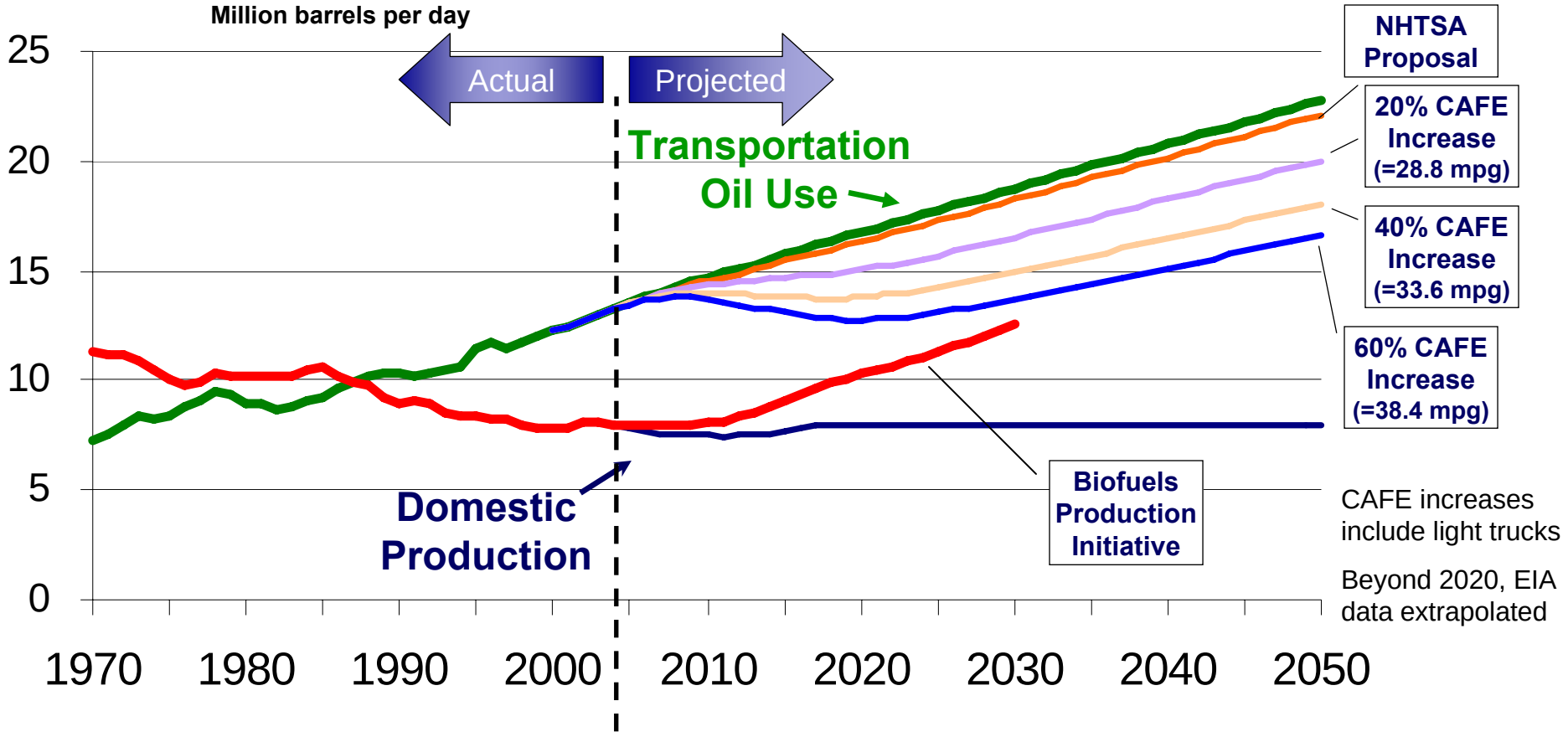


Neil Rossmeissl

Office of the Biomass Program

Energy Efficiency and Renewable Energy



CAFE increases include light trucks

Beyond 2020, EIA data extrapolated

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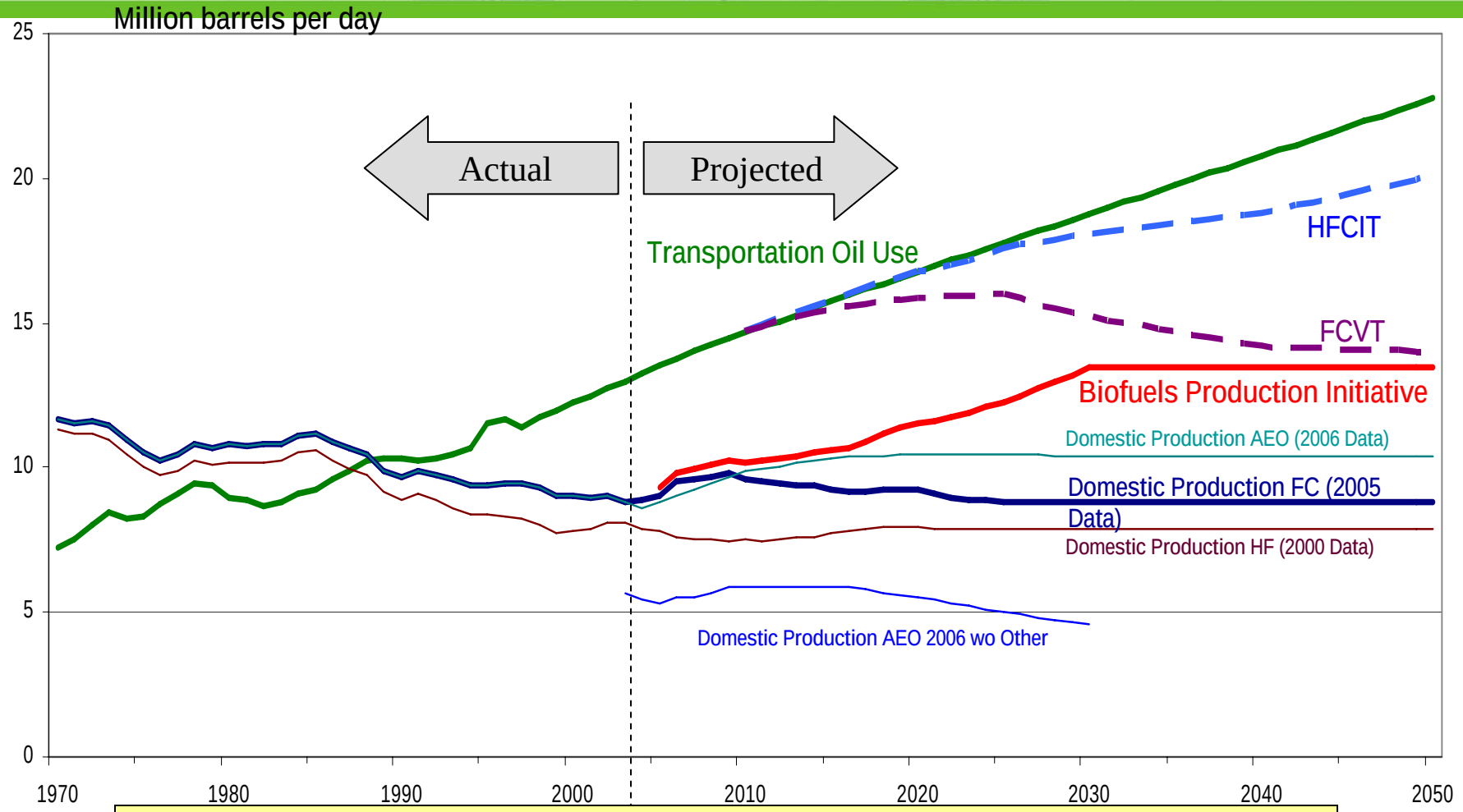
