

Potential of Cellulosic Ethanol in California

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**Cellulosic Ethanol Forum and Roundtable
Discussion
SCAQMD**

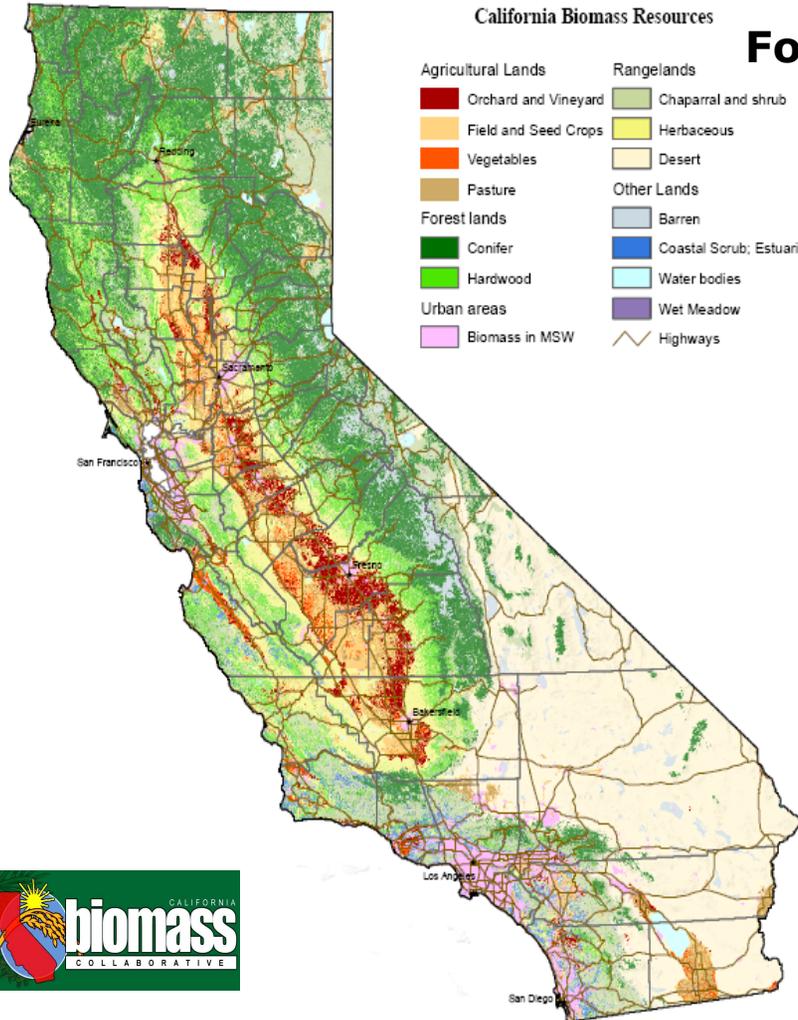
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Outline

- California's Biomass Resources
- Lignocellulosic Ethanol Potentials
- Research Agenda
 - Public Interest Energy Research in California
 - California Biomass Roadmap
 - Promising Approaches and Action Plan
 - Biofuels Grant Solicitation
- Concluding Remarks

