

BIOMASS CONVERSION TECHNOLOGIES

*Current Status, R&D Initiatives, Policy
Drivers, Challenges & Opportunities*

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Presentation to Solid Waste Task Force Meeting, SCAG

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SCAG Offices, 818 West 7th Street, 12th Floor

Conference Room – Riverside B

Los Angeles, CA 90017





Outline

- Introduction
- California's Energy Picture
- Strategic Value of Biomass
- Challenges & Opportunities
- Biomass Policy Drivers
- Status of Bioenergy in California
- Public Interest Energy Research Program
- PIER Biomass Research Activities
- Concluding Remarks





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The **California Energy Commission** is the state's primary energy policy and planning agency. Created by the Legislature in 1974 and located in Sacramento, California.

The Commission has five major responsibilities:

- Forecasting future energy needs and keeping historical energy data
- Licensing thermal power plants 50 megawatts or larger
- Promoting energy efficiency through appliance and building standards
- Developing energy technologies and supporting renewable energy
- Planning for and directing state response to energy emergency





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Petroleum (2005)

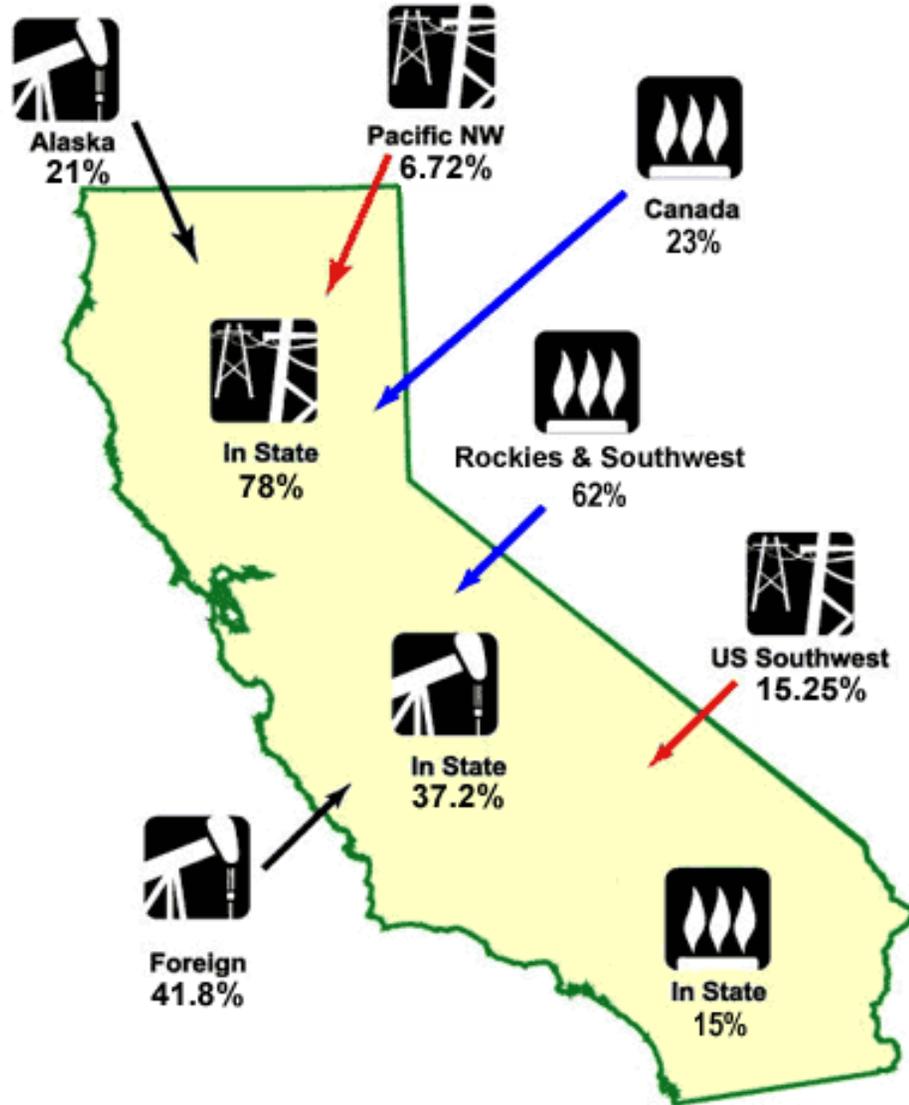
In State 37.22%
 Alaska 20.99%
 Foreign 41.79%

Electricity (2006)

In-State 78.03%
 Natural Gas 41.5%
 Nuclear 12.9%
 Large Hydro 19.0%
 Coal* 15.7%
 Renewable 10.9%
 Imports 21.97%
 PNW 6.72%
 DSW 15.25%

Natural Gas (2005)

In State 15.0%
 Canada 23.0%
 Rockies 24.0%
 Southwest 38.0%



CALIFORNIA'S ENERGY SOURCES

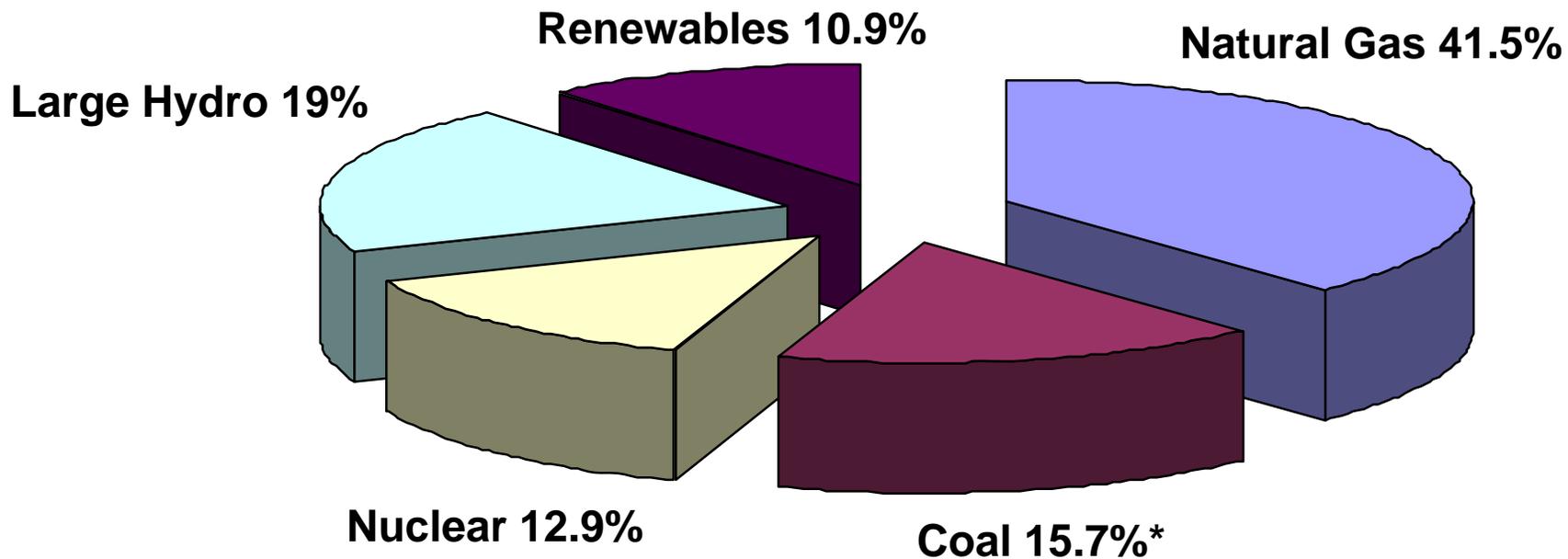
* Intermountain and Mohave coal plants, though outside California, are considered "in-state", since they are in California utilities' control areas.





California's Electricity Production in 2006

(Total=294,865 GWh)



*Intermountain and Mohave coal plants are considered in-state, since they are in California control areas.





California's Electricity Production 2006

Fuel Type	In-State	NW Imports	SW Imports	GSP	GSP Percentage
Coal {2}	17,573	5,467	23,195	46,235	15.7%
Large Hydro	43,088	10,608	2,343	56,039	19.0%
Natural Gas	106,968	2,051	13,207	122,226	41.5%
Nuclear	31,959	556	5,635	38,150	12.9%
Renewables	30,514	1,122	579	32,215	10.9%
Biomass	5,735	430	120	6,285	2.1%
Geothermal	13,448	0	260	13,708	4.7%
Small Hydro	5,788	448	0	6,236	2.1%
Solar {1}	616			616	0.2%
Wind	4,927	244	199	5,370	1.8%
TOTAL	230,102	19,804	44,959	294,865	100.0%

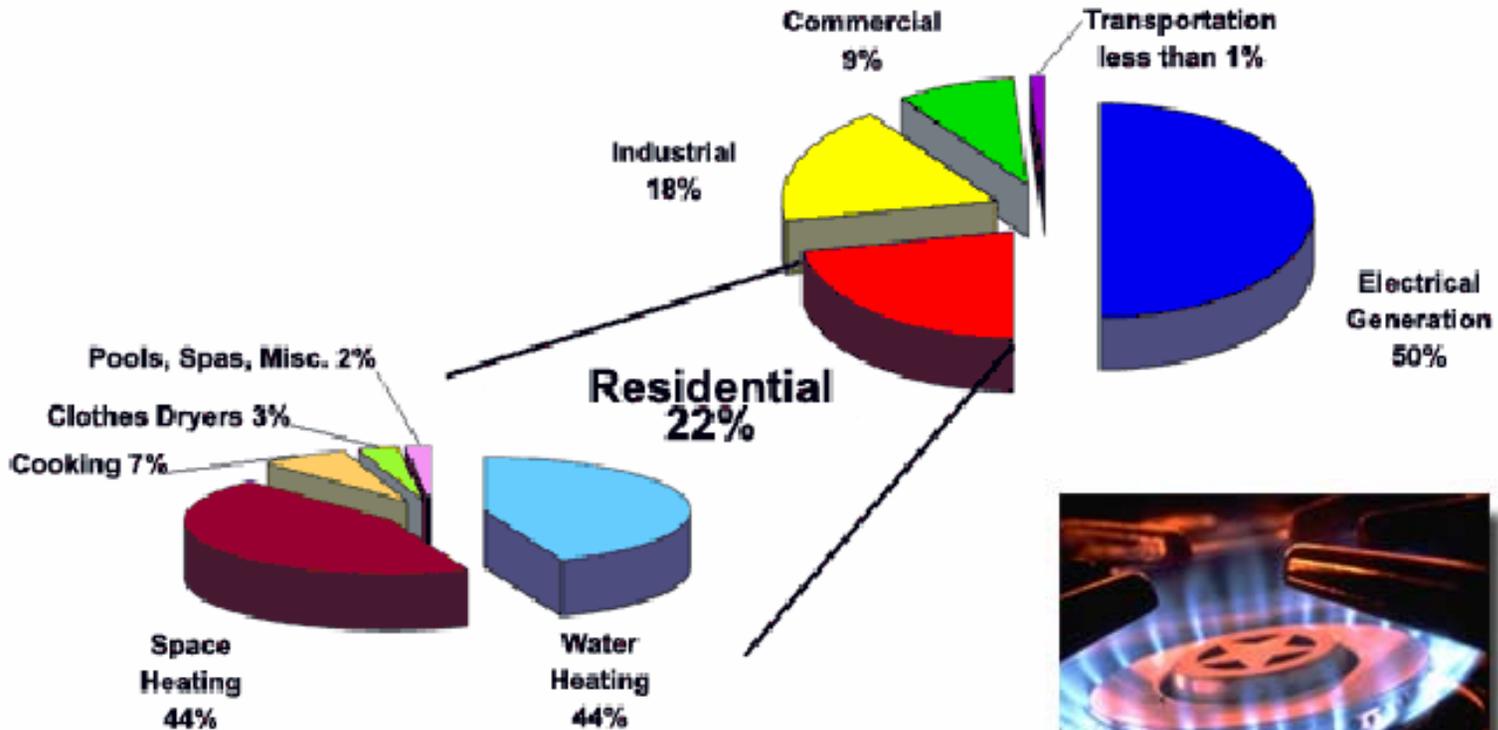
Source:

[2006 Net System Power Report](#), Energy Commission Publication # CEC-300-2007-007. (Acrobat PDF, 8 pages, 48 kilobytes, date on line April 12, 2007)



