

Bioenergy Development: A Solution to Global Warming

Valentino Tiangco, Ph.D.

Senior Technical Lead

Biomass - PIER Renewables Program

California Energy Commission

1516 Ninth St, MS-43

Sacramento, CA USA 95814-5504

Email: vtiangco@energy.state.ca.us

Presentation to 10th LEA/CIWMB Partnership Conference

16-18 October 2007

San Diego, CA



Overview of Presentation

- Policy Initiatives Affecting Bioenergy
- California's Responds to Global Warming
- California's Electricity, All Resources
- Projections to Meeting RPS
- A Glimpse of Bioenergy Development in California
- Public Interest Energy Research Program
- Biomass R&D Projects
- Concluding Remarks

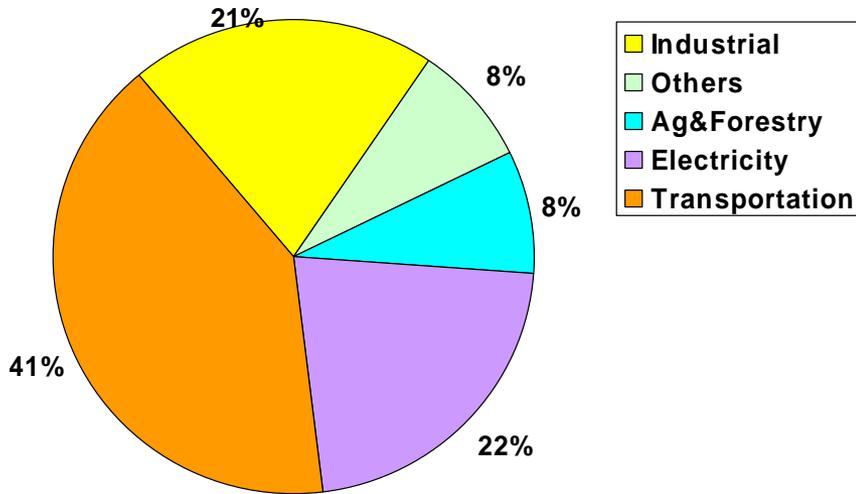
Policy Initiatives Affecting Bioenergy



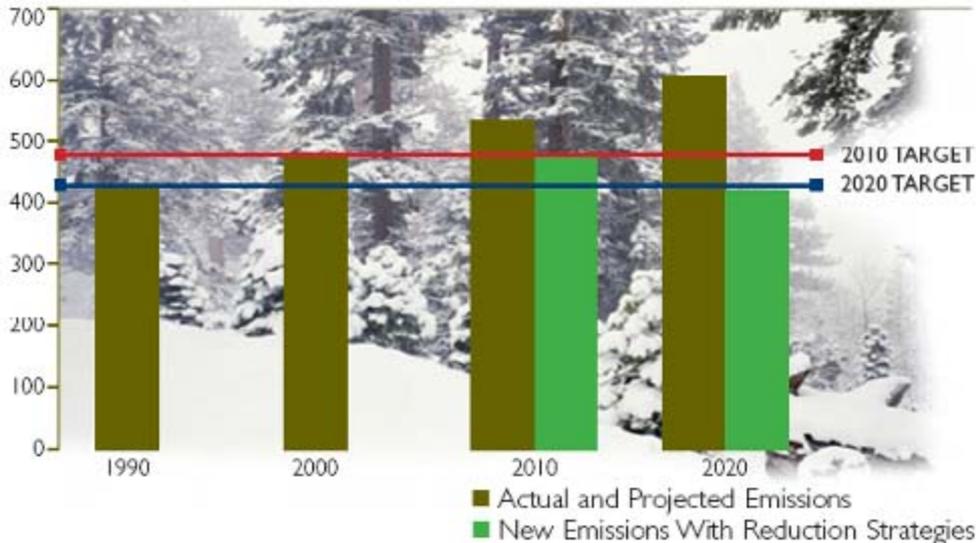
- **Governor's Executive Order S-06-06 –biomass & biofuels, (25 April 2006)**
- **Bioenergy Action Plan (July 13, 2006)**
- **AB 32 – Global Warming Solutions Act, (27 September 2006)**
- **Governor's GHG Reduction Targets (Executive Order S-3-05) (1 June 2005)**
- **Renewables Portfolio Standard, 20% by 2010 and 33% by 2020 (12 September 2002)**
- **Integrated Energy Policy Reports (IEPR) (2003, 2004 update, 2005, 2007)**
- **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)**
- **AB 1493: Vehicular emissions (22 July 2002)**
- **Governor's Executive Order (EO) 2-7-04: Hydrogen highway (20 April 2004)**
- **AB 1007: Alternative fuels (29 September 2005)**
- **SB 1368: GHG emissions from electricity generation (29 September 2006)**
- **EO S-01-07: Low carbon fuel standard (18 January 2007)**
- **CPUC Interim GHG Emissions Performance Standard:**
 - **New baseload generation: < CO₂ from NGCC (1,100 lbs CO₂/MWh)**
- **Federal: EPACT 2005, Healthy Forest Restoration Act, Farm Bill Title IX, Advanced Energy Initiative, Biofuels Initiative, HR 6, HR 3221, 30x'30, 20 in 10...**

California Responds to Global Warming

2000 - 2007



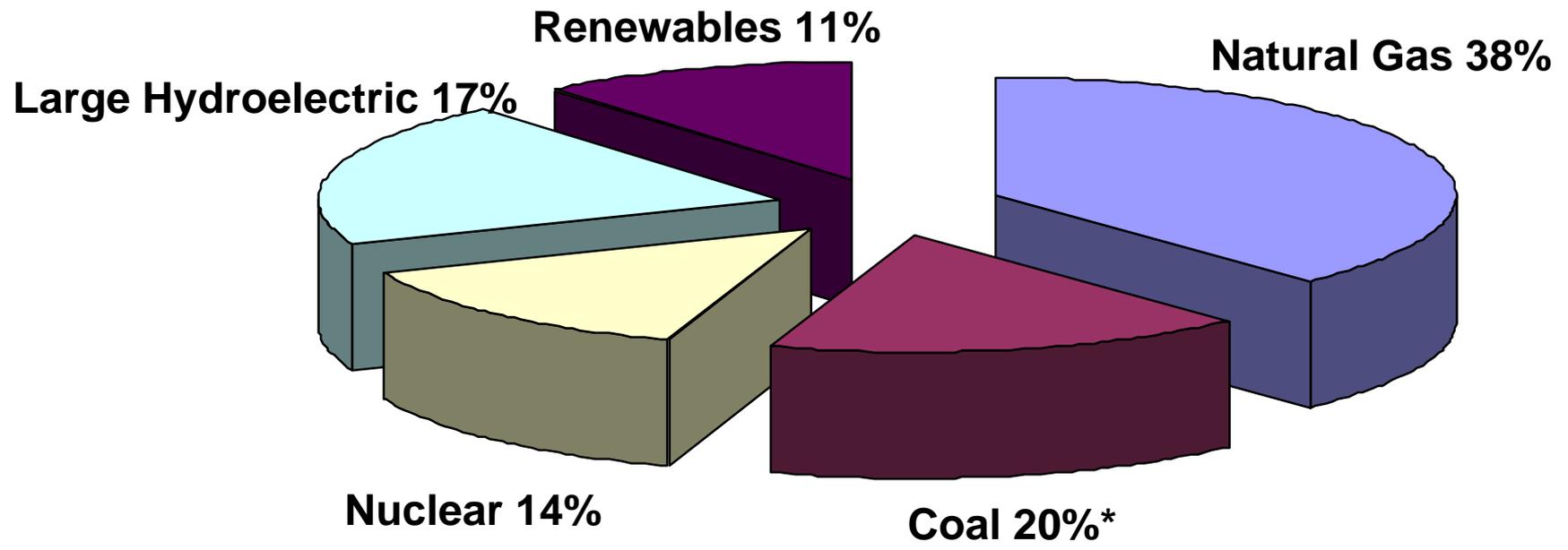
California Carbon Dioxide Emissions by Energy Sectors, 2004
~400 million metric tons carbon dioxide



