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# Low NOx HCCI Technology for CHP Applications

**California Energy Commission  
IEPR Lead Commissioner Workshop on  
Combined Heat and Power in California**

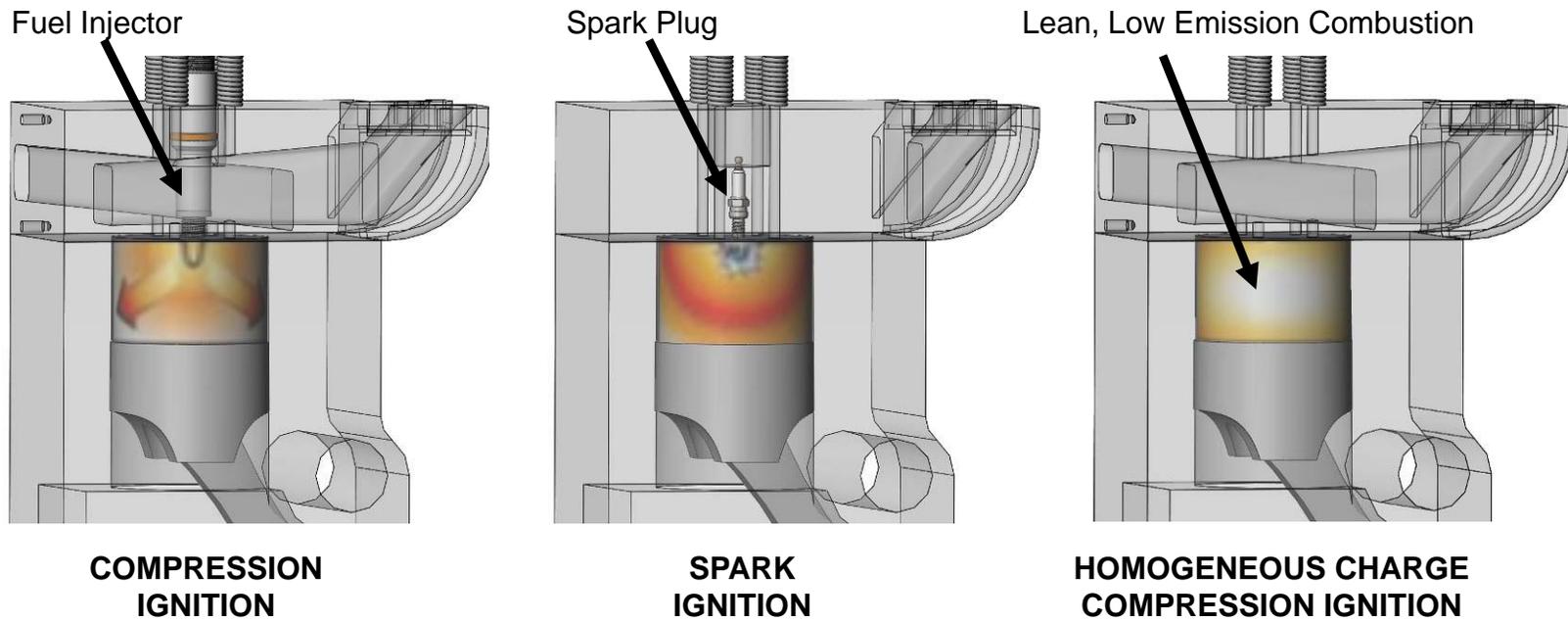
**February 16, 2012**



# What is HCCI?

HCCI is a combination of the well-known spark ignition and compression ignition engine concepts, enabling the use of fuels with very low energy content, such as biogas, to achieve

**high thermal efficiency** and **low emissions.**



## ***Benefits:***

- Highly efficiently: Electrical (>35%) / Thermal (>45%)
  - Reduced fuel consumption
  - Lower electricity costs for CHP owners
  - Displaces need for equivalent amount of fossil fuel
- Low emissions: No NOx after treatment required (< 3 ppm)
  - Reduced air pollutants
- Fuel Flexibility
  - Wide range of renewable gaseous biofuels (i.e. Syngas, digester gas, landfill gas)
- Low cost CHP system: ~ \$1200 \$/kW
  - Comparable to SI engine without ongoing exhaust after treatment costs

## ***Technical Challenges:***

- Biogas operation: Variable BTU content and composition
  - Expertise and state of the art control systems are required to sustain HCCI
- CHP heat transfer components: Conventional CHP components are limited for HCCI
  - HCCI exhaust gas is typically cooler than reciprocating engines
- Continuous operation: Variable thermal and electrical loading
  - Active specialized control systems are required to ensure operation over extended periods

To control HCCI combustion timing (when it fires)  
“active thermal conditioning” of the inlet charge is required