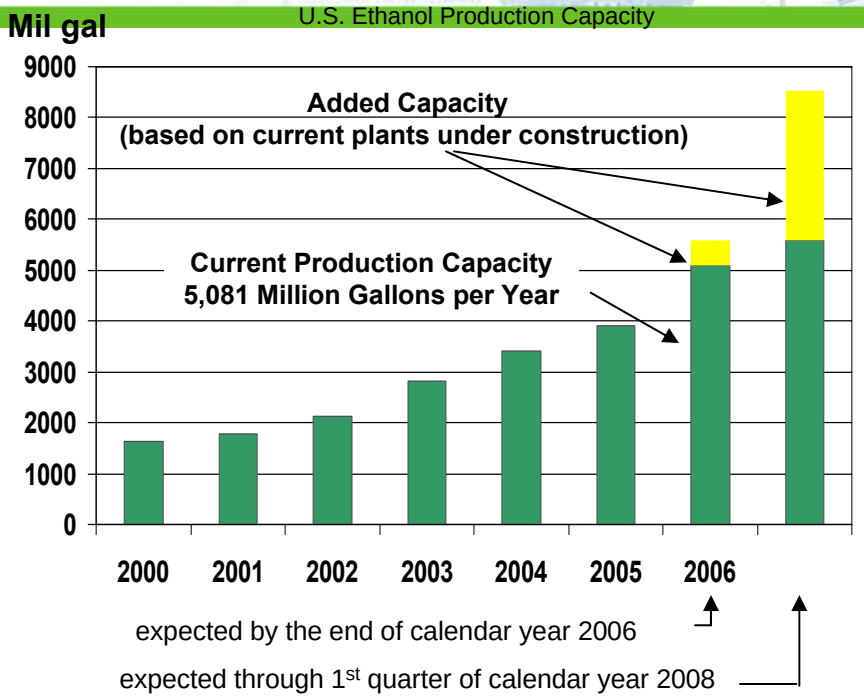
Biofuels Production Equal to ⅓ of Today's Gasoline Consumption

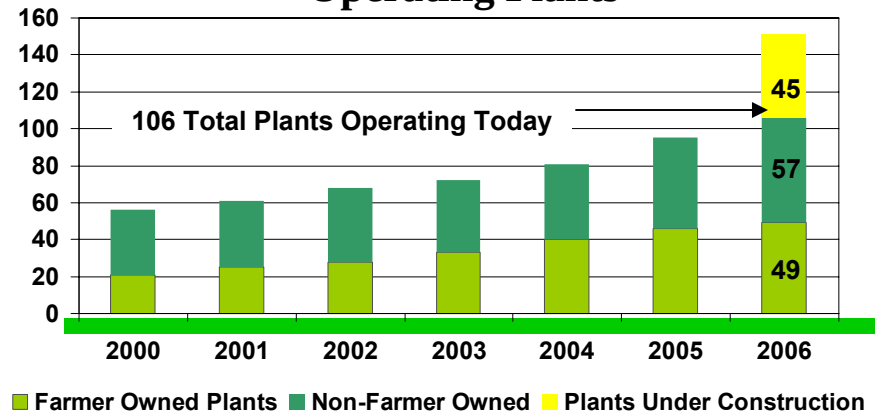


Efficient use of our liquid transportation fuels is an objective. Augmenting the Supply of that liquid fuel from more than one energy source is critical!

