

US EPA ARCHIVE DOCUMENT

NOx Emission Reduction: Technology Solutions for Small Biogas Projects

Pacific Southwest Organic Residuals Symposium

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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

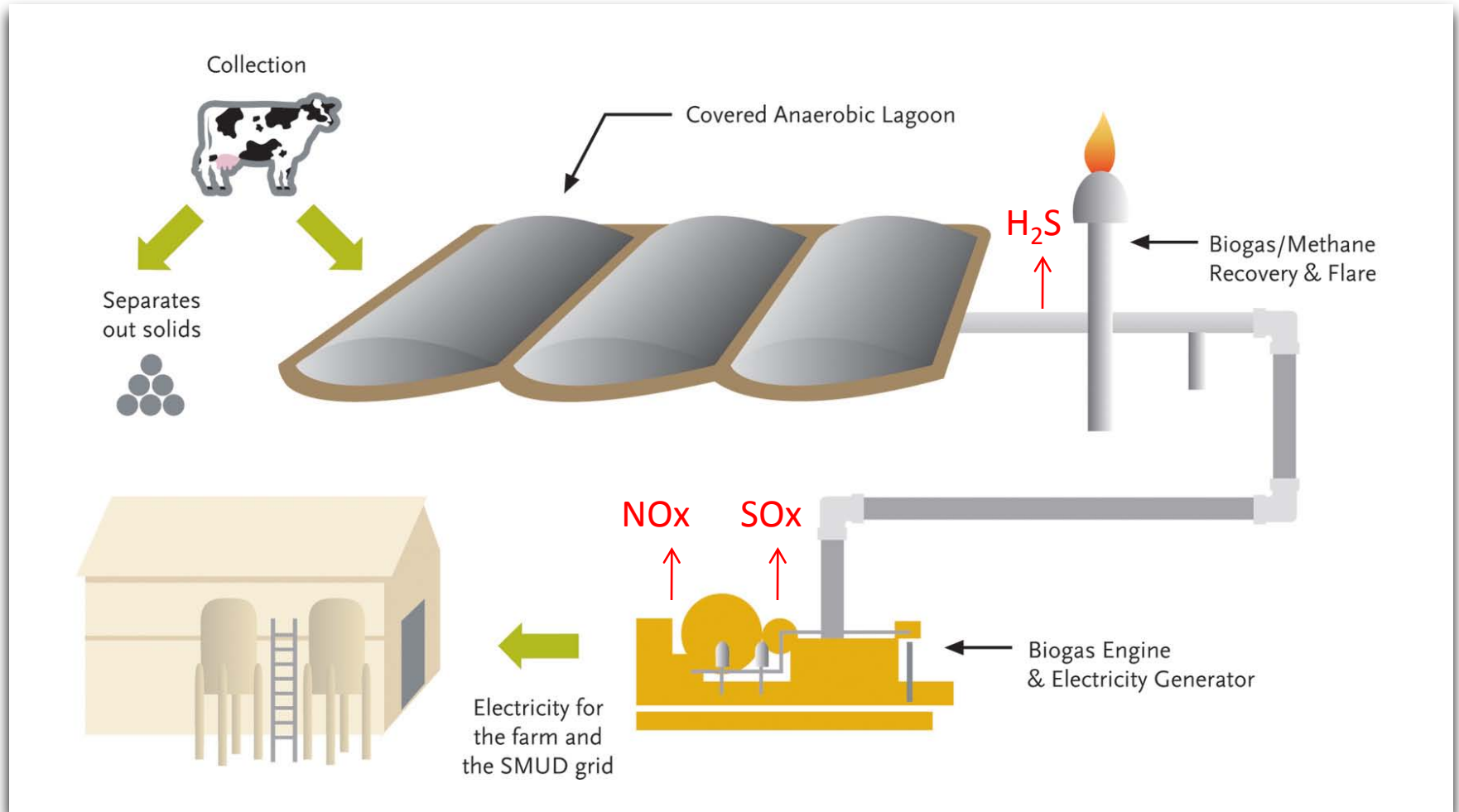
- Provided grants to help dairies build digesters
 - 13% capital cost incentive to match 25% USDA Rural Development grant
- Paid for 50% of the USDA grant application cost
- Helped with permitting, interconnection, and obtaining grants
- Offered net metering crediting all the farm meters at retail rates
- 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