2004 Natural Gas Use in California

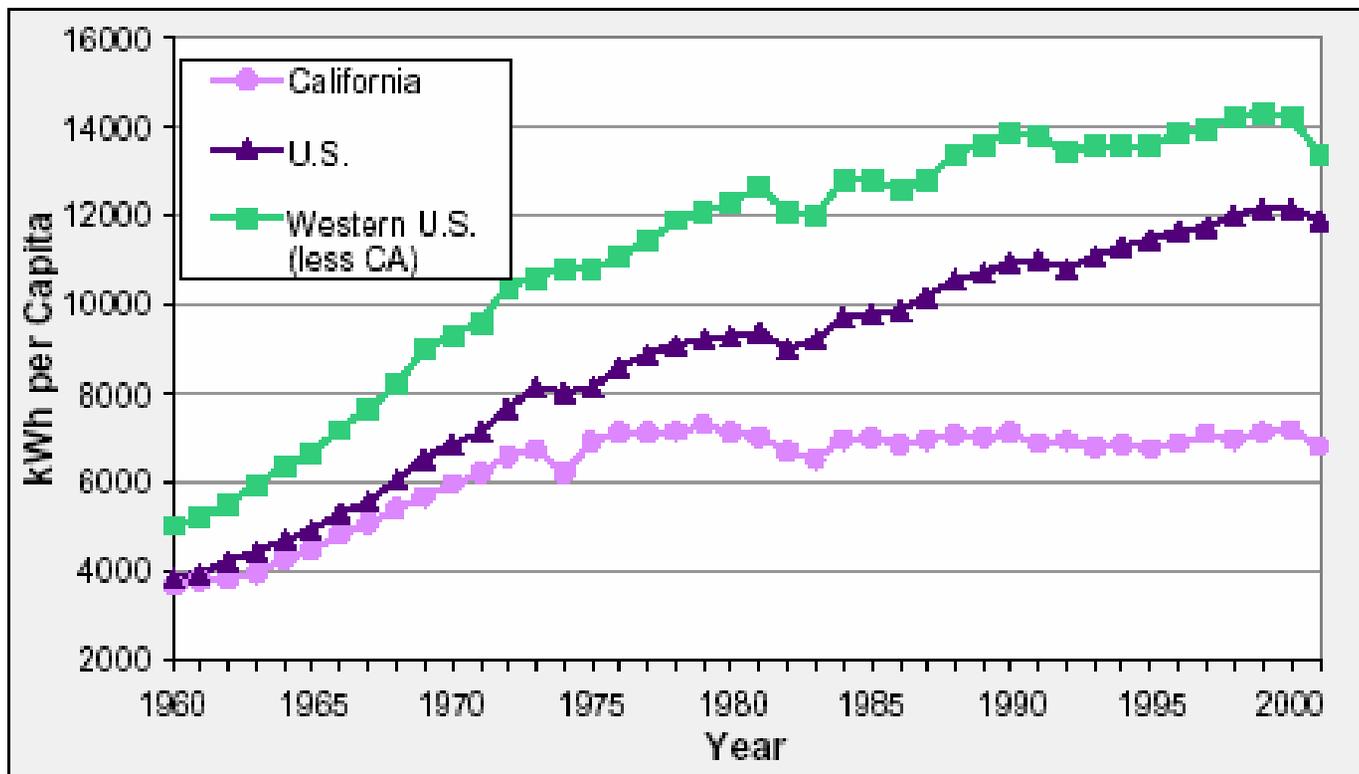
2004 Natural gas consumption ~ 228 Bcf



Biogas can displace natural gas broadly in direct uses.



Total Electricity Use Per Capita 1960- 2001



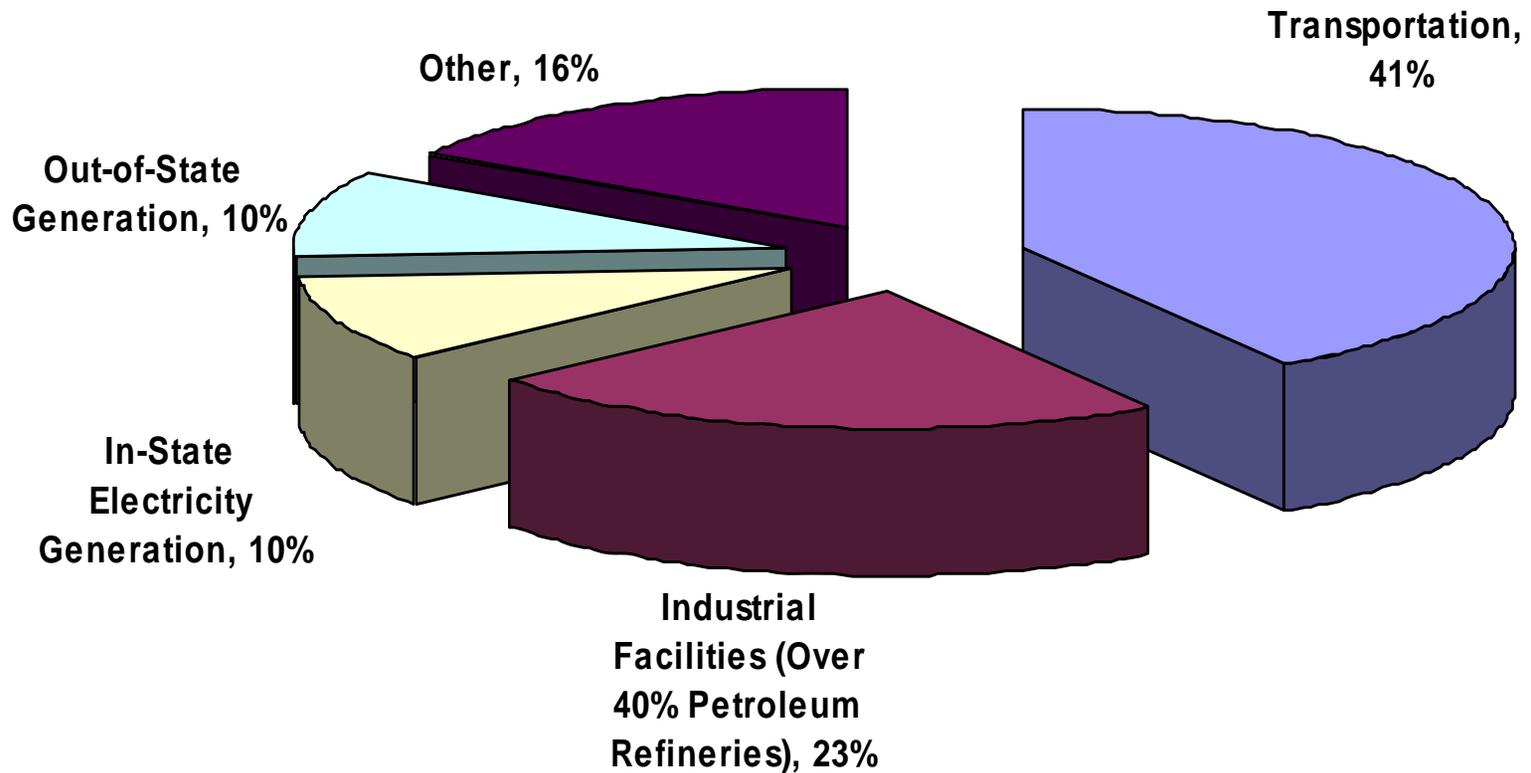
Californians use almost 50 percent less electricity than the U.S. average
Source: Energy Information Agency and California Energy Commission

*Efficiency has reduced the growth of CA electricity use
but new resources are still needed.*



California Greenhouse Gas Emissions

The total GHG emissions for 2004 are ~500 million tons of CO2 equivalent





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Strategic Value of Bioenergy

The U.S. has large, diverse and untapped biomass resources which can support greater use in electric power, fuels and chemicals.

U.S. Potential = 1.3 billion tons

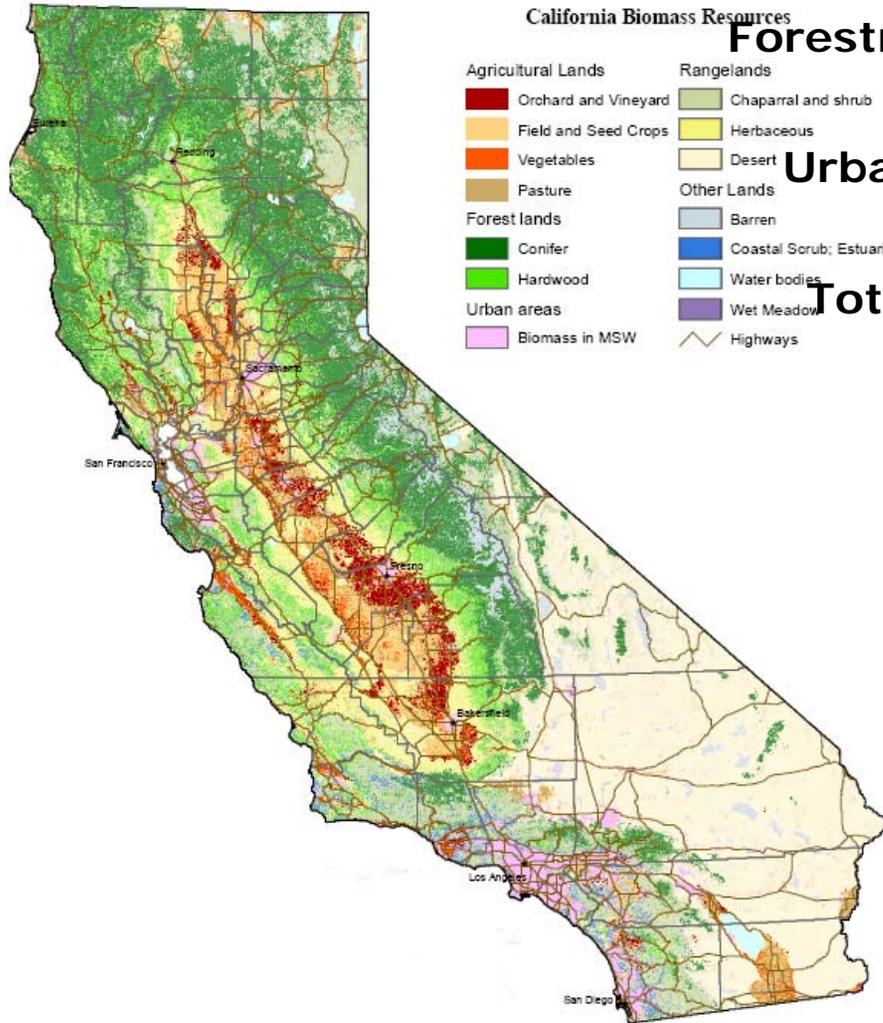
California = 80 million dry tons

Biomass is an energy resource capable of achieving state petroleum reduction, climate change, renewable energy and environmental goals.

Use of biomass for energy production can address the U.S. and California's waste disposal and environmental problems, while creating local jobs.

Other public benefits include improving forest health and human and animal health, while avoiding catastrophic wildfires.





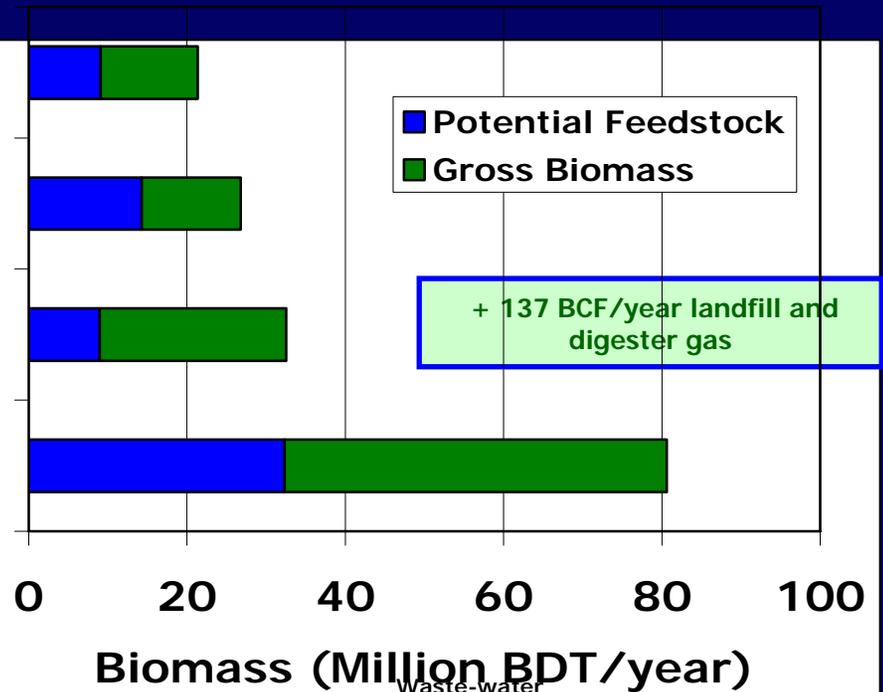
- California Biomass Resources**
- | | |
|--|---|
| Agricultural Lands | Rangelands |
| ■ Orchard and Vineyard | ■ Chaparral and shrub |
| ■ Field and Seed Crops | ■ Herbaceous |
| ■ Vegetables | ■ Desert |
| ■ Pasture | Other Lands |
| Forest lands | ■ Barren |
| ■ Conifer | ■ Coastal Scrub; Estuarine |
| ■ Hardwood | ■ Water bodies |
| Urban areas | ■ Wet Meadow |
| ■ Biomass in MSW | ~ Highways |

