

Biofuels: Biological Conversion Process

Workshop for Biofuels in California
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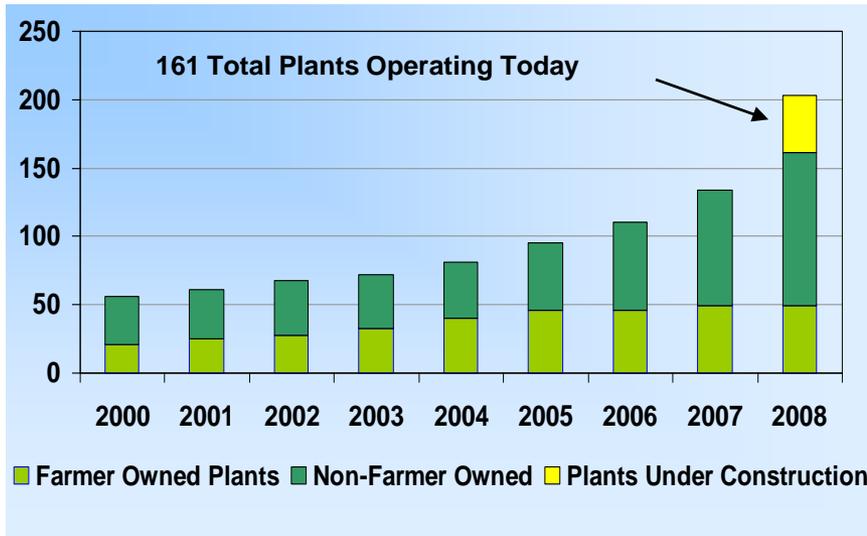
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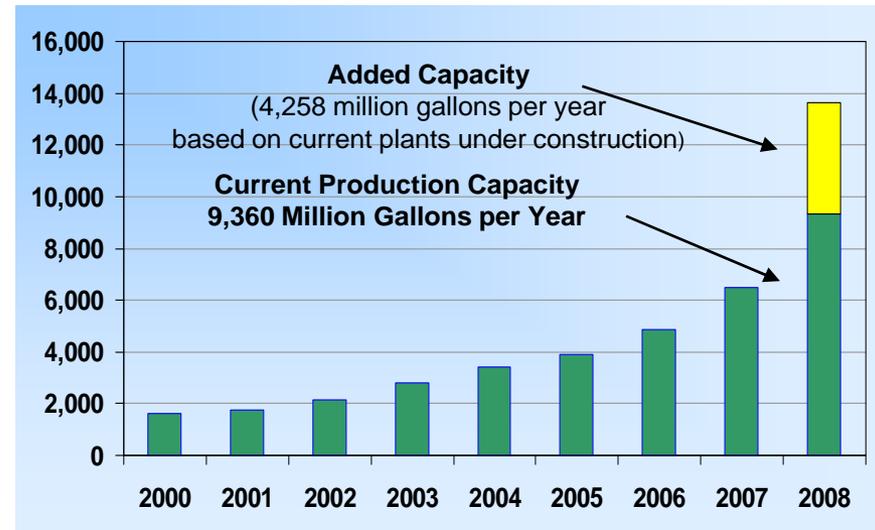
Pacific Northwest
NATIONAL LABORATORY

Ethanol Production Trends

- The capacity of the ethanol biofuels industry has nearly tripled since 2004.
- Current corn ethanol capacity plus plants under construction will nearly meet the EISA corn ethanol requirements.