- The intake charge temperature for methane based biogas needs to be elevated to auto-ignite in HCCI mode
- This is a function of:
  - Compression ratio
  - Boost pressure
  - Cylinder geometry
  - Block temperature
- Active control system

\*\*Courtesy of UC Berkeley Combustion Analysis Laboratory (CAL)

***“California dairies have a methane production potential of about 40 million ft<sup>3</sup>/day\*, translating to nearly 160,000 kW capacity potential in energy generation, nearly doubling California’s biomass based CHP capacity”***

Biomass Based CHP by Application**	Capacity (kW)	Share
Wastewater Treatment	68,235	37.65%
Justice/ Public Order	37,000	20.42%
Agriculture	25,940	14.31%
Food Processing	25,000	13.80%
Solid Waste Facilities	18,760	10.35%
Utilities	4,600	2.54%
District Energy	1,300	0.72%
Colleges/Universities	380	0.21%
<b>Total Biomass CHP Installed Capacity</b>	<b>181,215</b>	<b>100.00%</b>
<b>Projected Dairy Biogas Capacity</b>	<b>160,000</b>	



**“Dairies have significant market share in terms of biogas capacity”**

\*Ken Krich et al, Biomethane from Dairy Waste - A Sourcebook for the Production and Use of Renewable Natural Gas in California, p23-24, <http://www.calstart.org>

\*\*Energy and Environmental Analysis, Inc., Combined Heat and Power Units located in California, <http://www.eea-inc.com/chpdata/States/CA.html>

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**Market penetration for *Light Industrial* applications are encouraging:**

- Food Processing Plants
- Hotels
- Hospitals
- Waste Water Treatment Plants

**Optimal Site infrastructure is key:**

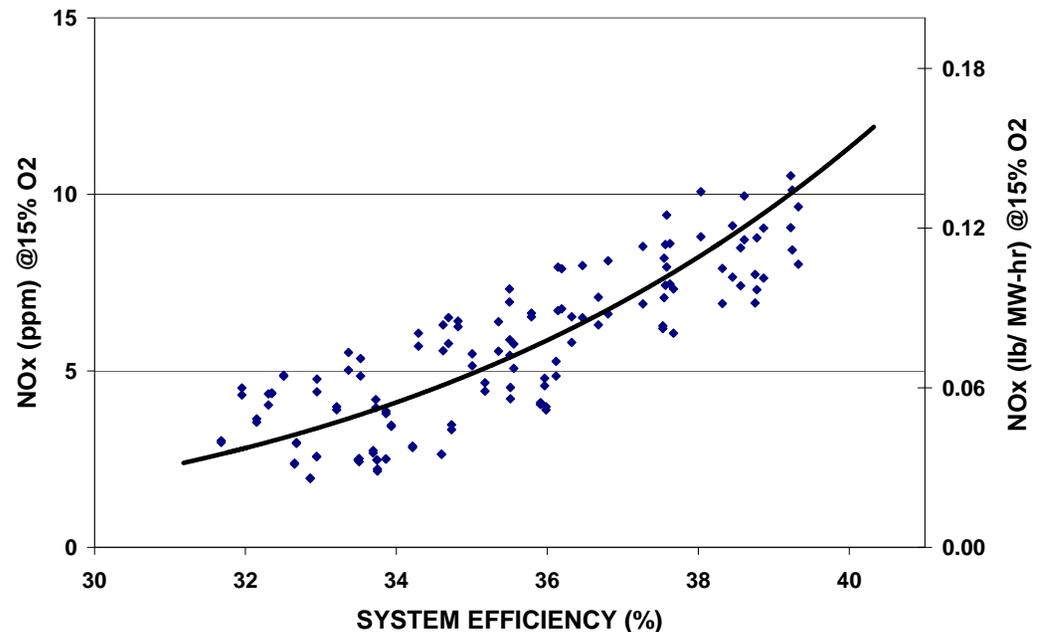
- Thermal load profile
- Electrical load profile

- **System 1: Landfill Gas HCCI**
  - Demonstrated a 30kW class HCCI system at an active landfill capable of achieving ultra low NOx and high efficiency
    - Final demo completed 2007
  
- **System 2: HCCI Biogas for DG**
  - Characteristics of system:
    - >35% efficiency
    - California ARB DG certifiable for biogas combustion
    - Industrial standard grid connection (Induction generator)
  
- **System 3: CHP HCCI**
  - Characteristics of system:
    - >80% CHP efficiency
    - California ARB DG certifiable for biogas combustion
    - HCCI specific heat recovery components

# Landfill Gas HCCI (30 kW)

(CEC PIER Grant #: PIR-02-003)