U.S. Ethanol Production Capacity

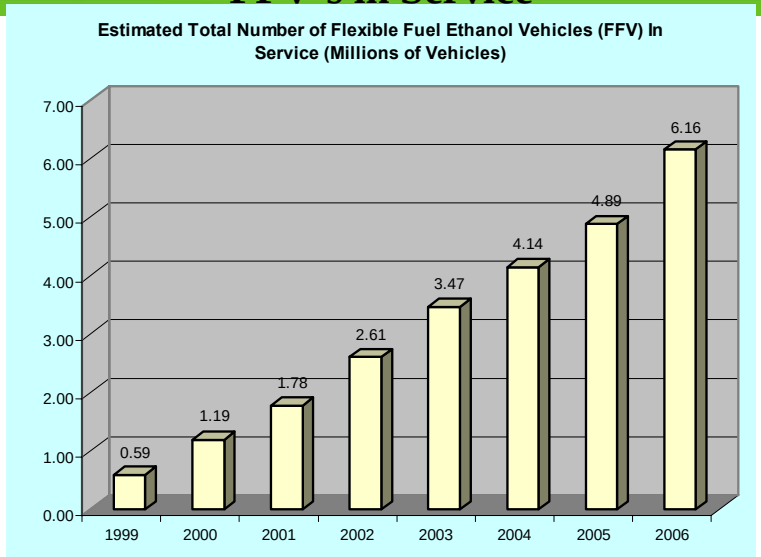


Operating Plants

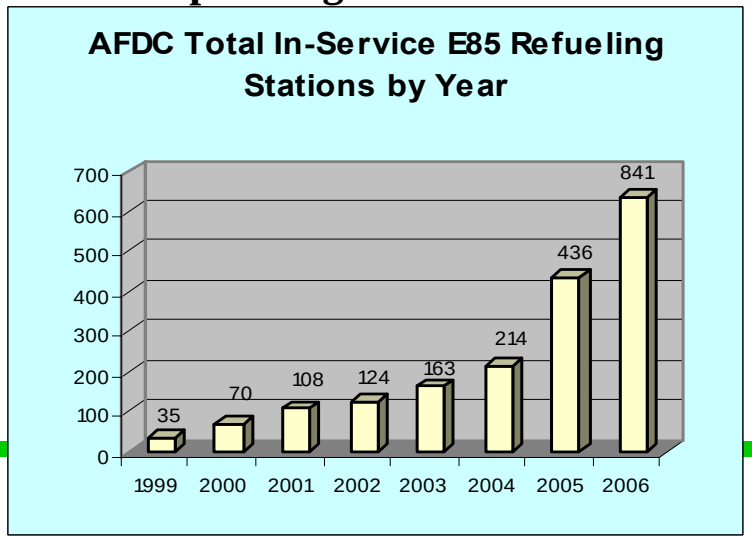


Source: Renewable Fuels Association, October 18, 2006

FFV's in Service



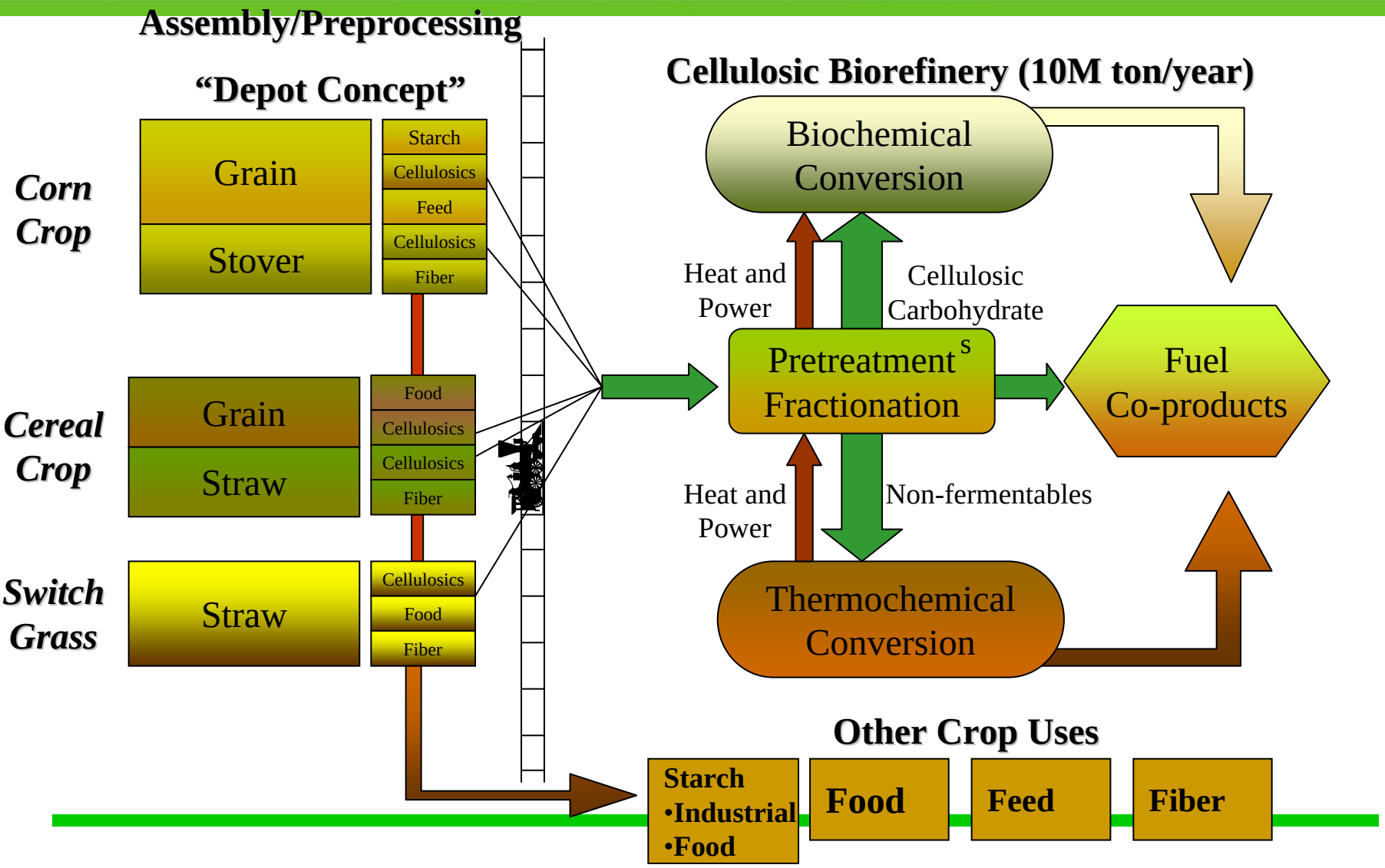
Operating E-85 Stations



Source: Alternative Fuels Data Center, September 22, 2006

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.


Assembly/Preprocessing
"Depot Concept"
Corn Crop
Grain
Stover
Starch
Cellulosics
Feed
Cellulosics
Fiber
Cereal Crop
Grain
Straw
Food
Cellulosics
Cellulosics
Fiber
Switch Grass
Straw
Cellulosics
Food
Fiber
Cellulosic Biorefinery (10M ton/year)
Biochemical Conversion
Heat and Power
Cellulosic Carbohydrate
Pretreatments Fractionation
Fuel Co-products
Heat and Power
Non-fermentables
Thermochemical Conversion
Other Crop Uses
Starch
•Industrial
•Food
Food
Feed
Fiber

