Bioenergy and Biofertilizer from Food and Agricultural Waste: Innovation from Lab to Commercial

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Bioenergy Derived from Plant Biomass and Waste

Biopower
Biofuels
  Biomethane
  Bioethanol
  Biodiesel
  Biogasoline
Why Bioenergy
(Energy, Environmental, Public Health and Economic Benefits)

• Renewable energy
• Low carbon fuel
• Divert waste from landfill
• Reduce air and water pollution, greenhouse gas emissions
• Provide jobs and economic development
California Renewable Energy Portfolio and Bioenergy Feed-in Tariff

• Renewable energy currently accounts for 20% of total electrical energy supply
• Renewables Portfolio Standards (RPS) requires that all electricity retailers in the state provide 33% of electricity with renewables by the end of 2020.
• SB1122 requires 250 MW of Bioenergy Procurement by Electrical Utilities,
  • 110 MW biogas energy from municipal and food waste sources,
  • 95 MW from dairy waste
  • 45 MW from forest waste
### Other California Policy Drivers for Bioenergy Development (McKinney, 2014)

<table>
<thead>
<tr>
<th>Policy Objectives</th>
<th>Policy Origin</th>
<th>Goals and Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG Reduction</td>
<td>AB 32, California Global Warming Solutions Act</td>
<td>Reduce GHG emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050 in California</td>
</tr>
<tr>
<td>Petroleum Reduction</td>
<td>California State Alternative Fuels Plan</td>
<td>Reduce petroleum fuel use to 15% below 2003 levels by 2020 in California</td>
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<tr>
<td>In-State Biofuels Production</td>
<td>California Bioenergy Action Plan</td>
<td>Produce in California 20 percent of biofuels used in state by 2010, 40 percent by 2020, and 75 percent by 2050</td>
</tr>
<tr>
<td>Low Carbon Fuel Standard</td>
<td>AB 32</td>
<td>10% reduction in carbon intensity of transportation fuels in California by 2020</td>
</tr>
<tr>
<td>Air Quality</td>
<td>Clean Air Act</td>
<td>80 percent reduction in NOx from current levels by 2023</td>
</tr>
<tr>
<td>ZEV Mandate</td>
<td>California Executive Order B-16-2012</td>
<td>Accommodate 1 M EVs by 2020 and 1.5 M by 2025 in California</td>
</tr>
</tbody>
</table>
Presidential initiatives

Carbon Neutrality Initiative

UC, a national leader in sustainability, has pledged to become carbon neutral by 2025, becoming the first major university to accomplish this achievement.

Sustainability

**Carbon neutrality**: UC is a national leader in sustainability research and practice. In an effort to become the first major research university system to achieve carbon neutrality, UC plans to expand and accelerate its climate action efforts over the next 11 years (2014-25). By entering the wholesale electrical market to access renewable energy, continuing to invest in energy efficiency, expanding renewable energy generation on campuses and transitioning from natural gas to biomethane to run our efficient electrical plant facilities, UC will accelerate its sustainability leadership while managing long-term operational costs. Learn more about sustainability at UC or about the [UC Carbon Neutrality Initiative](#).

In November 2013, President Janet Napolitano announced the Carbon Neutrality Initiative, which commits UC to emitting net zero greenhouse gases from its buildings and vehicle fleet by 2025, something no other major university system has done.

“We are the University of California, and there is no reason that UC can't lead the world in this quest, as it has in so many others.”
Waste to Biogas Energy

Biogas Energy
- Electricity and heat
- Natural gas
- Compressed natural gas
- Liquefied natural gas
- Gasoline
- Chemicals

Biogas
- CH₄, CO₂
- H₂, CO₂

Organic acids
- Sugars,
- Amino acids
- Fatty acids

Digester Effluent
- Nutrients
- Fibers
- Water

Anaerobic Digestion

Organic Waste
- Food
- Green
- Agricultural
Anaerobic Digestion
Benefits Energy, Environment and Health