- In 1988 GHG impacts review mandated
- In 2000, the California Greenhouse Gas Registry was established
- In 2002 AB1493 (Pavley) mandates 30% reduction GHG emissions in new light duty vehicles by 2016
- In 2005, AB 1007 requires plan to replace gasoline use with low carbon alternatives.
- **AB 32 – Global Warming Solutions Act of 2006; aggressive goals for 2020**
- **SB 1368 – GHG Emissions standards for IOUs and POUs**
- **AB 2021 – Energy Efficiency for POUs**
- **AB 2160 – Green Building Acquisition Financing for State Facilities**
- **SB107 – Accelerated RPS Goals – 20% by 2010**
- **SB1 – Renewables Goals for New and Existing Residential and Commercial Structures**
- **AB 2778 – Self-Generation Incentive Program for Fuel Cells and Wind**
- **SB 1250 – PIER and Renewables Incentive Programs Reauthorized**
- In 2007, Governor mandates development of Low Carbon Fuel Standard.



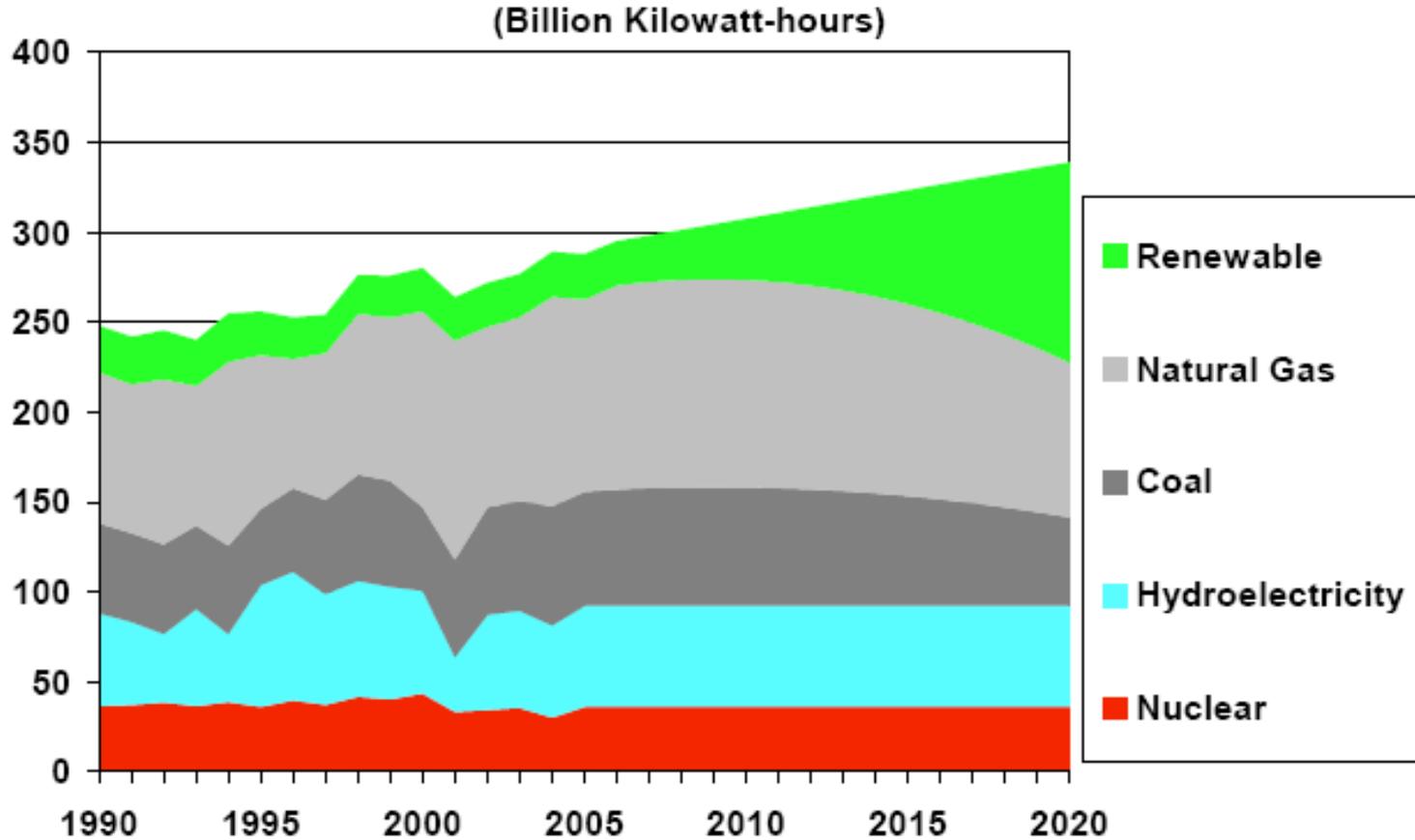
California's Electricity Production in 2005 (Total=288,245 GWh)