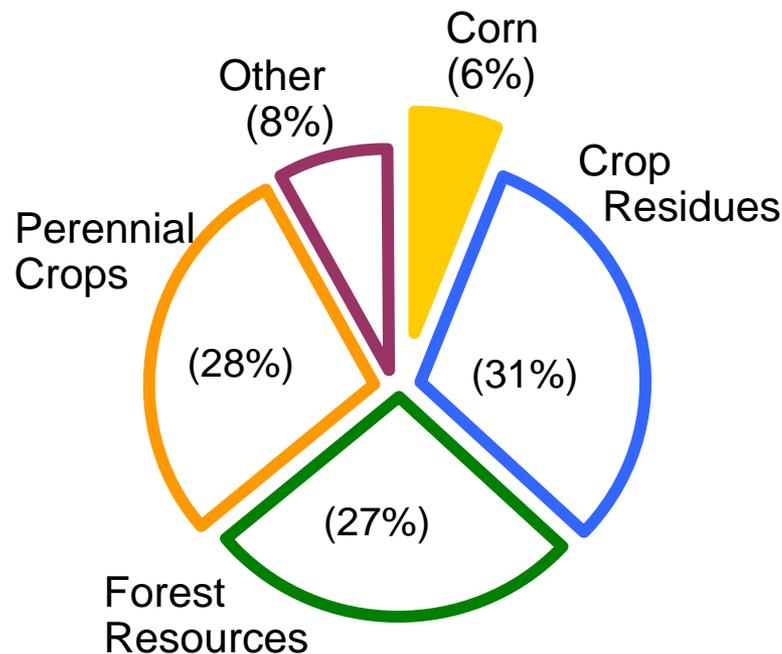
**U.S. Ethanol Production Facilities
2000 - 2008**



**U.S. Ethanol Production Capacity
(million gallons per year)**

Biofuels and Biomass Resources

Projected U.S. Biofuel Sources



Today: Nearly all ethanol is made from corn grain

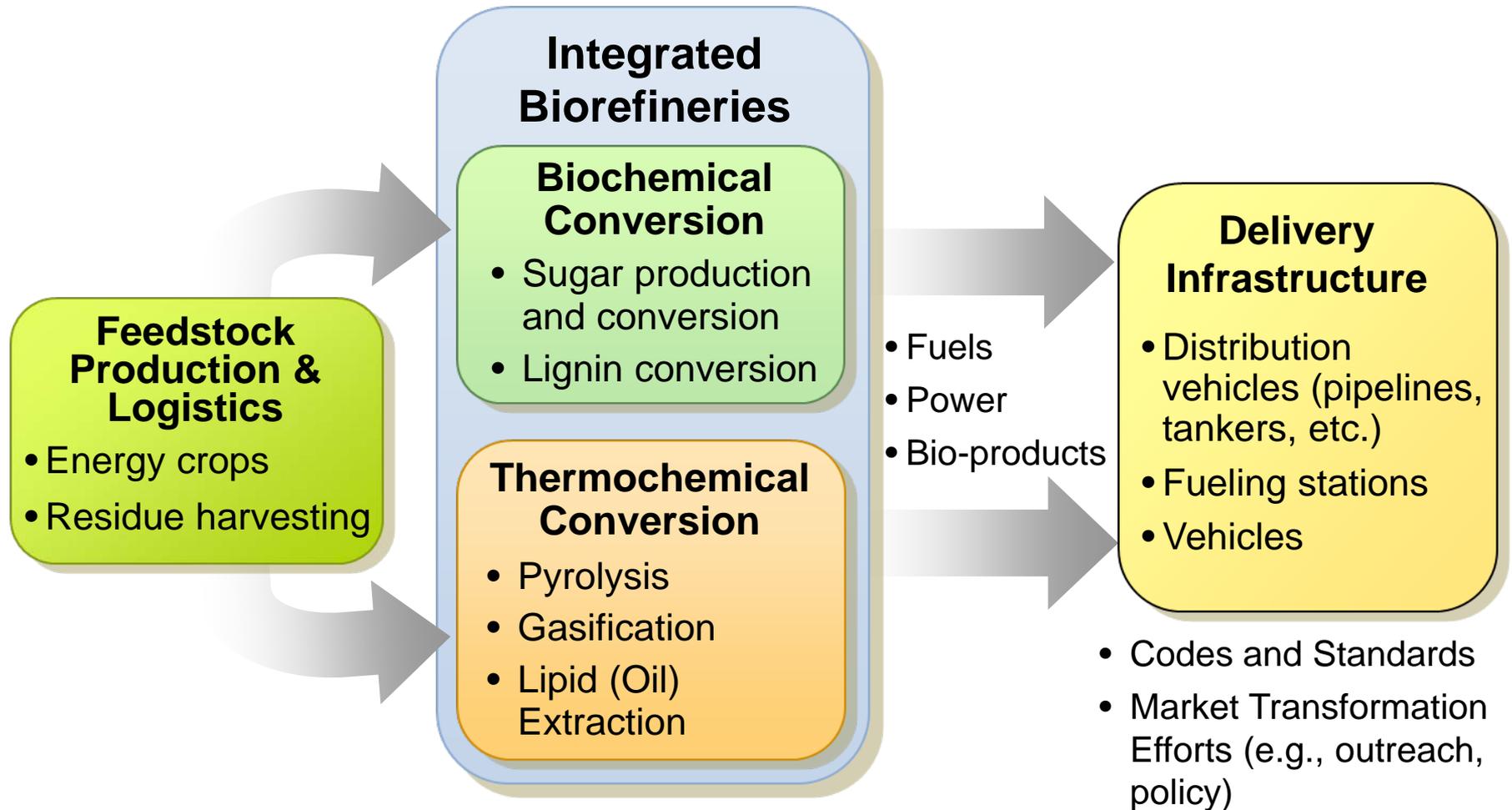
The Future: Cellulosic biomass will be the primary source for advanced biofuels