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



- Cal-Denier Dairy
 - ~ 500 cows
 - 65 kW genset

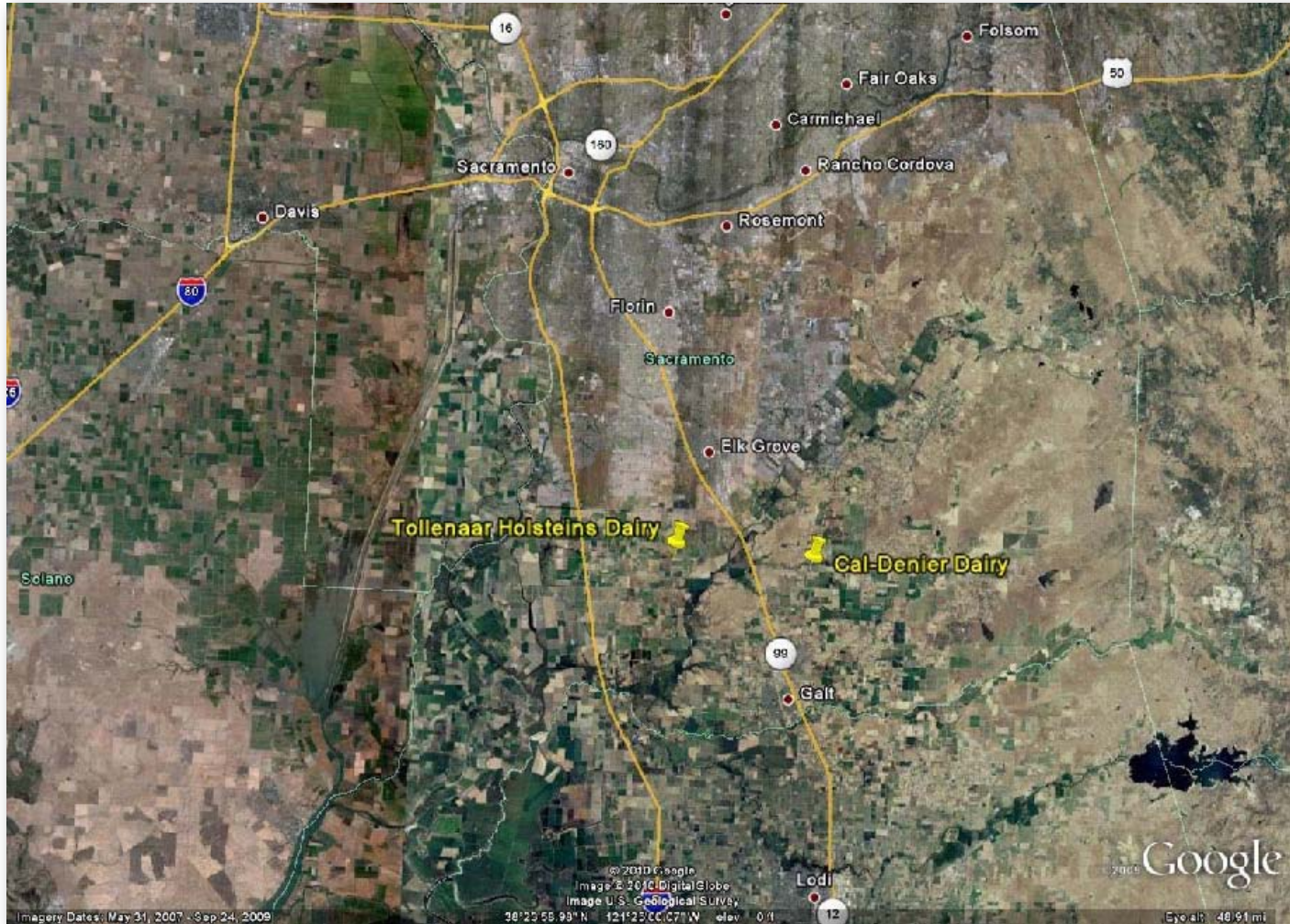


Tollenaar Holsteins Dairy



- Tollenaar Holsteins Dairy
 - ~ 1,100 cows
 - 212 kW genset

Location of Existing Projects





SMAQMD: Proposed Revision of Rule 202

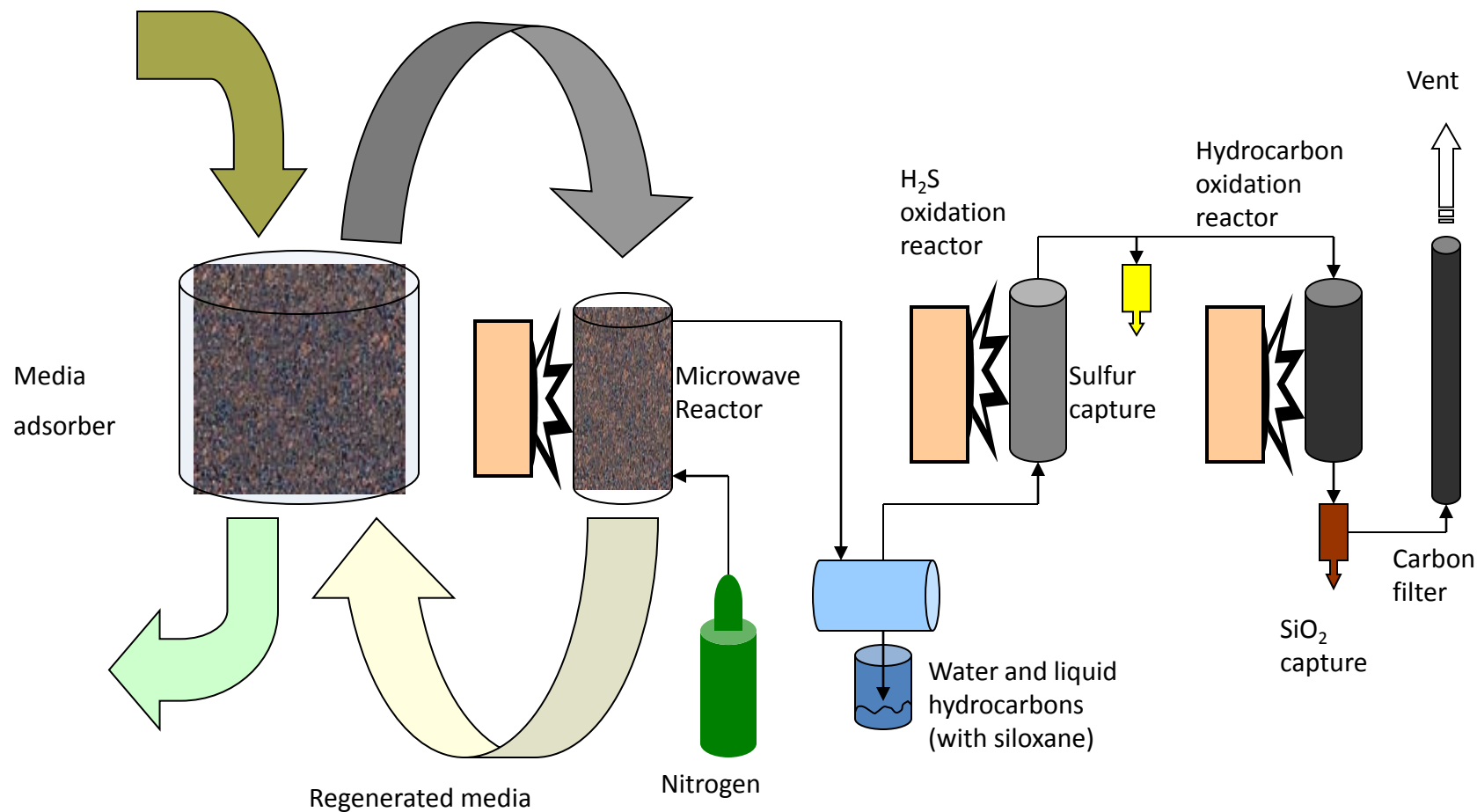
- Sacramento Metropolitan Air Quality Management District (SMAQMD) to amend its Rule 202, New Source Review, to bring NSR program up to date with state and federal laws. Bottom line: air emissions rules will be stricter than today
 - Decrease the BACT applicability threshold from 10 lb/day to zero of any non-attainment pollutant (e.g. ozone) or its precursors (e.g. NO_x), requiring BACT for all new or modified equipment that will increase emissions.
- Tollenaar and Denier permitted at 54 ppm for NO_x
- SMAQMD targeted BACT for NO_x = 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
 - $\text{H}_2\text{S} + \text{H}_2\text{O}_2 \rightarrow \text{S} + 2\text{H}_2\text{O}$