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

California Electricity, All Resources

Possible AB 32 scenario - equal CO2 emissions from coal and gas



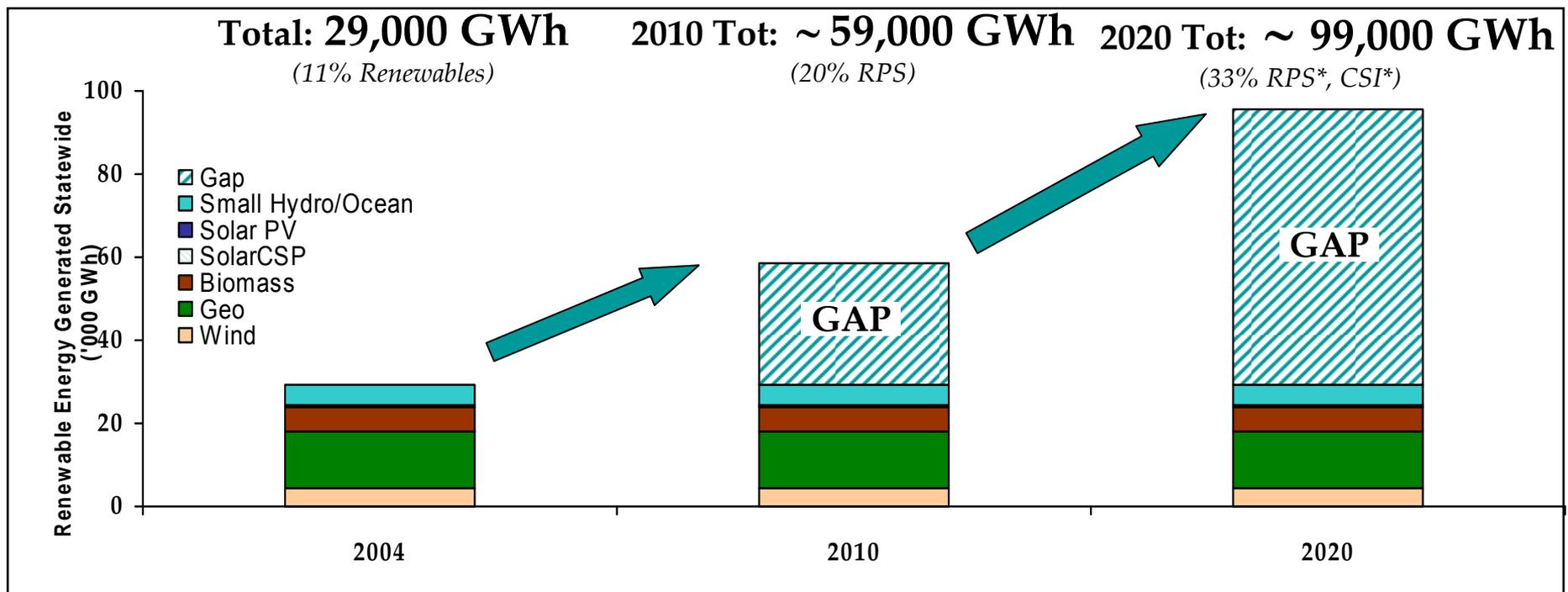
Ferguson, CEERT, March 2, 2007 before the CPUC

Meeting California's 2020 Emissions Goals in the Electricity Sector Will Present Major Technical and Institutional Challenges

Projections to Meeting RPS



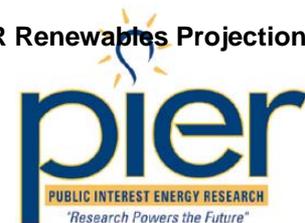
Projected Renewables to Meet California Policy Goals



Data Sources: 2004, CEC Electricity Report which includes all renewables in the State, not just IOUs; 2010 and 2020, PIER Renewables Projections

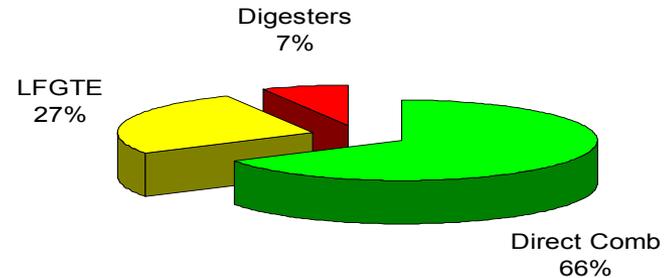
*RPS: Renewable Portfolio Standard

*CSI: California Solar Initiative



A Glimpse of Bioenergy Development in California

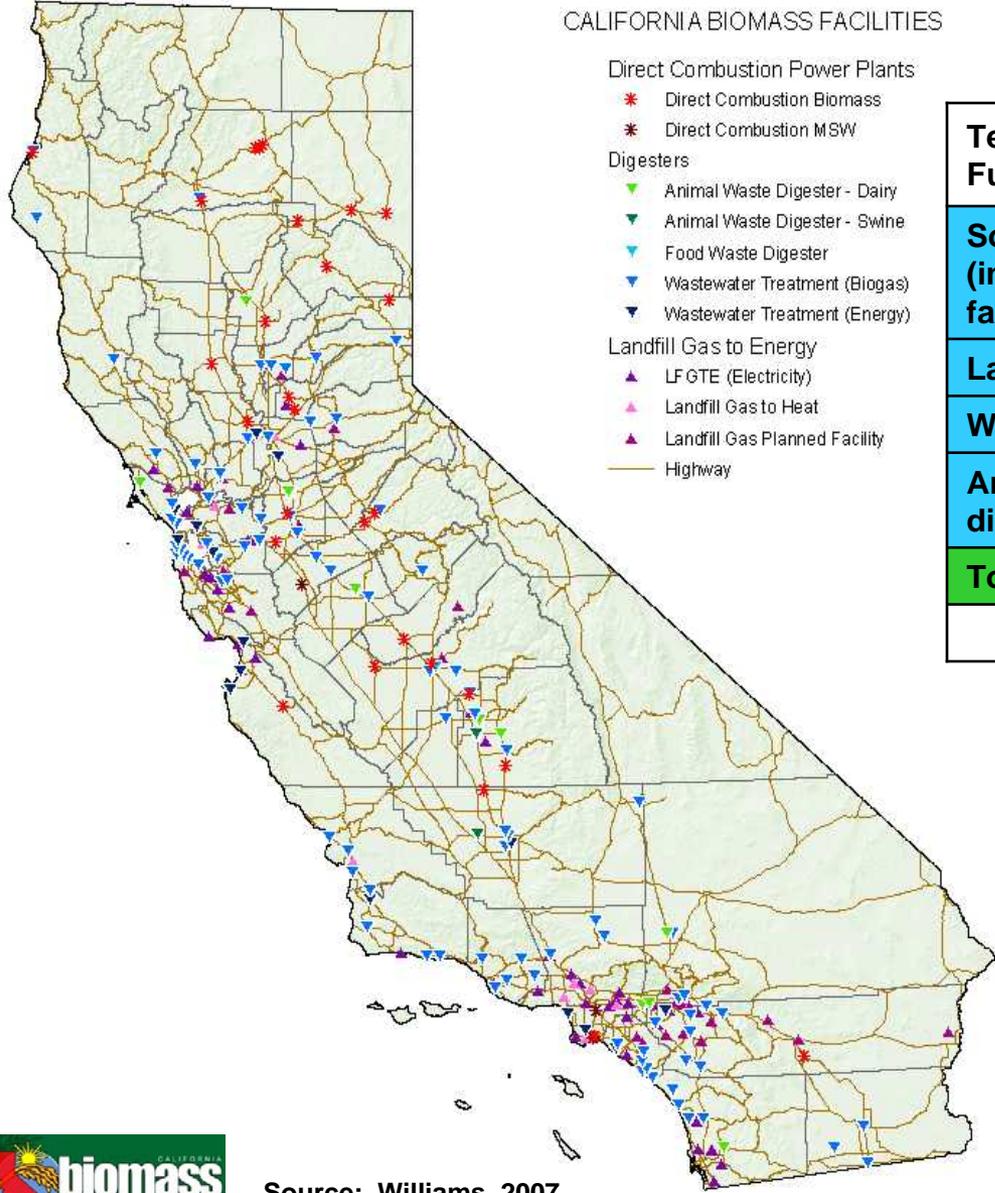
- Biomass Energy Facilities Provide ~1000 MW of Electricity Capacity through
 - Direct Combustion of Forestry, Ag and Urban Biomass
 - Landfill Gas to Energy (LFGTE) Facilities Convert Methane Rich Landfill Gas
 - Wastewater and Dairy Biogas Systems Process Biogas Into Useful Energy
- Biofuels - California consumers over 900 million gallons per year of ethanol and over 11 million gallons of biodiesel fuel.