Sources of Cellulosic Biomass:

- Agricultural residues
- Forestry residues
- Terrestrial & aquatic crops and trees grown for energy purposes
- Selected municipal, agricultural, and industrial wastes

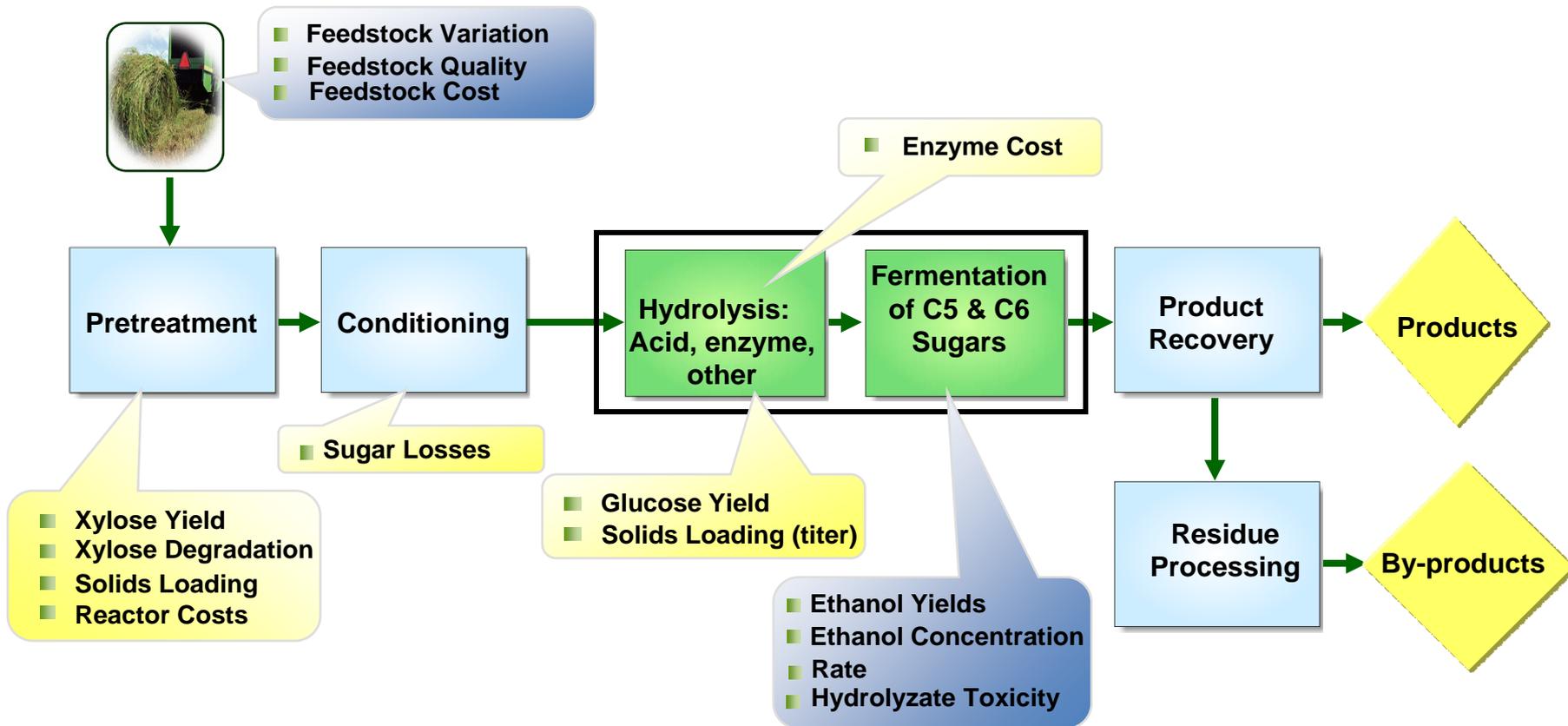
In the future, far more biofuels will be made from cellulosic biomass than from corn.