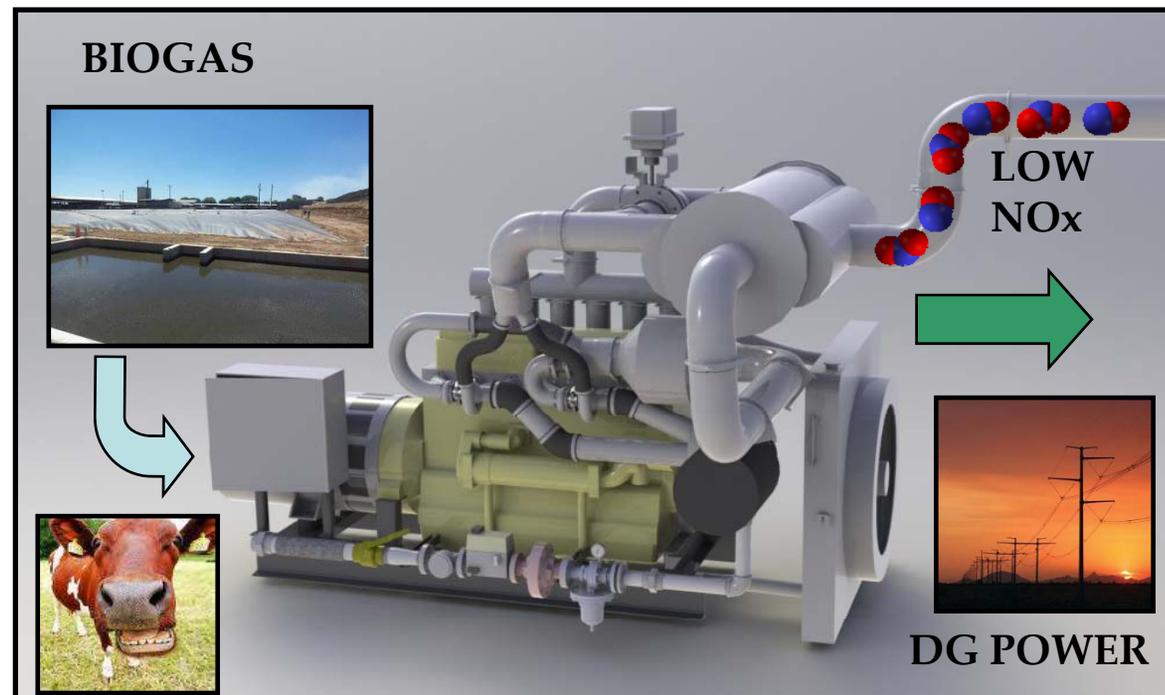
- Prototype HCCI engine demonstrated at an active California landfill site
- 500 hrs of operating time with LFG
  - Operating efficiency >35% over a range of operating conditions
  - NOx emissions on the order of 5 PPM



# HCCI Biogas for DG

(CEC PIER Grant #: PIR-08-042, PIER-RESCO PROGRAM)

- Larger engine block under development capable 100kW
- Low emission and high efficiency profile
- HCCI components:
  - Stock diesel engine block
  - Thermal conditioning system
  - HCCI control system