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

- ▲ LFGTE (Electricity)
- ▲ Landfill Gas to Heat
- ▲ Landfill Gas Planned Facility

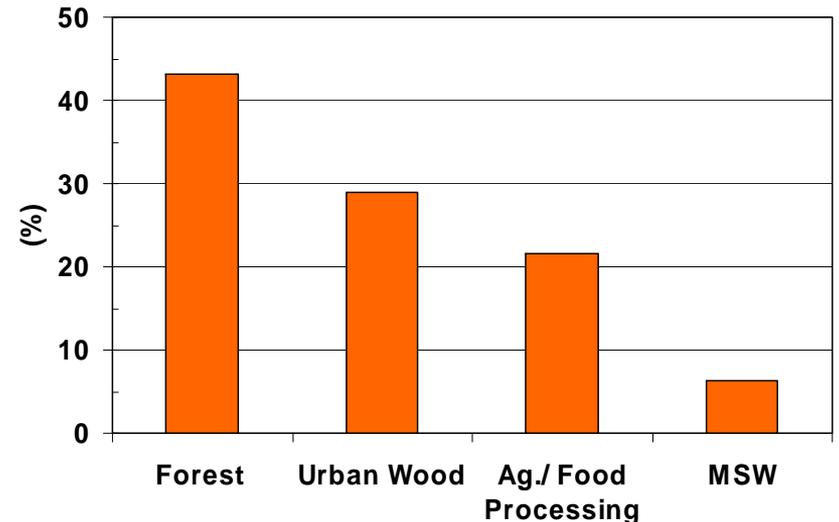
— Highway



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

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

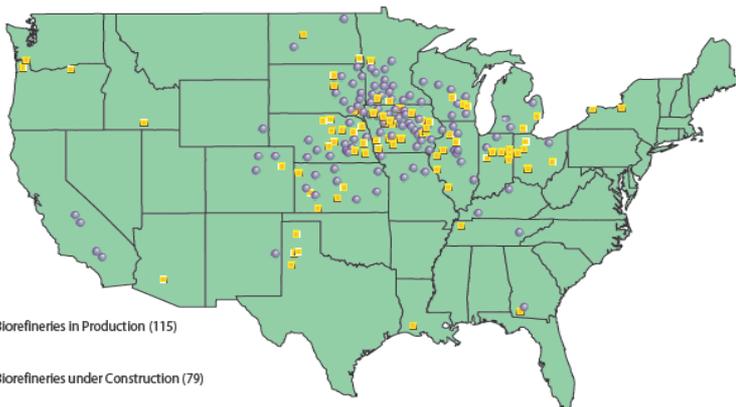
	RPS (%)	Renewable power under RPS (GWh/y)	20% Biomass goal (GWh/y)	Biomass capacity required above current 2005 (MW- 0.85 cap. Factor)
2010	20	58,575	11,700	575
2020	33	109,400	21,875	1,975
2050	33	136,500	27,300	2,670

Ethanol Locations in California

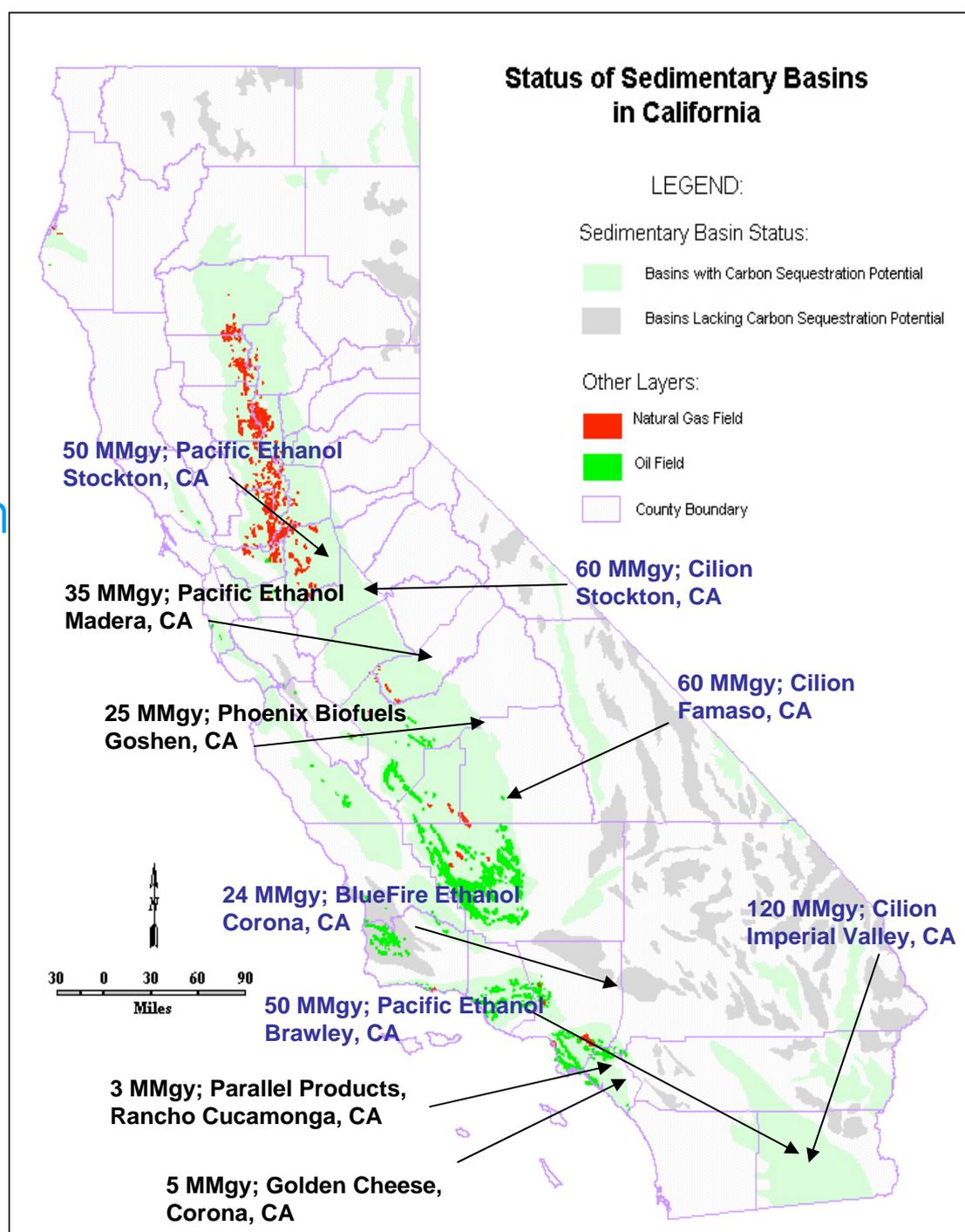
(2006)

