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)

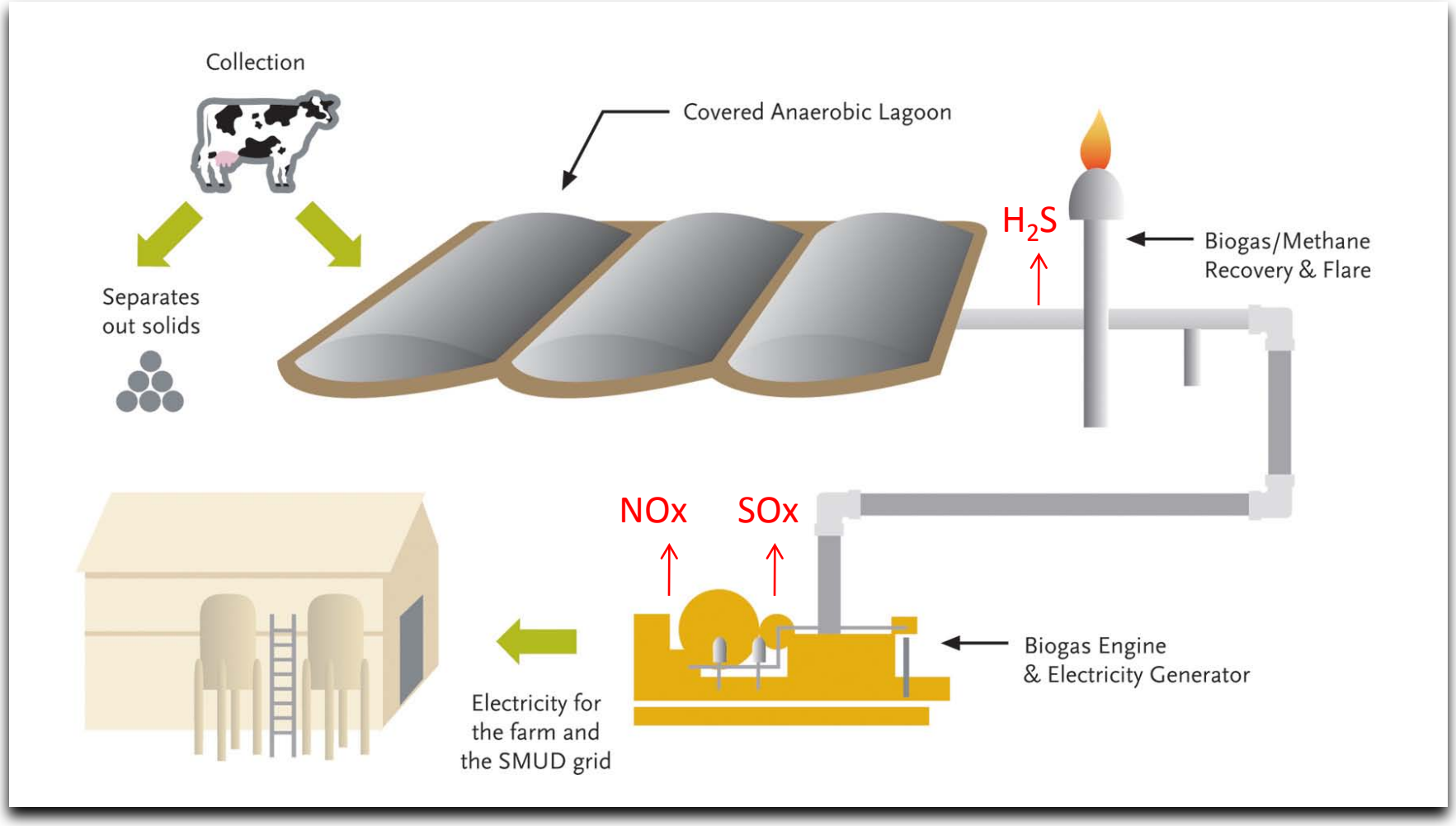
SMUD'S Dairy Digester Incentive Program

- 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