Agriculture

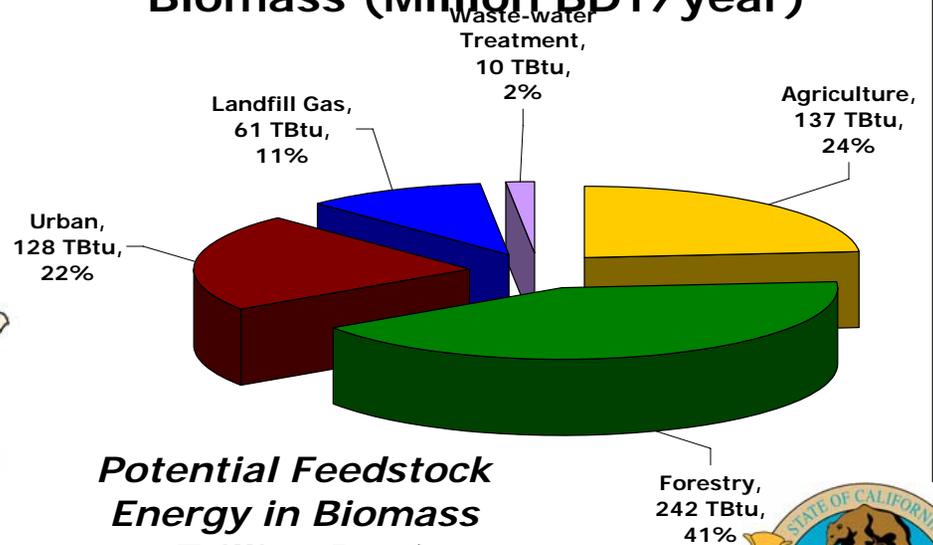
Forestry

Urban

Total



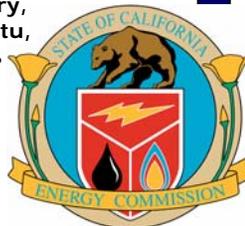
Biomass (Million BDT/year)



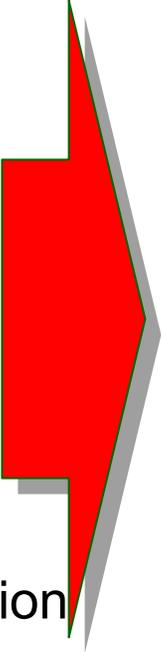
0 20 40 80 120 160 200 Miles

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

California Biomass Resources



Principal Biomass Conversion Pathways

- Production
 - Harvesting
 - Collection
 - Processing
 - Storage
 - Transportation
- 

- Thermochemical Conversion

- Combustion
- Gasification
- Pyrolysis

- Bioconversion

- Anaerobic/Fermentation
- Aerobic Processing
- Biophotolysis

- Physicochemical

- Heat/Pressure/Catalysts
- Refining
- Makes e.g. Esters (Biodiesel), Alkanes

- Energy

- Heat
- Electricity

- Fuels

- Solids
- Liquids
- Gases

- Products

- Chemicals
- Materials

Source: BM Jenkins, UC Davis



Total Categorical Bioenergy Potentials in California

Category	Biomass (Million BDT/year)	Energy in Product (Trillion Btu/year)	Total Capacity
Electricity CHP Heat	32	118 (35 TWh) 230	4,650 MWe 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





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Biomass is seen as a Waste Disposal Problem

- Reducing Landfill Capacity
 - About 40 million tons of biomass goes into landfills every year
- Contributing to Air Pollution and Fire Risk
 - Open field burning of crop residues emits more than 100,000 tons of air pollutants annually
 - Wildfires contribute over 1.1 million tons per year at a cost of >\$900 million/year
- Local Concerns
 - California's 1.7 million dairy cows generate odor and health concerns



Biomass Technology Gaps

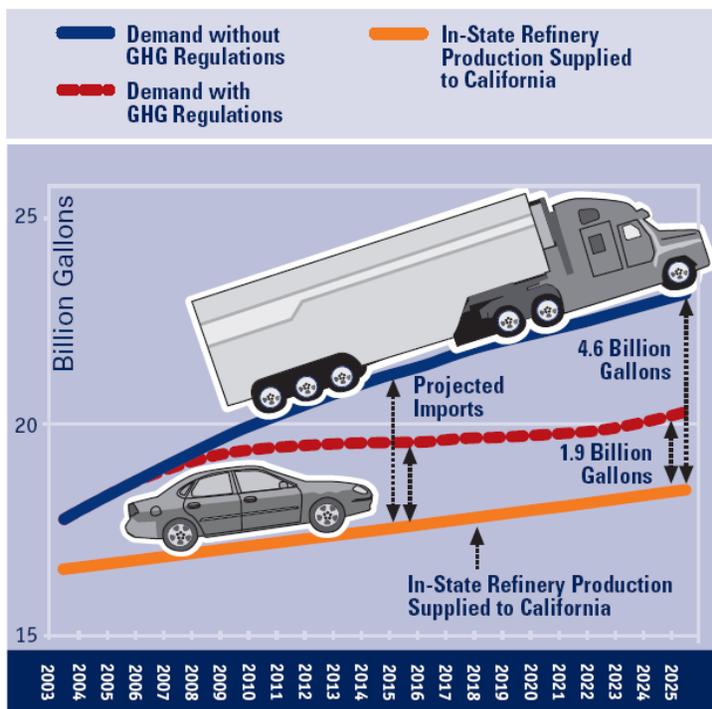
- Electricity Generation Gaps
 - Costs still need to come down to more competitive levels
 - Air emission profiles (esp. NO_x) need to meet or exceed regulations (e.g., CARB 2007 guidelines)
 - At utility-scale sizes, need development of super clean, super-efficient systems with high degree of responsiveness
 - At DG levels - small modular-scale, need to develop a track record
- Transportation Technology Gaps
 - Lack of commercial cellulosic to ethanol technologies
 - ◆ Development and demonstration of cellulosic facilities
 - ◆ Development of track record on performance and cost
 - ◆ Development of infrastructure for production & delivery of fuel
 - Lack of track record for biodiesel



Trends Petroleum and Non-Petroleum Consumption

The 2005 IEPR concluded that California needs to aggressively reduce its dependence on petroleum and introduce more non-petroleum options.

Projected Gasoline and Diesel Demand



Demand for Gasoline and Diesel Fuel

Demand continues, even in the face of record petroleum prices, for several reasons:

- Population growth and more on-road vehicles
- Low per-mile cost of gasoline for the past two decades
- Lack of alternatives to conventional gasoline and diesel fuels
- Consumer preference for larger, less fuel efficient vehicles
- Land use planning that places jobs and housing farther apart without transportation integration
- Lack of mass transit

Source: California Energy Commission, November 2005, 2005 Integrated Energy Policy Report





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California Biomass Energy Policy Drivers

- Governor's Executive Order S-06-06 –biomass & biofuels
- Bioenergy Action Plan (July 13, 2006, Governor announces action plan to reduce petroleum dependence and improve air quality)
- AB 32 – Global Warming Solutions Act
- Governor's GHG Reduction Targets (Executive Order S-3-05)
- Renewables Portfolio Standard, 20% by 2010 and 33% by 2020
- Integrated Energy Policy Reports (IEPR) (2003, 2004 update, 2005)
- Energy Action Plan (EAP) I and II (published 2003 and 2005 respectively)
- Governor's 2003 / 2004 IEPR response and Ten Point Plan
- US 2005 Energy Policy Act
- Western Governor's Association (Charter, 2005 Annual Report, 2003 Policy Roadmap)





In a letter dated August 23, 2005, ...

Governor Arnold Schwarzenegger expressed his support for the **California Biomass Collaborative** and reinvigorated the **Bioenergy Interagency Working Group**.

The Governor directed the **Working Group** to develop an **integrated, consistent and comprehensive** state policy on the use of biomass for electricity generation, as well as natural gas and petroleum substitution.



Governor Directs State Agencies to Expand Biofuels to Fight High Gasoline Prices

“It is critical that we do everything we can to reduce our dependence on petroleum based fuels. “

“Turning waste products into energy is good for the economy, local job creation and our environment.”

**---Governor Schwarzenegger
Sacramento, California
April 25, 2006**



EXECUTIVE DEPARTMENT
STATE OF CALIFORNIA
EXECUTIVE ORDER S-06-06

by the

Governor of the State of California

Executive Order S-06-06

(Issued April 25, 2006)

Production Targets for Bio-energy

Biofuels - the state shall produce a minimum of 20 percent of its biofuels within California by 2010, increasing to 40 percent by 2020 and 75 percent by 2050

Biomass to electricity (biopower) – the state shall meet a 20 percent target within the established state goals for renewable generation for 2010 and maintaining this level through 2020.

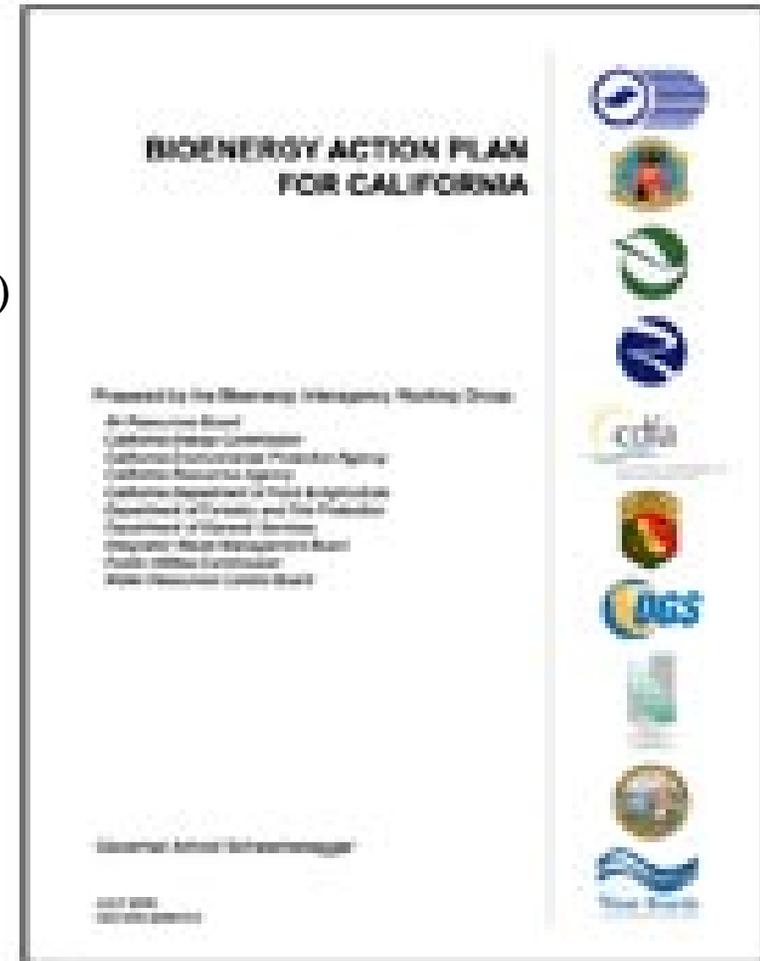


Bioenergy Action Plan

(Issued July 2006)

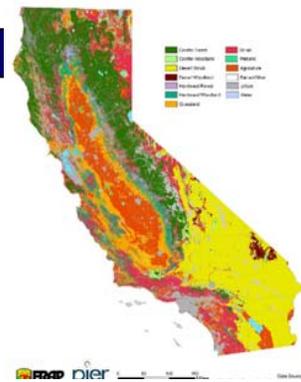
Multi-Agency Collaborations (Working Group)

- California Energy Commission
- California Air Resources Board
- California Environmental Protection Agency
- California Resources Agency
- Department of Food & Agriculture
- Department of Forestry & Fire Protection
- Department of General Services
- Integrated Waste Management Board
- Public Utilities Commission
- Water Resources Control Board



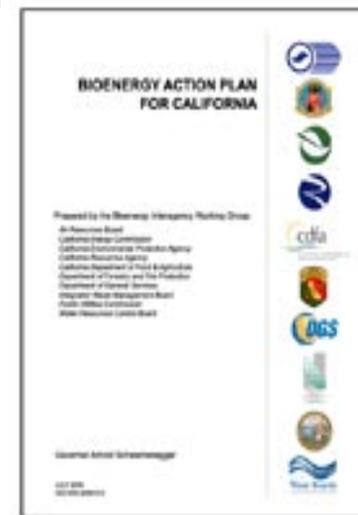
Each agency has individual responsibilities...