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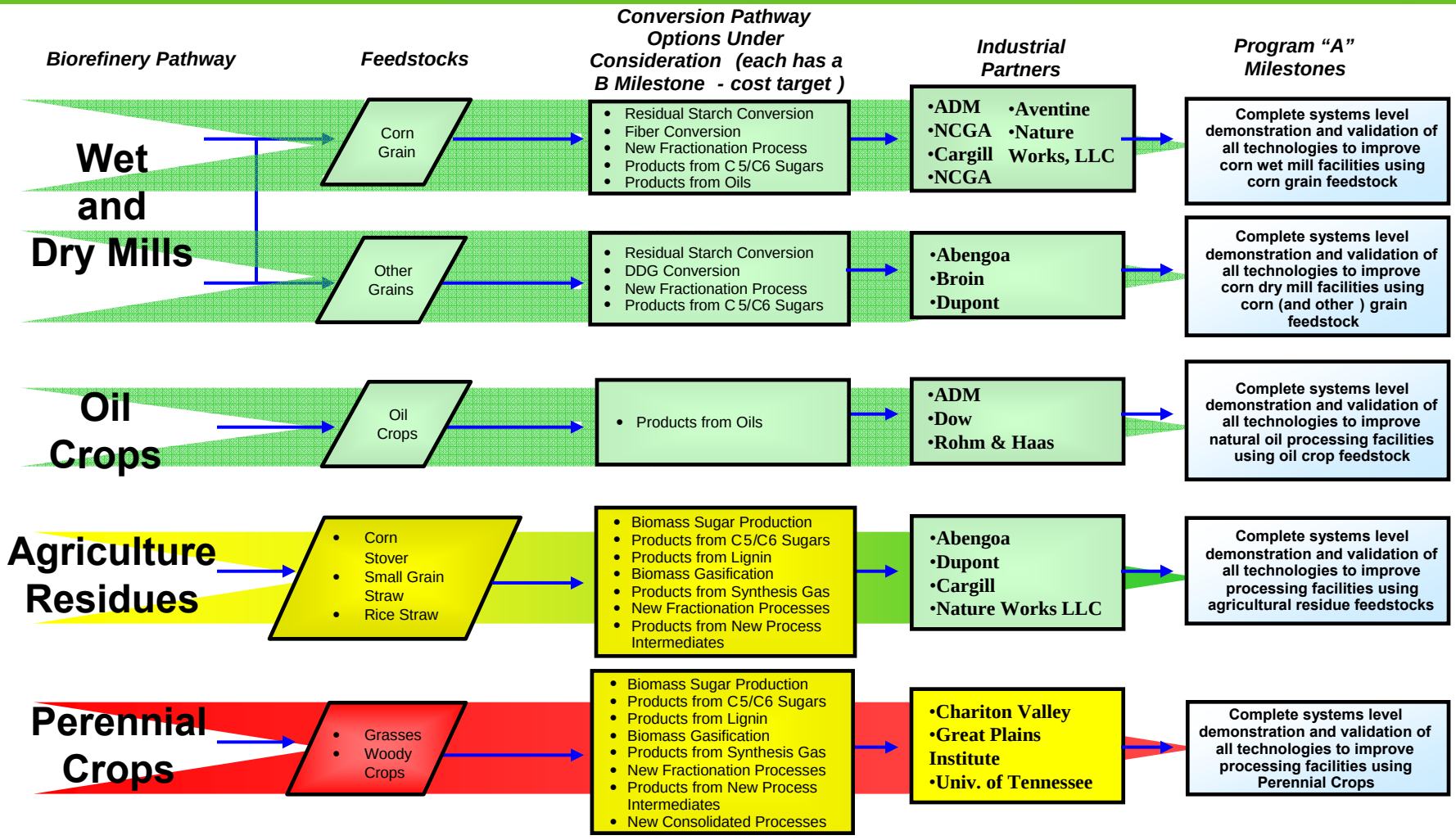
Pathway Approach



