NOx Emission Reduction: Technology Solutions for Small Biogas Projects

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Outline

• SMUD’s GHG Reductions and Renewable Energy Programs
• Local Biomass Program
• Dairy Digester Incentive Program
• Existing dairy manure projects
• Air Emissions Permitting in Sacramento
• Potential technical solutions
• New local dairy digester projects
SMUD’s GHG Reduction and Renewable Energy Programs

• SMUD’s strategic directive: Board is committed to environmental leadership through community engagement, continuous improvement in pollution prevention, carbon emissions reduction, energy efficiency, and resource conservation

• GHG reduction goal: 10% of 1990 levels by 2050
  – Energy Efficiency
  – Renewable Energy

• Renewable Energy Programs
  – RPS
  – Greenergy

• Renewable energy goals
  – 23.9% by 2010
  – 37%+ by 2020
SMUD’S Local Biomass Program

• Problem wastes used as resources in local waste-to-energy projects
  – Sustainable fuel supply
  – Mature or commercial-ready technologies
  – Dairy manure, grease, food, landfills, MSW, fuel-loaded forests

• Promote global and local environmental benefits
  – Reduce GHG emissions
  – Divert waste from landfills
  – Encourage alternative waste disposal methods
  – Reduce groundwater contamination

• Bring local economic benefits
  – Promote the creation of local jobs
  – Source of steady income to local business through electricity sales

• Utilize existing infrastructure where possible
  – Wastewater treatment plants
  – Landfills
Biomass Resources & Conversion Technologies

• Local Resources:
  – Animal manure
  – Food waste
  – Grease waste
  – MSW
  – Urban and forest wood
  – Sludge

• Conversion technologies
  – Anaerobic Digestion
  – Gasification
  – Pyrolysis
  – Combustion (wood waste only)
SMUD’S Dairy Digester Incentive Program

• Then
  – Provided grants to help dairies build digesters
    • 13% capital cost incentive to match 25% USDA Rural Development grant
  – Paid for 50% of the USDA grant application cost
  – Helped with permitting, interconnection, and obtaining grants
  – Offered net metering crediting all the farm meters at retail rates
  – Signed PPAs for surplus electricity
SMUD’S Dairy Digester Incentive Program

• Now
  – Maintaining interest in promoting and facilitating local dairy digester project development
  – Reducing involvement with project implementation
  – Adapting to new business model in which developers finance, permit, build, own and operate projects
  – Partnering with farmers and/or project developers to submit grant proposals
  – Managing compliance with grant disbursement requirements
  – Providing some assistance with permitting and interconnection
  – Offering FIT rates for PPAs
Dairy Manure Digesters

Collection

-covered Anaerobic Lagoon

H₂S → Biogas/Methane Recovery & Flare

Separates out solids

Electricity for the farm and the SMUD grid

Biogas Engine & Electricity Generator

NOx

SOx
Existing Dairy Manure Projects

- **Cal-Denier Dairy**
  - Start-up: July 2008
  - ~ 500 cows
  - 65 kW genset
  - Potential to generate ~ 450,000 kWh/year

- **Tollenaar Holsteins Dairy**
  - Operational in April 2009
  - ~ 1,100 cows
  - 212 kW genset (originally 450 kW)
  - Potential to generate ~1,400,000 kWh/year
  - Generated 735,742 kWh between April 2009 – March 2010, enough energy to power ~ 80 single family homes in Sacramento
Cal-Denier Dairy

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Tollenaar Holsteins Dairy

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Location of Existing Projects
SMAQMD: Proposed Revision of Rule 202

- Sacramento Metropolitan Air Quality Management District (SMAQMD) to amend its Rule 202, New Source Review, to bring NSR program up to date with state and federal laws. Bottom line: air emissions rules will be stricter than today
  - Decrease the BACT applicability threshold from 10 lb/day to zero of any non-attainment pollutant (e.g. ozone) or its precursors (e.g. NOx), requiring BACT for all new or modified equipment that will increase emissions.
- Tollenaar and Denier permitted at 54 ppm for NOx
- SMAQMD targeted BACT for NOx = 9 ppm
SMUD’s Innovative Clean Air Technology (ICAT) Project

- Objective: Demonstrate an integrated emission control process for NOx removal on the engine exhaust and sulfur (H2S) removal in the biogas at Tollenaar Holsteins Dairy

- Partners: SMUD (prime), Cha Corporation, Applied Filter Technology, Gerling Applied Engineering, CARB (ICAT Program Funding)

- NOx reduction (target 5 ppm or less)
  - Activated carbon & silica gel bed used to absorb NOx in the exhaust
  - Microwave technology regenerates the carbon media for reuse and decomposes NOx molecules