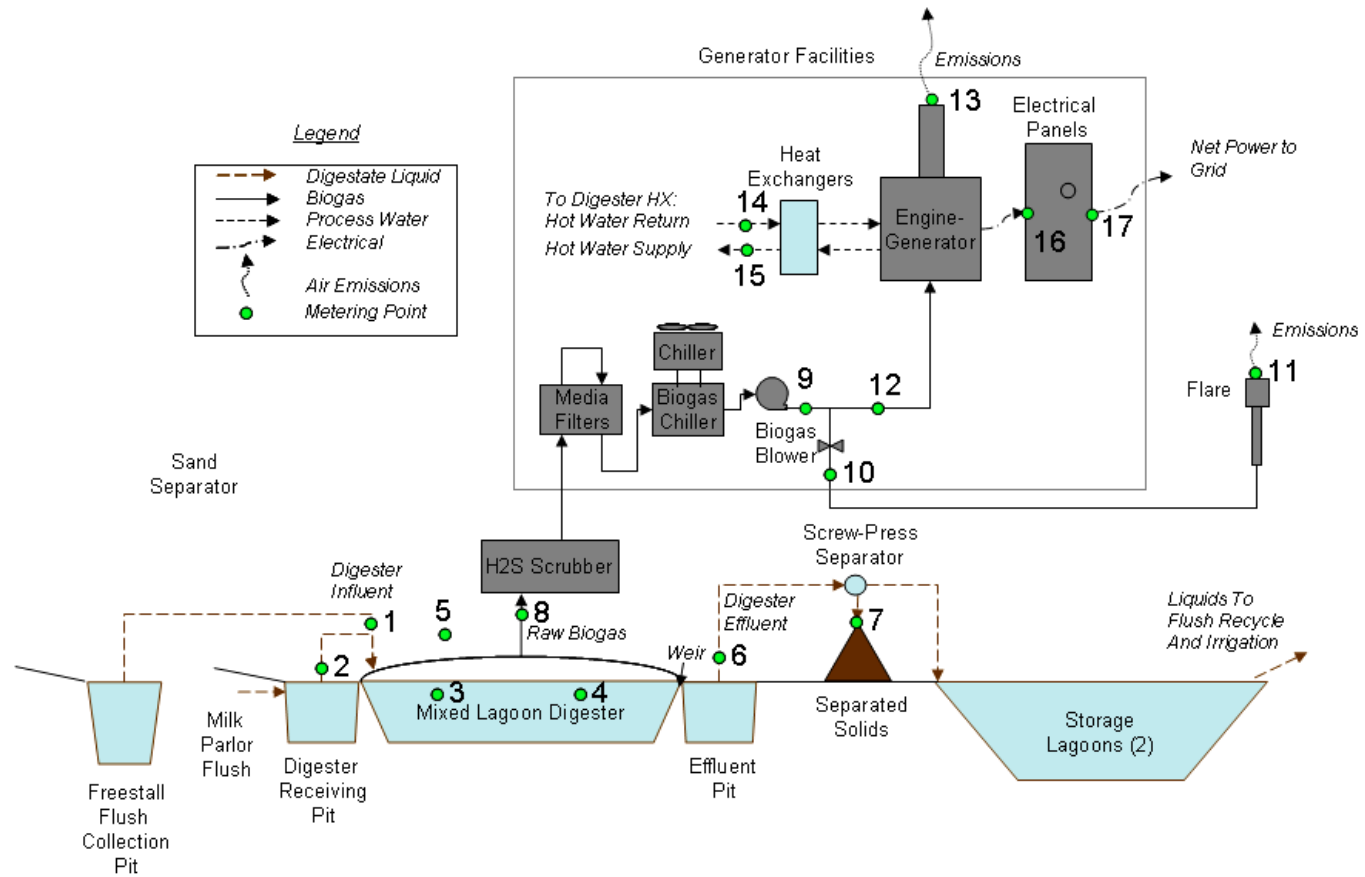
Media Adsorption with Microwave Regeneration and Oxidation Reactor System Media