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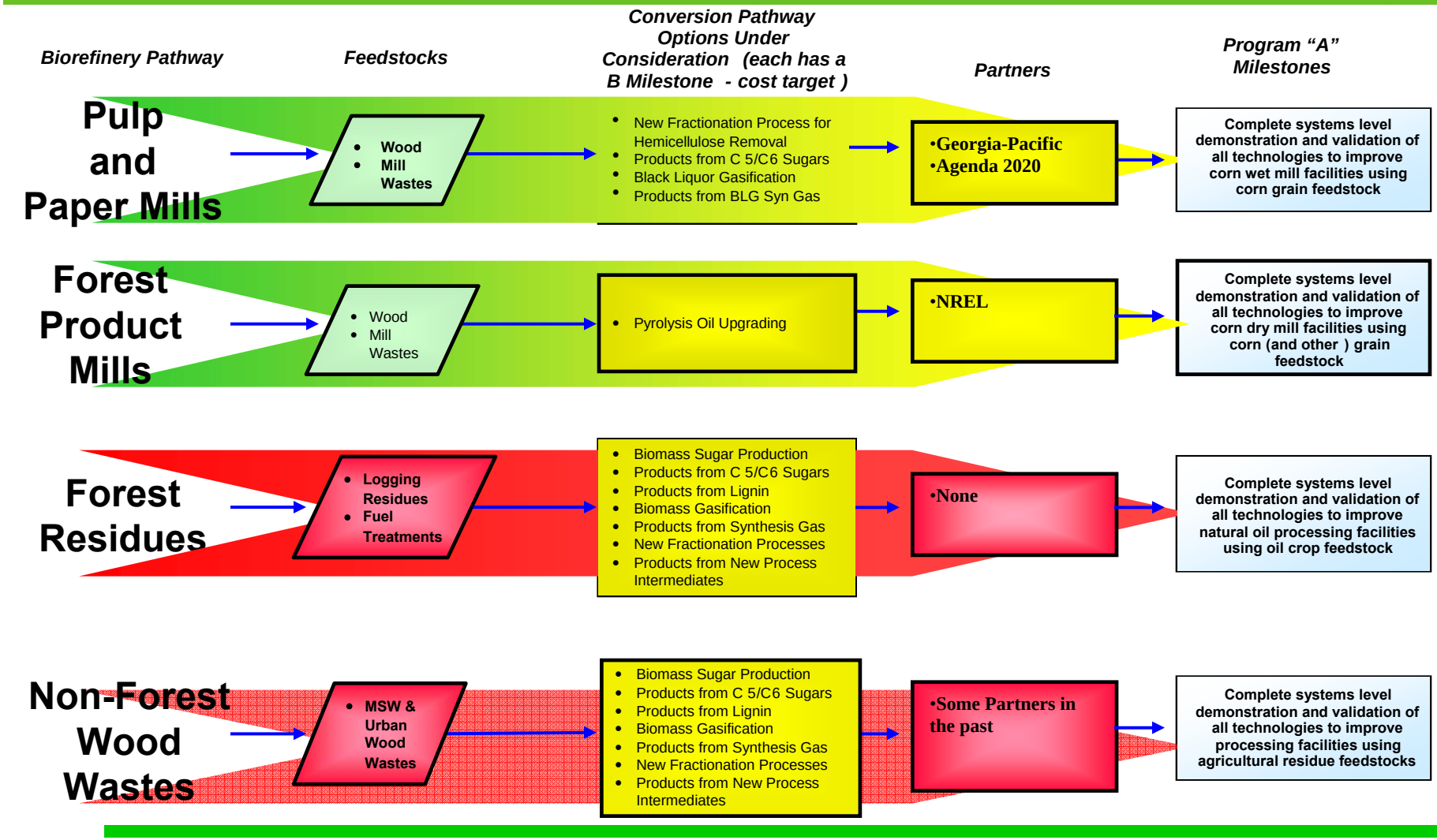
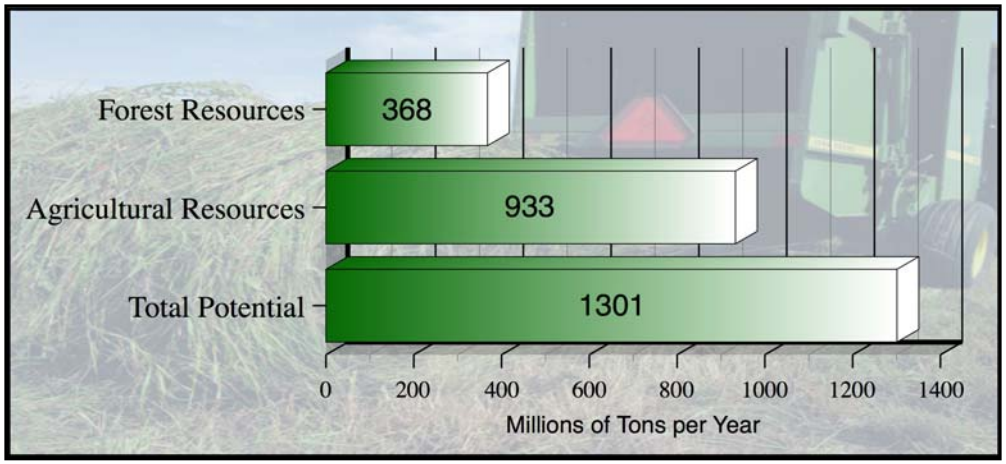
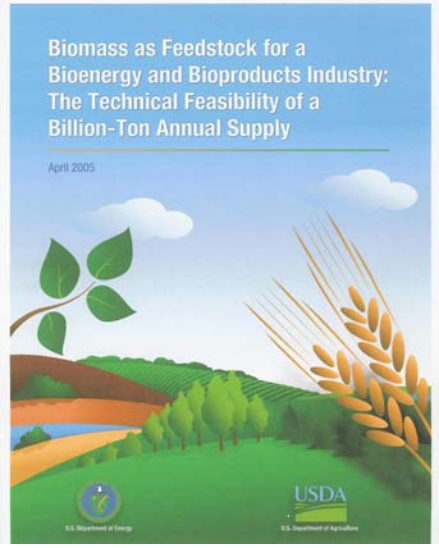
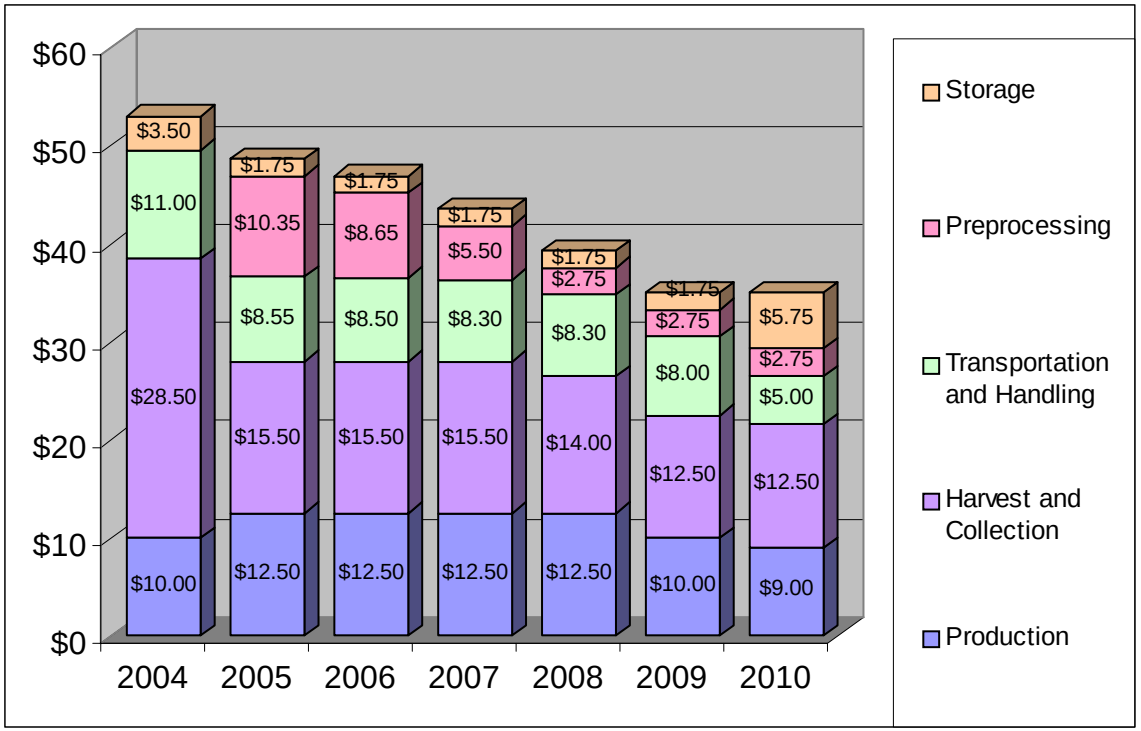
Pathway Approach



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.