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Tollenaar Holsteins Dairy

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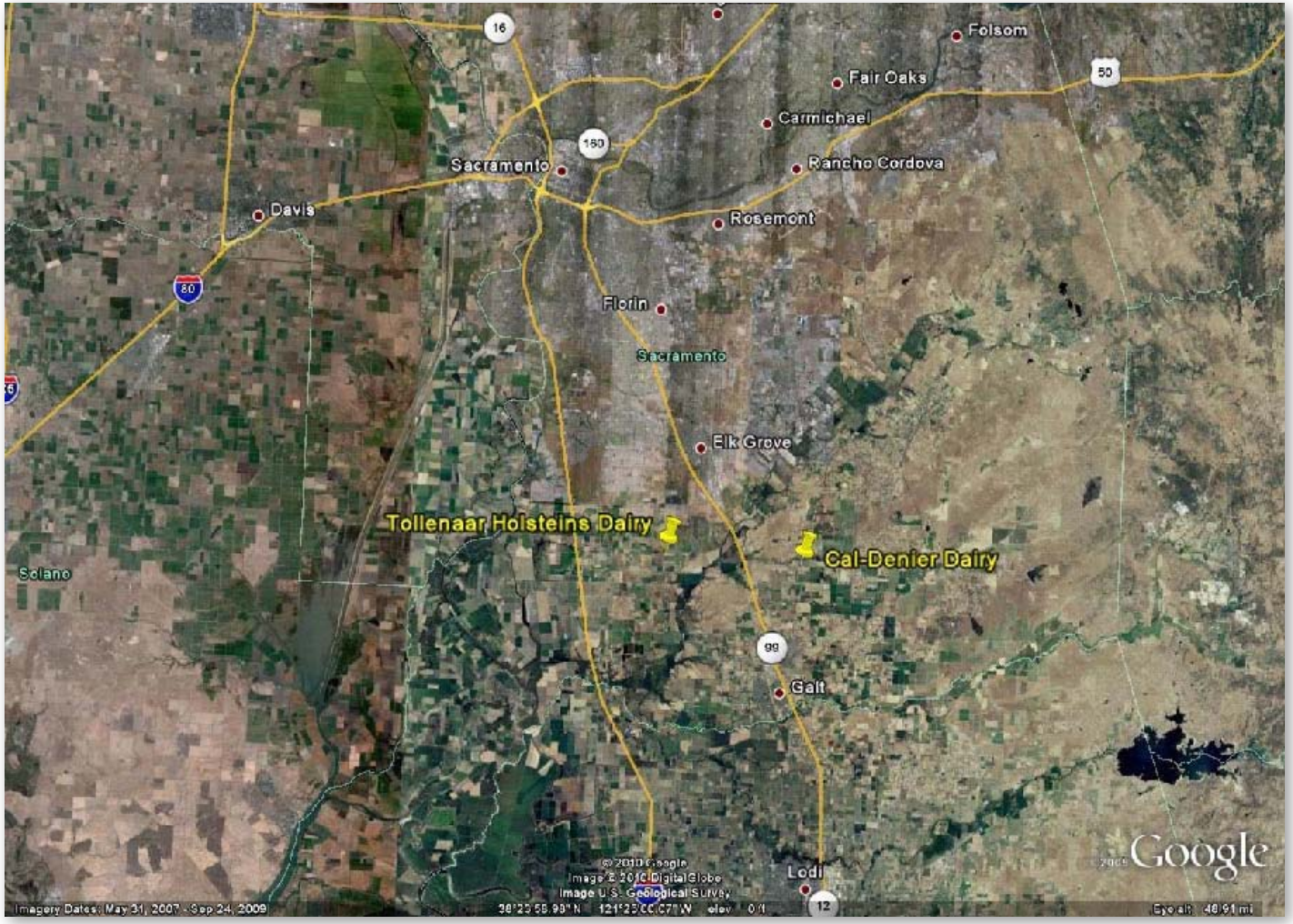
Location of Existing Projects