Bioenergy Action Plan -- Five Policy Objectives

1. Maximize the contributions of bioenergy toward achieving the state's petroleum reduction, climate change, renewable energy, and environmental goals.
2. Establish California as a market leader in technology innovation, sustainable biomass development, and market development for bio-based products.
3. Coordinate research, development, demonstration, and commercialization efforts across federal and state agencies.
4. Align existing regulatory requirements to encourage production and use of California's biomass resources.
5. Facilitate market entry for new applications of bioenergy including electricity, biogas, and biofuels.

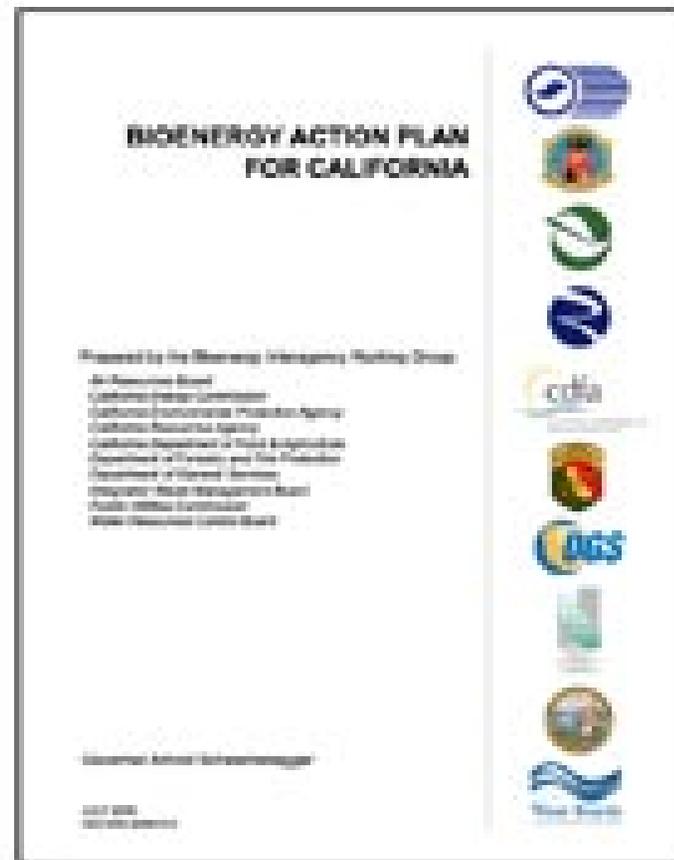


Bioenergy Action Plan

(Issued July 2006)

Energy Commission Responsibilities:

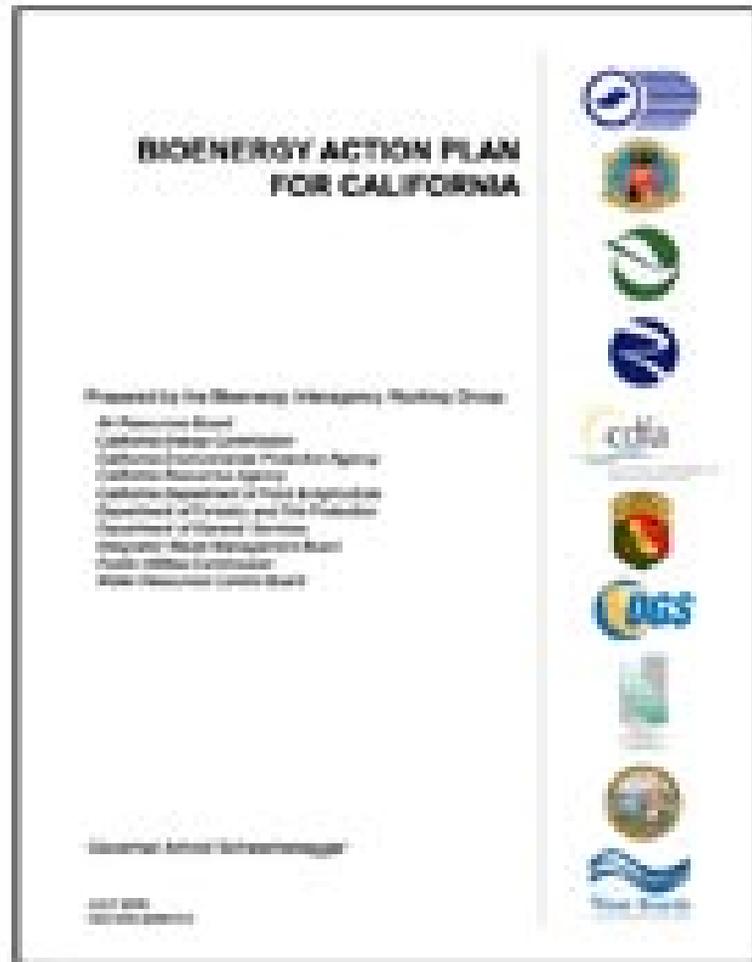
- Report on progress in implementing the state policy objectives, biomass production targets, and actions detailed in this Action Plan in the IEPR...
- Complete comprehensive “road map” to guide future research, development, and demonstration activities through the California Biomass Collaborative...
- Prepare the State Alternative Fuels Plan, as required by AB 1007, by June 30, 2007...among other things, will identify actions and incentives to increase the production and use of biofuels and to develop an extensive and convenient E-85 network in new and retrofitted service stations in California.



Bioenergy Action Plan (Issued July 2006)

Members of the Bioenergy Interagency Working Group:

- commit to the near term actions to achieve the state's bioenergy policy objectives and biomass production targets
- will work to secure necessary resources for the activities proposed in the plan through the state budget process and pursue legislative initiatives
- will create necessary institutional and regulatory changes that will substantially increase the production and use of biomass for energy in California that benefits the economy and protects the environment



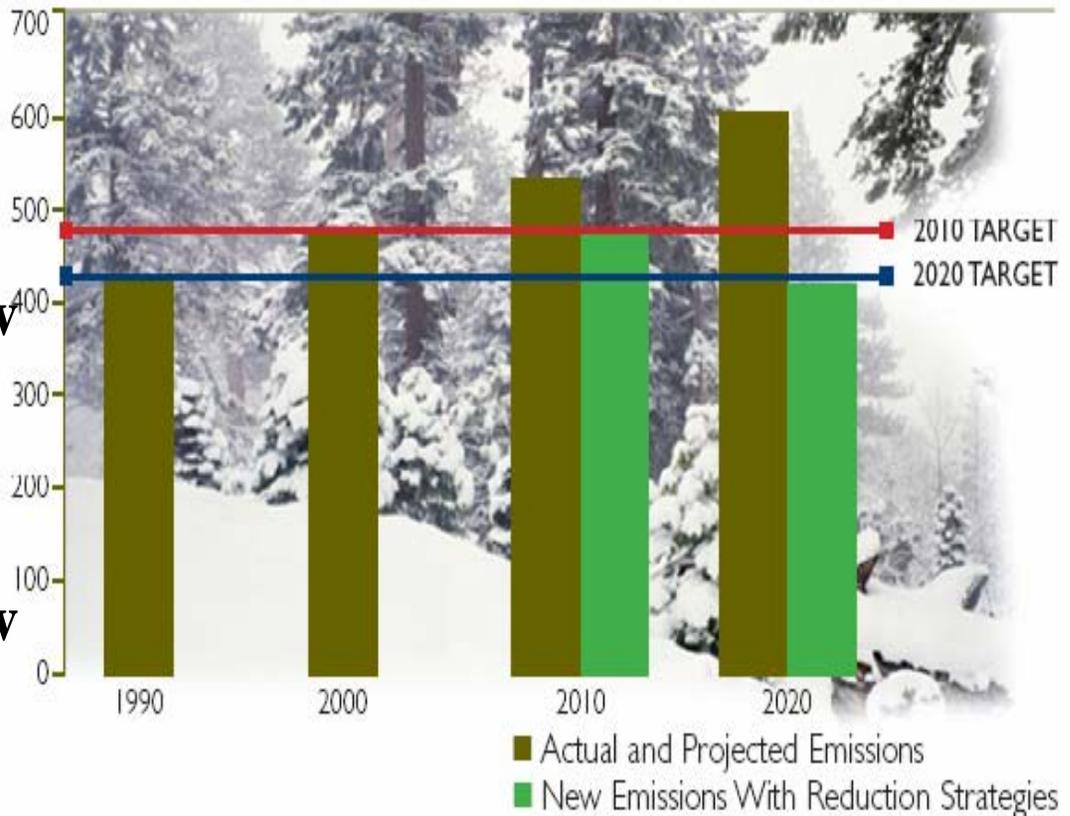
AB 32 – Global Warming Solutions Act of 2006

Emissions reduction targets:

•Yr 2010 – reduce to 2000 levels (11% below business as usual)

•Yr 2020- reduce to 1990 levels (25% below business as usual)

•Yr 2050- reduce to 80% below 1990 levels





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California Bioenergy Status

- Biomass power facilities produce ~1,000 MW of electrical capacity:
 - **Combustion of Forestry, Agricultural and Urban Residues for Power**
 - **Convert Methane Rich Landfill Gas to Energy**
 - **Construct Wastewater/ Dairy Biogas Systems that process Biogas.**
- Biofuels - Californians consumed over 900 million gallons of ethanol and over 43 million gallons of biodiesel in 2006.



In-state Production and Use Goals

Increase in-state production and use of bioenergy, including ethanol and bio-diesel fuels made from renewable resources:

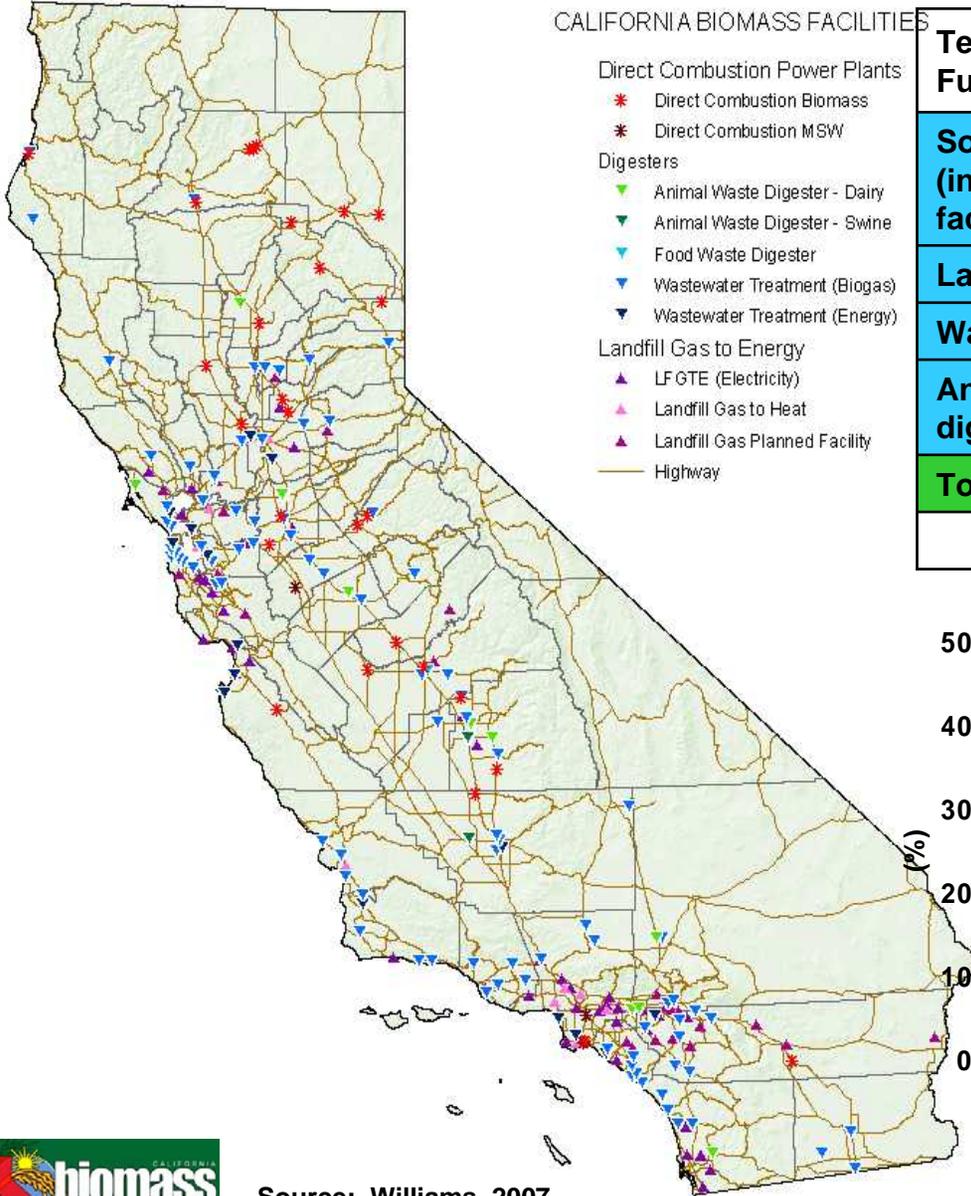
- **For biofuels**, the state shall produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050.
- **For biomass for electricity**, the state meet a 20 percent target within the established state goals for renewable generation for 2010 and 2020.