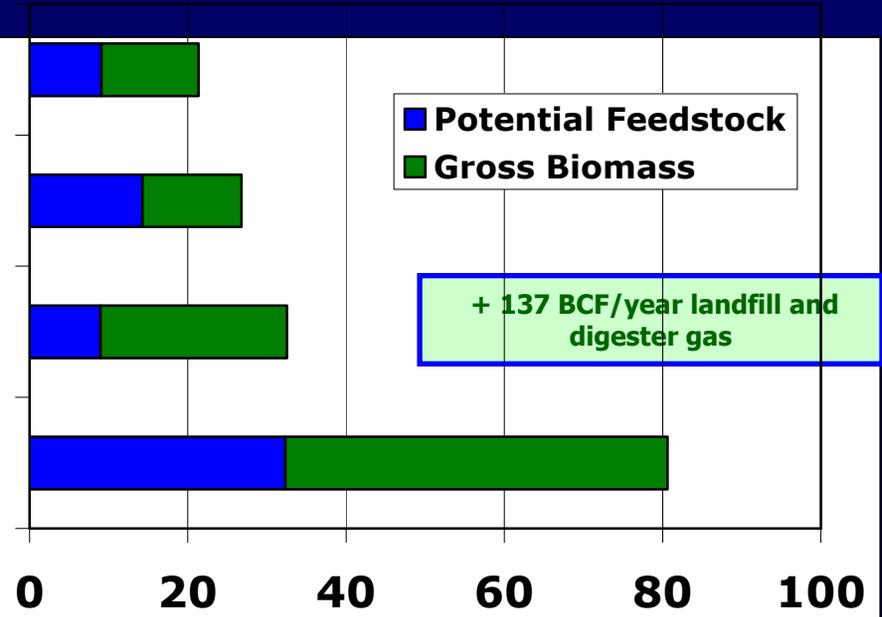


Agriculture

Forestry

Urban

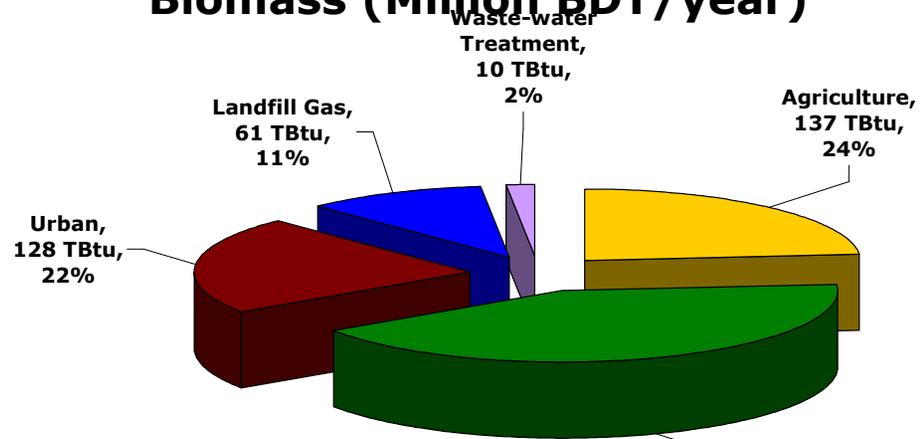
Total



■ Potential Feedstock
■ Gross Biomass

+ 137 BCF/year landfill and digester gas

Biomass (Million BDT/year)



Potential Feedstock Energy in Biomass
507 Trillion Btu/year



Data sources: CDF FVEG 2002 Version 2
DWR Land Use 1994 - 2004, National Land Cover Data, 2002

California's Abundant Biomass Resources





Total Categorical Bioenergy Potentials in California

Category	Biomass (Million BDT/year)	Energy in Product (Trillion Btu/year)	Total Capacity
Electricity	32	118 (35 TWh)	4,650 MWe
CHP Heat		230	9,050 MWt
Heat	32	350	11,700 MWt
Biochemical Biofuel	32	188	1.5 BGY gasoline equivalent
Thermochemical Biofuel	27*	250	1.7 BGY diesel equivalent
Biomethane	5 + Landfill gas and WWTP	106	106 BCF/y methane
Hydrogen (bio + thermal)	32	305	2.5 Million tons/y

* Tonnage for thermochemical biofuel assumed to be constrained by moisture content.

Current California consumption:

16 billion gallons gasoline + 4 billion gallons diesel = 2,500 Trillion Btu/year direct energy content

300 TWh/y electrical energy = 1,024 Trillion Btu/year direct energy





California Lignocellulosic Ethanol Potential

Biomass Resource	Technical Potential (million dry ton/yr)	Potential Ethanol	
		(million gallons/y)	(million gge/y)
Field and Seed	2.3	160	105
Orchard/Vine	1.8	125	83
Landfilled Mixed paper	4.0	280	187
Landfilled Wood & Green	2.0	140	93
Forest Thinnings	14.2	990	660
Totals- Current California	24.2	1,695	1,130
1.5 Million Acres Dedicated Energy Crop			
Low Yield (5 BDT/acre, 80 gallons/ton)	7.5	600	400
High Yield (9 BDT/acre, 100 gallons/ton)	13.5	1,350	900
State potentials w/ 1.5 M acres energy crop	Low Yield	32	2,295
	High Yield	38	3,045
		Range	1,530



Source: Williams, R. B. 2006. California Biomass Collaborative

Ethanol Goals

In-state ethanol production goals for several blend rate scenarios



In-state biofuel goals (million gallons per year)