Routes to Cost-Competitive Biofuels from Lignocellulosic Biomass



Success relies on simultaneous development of the supply, conversion, and demand infrastructures for cellulosic ethanol.

Biochemical Conversion of Lignocellulosic Biomass



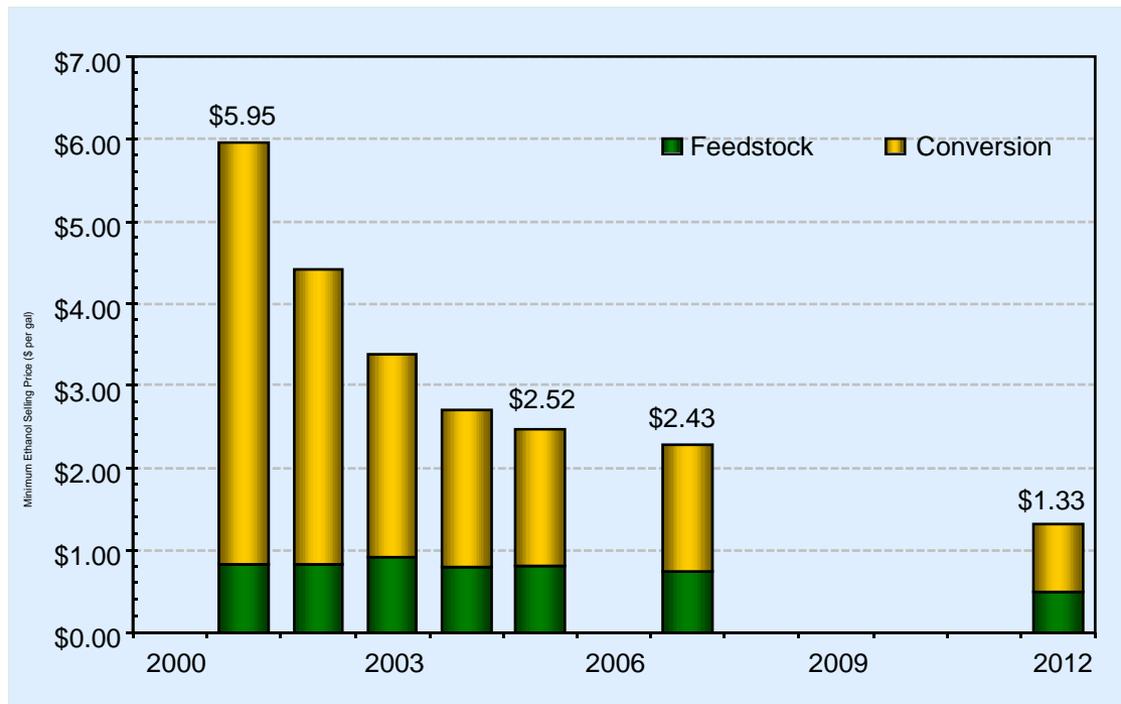
Successful Hydrolysis and Fermentation of complex sugars is key to biochemical processes

Status of Biological Conversion Technologies

- ▶ R&D over 30 years has significantly advanced the state of technology
 - Improved hydrolysis
 - Reduced enzyme costs
 - Improved fermentation organisms
- ▶ RD&E is continuing at the federal level
 - Bioenergy Centers focused on basic research
 - Enzyme improvement
 - Ethanologen improvement
 - And others

Research is Reducing the Projected Cost of Ethanol from Lignocellulosic Biomass

- The combination of cellulosic biofuels cost reduction and current demonstration projects are poised to spur investment in advanced biofuels, helping to achieve the RFS objectives of EISA.



State of Technology
(yr \$2007(est.))

Source: U.S. Dept. of Energy

Status of Biochemical Conversion Technologies (cont.)