Current Biomass Power Capacity in California

CALIFORNIA BIOMASS FACILITIES

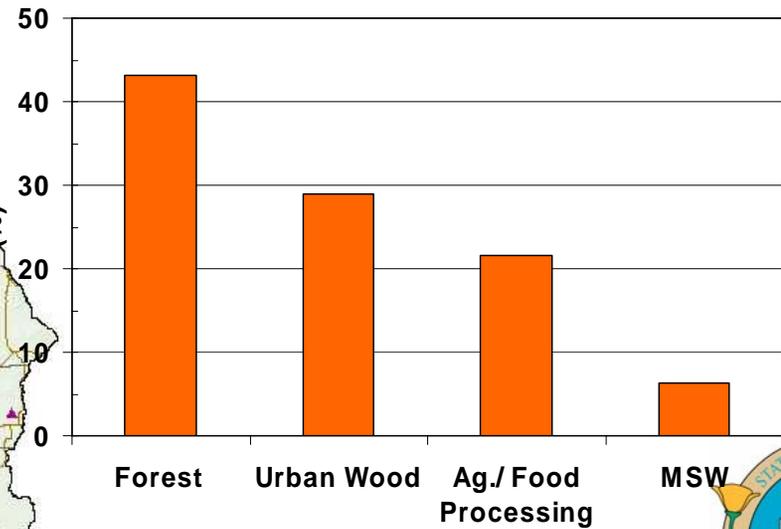
- Direct Combustion Power Plants
- * Direct Combustion Biomass
 - * Direct Combustion MSW
- Digesters
- ▼ Animal Waste Digester - Dairy
 - ▼ Animal Waste Digester - Swine
 - ▼ Food Waste Digester
 - ▼ Wastewater Treatment (Biogas)
 - ▼ Wastewater Treatment (Energy)
- Landfill Gas to Energy
- ▲ LFGE (Electricity)
 - ▲ Landfill Gas to Heat
 - ▲ Landfill Gas Planned Facility
- Highway



Technology/ Fuel Source	Number of facilities	Gross Capacity (MW)
Solid Fuel Combustion (includes 3 MSW facilities)	30	640
Landfill gas-to-energy	60	275
Wastewater treatment *	20	64
Animal and food waste digester	22	5.7
Totals	132	985

* Suspect - Probably higher

Solid Combustion Fuel Sources



Source: Williams, 2007

Accelerated Renewables Portfolio Standard (RPS)

20% of retail electricity sales to
come from renewable resources
by **2010**, and

33% by **2020**



Biomass needed to meet goal of a 20% share of the State Renewables Portfolio Standard (RPS)

	RPS (%)	Renewable power under RPS (GWh/y)	20% Biomass goal (GWh/y)	Biomass capacity required above current 2005 (MW- 0.85 cap. Factor)
2010	20	58,575	11,700	575
2020	33	109,400	21,875	1,975
2050	33	136,500	27,300	2,670



Biofuel Goals

Instate biofuel production goals for several blend rate scenarios (million gallons per year)

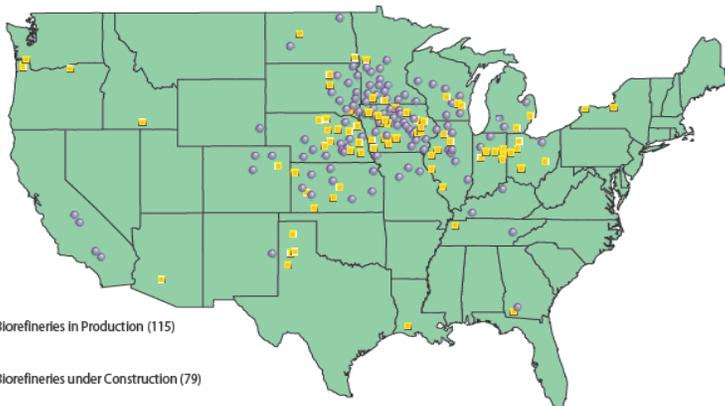


Year	Ethanol			Biodiesel			
	E5.7	E10	E20	B2	B5	B10	B20
2010	183	325	675	13	32	65	130
2020	390	700	1430	35	85	170	345
2050	900	1,570	3,250	150	375	750	1,490

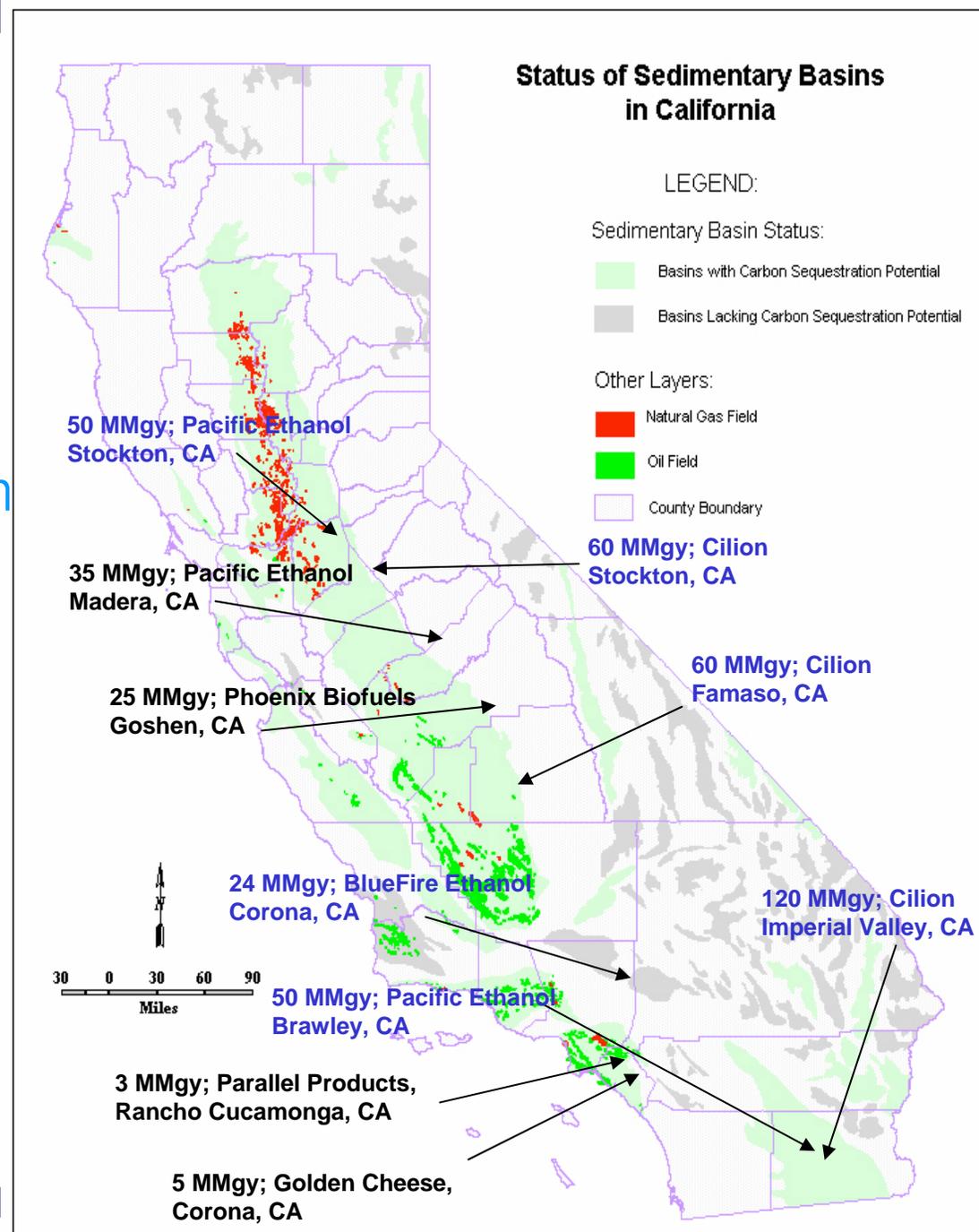
Ethanol Locations in California (2006)

- Existing ethanol facilities (68 Million Gallons)
- Proposed plants (364 Million Gallons)

U.S. Ethanol Biorefinery Locations



Source: Renewable Fuels Association
4.3.07

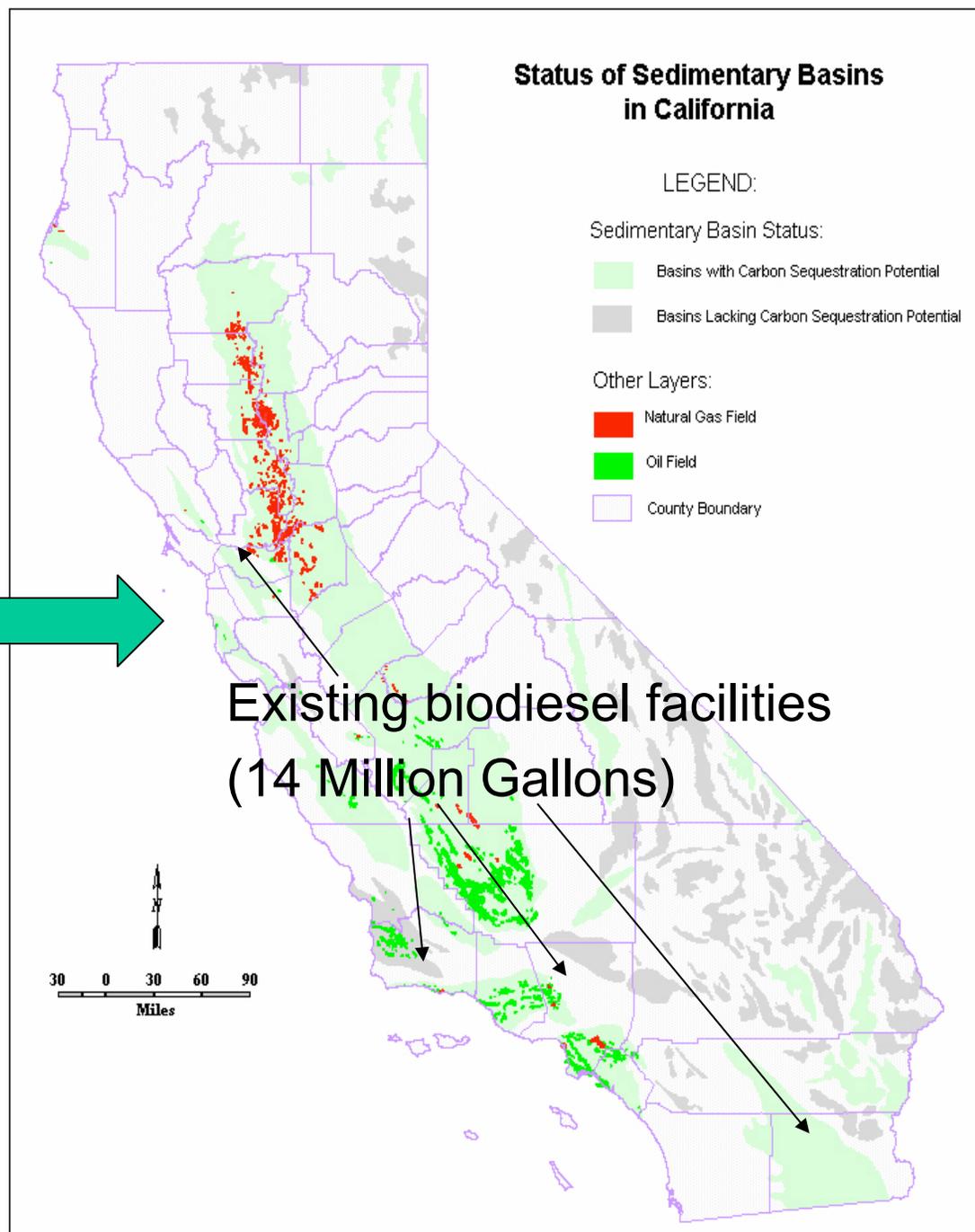


Biodiesel Consumption in California (2006) 43 Million Gallons

Biodiesel imports
(29 Million Gallons)