Detail of Mixed Media



Overall System Diagram



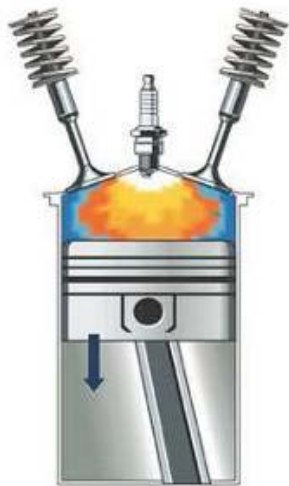


HCCI Project

- 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



SPARK IGNITED
ENGINE

*GM CONCEPT



HCCI FLAMELESS IGNITION

- The intake charge for methane base biogas needs to be $\sim 180^{\circ}\text{C}$ 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

Key Previous Project Results

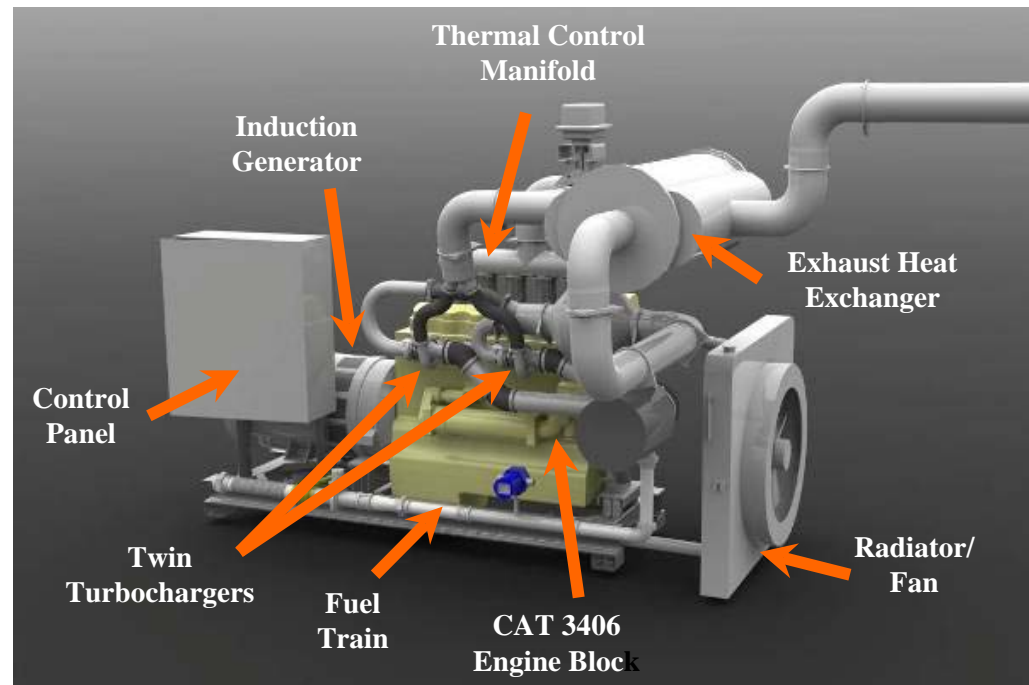
- Working under a PIER CEC grant, MEI demonstrated a 30 kW landfill gas fueled HCCI engine
- This project established the viability of converting conventional, off-the-shelf compression ignition engines to HCCI operation, while achieving CARB 2007 standards
- Developed a prototype six cylinder HCCI engine/genset 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%)
 - NO_x 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

