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

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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)
- 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)
- Energy Action Plan (EAP) I and II (published 2003 and 2005 respectively)
- Governor’s 2003 / 2004 IEPR response and Ten Point Plan
- 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…
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 Responds to Global Warming 2000 - 2007

California Carbon Dioxide Emissions by Energy Sectors, 2004

~400 million metric tons carbon dioxide
California’s Electricity Production in 2005
(Total=288,245 GWh)

- Natural Gas 38%
- Large Hydroelectric 17%
- Renewables 11%
- Nuclear 14%
- Coal 20%*

*Intermountain and Mohave coal plants are considered in-state, since they are in California control areas.
Meeting California’s 2020 Emissions Goals in the Electricity Sector Will Present Major Technical and Institutional Challenges
Projected Renewables to Meet California Policy Goals

Total: 29,000 GWh (11% Renewables)

2010 Tot: ~ 59,000 GWh (20% RPS)

2020 Tot: ~ 99,000 GWh (33% RPS*, CSI*)

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

**Solid Combustion Fuel Sources**

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

* Suspect - Probably higher

**Source:** Williams, 2007
Biomass needed to meet goal of a 20% share of the State Renewables Portfolio Standard (RPS)

<table>
<thead>
<tr>
<th>Year</th>
<th>RPS (%)</th>
<th>Renewable power under RPS (GWh/y)</th>
<th>20% Biomass goal (GWh/y)</th>
<th>Biomass capacity required above current 2005 (MW- 0.85 cap. Factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>20</td>
<td>58,575</td>
<td>11,700</td>
<td>575</td>
</tr>
<tr>
<td>2020</td>
<td>33</td>
<td>109,400</td>
<td>21,875</td>
<td>1,975</td>
</tr>
<tr>
<td>2050</td>
<td>33</td>
<td>136,500</td>
<td>27,300</td>
<td>2,670</td>
</tr>
</tbody>
</table>
Ethanol Locations in California (2006)

- **Existing ethanol facilities (68 Million Gallons)**
  - 24 MMgy; BlueFire Ethanol Corona, CA
  - 50 MMgy; Pacific Ethanol Brawley, CA
  - 50 MMgy; Pacific Ethanol Stockton, CA
  - 35 MMgy; Pacific Ethanol Madera, CA
  - 25 MMgy; Phoenix Biofuels Goshen, CA
  - 60 MMgy; Cilion Stockton, CA
  - 60 MMgy; Cilion Stockton, CA
  - 60 MMgy; Cilion Stockton, CA
  - 60 MMgy; Cilion Stockton, CA
  - 120 MMgy; Cilion Imperial Valley, CA
  - 3 MMgy; Parallel Products, Rancho Cucamonga, CA
  - 5 MMgy; Golden Cheese, Corona, CA

- **Proposed plants (364 Million Gallons)**

U.S. Ethanol Biorefinery Locations

Status of Sedimentary Basins in California

**LEGEND:**
- **Sedimentary Basin Status:**
  - Basins with Carbon Sequestration Potential
  - Basins Lacking Carbon Sequestration Potential
- **Other Layers:**
  - Energy Storage Field
  - Oil Field
  - County Boundary

Source: Renewable Fuels Association
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
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
  – 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
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
• **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 NOx emissions of 0.265 lb/MWh and availability higher than 90%
**HCCI using Landfill Gas**

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

Contractor: Makel Engineering

**The HCCI Combustion Process**

- 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

Source: Per Amneus, Lund Institute of Technology
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

<table>
<thead>
<tr>
<th>EFFICIENCY (%)</th>
<th>NOx (ppm)-(lb/MW-hr)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-39</td>
<td>8-14 (.10-.17)</td>
</tr>
<tr>
<td>33-37</td>
<td>4-8 (.05-.10)</td>
</tr>
<tr>
<td>31-33</td>
<td>2-4 (.03-.05)</td>
</tr>
</tbody>
</table>
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 reformate
### BioHALO- NOx results Using simulated landfill gas & synthetic reformate

<table>
<thead>
<tr>
<th>IMEP (bar)</th>
<th>IMEP COV (%)</th>
<th>NOx (Corrected to 15% O2) [ppm]</th>
<th>NOx (g/bhp hr, 15% O2)</th>
<th>H2 LHV/CH4 LHV</th>
<th>NOx (lb/MW hr), 15% O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4</td>
<td>8.1</td>
<td>5</td>
<td>0.035</td>
<td>13.5%</td>
<td>0.10</td>
</tr>
<tr>
<td>6.9</td>
<td>11.0</td>
<td>7</td>
<td>0.044</td>
<td>11.4%</td>
<td>0.13</td>
</tr>
<tr>
<td>6.6</td>
<td>8.7</td>
<td>10</td>
<td>0.071</td>
<td>7.5%</td>
<td>0.21</td>
</tr>
<tr>
<td>6.8</td>
<td>12.4</td>
<td>9</td>
<td>0.078</td>
<td>14.7%</td>
<td>0.23</td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>4</td>
<td>0.043</td>
<td>14.2%</td>
<td>0.13</td>
</tr>
<tr>
<td>6.1</td>
<td>8.7</td>
<td>8</td>
<td>0.044</td>
<td>10.7%</td>
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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
• **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
• **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
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...

- 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 refurnished 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
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

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