Year	Ethanol			Executive Order S-06-06 and Bioenergy Action Plan articulated goals for in- state biofuel production (i.e., by 2010 20% of state's biofuel should be produced in-state, increasing to 40% by 2020, and 75% by 2050.
	E5.7	E10	E20	
2010	183	325	675	
2020	390	700	1430	
2050	900	1,570	3,250	

Source: Williams, R. B. 2006. California Biomass Collaborative



Biofuels: Opportunity and Challenge

Opportunity

- **Global Energy Security**
- **Economy**
 - Energy Price Stability
 - Balance of Trade
 - National Debt
- **Environment**
- **Fuel Diversity**

Challenge

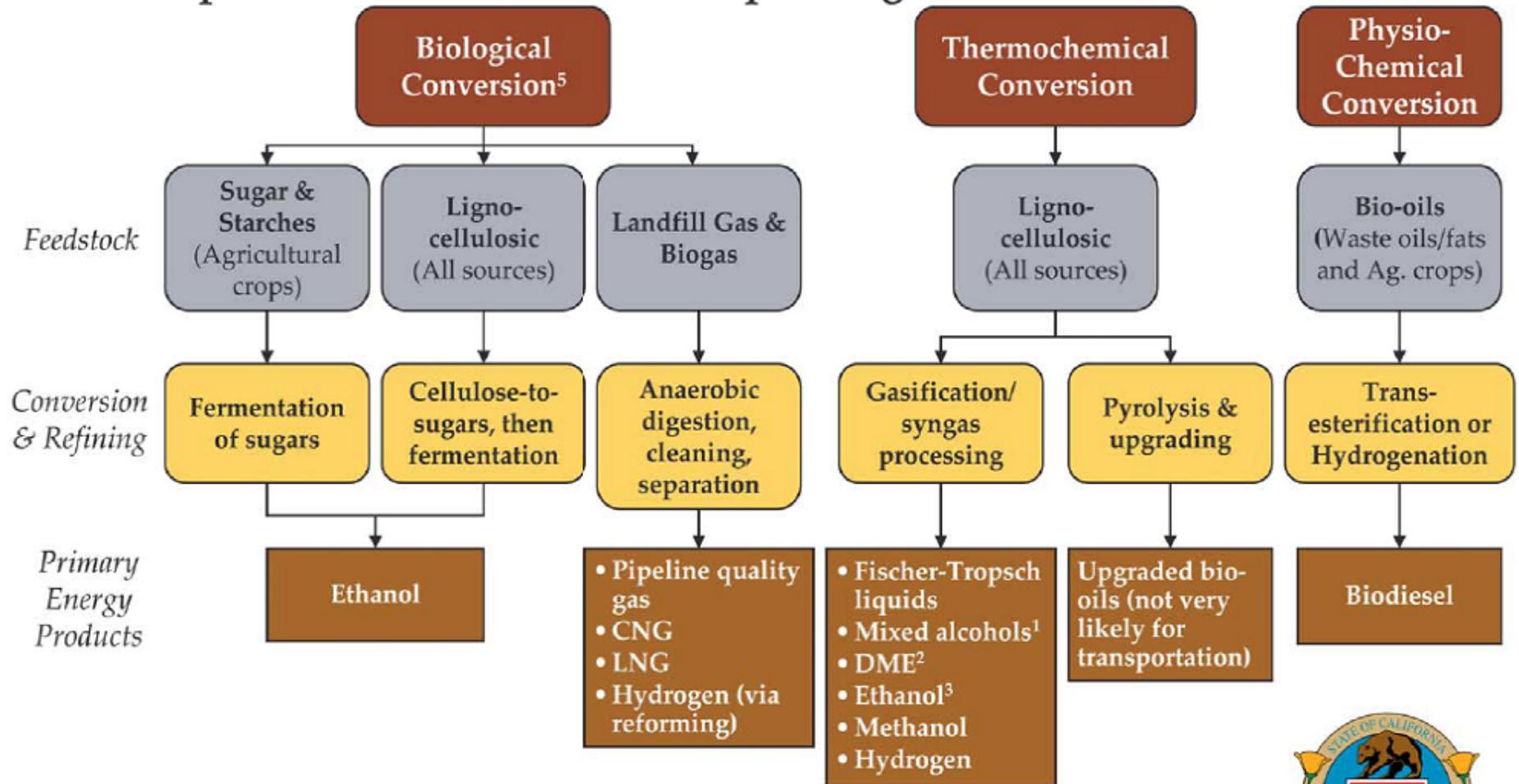
- **Biomass Cost**
 - Feedstock
 - Conversion
 - Delivery
- **Biofuels - RD&D Breakthroughs**
- **Permitting**
- **Policy**