R&D Challenges for Feedstocks

Harvest & Collection	Feedstock Cost Threshold ($/dry ton)	$52.00	$35.00
	Single-Pass Capacity (% of grain only harvest capacity)	39%	85%
	Selective Harvest Dockage/Quality Credits*	0%	4.5%
Mechanical Preprocessing	(Dry) Capacity (dry tons/kW-hr)	0.028	0.033
	(Dry) Bulk Density (dry lbs/cu-ft)	10.0	14.0
	(Dry) Fractionation Quality Credits* (% cost threshold)	0%	7%
	(Wet) Capacity (dry tons/kW-hr)	0.012	0.025
	(Wet) Fractionation Quality Credits* (% cost threshold)	0%	5%
	(Wet) Shrinkage (% net fermentable sugar loss)	>15%	5%
Storage	(Wet) Stored Production Credit** (% ethanol in feedstock wt/wt)	0%	4%
Transportation & Handling	Field Handling Efficiencies (dry tons/labor-hr)	6.3	7.7
	Plant Handling Efficiencies (dry tons/labor-hr)	10.6	26.6

*Improved composition for greater product yield, optimized particle size, & optimized digestibility characteristics
**Ethanol production in storage from sugars otherwise lost in treatment

R&D Challenges for Fermentation

	Barrier	2005	2012 Goal
Feedstock →	Minimum Ethanol Selling Price	$2.26	$1.07
	Installed Capital per Annual Gallon	$3.04	$1.85
	Yield (gallon/dry ton)	65	90
	Feedstock Cost ($/dry ton)	$53	$35
Pretreatment	Xylan to Xylose	63%	90%
	Xylan to Degradation Products	13%	5%
Conditioning	Xylose Sugar Loss	13%	0%
	Glucose Sugar Loss	12%	0%
Enzymes →	Enzyme Contribution* ($/gal EtOH)	$0.32	$0.10
	Combined Saccharification & Fermentation Time (d)	7	3
Saccharification & Fermentation	Xylose to Ethanol	76%	85%
	Minor Sugars to Ethanol	0%	85%

*Model value, slightly lower than metric value

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R&D Challenges for Thermochemical Conversion

	Barrier	2005	2012 Goal
	Minimum Ethanol Selling Price	$1.61	$1.07
	Higher Alcohol Co-Product Value (% market value)	85%	69%
	Minimum Mixed Alcohol Selling Price ($/gal ethanol equivalent)	$1.80	$1.25
	Installed Capital Cost ($/annual gal MA)	$2.71	$2.00
	Operating Cost ($/annual gal MA)	$0.81	$0.49
	Ethanol Yield (gal/dry ton)	56	67
	Mixed Alcohol Yield (gal/dry ton)	77	89
	Feedstock Type	Wood Chips	Biorefinery Residues
Cleanup & Conditioning	Tar reformer exit methane (mol% - dry basis)	8.25	1.73
	Tar reformer light HC reforming (% CH4 conversion)	20%	80%
	Tar reformer heavy HC reforming (% benzene)	70%	99%
	Tar reformer heavy HC reforming (% tar conversion)	95%	99.9%
	SMR Light HC reforming (% CH4 conversion)	79%	N/A
	Sulfur Removal	1ppmv (SMR)	50ppmv (MA)
	CO2 Recycle (lb/lb dry feed)	1.72	0.66
	Compression for fuel synthesis (psia)	2,000	1,000
	Single pass CO conversion	38.5	50
	Overall CO conversion	96.9	98.1
	CO selectivity to alcohols	80	90

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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

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Federal Agency Collaboration – Guiding Legislation

- 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 (30 representatives from industry, academia, non-profit, state, forestry, agricultural sectors)
    - Vision for Bioenergy & Biobased Products in the US (currently being updated
    - Roadmap for Bioenergy & Biobased Products in the US (currently being updated)
  - Interagency Biomass R&D Board (cabinet-level representatives from DOE/USDA/DOI/EPA/NSF/OFEE/DOT)
- 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 FY02 – FY06
  - Continuation of the Bioenergy Program (Section 9010)

- ✓ The only domestic & renewable option for liquid transportation fuels coupled with vehicle efficiency to reduce imports.
- ✓ Resource base sufficient to supply a large fraction of U.S. needs
- ✓ The “net” energy balance is very good.
- ✓ A sustainable solution to meet the near-term “gap” caused by Peak Oil
- ✓ Science & Technology will create many other opportunities that extend beyond today’s ethanol & biodiesel

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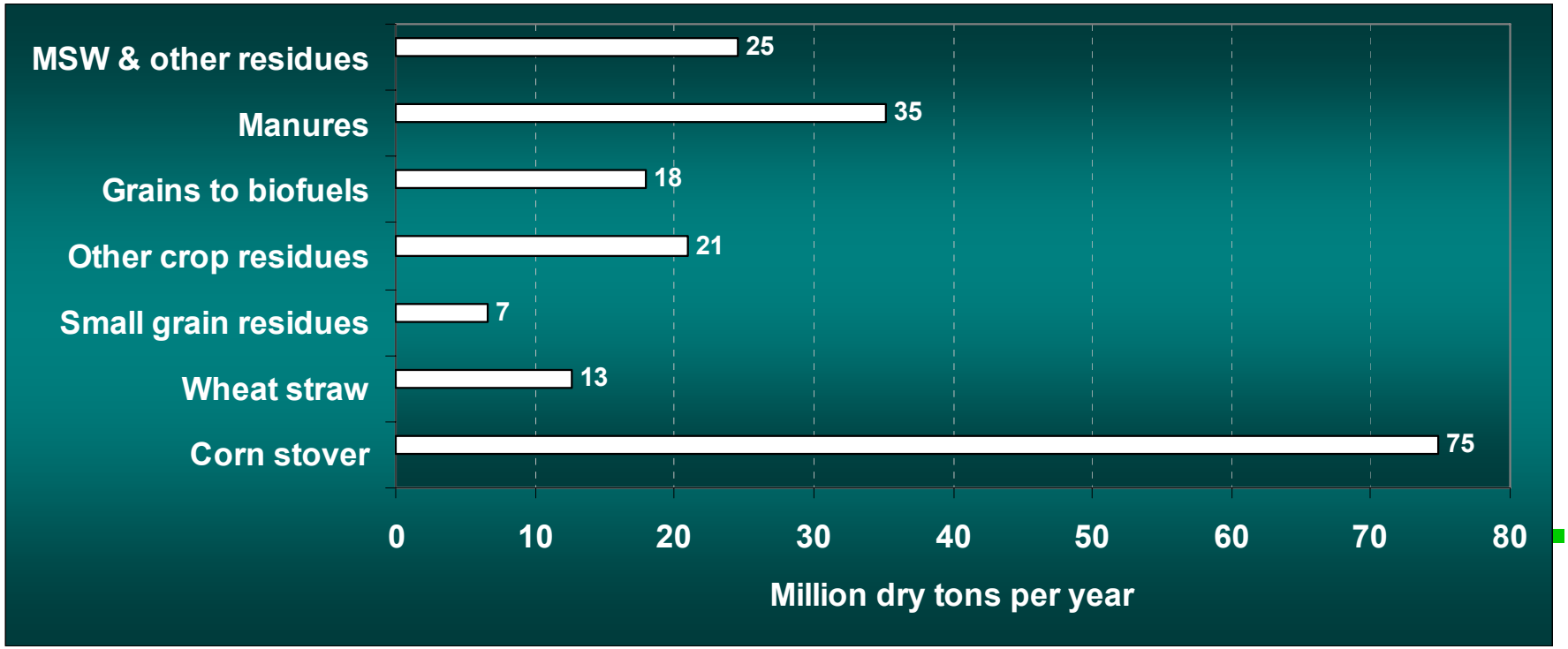
Biorefining Depends on Feedstock