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

U.S. Ethanol Biorefinery Locations



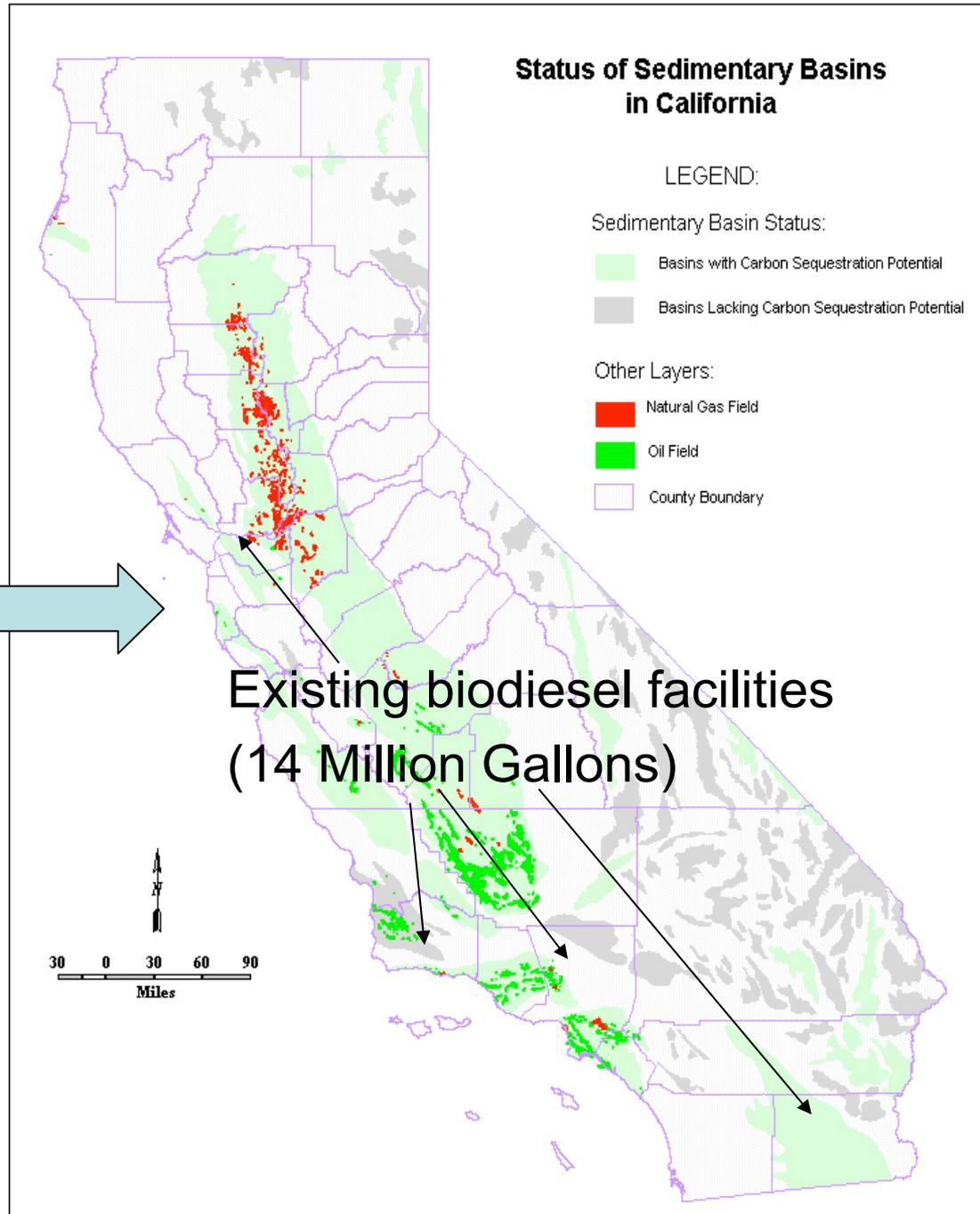
Source: Renewable Fuels Association
4.3.07



Biodiesel Consumption in California (2006)

43 Million Gallons

Biodiesel imports
(29 Million Gallons)