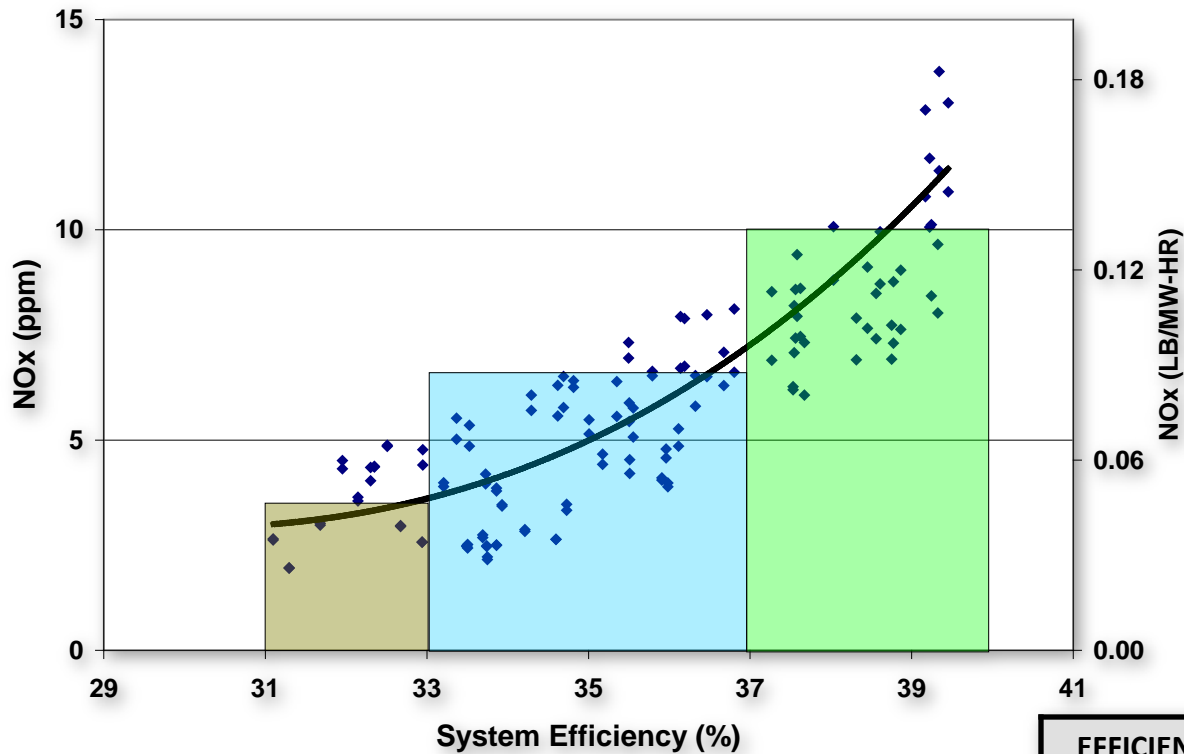


CAT 3406 engine block



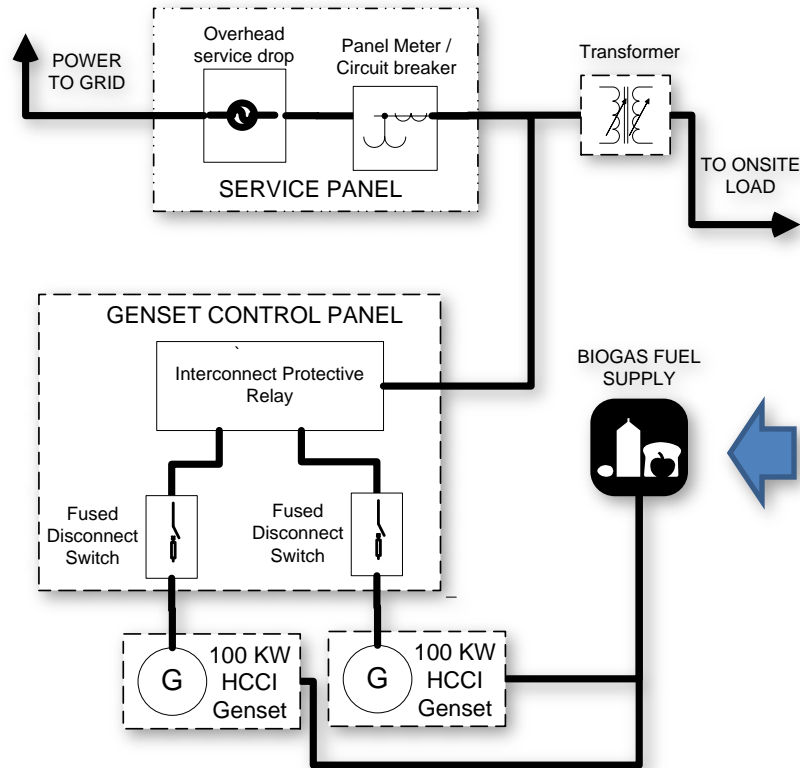
System components for the scaled up HCCI system