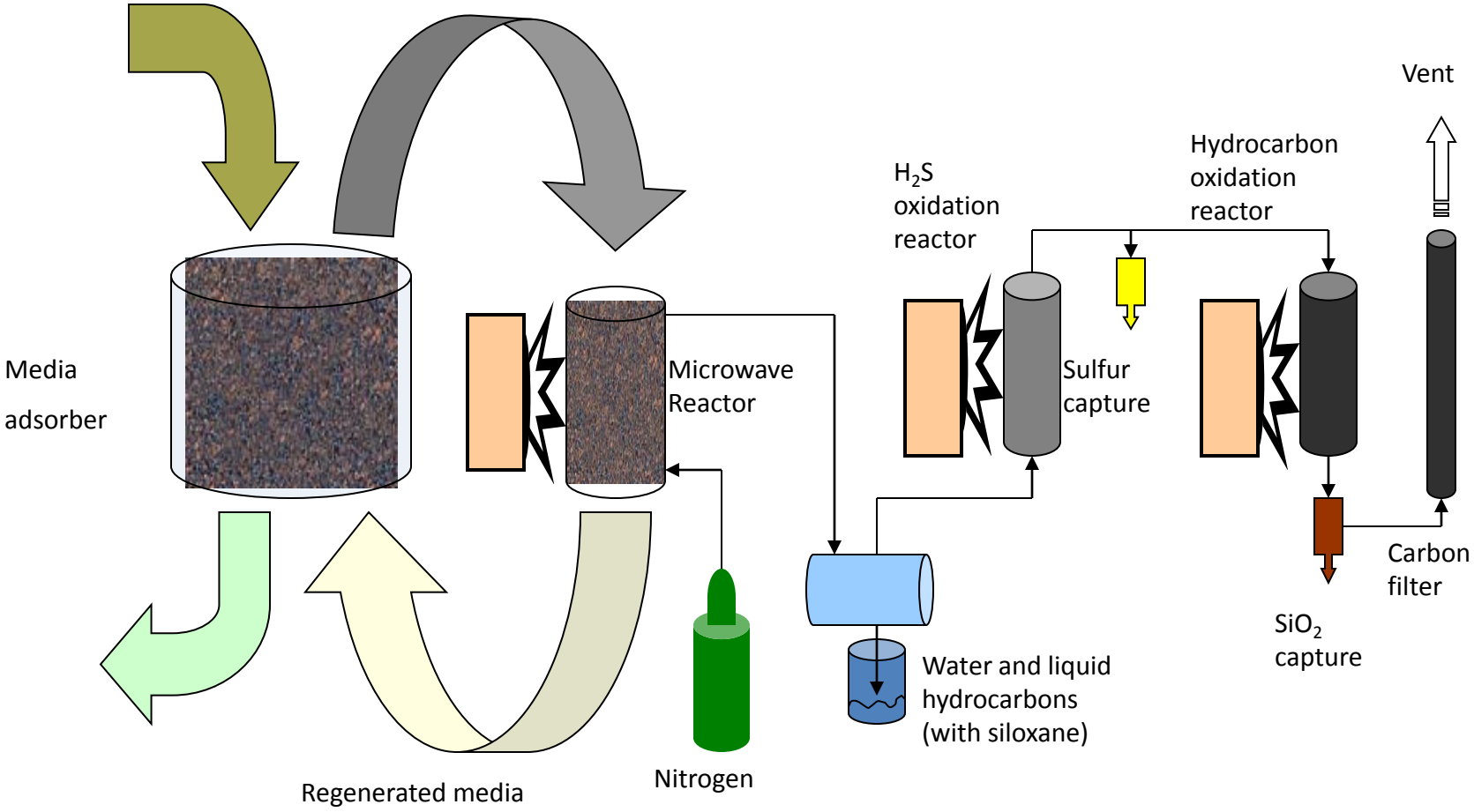
SMAQMD: Proposed Revision of Rule 202

- 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

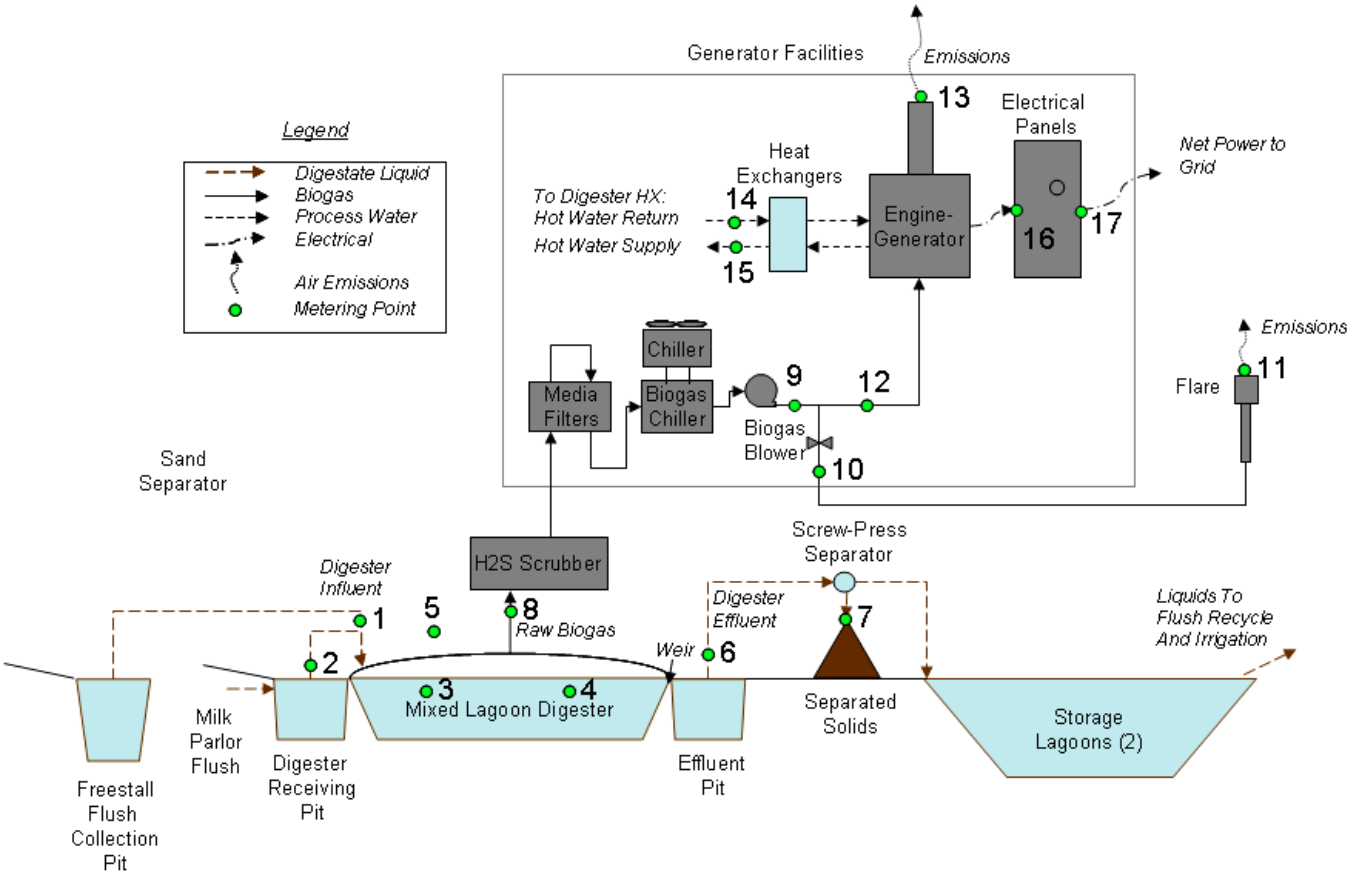
- Objective: Demonstrate an integrated emission control process for NOx removal on the engine exhaust and sulfur (H2S) removal in the biogas at Tollenaar Holsteins Dairy
- Partners: SMUD (prime), Cha Corporation, Applied Filter Technology, Gerling Applied Engineering, CARB (ICAT Program Funding)
- NOx 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
    - $H_2S + H_2O_2 \rightarrow S + 2H_2O$