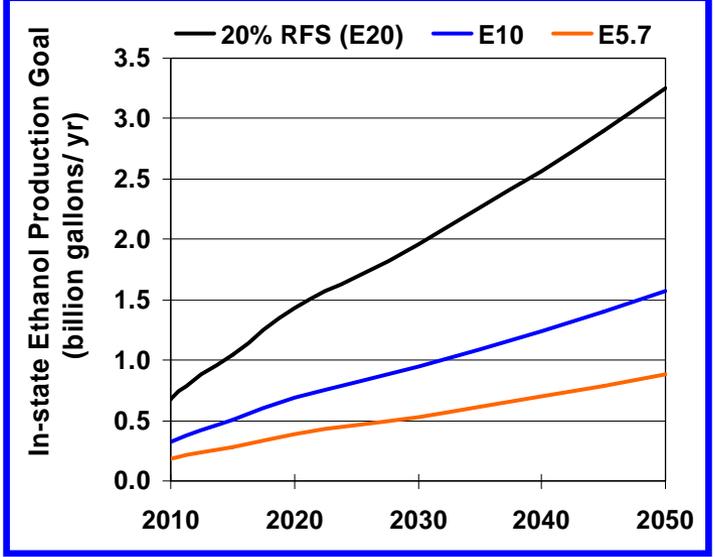


In-state biofuel production goals for blend rate scenarios

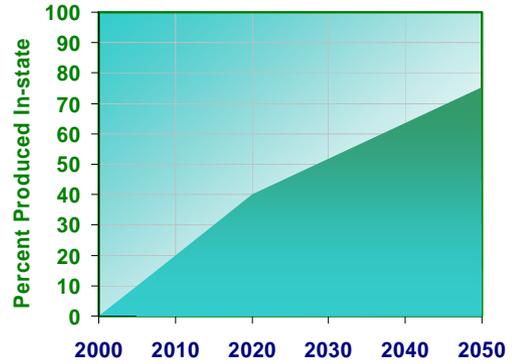
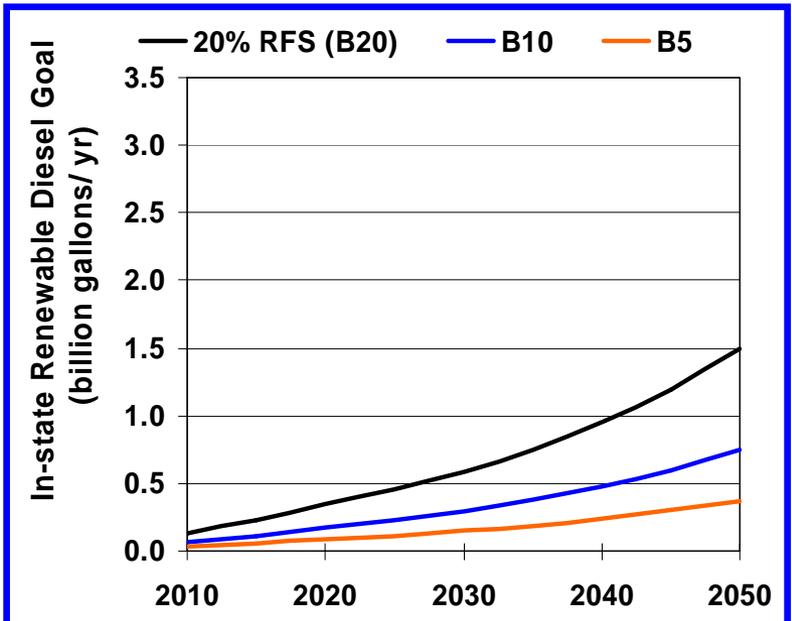


- Assuming projected transportation fuel growth rates and
- Executive Order S-06-06 goals for in-state biofuel production
 - 20% by 2010
 - 40% by 2020
 - 75% by 2050

Ethanol



Renewable Diesel



Source: Williams, 2007



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

SB 1250 Reauthorized PIER in 2006 and Established Solution- Focused Goals



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.”

Biomass RD&D Activities



- Technology Development
 - Direct Combustion/Co-firing Systems
 - Biogas (Landfill Gas, biogas from AD of manures, food waste & waste water)
 - Thermal Gasification and Pyrolysis
 - Biofuels and Biorefineries
- Analysis and Planning
 - California Biomass Collaborative Support
 - 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 RD&D Program Plan
 - PIER Transportation RD&D

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

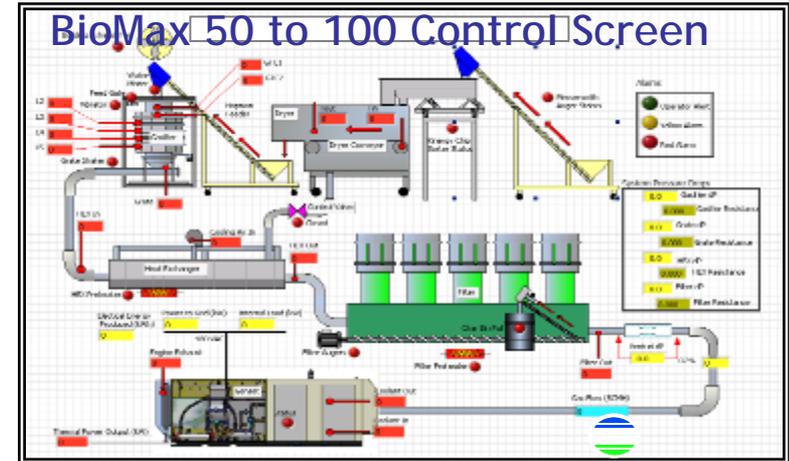


PIER Biomass R&D Projects

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



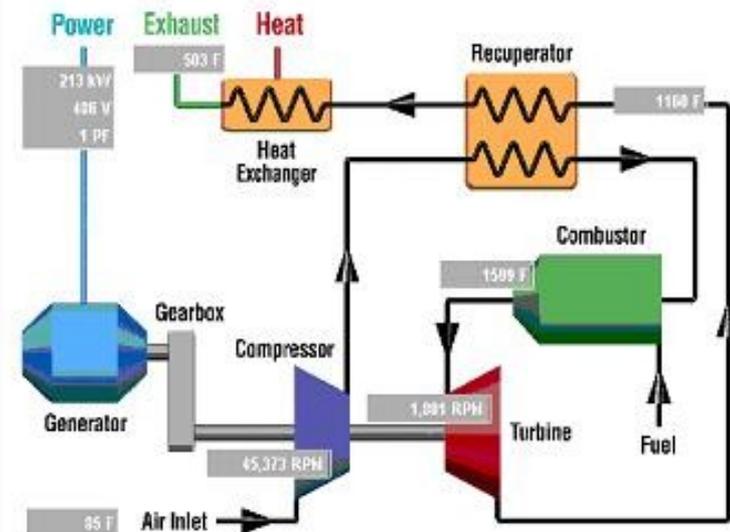


250 kW Microturbine Using Landfill Gas

- **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



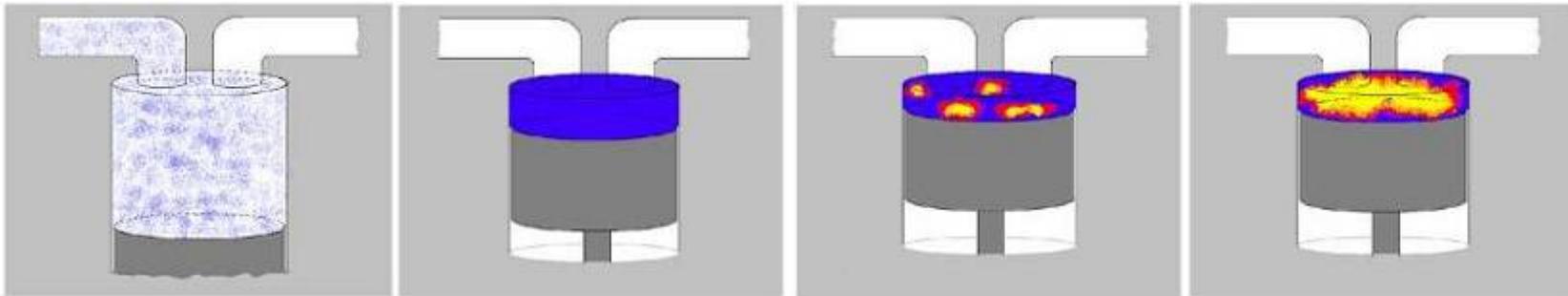
HCCI using Landfill Gas

Makel's HCCI: (*homogeneous charge compression ignition*) Low NO_x 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