HCCI Efficiency and NOx with LFG



EFFICIENCY (%)	NOx (ppm)-(lb/MW-hr)*
37-39	8-14 (.10-.17)
33-37	4-8 (.05-.10)
31-33	2-4 (.03-.05)

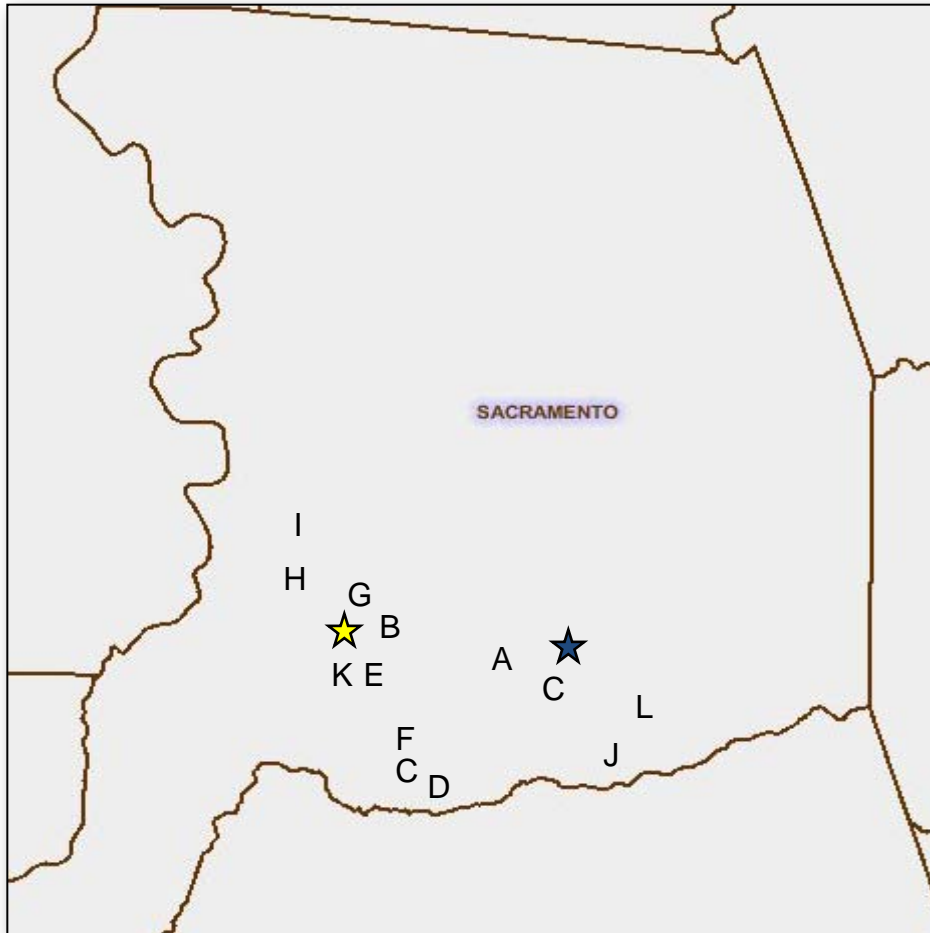
Site Integration



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