Agricultural Resource Scenarios

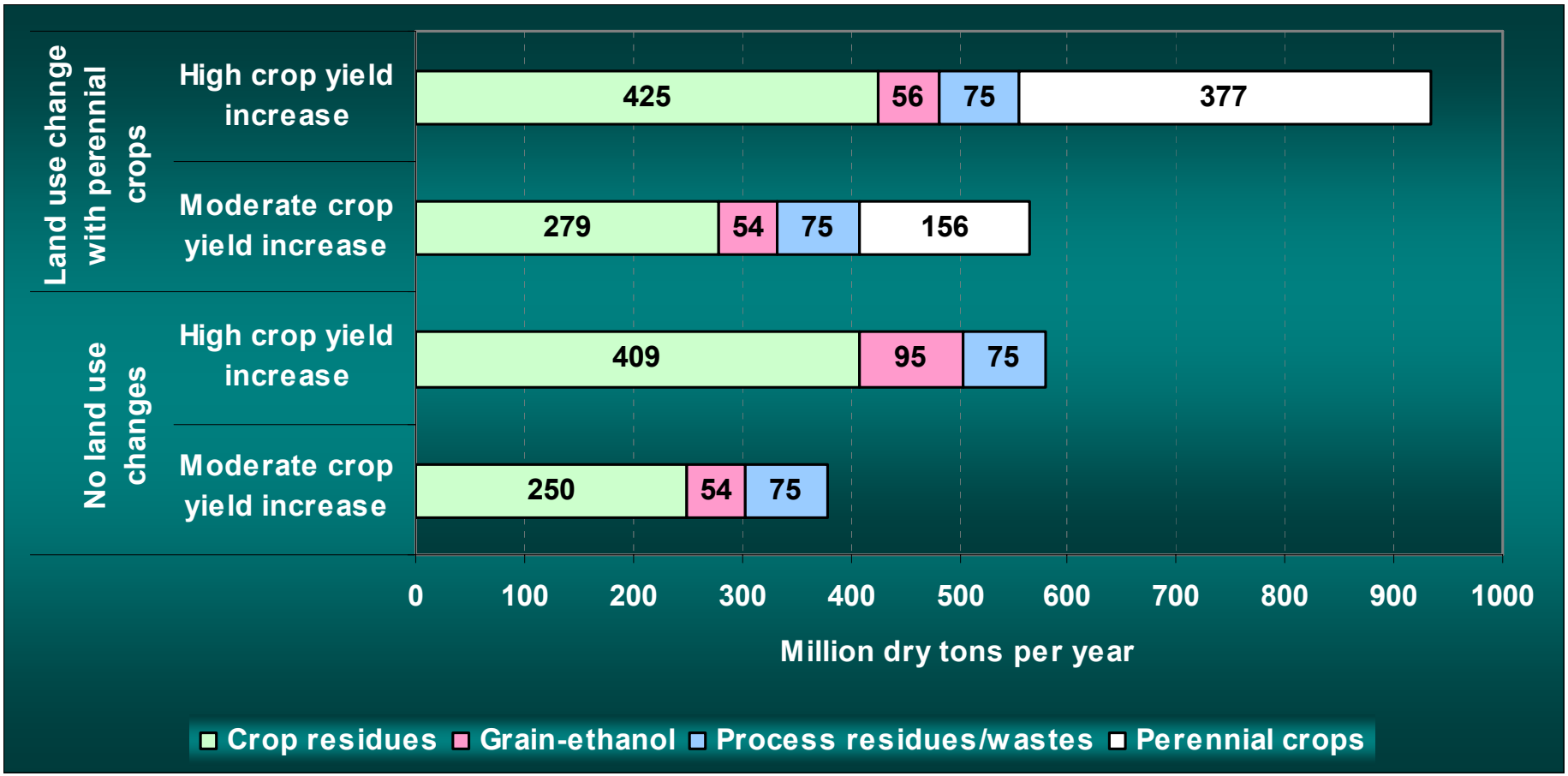
Current availability of biomass from agricultural lands is based on data and analysis

- Total current availability of biomass is ~ 193 million dry tons/year
- Slightly more than one-fifth is currently used
- Corn stover is largest source of agriculture-derived biomass