Media Adsorption with Microwave Regeneration and Oxidation Reactor System Media



Detail of Mixed Media

Overall System Diagram

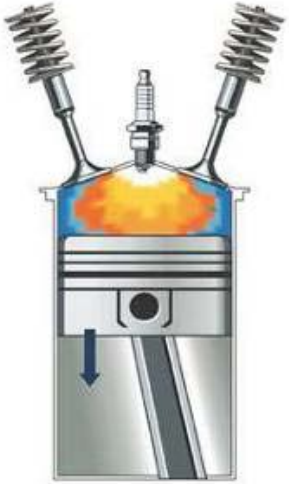


HCCI Project

- 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

HCCI FLAMELESS IGNITION

*GM CONCEPT

- The intake charge for methane base biogas needs to be ~ 180oC 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

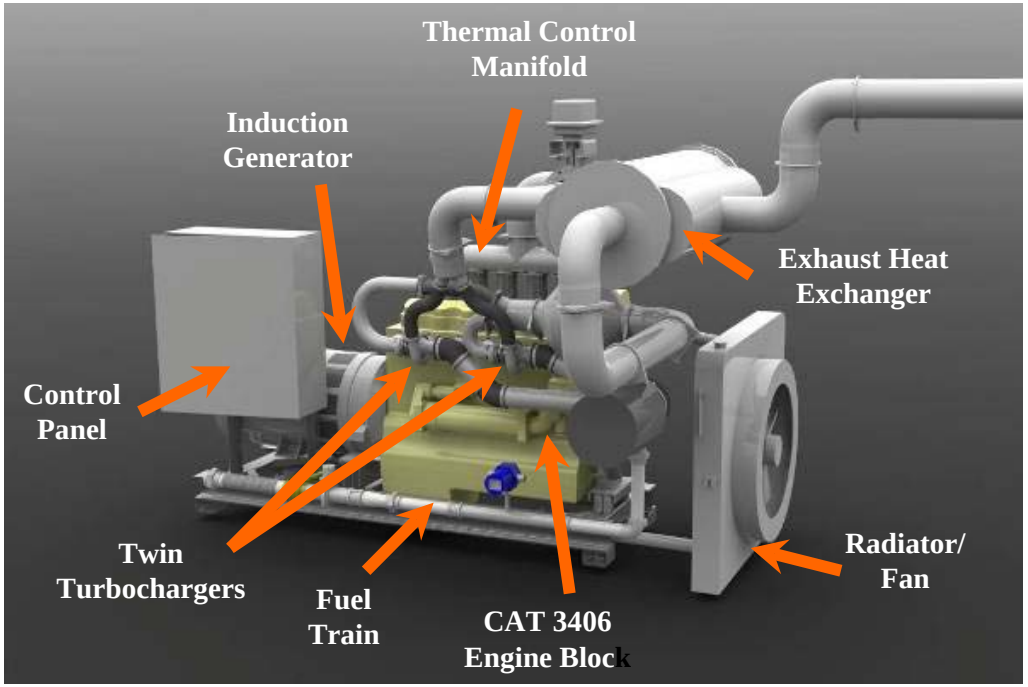
Key Previous Project Results

- 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%)
  - 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