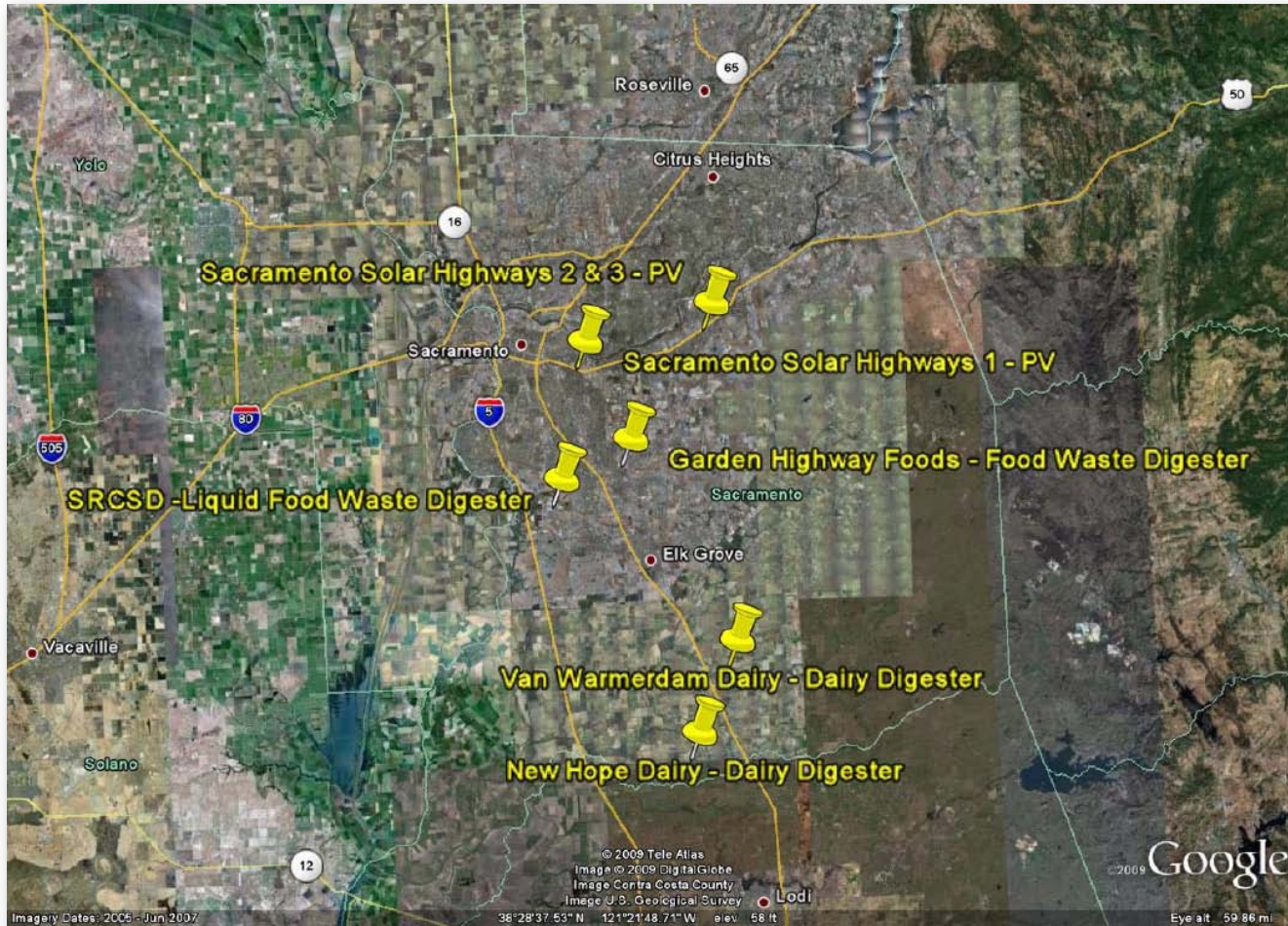
CRED Projects

- 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 Dairy 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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