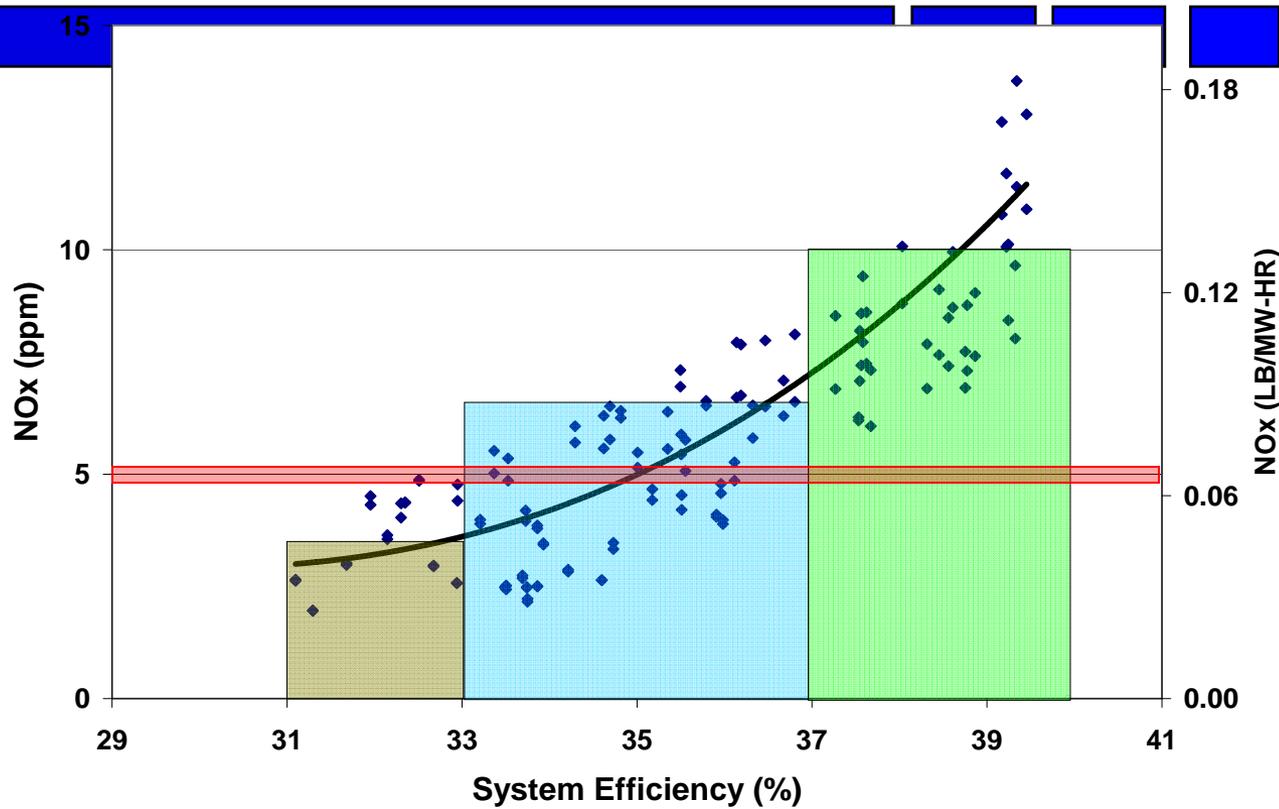
Makel - Project Performance Goals



- ➔ 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



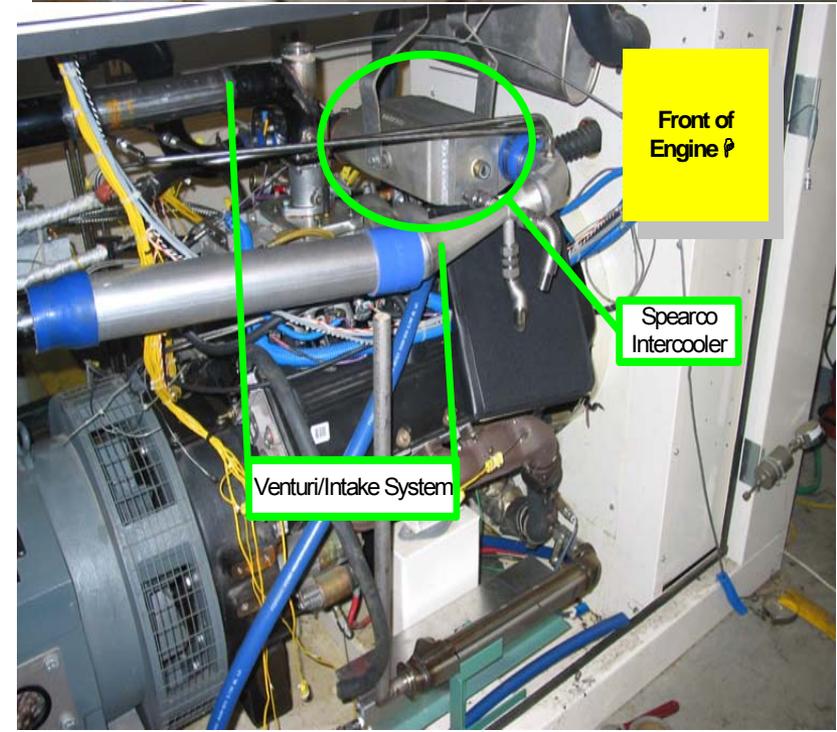
Efficiency and NOX with LFG



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

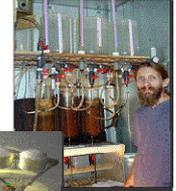
- **Contractor:** IEUA
- **Project Location:** Chino, CA
- **Goals:**
 - Demonstrate a cost-effective European centralized digester for codigestion of dairy manure and food wastes
 - Generate 1.5 MW of electricity to be used on site
- **Status:**
 - Under Construction