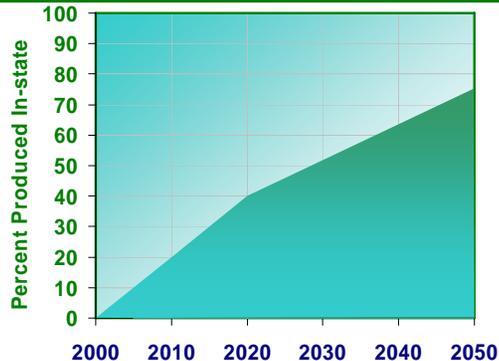


Existing biodiesel facilities
(14 Million Gallons)



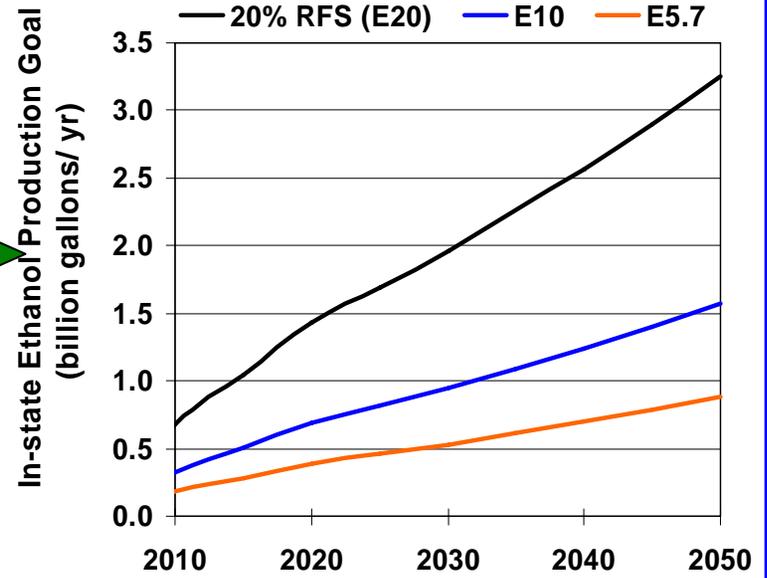
In-state biofuel production goals for blend rate scenarios

- Assuming projected transportation fuel growth rates and
- Executive Order S-06-06 goals for in-state biofuel production
 - 20% by 2010
 - 40% by 2020
 - 75% by 2050

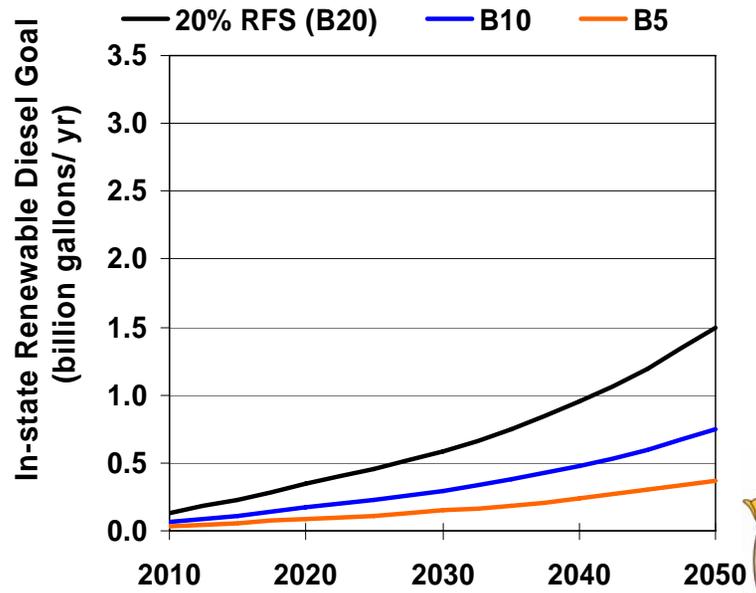


Source: Williams, 2007

Ethanol



Renewable Diesel





BP & Chevron - Investing on Biofuels

- **BP selects UC Berkeley to lead \$500 million energy research consortium with partners Lawrence Berkeley National Lab, University of Illinois**
- **U.C. Davis Gets Funding from Chevron for Alternative Fuels Research.** University of California at Davis researchers received up to **\$25 million** in funding from Chevron Corp. to spend the next five years developing clean and affordable, renewable transportation fuels from farm and forest residues, urban wastes and crops grown specifically for energy.



Renewable Energy Program Production Incentives for Biomass

● Existing Renewable Facilities Program

- Has helped 33 biomass facilities remain competitive or return to service by paying more than \$150 million for 640 MW of renewable energy capacity
- Provided \$6 million for the 2004 Agriculture-to-Biomass Program to improve air quality in CA's agricultural areas

● New Renewable Facilities Program

- Of the 68 participating "new" renewable generating facilities, 20 are biomass projects
- 17 biomass facilities have been completed and are producing electricity representing 50 MW of capacity
- More than \$14 million in payments has supported 1,201 gigawatt-hours of biomass generation
- When completed, all 20 biomass facilities will bring 64 MW of new renewable capacity to California's electricity grid



Renewables Portfolio Standard (RPS)

- **Investor Owned Utility RPS Biomass Contracts**

(signed since 2002)

- As of March 22, 2007, RPS solicitations and bilateral agreements have resulted in signed contracts with biomass facilities for 285 - 391 MW of capacity (range reflects build-out options).

- **RPS Certification**

- 96 biomass facilities are certified and 21 are pre-certified as eligible for the RPS representing 1,819 MW of capacity.





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Public Interest Energy Research (PIER) Program

- **IOU Ratepayer-funded 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 Biomass

General Goal

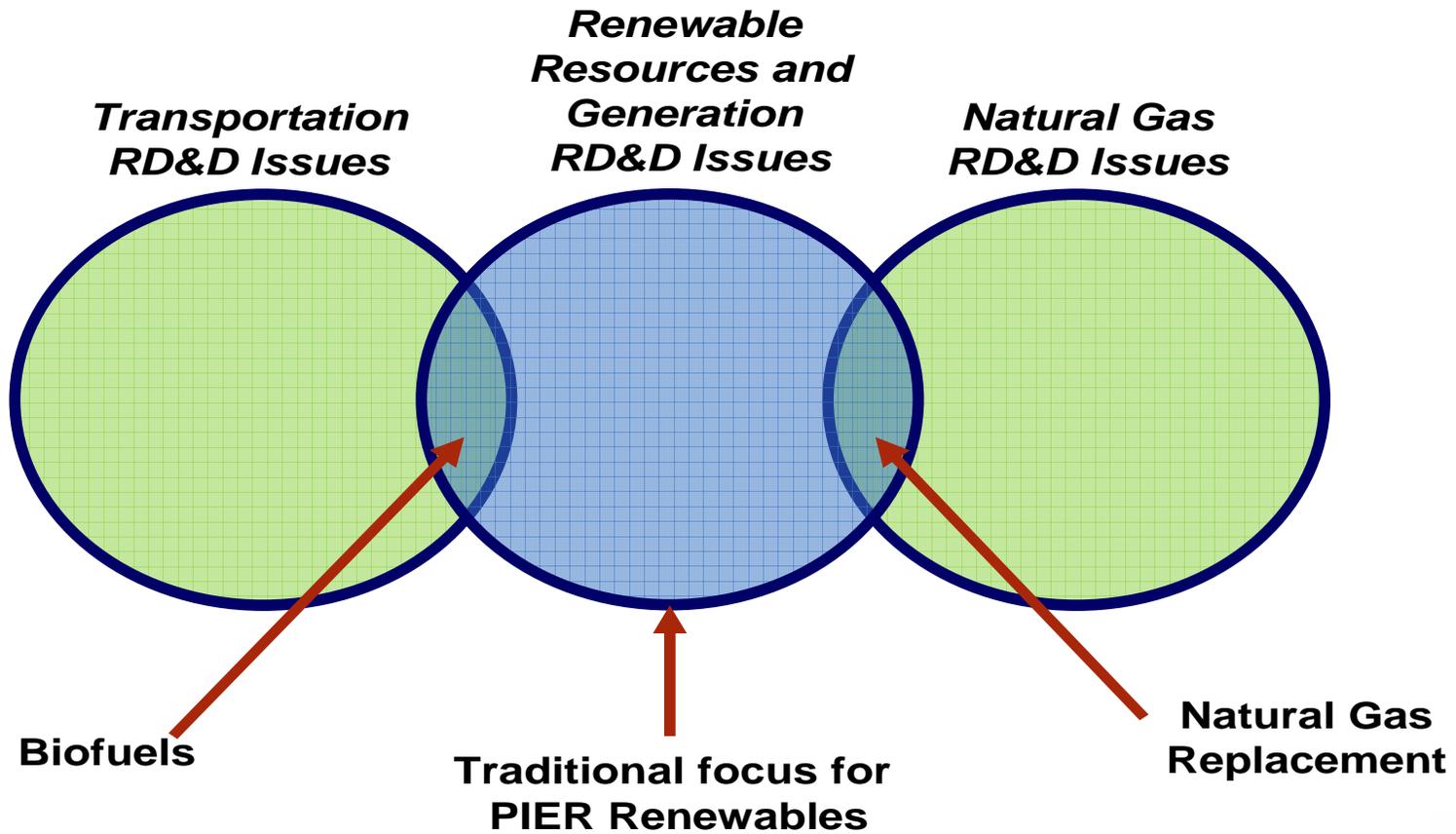
- “Develop and help bring to market, energy technologies that provide increased environmental benefits, greater system reliability, and lower system costs”

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.”



PIER Renewables Program RD&D Focus



Stages of Technology Development & PIER Renewables Role

Stages of Technology Development

Research	Development	Demonstration	Commercialization	
			Market Entry	Market Penetration
<ul style="list-style-type: none"> • General assessment of resources and market needs • Assess general magnitude of economics • Concept and bench testing • Basic research and sciences (e.g., materials science) 	<ul style="list-style-type: none"> • Research on component technologies • Development and initial of product offering • Pilot testing 	<ul style="list-style-type: none"> • Integrate component technologies • Initial system prototype for debugging • Demonstrate basic functionality • Ongoing development to reduce costs or for other needed improvements • “Technology” (systems) demonstrations • “Commercial” demonstration • Standards creation • Testing and certification 	<ul style="list-style-type: none"> • Initial orders • Early movers or niche segments • Product reputation is initially established • Business concept implemented • Market support usually needed to address high production cost 	<ul style="list-style-type: none"> • Follow-up orders based on need and product reputation • Broad(er) market penetration • Infrastructure developed • Full-scale manufacturing

PIER Renewables Technology Research

PIER Renewables co-funds research for renewable technologies from applied research to the demonstration stage

PIER Renewables Policy and Adoption Support Research

PIER Renewables funds research to support policy development, adoption and integration for renewables energy technologies in all stages of development



PIER-Biomass R&D Activities

- Technology Development
 - Direct Combustion/Co-firing Systems
 - Biogas
 - Thermal Gasification/Pyrolysis
 - Biofuels