Agricultural Resource Summary

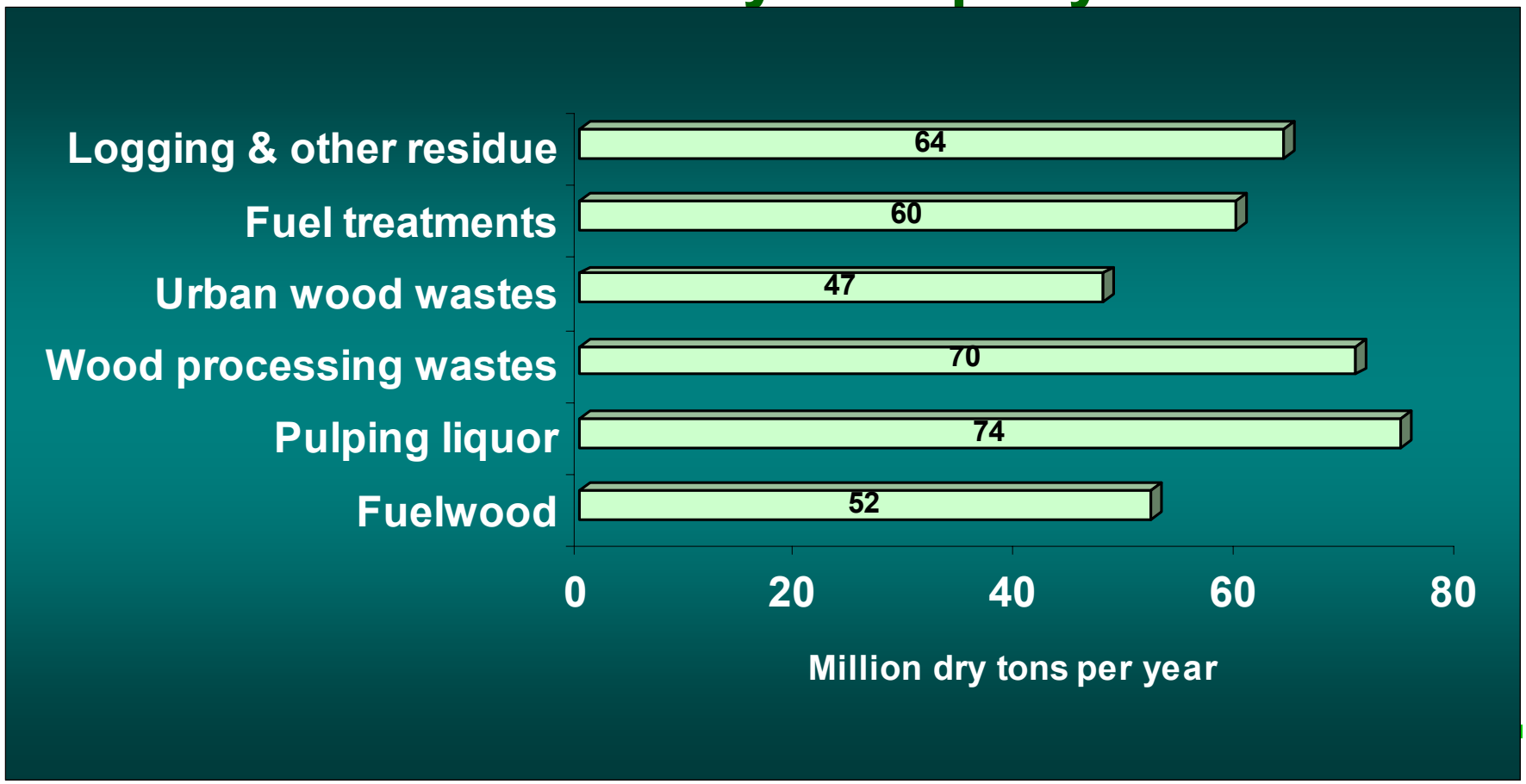
Sustainable agricultural resource potential exceeds 930 million dry tons



Forest Resource Summary

The sustainable forest resource potential

~ 370 million dry tons per year



Data Sources and Notes for "Biofuels Production Initiative"

- **Existing Fuels Market**
  - 139.6 billion gallons of finished motor gasoline in 2004: EIA Petroleum Supply Annual 2004, Volume 1, Table 3. U.S. Daily Average Supply and Disposition of Crude Oil and Petroleum Products, 2004, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/current/pdf/table_03.pdf
  - 37.1 billion gallons of on-highway diesel in 2004: EIA Fuel Oil and Kerosene Sales 2004, Table 13. Adjusted Sales of Distillate Fuel Oil by Energy Use in the United States: 2000-2004, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/fuel_oil_and_kerosene_sales/historical/2004/pdf/table13.pdf
  - Energy Policy Act of 2005, H.R.6, Sec. 1501 Renewable Content of Gasoline: "any gasoline sold or introduced to commerce in the U.S. must contain, on an annual average basis, the applicable volume of renewable fuel." applicable volume is 4 billion gallon per year in 2006 and increases steadily to 7.5 billion gallon per year in 2012.
  - State MTBE ban information from *Ethanol Industry Outlook 2005*, Renewable Fuels Association, http://www.ethanolrfa.org/industry/outlook/
  - 2002 MTBE Demand: *Transportation Energy Data Book, Edition 24,* Oak Ridge National Laboratory, Center for Transportation Analysis, 2004. ~93,500 Btu/gal MTBE.
  - MTBE-Ethanol equivalent: conversion from *Ability of the U.S. Ethanol Industry to Replace MTBE*, AUS Consultants, March 2000, retrieved from http://www.ethanolrfa.org/resources/reports/
  - # of FFV (as of the end of production of model year 2005): National Ethanol Vehicle Coalition, "Frequently Asked Questions," Accessed Jan 17 2006, http://www.e85fuels.com/e85101/faq.php. Fuel consumption is estimated using the ratio of 1.9 million FFV to 1.5 B gal/yr ethanol. Ratio is from "Legislative Information Alert: E85 Infrastructure Development," National Ethanol Vehicle Coalition, Accessed Dec 27 2005, http://www.e85fuel.com/pdf/infrastructure.pdf and from "For Your Information," National Ethanol Vehicle Coalition, July 27 2001, http://www.e85fuel.com/news/072701.htm. Note that the much of the 1.5 million FFVs on the road use gasoline and not E85. Approximately 100,000 FFVs (Federal and State government, and fuel provider fleets vehicles only) ran on E85 in 2004 (EIA, DOE, Alternatives to Traditional Transportation Fuels, Table 21. Number of Onroad Alternative Fuel Vehicles in Use by User, Weight Class, Fuel Type and Configuration, 2004, October 2005, http://www.eia.doe.gov/cneaf/alternate/page/atftables/atf21-35_04.html)

Activity	Funding ($ in thousands) FY 2005 Approp	FY 2006 Approp	FY 2007 Request
Feedstock Infrastructure	1,984	479	9,967
Platforms R&D	29,288	15,140	50,530
Utilization of Platform Outputs R&D	20,473	23,322	89,190
Congressionally Directed Activities	35,332	51,777	0
Technical/Program Management	394	0	0
TOTAL	87,471	90,718	149,687