• **Reduce** organic waste – food, green and agricultural – from landfills;

• **Produces** bioelectricity, heat & renewable Compressed Natural Gas to power homes and vehicles;

• **Converts** byproducts to valuable organic soil amendments for farming; and

• **Captures** greenhouse gases & other harmful emissions.
## Anaerobic Digesters and Landfills in USA

<table>
<thead>
<tr>
<th>Type</th>
<th>Existing</th>
<th>Potential to Add</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm Digesters</td>
<td>289</td>
<td>8000</td>
<td></td>
</tr>
<tr>
<td>Wastewater Treatment</td>
<td>1241</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>Landfills</td>
<td>636</td>
<td>450</td>
<td></td>
</tr>
</tbody>
</table>

*Operational US Biogas Systems*
Dairy Manure Digesters
Biogas Energy from Onion Waste

- Biogas powers two 300-kW fuel cells, generating 0.6 MW of electricity.
- Satisfies 95% of Gill’s base load requirements

Digester processes 30,000 gal of onion juice per day, Producing biogas containing 70% methane
Great Potential from Solid Organic Residuals:
Food Processing and Agricultural Residues, Animal Manures, Municipal Solid Waste,
UC Davis Biogas Energy Project

• Research and demonstration of anaerobic digestion and biogas energy technologies for converting various organic residuals into biogas energy and biobased products

• Public education on waste to energy conversion and environmental management
UC Davis Biogas Project Sponsors
High Solids Anaerobic Digestion Technology Developed at UC Davis

• Thermophilic digestion (three stage)
• Capable of treating a variety of organic solid waste
• Fast digestion rate and short retention time
• High biogas energy output
• Destruction pathogens in waste, producing safe biofertilizers
Lab to Commercial Scale Up for the High Solids Anaerobic Digestion (HSAD) Technology

**Microbiology Engineering**
- Determine digestibility
- Pilot Design

**Feedstock Demonstration**
- Pilot Construction
- Pilot Testing
- Effluent digester Stability

**Economic and Environmental Analyses**
- Design of commercial plant

**2000 - 2004**
- Process scale-up
- Pilot testing
  - 50,000 Gallons

**2004 - 2005**
- Concept development
- laboratory testing
  - 0.5-6 Gallons

**2005**
- Microbiology Engineering

**2007 - 2008**
- Feedstock Demonstration

**2007 - 2010**
- Pilot Construction
- Pilot Testing
- Effluent digester Stability

**2008 - 2011**
- Economic and Environmental Analyses
- Design of commercial plant

**2011 - 2012**
- Commercialization By CleanWorld

**Engineering design**
- Equipment selection
- Construction,
  - Operation, Monitoring,
  - >300,000 Gallons
UC Davis Biodigester:
Powering Campus with Food and Farm Waste

Jointly developed by CleanWorld and UC Davis
Digester Feedstock:
Food Waste
Animal Waste
UC Davis Biodigester for Waste to Energy Conversion

• Treats 20,000 tons per year of mixed organic wastes
• Combines biogas and landfill gas to generate 5.6 GWh electricity per year
• Reduce greenhouse gas emissions
  – Electricity ≈ 4,000 metric tons CO$_2$e
  – Feedstock emissions ≈ 6,000 metric tons CO$_2$e

Operation Since January 2014
Public Education with UC Davis Biodigester
WEST VILLAGE
A Zero Net Energy Community
Fertilizer and Soil Products from Digestate

• Custom design soil products according to plant needs
  - Nutrients
  - Microbes
  - Pathogen free
Testing Digestate As Organic Fertilizer Products

Testing Variables
- Digestate dilution
- Application rate
- Application schedule

Measurement
- Plant size
- Plant biomass
- Chlorophyll in leaves
- Nutrients uptake
- Soil properties
Field Testing of Digestate
Project Sponsors

- California Energy Commission
- CalRecyle
- California Department of Food and Agriculture
- US Department of Energy
- US Department of Agriculture