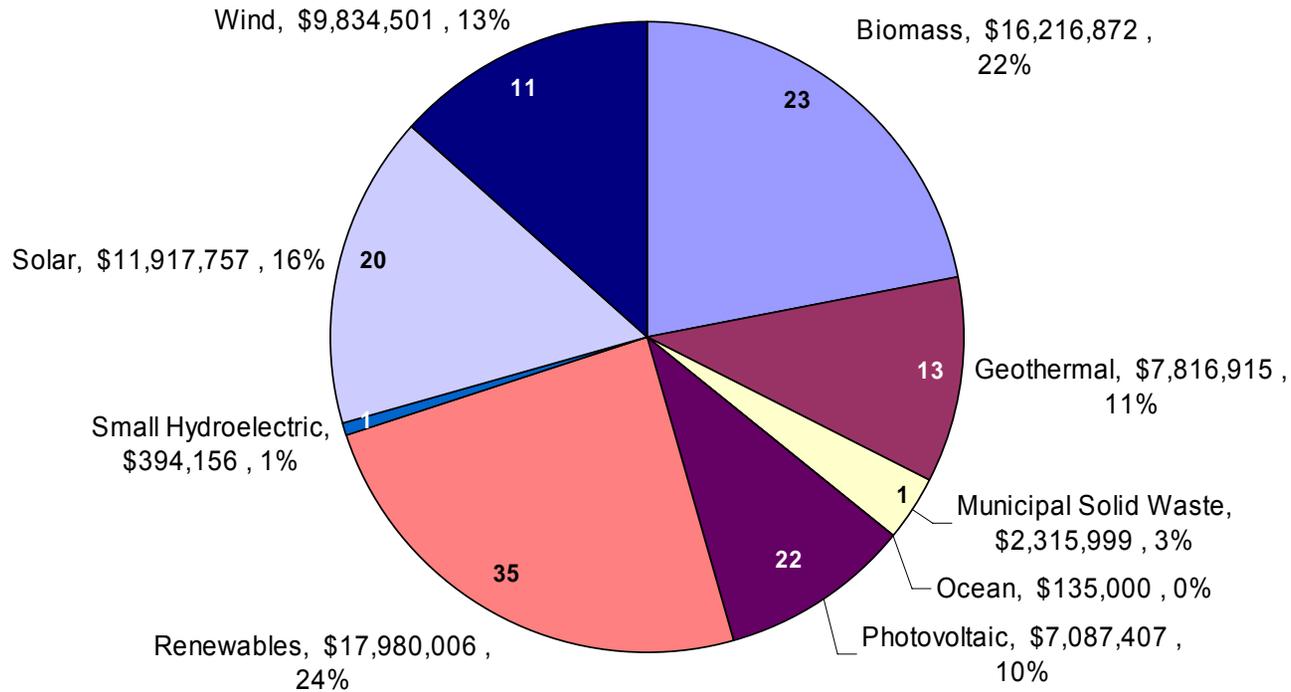
- Analysis and Planning
 - California Biomass Collaborative
 - ◆ Biomass Roadmap for biomass development
 - ◆ Biomass Resource Assessments
 - ◆ Biomass Performance Reporting System
 - Strategic Value Analysis
 - ◆ Linking cost competitive biomass resources to electricity system needs while addressing public benefits

- Natural Gas Replacements by Biomass
 - Implement Natural Gas Program Plan
 - PIER Transportation



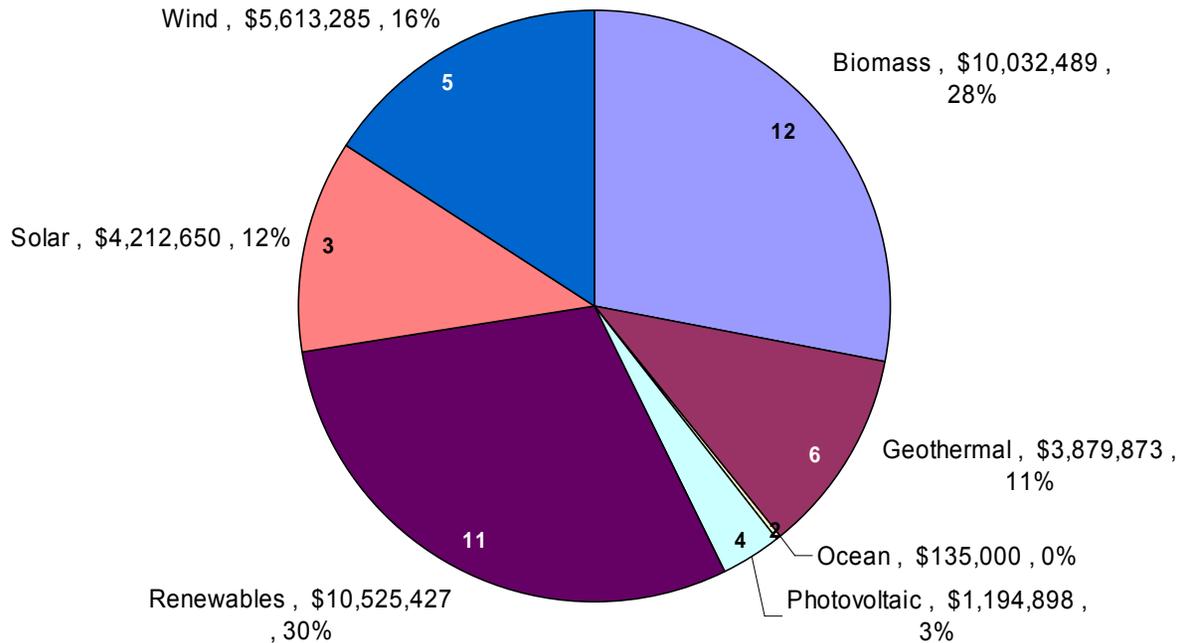
PIER Portfolio Summary

Renewables Projects - Active and Closed
128 Projects, \$73.7 Million



PIER Portfolio Summary

Renewables Projects - Active
43 Projects, \$35.6 Million



California Biomass 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





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- Status of Bioenergy in California
- Public Interest Energy Research Program
- **PIER Biomass Research Activities**
- Concluding Remarks

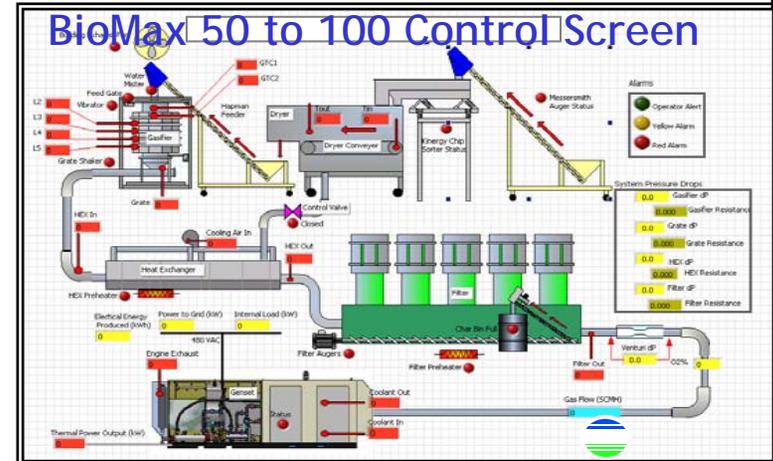


PIER Biomass R&D Projects



50 kW Small Modular Biopower System

- Contractor: Community Power Corporation
- Goals:
 - Design, develop and demonstrate a 50 kW modular gasification system for grid interconnection, and combined heat and power using forest residue.
 - Improve cost competitiveness of the biomass energy conversion technologies and reduce environmental risks and costs of California's electricity.
- Project Site
 - Harwood products, Branscomb, CA
- Status:
 - Completed the design and fabrication of the SMB components
 - Completed Shop testing at CPC
 - NOx = 0.39 lb/MWh using catalytic converters
 - CO = 4.47 lb/MWh
 - Field testing expected to start in July 2007

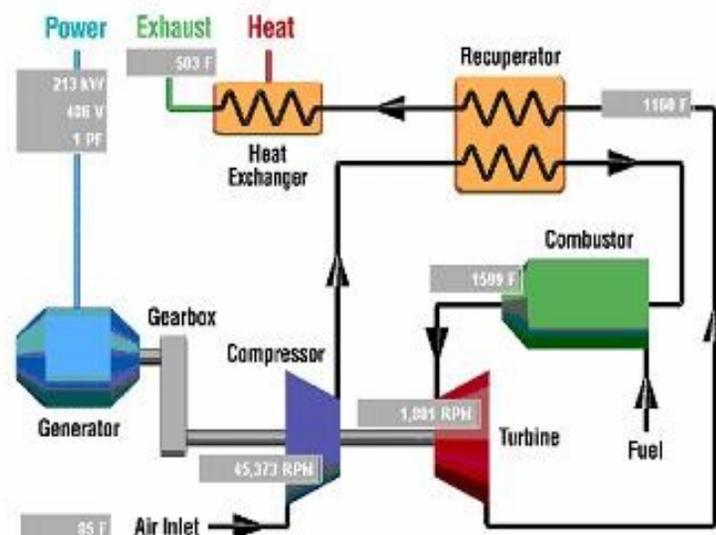


250 kW Microturbine Using Landfill Gas

- **Goals:**
 - Provide a low-cost high efficiency distributed power generation engine that runs on landfill gas
 - Efficiently use landfill gas to generate electricity (removing greenhouse gas from environment) while limiting emissions to very low levels
- **Project Team:**
 - SCS Engineers, Ingersoll-Rand & City of Burbank
- **Location:**
 - City of Burbank – Landfill No. 3
- **Results:**
 - Modified natural gas microturbine to accept landfill gas
 - Installed microturbine and balance of plant
 - Performed a seven-day reliability test
 - Completed 12-month demonstration test since June 23, 2005
 - Tested over 10,000 hours of operation with NO_x emissions of 0.265 lb/MWh and availability higher than 90%



250 kW Microturbine Engine Cycle



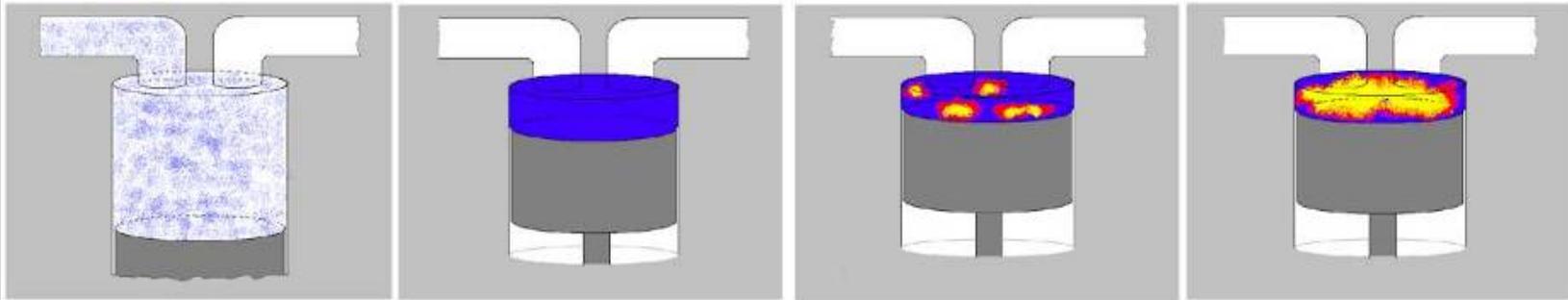
HCCI using Landfill Gas

Makel's HCCI: (homogeneous charge compression ignition) Low NOx Generator – Butte County Landfill

Contractor: Makel Engineering



The HCCI Combustion Process



Source: Per Amneus, Lund Institute of Technology

- Homogeneous mixture formed early in cycle
- Mixture compressed to high temperature and pressure
- Fuel/air chemistry results in ignition near top dead center
- Very rapid combustion event follows ignition

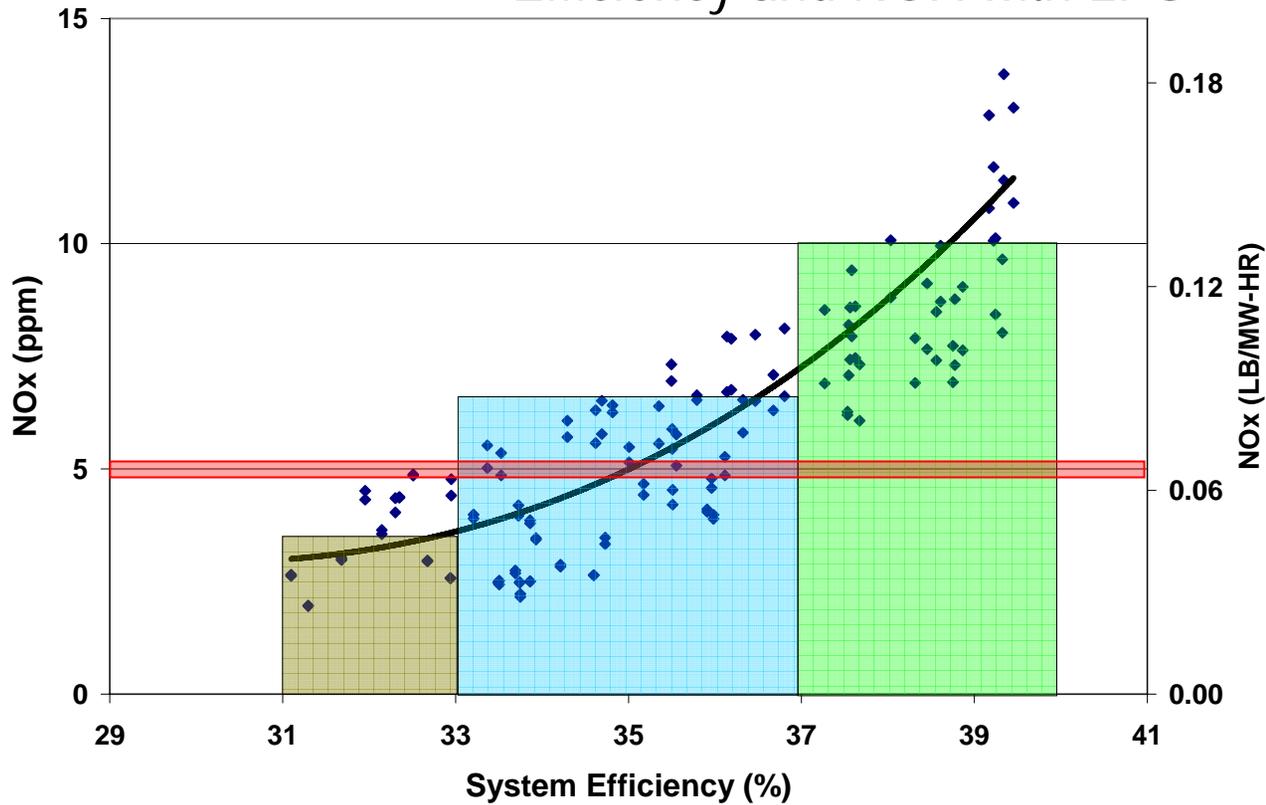


Makel - Project Performance Goals

- System efficiency of 35% operating on LFG
- System stability of less than 10% efficiency variation
- System durability of greater than 10,000 hours between overhauls
- System NOx emission of approximately 5 ppm (0.07 lb/MW-hr)
- System cost of less than 750 \$/kW
- System electricity generation of less than 0.05 \$/kWh