Conversion pathways to convert biomass residues to transportation fuels

Biofuels » Options for Conversion and Refining

Using the four major feedstocks there are multiple pathways to create transportation fuels (and other liquid & gaseous fuels).



Biorefining Approaches for Lignocellulose

- Thermochemical

- Biochemical

Thermolytic
Solids
Oils

Gasification,
Pyrolysis

- Synthesis gas
 - (CO + H₂ + other)

Catalytic
Synthesis

- Hydrocarbons, mixed alcohols, hydrogen, ammonia, SNG, ethanol, higher alcohols...

Pretreatment,
Hydrolysis

Hydrolytic
Cellulose
Hemicellulose

- Sugar monomers, acids

Fermentation

- Ethanol, higher alcohols, biomethane, acids...

B.M. Jenkins , 2005. California Biomass Collaborative



Public Interest Energy Research (PIER) Program

- IOU Ratepayer-funded RD&D program launched in 1997
- Addresses electricity, natural gas, and **transportation sectors**
- ~\$80M annual budget; nearly \$400M in projects
- **A leader in no/low-carbon technology and global climate change research programs**
 - Efficiency and Demand Response
 - **Renewables**
 - Clean Fossil Fuel Generation – Distributed Generation, Combined Heat & Power
 - **Transportation**
 - Energy Systems Research – Transmission and Distribution, Grid Interconnection
 - Environmental Impacts – Air, Water, Climate, Communities
- **Strong emphasis on collaborations**
 - Avoid duplication/builds on past work/ensures relevance
 - Regular coordination with IOUs via the Emerging Technology Coordinating Council to transition research to the marketplace
 - State Agency Partnerships (DGS/DOF, ARB, T-24,CDF,CAGR,CalEPA, IWMB)
 - Market Partnerships (California builders, Collaborative for High Performance Schools, California Commissioning Collaborative, major equipment manufacturers)
 - Use California Capabilities (Universities, National Laboratories, High Technology Companies)
 - Leverage/complement Federal Investments



PIER Goals Are Solution- Focused and Include Biofuels/Biomass

General Goal

- “Develop and help bring to market, energy technologies that provide increased environmental benefits, greater system reliability, and lower system costs”

Specific Goals

- Develop and help bring to market
 - “Advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers.
 - “Increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards, and that benefit electric utility customers.
 - “Advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers.
 - “Advanced electricity technologies that reduce or eliminate consumption of water or other finite resources, increase use of renewable energy resources, or improve transmission or distribution of electricity generated from renewable energy resources.”





AB 1007

- **AB 1007 Process:** State plan to increase the use of alternative transportation fuels—Alternative Fuels Plan
 - Energy Commission with other agencies preparing plan to reduce petroleum use
 - Plan does not pick technology “winners” and “losers.” Instead, “provides a comprehensive framework for the state to ensure that all fuel and technology options are given an opportunity to compete in the California transportation market.”
- **Scope:**
 - Evaluate fuels on full fuel-cycle assessment of emissions
 - Set goals for 2012, 2017, 2022 for increased use of alternative fuels
 - Recommend policies to ensure alternative fuel goals are attained, including:
 - ◆ Fuel and vehicle standards
 - ◆ Requirements and incentives to ensure vehicles use alternative fuels
 - ◆ Requirements and incentives to ensure fueling stations are available
 - ◆ Incentives and other encouragement for RDD&D of alternative fuel capable vehicles
- AB 1007 allows until 30 June 2007 for completion of plan.



California Policy Initiatives in Bioenergy

- California Bioenergy Action Plan
 - Agency actions relating to biomass development
- Governor's Executive Order S-06-06
 - (Biofuel targets from in-state biomass:
 - ◆ 20% by 2010, 40% by 2020, 75% by 2050
 - Biopower target:
 - ◆ Maintain 20% share of renewable electricity for 2010 and 2020



California Biomass Research Plan

- A Roadmap

Vision: Sustainable biomass resources energize a healthy and prosperous California through the environmentally beneficial production and use of renewable energy, biofuels, and bioproducts.