- H2S reduction (target 10 ppm or less)
  - Liquid contact tower containing iron chloride solution
  - Peroxide reacts with H2S to form elemental sulfur and water
    - \( \text{H}_2\text{S} + \text{H}_2\text{O}_2 \rightarrow \text{S} + 2\text{H}_2\text{O} \)
Media Adsorption with Microwave Regeneration and Oxidation Reactor System Media

- Regenerated media
- Nitrogen
- Microwave Reactor
- H$_2$S oxidation reactor
- Sulfur capture
- Hydrocarbon oxidation reactor
- Carbon filter
- Water and liquid hydrocarbons (with siloxane)
- SiO$_2$ capture
- Media adsorber
- Vent

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Detail of Mixed Media
Overall System Diagram
HCCI Project

- Biogas fueled **Homogeneous Charge Compression Ignition** (HCCI) power generation system for distributed generation
- MEI and UCB researchers are developing a Scaled up HCCI system based on the existing 30 kW HCCI LFG system
- Objective: Demonstrate an HCCI engine using dairy manure digester biogas at a dairy farm in the Sacramento County
- Partners: Makel Engineering, SMUD, CEC’s Public Interest Energy Research (PIER)
- Technology potential
  - NOx reduction target 5 ppm or less
- Status
  - Scale up design from demonstrated 30 kW engine to a 200 kW Cummins (or two 100 kW Caterpillars – lower cost engine block) under way
  - Equipment expected to arrive at Tollenaar’s by early 2011
HCCI and Biogas

- To control HCCI combustion timing, active thermal conditioning of the inlet charge is required

- The intake charge for methane base biogas needs to be ~ 180°C to ignite in HCCI mode

- This is a complex function of:
  - Compression ratio
  - Boost pressure
  - Cylinder geometry
  - Block temperature

- Low temperature exhaust
  - Low NOx formation

*GM CONCEPT

SPARK IGNITED ENGINE  
HCCI FLAMELESS IGNITION

*GM CONCEPT
Key Previous Project Results

- Working under a PIER CEC grant, MEI demonstrated a 30 kW landfill gas fueled HCCI engine
- This project established the viability of converting conventional, off-the-shelf compression ignition engines to HCCI operation, while achieving CARB 2007 standards
- Developed a prototype six cylinder HCCI engine/genset using combination of stock diesel engine components and custom intake/exhaust system
- Demonstrated attended operation of system at an active California landfill site currently flaring LFG
- Achieved over 500 hrs of operating time with LFG
  - Operating efficiency 35%
  - Variation in efficiency of approximately 5% (i.e. 33% to 37%)
  - NOx emissions on the order of 5 PPM (0.07 lb/MW-hr)
  - Post test inspection of engine indicated no significant change in critical components (cylinders, pistons, etc.)
HCCI Scale Up Project

- Under a separate PIER-RESCO program, MEI is currently developing a “scaled up version” of the previously demonstrated 30 kW unit
  - Capable of achieving California ARB 2007 targets for combustion of biogas
  - Targeting 200kW of electrical power output
HCCI Efficiency and NOx with LFG

System Efficiency (%) vs. NOx (ppm)

<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>
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</tbody>
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Site Integration

POWER TO GRID

Overhead service drop
Panel Meter / Circuit breaker

SERVICE PANEL

Transformer

TO ONSITE LOAD

BIOGAS FUEL SUPPLY

GENSET CONTROL PANEL

Interconnect Protective Relay
Fused Disconnect Switch
Fused Disconnect Switch

100 KW HCCI Genset
100 KW HCCI Genset

Dual 100 KW Configuration
Potential Projects

• Largest 15 out of 43 dairies in the Sacramento County could support a manure digester

★ – 1200
A – 1196
C – 1075
B – 953
★ – 837
C – 745
D – 728
E – 693
F – 589
G – 563
H – 520
I – 468
J – 468
K – 451
L – 399
CRED Projects

• Award from DOE’s Community Renewable Energy Deployment program (CRED), under American Recovery and Reinvestment Act (ARRA) - $5,000,000

• 5 projects
  – Solar Highways
  – County Wastewater Treatment Plant - Co-Digestion of Fats, Oils & Grease Waste and other liquid wastes
  – Garden Highway Foods Anaerobic Digester
  – Warmerdam Dairy
  – New Hope Dairy
CRED Diary Digester Projects

- Warmerdam Dairy
  - 700 kW dairy digester project using an internal combustion engine with SCR
- New Hope Dairy
  - 500 kW dairy digester project using novel low emissions IC engine
CRED Project Locations
Q & A
Thank you!

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