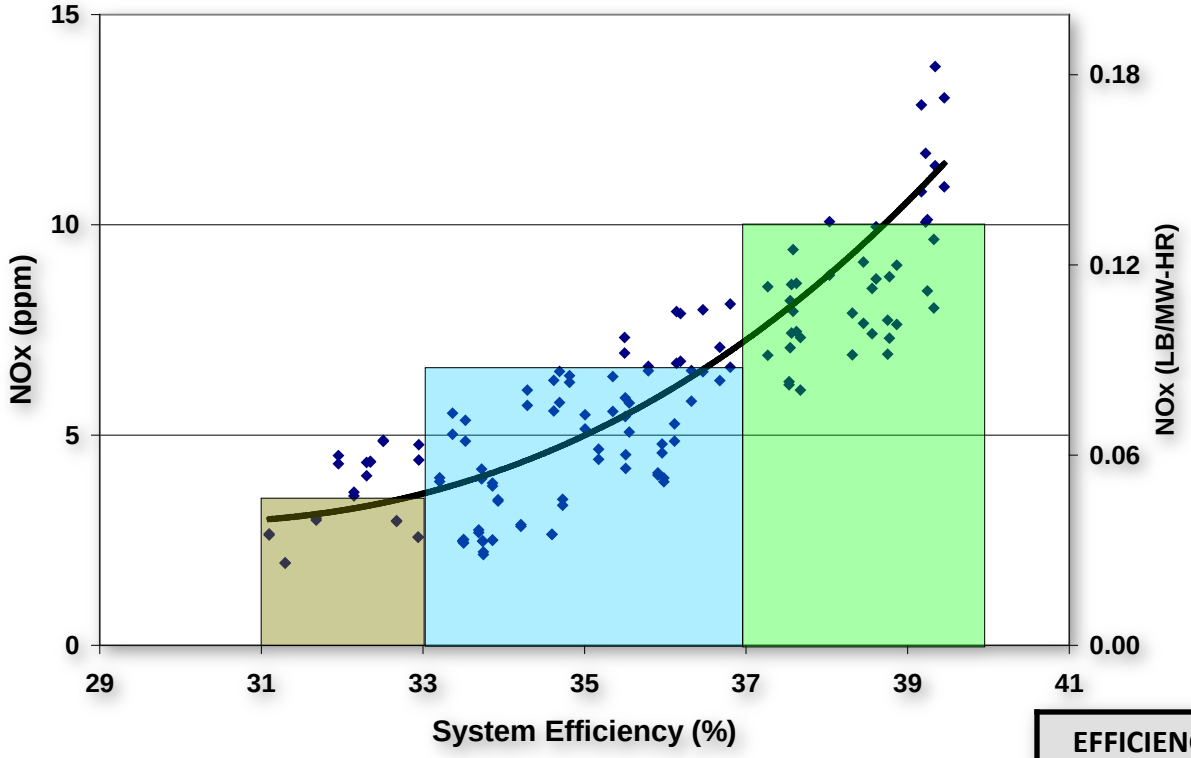
- Under a separate PIER-RESCO program, MEI is currently developing a "scaled up version" of the previously demonstrated 30 kW unit
  - Capable of achieving California ARB 2007 targets for combustion of biogas
  - Targeting 200kW of electrical power output

CAT 3406 engine block



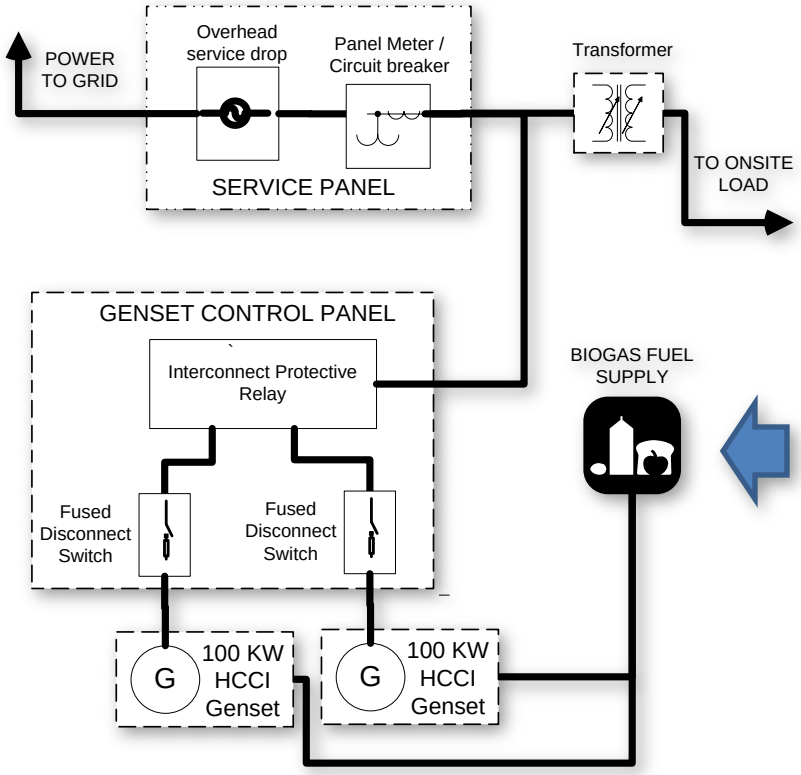
System components for the scaled up HCCI system