Priority Areas

- Resource access and feedstock markets and supply
- Market expansion, access, and technology deployment
- **Research, development, and demonstration**
- Education, training, and outreach
- Policy, regulations, and statutes

RD&D

1. Resource Base, Sustainability and Access
2. Bioscience/Biotechnology
3. Biomass Conversion
4. Feedstock Processing
5. Systems Analysis
6. Knowledge/Information Resources





RD&D Actions

Sustainability and Access to the Resource Base,

Best Practices for sustainable development of biomass

- Identify best practice knowledge gaps for all resource types
- Fill in knowledge gaps: determine best practices
- Update as knowledge and techniques evolve

Inventory Assessment and Monitoring-

- Improve factors used for estimating gross and technically recoverable biomass: agricultural residue and forest
- Develop or expand resource economic models
- Develop & adapt remote sensing technologies for better inventory resolution and monitoring of sustainable practice
- Improve GIS-based biomass resource models to facilitate industry siting
- Periodic updates of assessment and monitoring techniques





RD&D Actions

Resource Base, Sustainability and Access

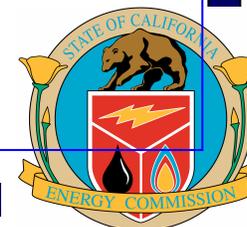


Dedicated Energy Crops:

- Evaluate energy crop potential in California (starch, sugar and oil crops as well as lignocellulose crops)
 - assess yields, production practices, environmental considerations, and economics of energy crops for: marginal, idle, and currently producing lands
- Evaluate the long-term sustainability of dedicated energy cropping systems in California
- Improve agronomic techniques to reduce water and other inputs
- Assess potential for biomass crops in remediation of saline, marginal or idle agricultural lands

Infrastructure related research actions:

- Find innovative solutions to ethanol/gasoline distribution incompatibility
 - Develop biofuels that are fungible with petroleum industry and enhance fueling infrastructure to allow for alternate fuels
- Develop, and deploy California-relevant biomass/fossil cofiring solutions to increase production of biopower (e.g., co-firing w/natural gas, solid fuel & natural gas 'hybrid' boilers, etc.)





RD&D Actions

Feedstock Processing



-Harvest Systems

- Develop innovative or improved harvest systems for:
 - small diameter wood and shrubs for forest fuels reduction activities
 - dedicated biomass crops and agricultural residues

-Biomass Processing

- Develop and improve techniques that increase energy density and extend storage life
- Develop innovative separation and processing techniques for access to MSW biomass

-Logistics

- Develop and optimize logistics for feedstock harvest, transport, preparation/processing and storage





RD&D Actions Biosciences and Biotechnology

Bioscience/biotech challenges related to bioenergy include:

- developing a better understanding of the biosynthesis, structure, and disassembly of the plant cell wall,
- modification of plant properties of energy crops;
 - increase cellulose:lignin ratio,
 - develop in-plant enzyme systems,
 - enhance yields,
 - reduce water and other input requirements

-Coordinate with Federal and other activities

Currently there is much activity in energy related bioscience and biotechnology (Federal, state, private and international).

- Leverage state funds to increase federally sponsored research in California
- Participate in international research programs
- Adapt and build upon results from Federal, European, and other research activities





RD&D Actions Biosciences and Biotechnology

- **Bioconversion of California Feedstocks**

Much of the federal effort is devoted to enzymatic hydrolysis techniques for corn stover, to facilitate corn-based biorefineries, and switchgrass, a prairie grass native to the North American Great Plains.

- Establish program to develop cellulase and other enzymes suitable for conversion of California feedstocks (wood and herbaceous crops and residues, thinnings, components of solid waste, etc.)
- Develop and demonstrate enzymes for California feedstocks. Coordinate with energy crop development.