- ▶ Commercial and near-commercial demo facilities are underway
 - Large-scale demos co-funded by Department of Energy through the “932 EPACT” legislation
 - “10% Scale” demos funded in FY08
 - Smaller facilities for advanced biofuels to be funded in FY09

EPACT Section 932 “Commercial-Scale” Biorefineries

DOE investments in cellulosic biofuels

Performers	Feedstock Type	Conversion Technology	Location	Status
Bluefire	Sorted MSW	Biochemical-Concentrated Acid Hydrolysis	Mecca, CA	Lease and NEPA issues being resolved. Anticipate an Award 2 for construction in FY09.
Poet	Corn Cob Corn Fiber	Biochemical	Emmetsburg, IA	NEPA EA for public comment. Currently negotiating for an Award 2 TIA by end of FY08.
Range Fuels	Woody Waste	Gasification + Mixed Alcohol synthesis	Soperton, GA	Award 2 TIA issued, engineering and construction in progress.
Abengoa	Agricultural Residue	Biochemical	Hugoton, KS	NEPA EIS process initiated. Award 2 anticipated in FY09.

Demonstration-Scale Biorefineries Selected in FY08

Performers	Feedstock Type	Conversion Technology	Location
Ecofin	Corn Cobs, Corn Fiber	Biochemical-Solid State Fermentation	Washington County, KY
ICM	Switchgrass, Forage Sorghum, Stover	Biochemical	St. Joseph, MO
Lignol Innovations	Woody Biomass	Biochemical-Organisolve	Grand Junction, CO
Mascoma	Switchgrass	Biochemical	Upper Peninsula, MI
NewPage	Woody Biomass - Mill Residue	Thermochemical-Fischer-Tropsch	Wisconsin Rapids, WI
Pacific Ethanol	Wheat Straw, Stover, Poplar Residuals	Biochemical-Biogasol	Boardman, OR
RSE	Woody Biomass - mill residues	Biochemical-Pentose Extraction	Old Town, ME
Verenium Biofuels Corp.	Energy Cane and Bagasse	Biochemical Process	Jennings, LA
Flambeau River Biofuels LLC	Forest residues and wood waste	Thermochem to Fischer-Tropsch	Park Falls, WI

Additional Bioconversion Options

- ▶ Production of biofuels other than ethanol
 - Bio-butanol
 - Similar to ethanol production – produce simple sugars
 - Use different organisms to produce butanol
 - Butanol not currently authorized for motor gasoline
 - Others
- ▶ Mixed thermal/biological conversion pathways
 - Gasify biomass to make syngas (CO + H₂)
 - Use biological organisms to convert syngas to ethanol
- ▶ Vegetable oils from algae
 - Potentially high productivity
 - Focus is on growing the feedstock, not converting the oil
- ▶ Others

Considerations for California

- ▶ The biomass feedstock base is highly varied and dispersed
 - Forest residues
 - Agricultural residues
 - Waste-derived biomass
 - Others
- ▶ Conversion technologies must deal with this variability
 - Robust hydrolysis techniques may result in lower sugar yields
 - Enzymatic approaches generate more sugars but may require more uniform biomass feedstock
- ▶ Other fuels in addition to ethanol may be required to meet aggressive goals
 - Ethanol in gasoline currently approved for E-10 or E-85
 - 10% “blend wall” currently exists
 - Infrastructure requirements required
 - Infrastructure compatible biofuels may be helpful

California: Suggestions for Going Forward

- ▶ Make ***certain*** the biomass feedstock availability issue is clearly understood
 - Not only how much biomass is “out there” -- but also how much is actually *recoverable* and at what *cost*
- ▶ Facilitate the infrastructure
 - Streamline regulations so new facilities can be built
 - Legislative incentives and/or directives will be required
- ▶ RD&D Needs
 - Leverage U.S. DOE efforts on ethanol
 - Develop improved techniques to separate ethanol from water
 - Assist with scale-up and demonstration of promising technologies
 - Utilize the expertise of California Universities to advance the next generation of biofuels, including hydrocarbon-like fuels
 - Advanced fuels reduce the need for infrastructure changes
 - Will assist with 2020 and 2050 goals
 - Examine the feasibility of algal biofuels production in California
 - Leverage information from recent workshops
 - Assist with pre-commercial scale-up and demo of first-generation growth technologies
 - Understand land and water-use sustainability issues