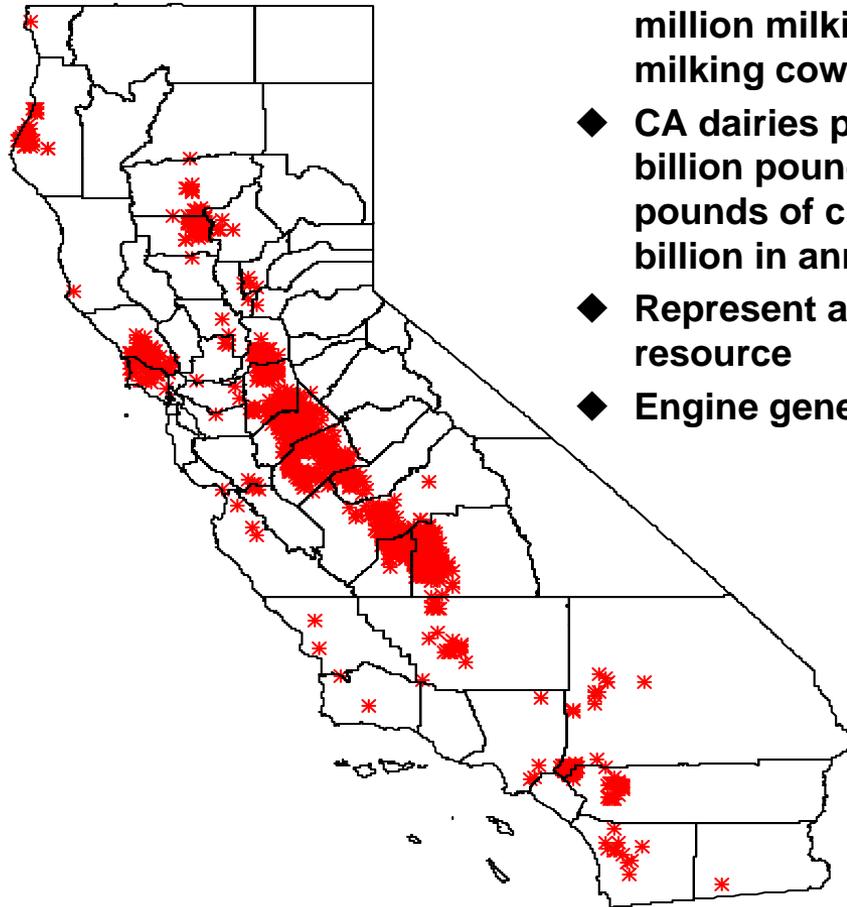
UC Davis' High Solids Digester



- **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 starts 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

Biogas Digesters Installed at 11 Dairies in CA & more...



Castelanelli



Cottonwood



Hilarides



Straus



Laurencio



Meadowbrook



Van Ommering



Eden-Vale



Koetsier



IEUA

- 11 systems awarded (9 Buydown and 2 Incentive) ~ generating **3.3 MW** total
- 6 Covered lagoons and 5 plug flow digesters
- 6 new systems in which 4 are installed by RCM and 1 installed by Sharp Energy and 2 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

Dairy Power Production Program



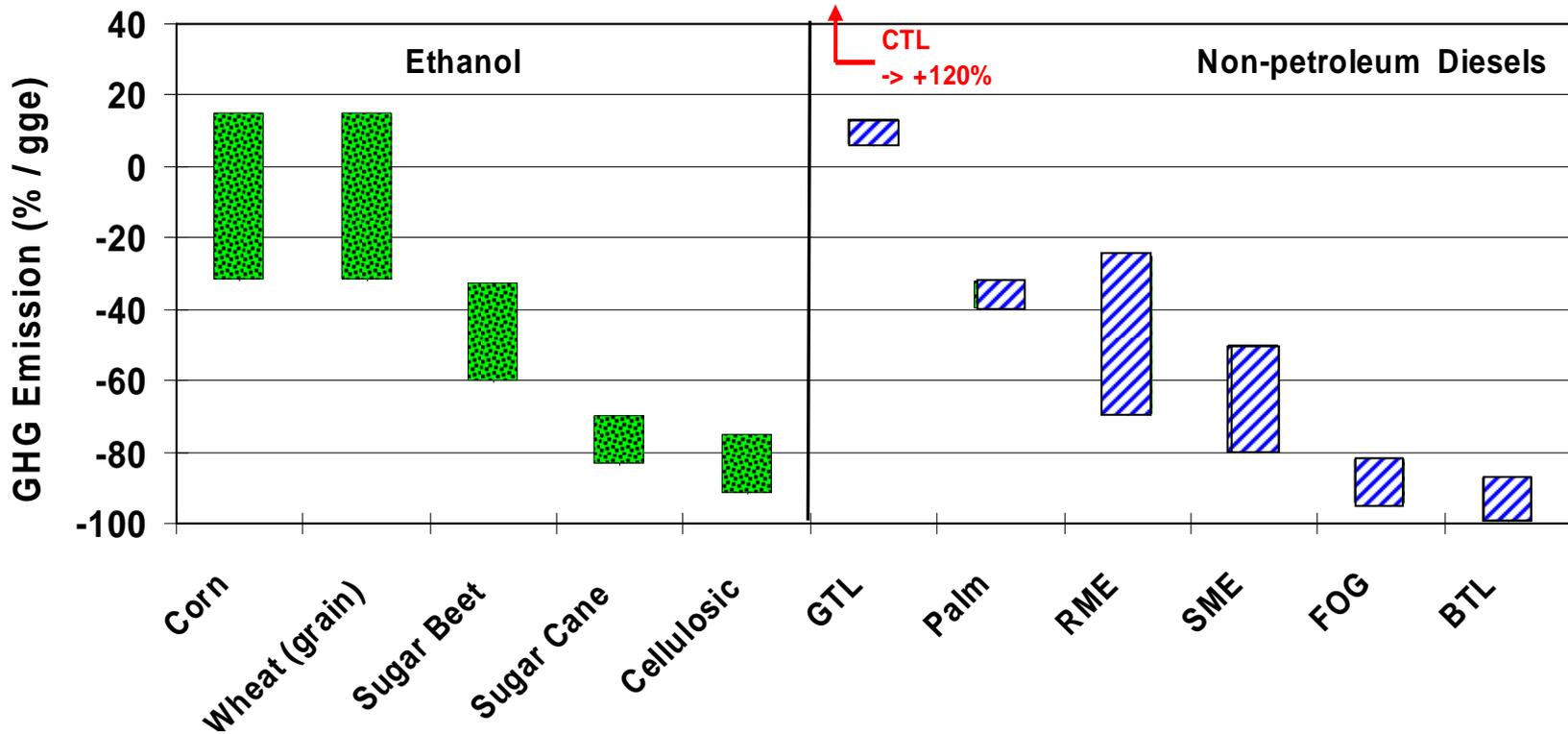
St Anthony

California - Biofuels PIER RD&D

Projects

- Metcalf & Eddy and San Francisco Public Utility Commission: Brown Grease Recovery and Biofuel Production Demonstration (\$995,791.00)
- Renewable Energy Institute International: Demonstration of an Integrated Biofuels and Energy Production System (\$996,093.00)
- Bluefire Ethanol: California Lignocellulosic Biorefinery Project (\$995,938.00)

Greenhouse gas benefits from some biofuels



Source: R.B. Williams & B.M. Jenkins (2007)

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.



Concluding Remarks



- **California has abundant biomass resources.**
- **Bioenergy development in California can contribute to improved air quality, reduced petroleum dependence, reduced GHG emissions, reduced waste disposal, reduced catastrophic wildfires, and improved energy security.**
- **Achieving the state's policy and environmental goals for bioenergy development for electricity and transportation sectors will require substantial investment in RD&D, production facilities, infrastructure, and commercial development of advanced technologies:**
 - **Small modular biomass systems that can help address electricity needs while simultaneously helping reduce wildfires and landfill capacity problems**
 - **Super clean, super-efficient bioenergy systems with high strategic value to California**
 - **Biofuels, alternative fuels and advanced technology vehicles**
 - **Resolving potential barriers to bioenergy development**
 - **Perform life cycle analysis to account for GHG emissions & other benefits**
 - **Working closely and cooperatively with key stakeholders to meet California's market needs and take advantage of unique opportunities**

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

Kiitos Efcharist

Dzieki Terima kasih Labai dekoju