HCCI Efficiency and NOx with LFG



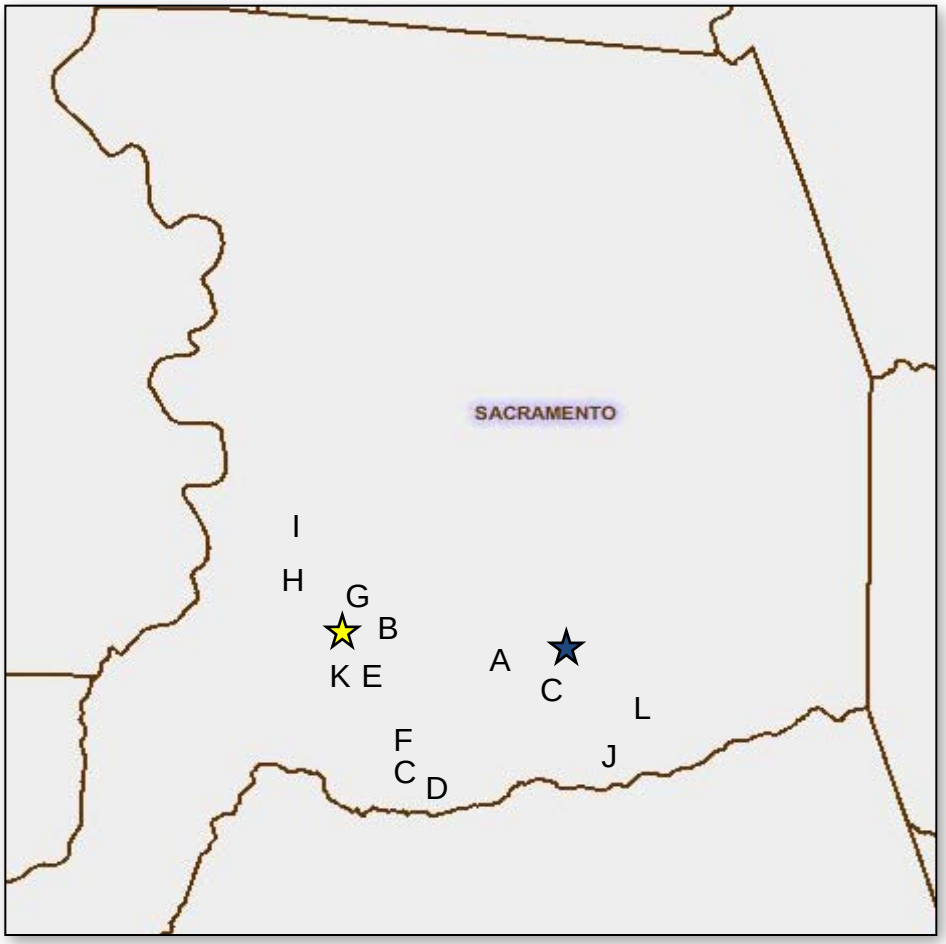
EFFICIENCY (%)	NOx (ppm)-(lb/MW-hr)*	
37-39	8-14	(.10-.17)
33-37	4-8	(.05-.10)
31-33	2-4	(.03-.05)