Efficiency and NOX with LFG

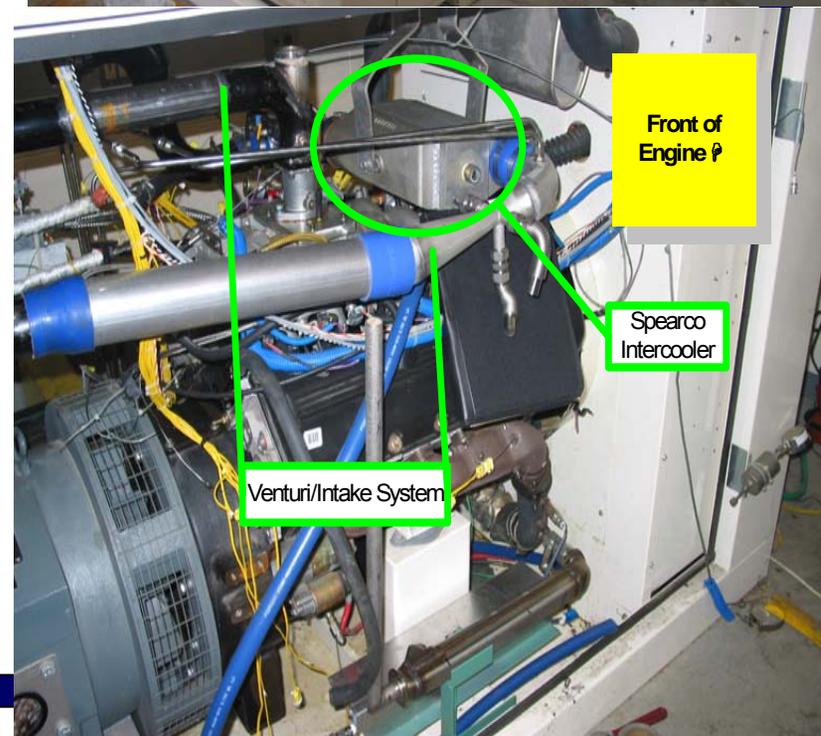


EFFICIENCY (%)	NO _x (ppm)-(lb/MW-hr)*
37-39	8-14 (.10-.17)
33-37	4-8 (.05-.10)
31-33	2-4 (.03-.05)



Application of Hydrogen Assisted Lean Operation to Biogas-Fueled Reciprocating Engines (Bio-HALO)

- Contractor: **TIAX LLC**
- Goals:
 - **Demonstrate an innovative new engine system**
 - **With NOx emissions at 0.032 g/bhp-hr**
 - **Successful demonstration of a landfill gas autothermal reformer with 70% efficiency**
 - **Costs < \$1000/kW**
- Project Site:
 - **TBD**
- Status:
 - **Engine fabricated and tested on simulated landfill gas & synthetic reformat**



BioHALO- NOx results Using simulated landfill gas & synthetic reformat

IMEP (bar)	IMEP COV (%)	NOx (Corrected to 15 % O2) [ppm]	NOx (g/bhp hr, 15% O2)	H2 LHV/CH4 LHV	NOx (lb/MW hr), 15 % O2
5.4	8.1	5	0.035	13.5%	0.10
6.9	11.0	7	0.044	11.4%	0.13
6.6	8.7	10	0.071	7.5%	0.21
6.8	12.4	9	0.078	14.7%	0.23
N/A	N/A	4	0.043	14.2%	0.13
6.1	8.7	8	0.044	10.7%	0.13
5.9	3.7	7	0.047	14.7%	0.14
6.6	8.7	10	0.071	7.5%	0.21



Yolo County's BioReactor

- **Contractor: SMUD/Yolo Co.**
- **Goals:**
 - **Successful demonstration of bioreactor concept at full-scale**
 - **Accelerate decomposition of waste by 2/3rds normal timeframe**
 - **Document economic viability**
- **Project Site:**
 - **Yolo County landfill**
- **Status:**
 - Collected data shows that landfill bioreactor can accelerate organic portion of the solid wastes decomposition and methane recovery rates 4 to 7-fold as compared with conventional operation
 - The project has documented technical data needed to establish environmental and renewable energy benefits to help facilitate regulatory acceptance



Valley Fig Growers' Anaerobic Digester for Food Wastes

- **Contractor:** Valley Fig Growers
- **Goals:**
 - *Demonstrate successful use of ADT for pre-treatment of food processing wastewater*
 - *Save ~ \$100,000/yr in waste discharge costs paid by VFG*
 - *Demonstrate CHP application of microturbine at site*
- **Project Site:**
 - **Valley Fig (Fresno)**
- **Status:**
 - Installed a covered lagoon that reduces BOD and SS by over 90% and generates 25 to 65 kW of electricity for use on-site
 - Save an annual cost of \$100,000 that VFG currently pays to the Fresno city
 - Reduce greenhouse gas (methane) emission at 148 tons per year
- **Awards Received**
 - A Certificate from the City of Fresno in recognition of the merits of biogas digester installed
 - An Honor Award in CELSOC's (Consulting Engineers and Land Surveyors of California) 2007 Engineering Excellence Award Competition



Inland Empire Utility Agency (IEUA) Centralized Digester

- **Contractor:** IEUA
- **Project Location:** Chino, CA
- **Goals:**
 - Demonstrate a cost-effective European centralized digester for codigestion of dairy manure and food wastes
 - Generate 1.5 MW of electricity to be used on site
- **Status:**
 - Under Construction

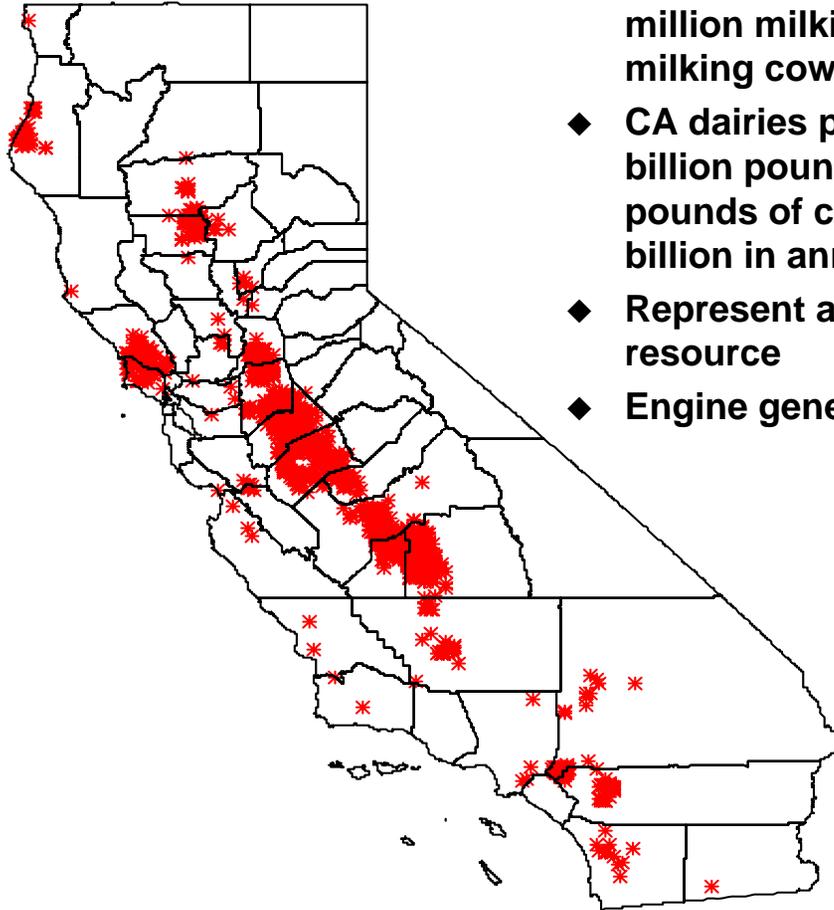


UC Davis' High Solids Digester

- **Contractor: UC Davis & OnSite Power**
- **Goals:**
 - Scale up, test and demonstrate APS high solids digester
 - ◆ 3 tpd size at UC Davis
 - ◆ 25 tpd at Norcal Waste
 - Methane generation rate > 6 ft³ CH₄/lb of VS
 - Achieve CARB 2007 NOx goals
- **Project Site:**
 - UC Davis & City of Industry
- **Status:**
 - Digester construction is complete
 - Public Opening on October 24, 2006
 - Pilot testing will start in April 2007



Distribution of Dairies in California



- ◆ California is home to about 1.67 million milking cows – 18% of US milking cows
- ◆ CA dairies produce more than 27 billion pounds of milk, 1.25 billion pounds of cheese and generate \$3 billion in annual sales
- ◆ Represent a significant bioenergy resource
- ◆ Engine generators at 10 CA dairies



Dairy Power Production Program

Biogas Digesters Installed at 10 Dairies in CA & more...



Castelanelli



Cottonwood



Hilarides



Straus



Laurenco



Meadowbrook



Van Ommering



Eden-Vale



Koetsier



IEUA

- 10 systems awarded (8 Buydown and 2 Incentive) ~ generating **2.5 MW** total
- 5 Covered lagoons and 5 plug flow digesters
- 6 new systems in which 4 are installed by RCM and 1 installed by Sharp Energy and 1 installed by Williams Engineering
- 4 refurbished systems
- Lactating cows range from 245 to 7931
- Dairy manure or mixture of dairy manure with cheese wastewater, creamery wastewater, and food processing wastewater



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 grease, and purpose-grown crops.
- Released date: Oct 31, 2006
- Due date: Jan 4, 2007, 19 proposals received
- Award date: NOPA Released on March 14, 2007 for 3 projects



California - Biofuels RD&D Projects

- Metcalf & Eddy and San Francisco Public Utility Commission: Brown Grease Recovery and Biofuel Production Demonstration
- Renewable Energy Institute International: Demonstration of an Integrated Biofuels and Energy Production System
- Bluefire Ethanol: California Lignocellulosic Biorefinery Project





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Concluding Remarks

- **California has abundant biomass resources**
- **The PIER Program & Bioenergy Interagency Working Group and its member agencies are committed on making CA biomass resources part of the State's energy future**
 - **Planning and implementation of policy drivers**
 - **Resolving potential barriers to renewables 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**
- **Develop Clean and Affordable Biomass Systems**
 - **Biogas & Biofuel systems that meet or exceed air & water quality standards**
 - **Advanced biopower systems that can help address electricity needs while simultaneously helping reduce wildfires and landfill capacity problems**
 - **Super clean, super-efficient biomass energy conversion systems with high strategic value to CA**



Thank You

Grazie Gracias

Merci Dankë

Danke schön Dankschen

Salamat po Khawp khun makh

Danyavad Tack så mycket

Arigato gozaimasu Dank u

Dank u wel Dziakuju

Kamsahamnida Shokran

Kiitos Efcharist

Dzieki Terima kasih Labai dekoju



Additional information can be found at:

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

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

http://www.energy.ca.gov/2005_energypolicy/