- **Develop Energy Crops Suitable for California that have:**

- enhanced yields
- higher cellulose:lignin ratio
- reduced resistance to hydrolysis and fermentation treatments
- in-plant enzymes or new hydrocarbon expression/production routes
- reduced agronomic inputs and enhanced disease and pest resistance
- Multiple traits suitable for both bioproducts and bioenergy





RD&D Actions

Biomass Conversion

- Thermochemical Conversion

- Demonstrate in California advanced heat, power, and syngas systems for improved efficiency and environmental performance. Some will have potential application to thermochemical and advanced biorefineries (i.e., biomass integrated gasifier combined cycle [BIGCC])
- Replicate BIGCC demonstrations and improve economics and performance
- Improve and demonstrate advanced systems that can meet environmental performance requirements (especially air permitting and NOx issues) e.g., DG, CHP, and cooling technologies
- Demonstrate and verify municipal solid waste conversion systems
- Deploy and commercialize these advanced thermochemical systems

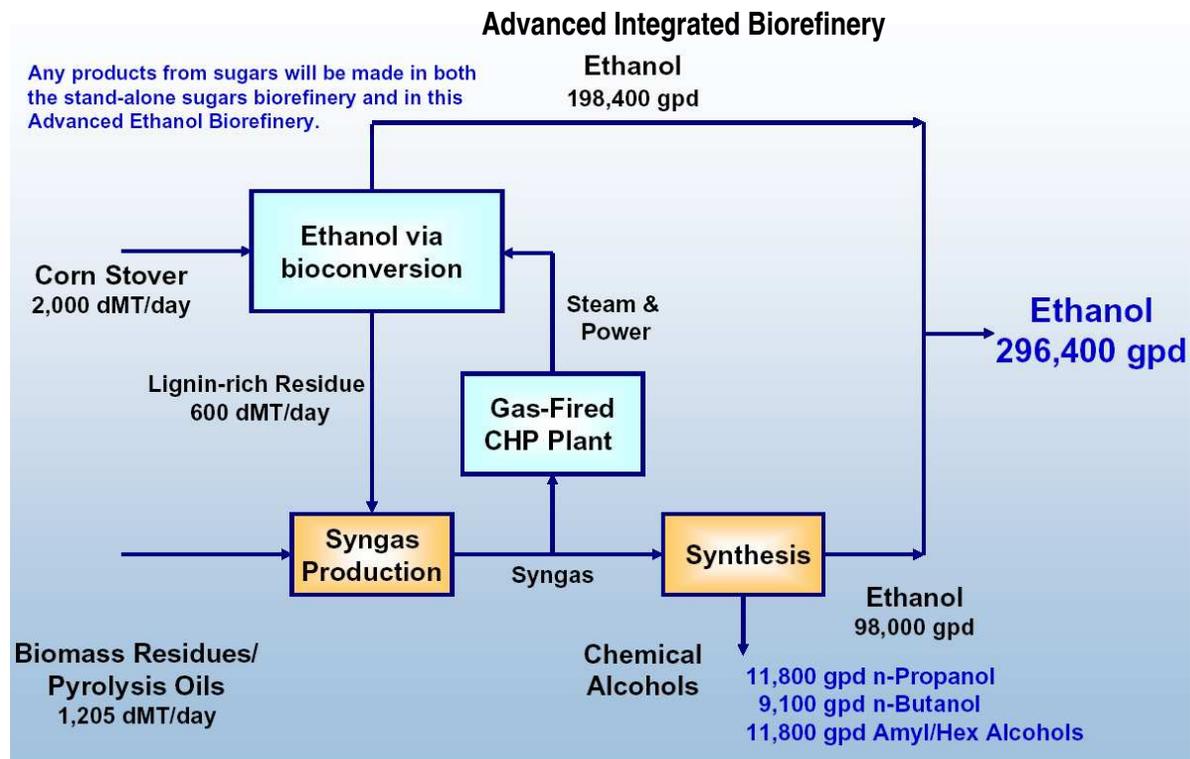


RD&D Actions Biomass Conversion

- **Biorefinery technologies and systems**

Biorefineries need to be demonstrated using California feedstocks and under California environmental performance standards.

Advanced biorefineries will likely integrate biochemical and thermochemical techniques.



Source: Bain, 2005



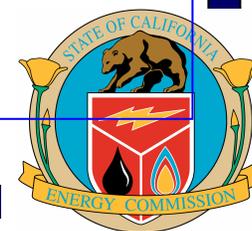
RD&D Actions Biomass Conversion

- **Biorefinery technologies and systems**

Gasifier and gas clean-up technologies developed for power systems lead naturally to biomass-to-liquid fuels (BTL) systems.