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

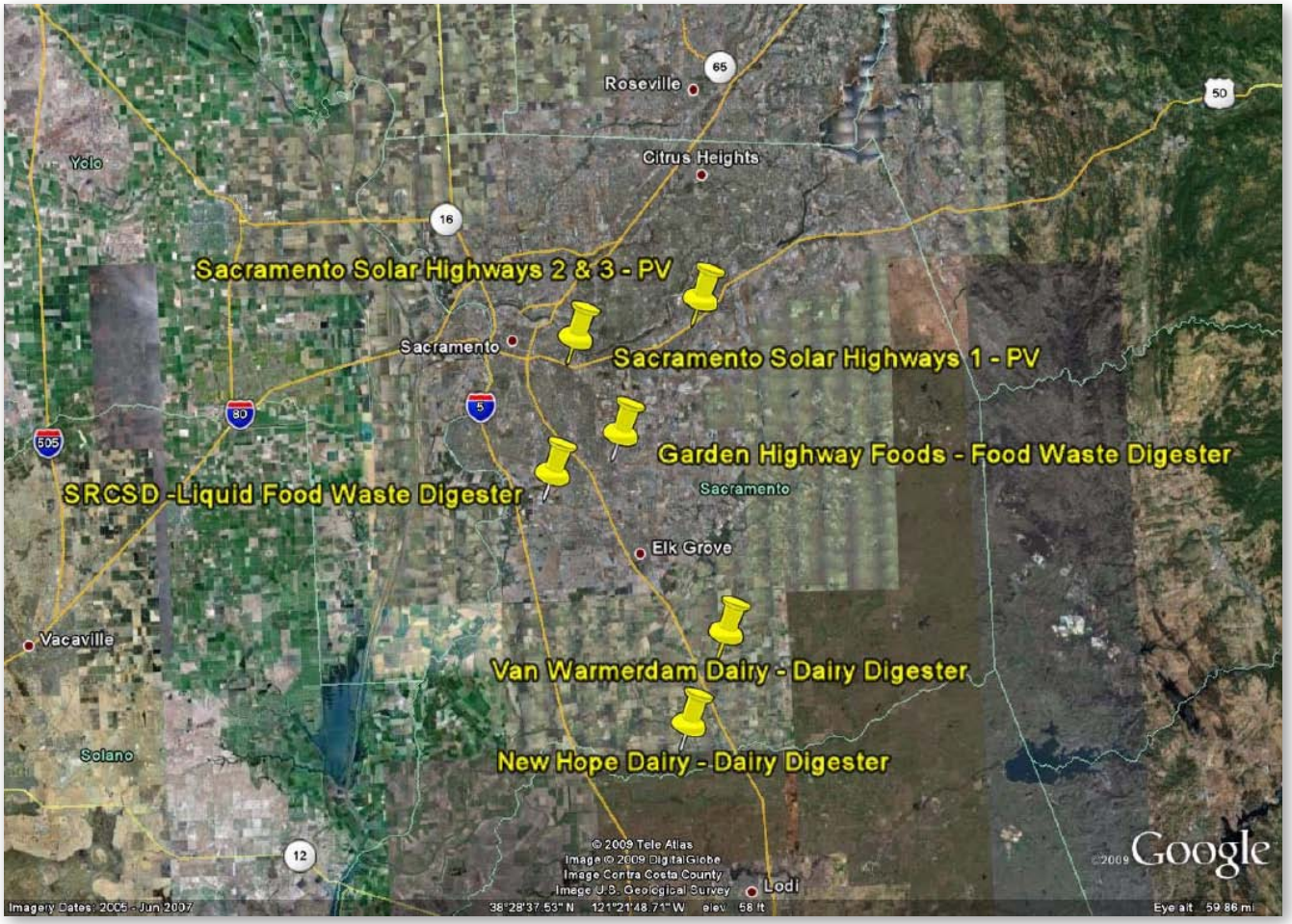
CRED Projects

- 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 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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