BTL, or bio-synthesis gas to liquids using Fischer-Tropsch or other catalytic methods, have theoretically high yields and very low life-cycle carbon emissions. These types of facilities might also be integrated into California's existing refinery infrastructure.

- Develop systems and components to adapt BIGCC systems to liquid fuels production (feedstock handling, gas cleaning, syn-gas conversion, catalysts, etc.).
- Demonstrate thermochemical biomass to liquids (BTL) technologies
- Develop Integrated biorefineries (thermochemical and biochemical platforms) using demonstrated systems and crops developed for California conditions
- Demonstrate and deploy integrated biorefineries (combined thermochemical & biochemical platforms)





RD&D Actions Systems Analysis

Systems analyses are important to optimizing facility scale and ensuring full life cycle impacts are properly assessed. The latter is particularly important for developing informed policy and regulations (which includes policies to monetize societal benefits of biomass management and utilization).

- **Life-cycle assessment (LCA)**

- Conduct Life-cycle assessments (LCA) for both in-state resources as well as imported biomass
- Document and value external benefits for cost internalization (update as knowledge and techniques evolve)
- Conduct comprehensive LCA of integrated waste management strategies in order to inform policy and technology innovation
 - This comprehensive life cycle assessment must compare the full range of alternative waste management techniques and strategies including landfilling, composting, conversion of all types with energy and product recovery, and recycling. The LCA needs to include disposal and recycling processes in states and foreign countries that receive California waste or recycling stock.





RD&D Actions Systems Analysis

- *Larger scale development of biomass will increase competition for land and water resources.*
- *Effects of climate change on biomass productivity, use and other system impacts including soil carbon should be analyzed.*
- *Understanding and resolving environmental justice issues associated with biomass development is needed as well.*

- **Socioeconomic/ Resource competition/Climate change effects**

- Determine economic impacts of biomass management & increased use for heat, power and fuels
- Investigate future land and resource-use scenarios: crop land and water adequacy for expanded biomass production (food/energy crop/urban lands competition)
- Assess environmental justice issues for future resource development
- Assess climate change effects on biomass productivity, water availability, use and other system impacts including soil carbon
- Develop predictive tools for climate and land-use change with respect to biomass supply and utilization





RD&D Actions Establish Biomass Research Centers

Biomass research centers are needed in California to foster development of new technologies and gain greater understanding of environmental life-cycle consequences. Biomass centers at universities can train engineers, scientists, and other professionals to meet the needs of an expanding bioenergy and biotechnology industry.

Biomass research centers should;

- support the full range of research from basic biosciences to long-term crop production trials, conversion technologies and integrated processing techniques and systems.
- include expertise in economics and systems analysis, public policy, environmental review and permitting.
- develop and maintain institutional knowledge and contribute to public outreach through conferences, workshops, certificate training programs, regular extension activities, and other means.
- serve as proving grounds where new technologies and ideas can be independently evaluated and demonstrated.



California - Biofuels RD&D Grant Solicitation

- PIER Funding Available: \$3 million
- This is a targeted grant solicitation with the intent of accelerating RD&D of biofuel energy conversion technologies and refineries using lignocellulosic biomass such as agricultural and forest residues, urban waste, and food waste, beverages, waste greese, and purpose-grown crops.
- Released date: Oct 31, 2006
- Due date: Jan 4, 2007, 19 proposals received
- Award date: March/April 2007 for 3 projects



Concluding Remarks

- California is serious about Biofuels & Bioenergy
- The Bioenergy Interagency Working Group and its member agencies and the PIER Program are focused on making CA biomass resources part of the State's energy future
 - Planning and implementation of policy drivers
 - Resolving potential barriers to biofuels & biopower development
 - Developing the next generation of biomass to energy conversion systems that will help make California's electricity and transportation fuels more cost competitive, reliable, safer and cleaner
 - Working closely and cooperatively with key stakeholders to meet California's special needs and take advantage of unique opportunities



Thank You

Additional information

The Energy Commission's web site has extensive information on the ongoing bioenergy work in California at:

http://www.energy.ca.gov/bioenergy_action_plan

<http://www.energy.ca.gov/pier/>