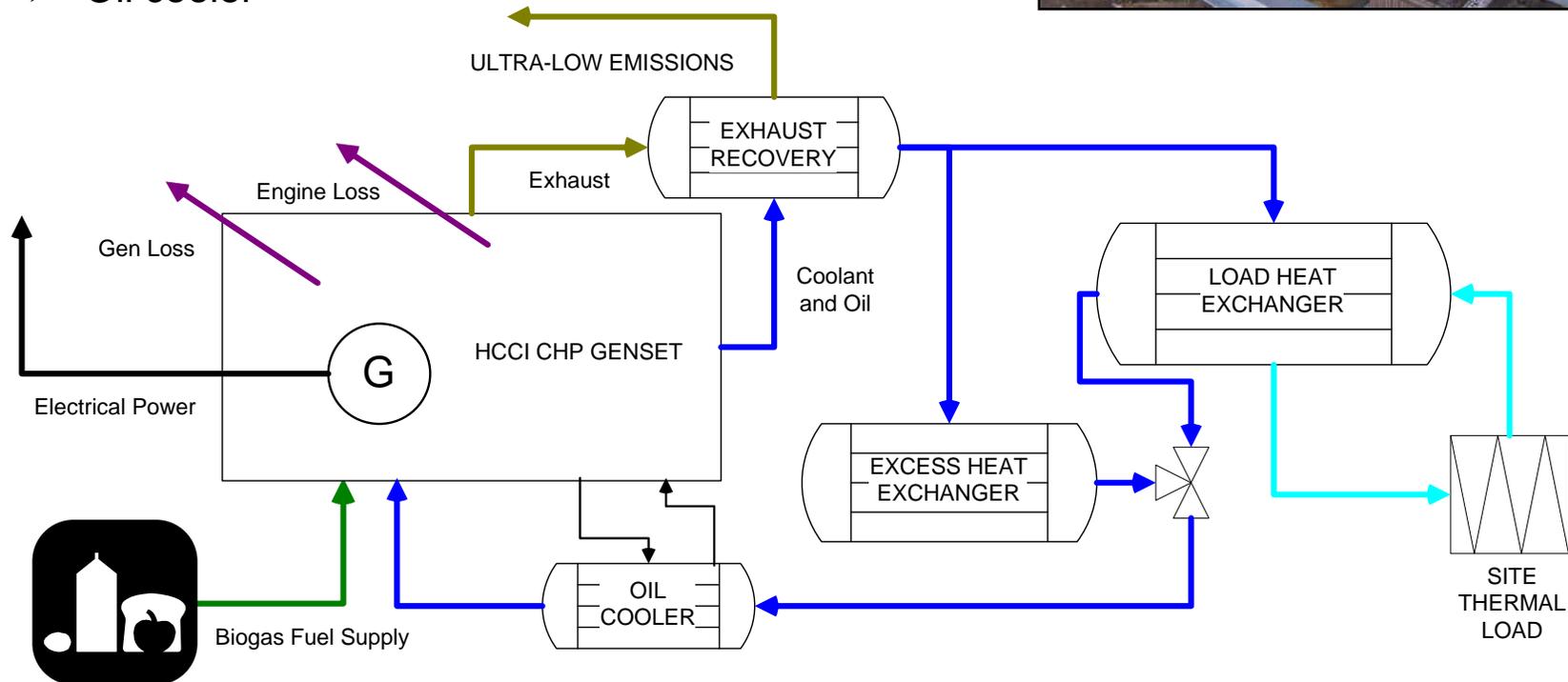


**Concept for scaled up HCCI systems**

# HCCI CHP System

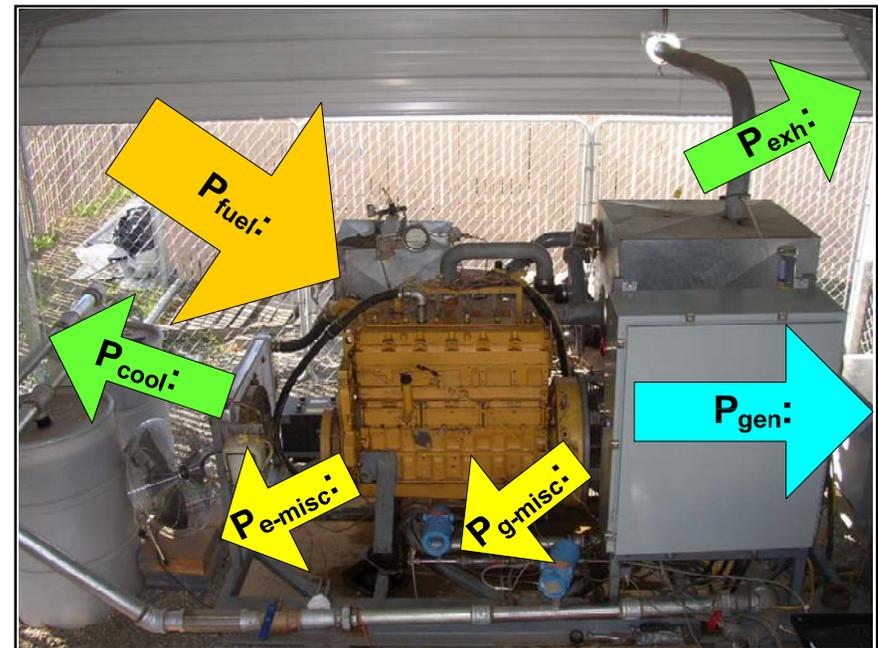
(CEC PIER Grant #: PIR-09-014, PIER-EPAG PROGRAM)

- Using closed loop recovery system, CHP efficiencies in the 80%-90% range are expected
- Heat recovery components:
  - Standard engine water jacket
  - Exterior engine block jacketing
  - Exhaust heat exchanger
  - Oil cooler



**Consistent with modeling, testing with simulated biogas (~60% methane, ~40% carbon dioxide) indicates that CHP efficiencies > 80% can be achieved**

Sym.	Definition	Fraction of $P_{fuel}$ : (%)
$P_{fuel}$	Power from combustion of fuel	100%
$P_{cool}$	Power rejected by engine coolant and oil	30%
$P_{exh}$	Power loss from escaping exhaust gases (after heating intake charge)	20%
$P_{e-misc-loss}$	Engine power losses	11%
$P_{g-misc-loss}$	Generator power losses	4%
$P_{gen}$	Electrical power output	35%



## Working in conjunction with SMUD:

### Tollenaar Holsteins Dairy in Elk Grove, CA

- Site specifics:
  - 2000 head
  - Currently installed digester
  - Producing ~150kW of electricity
- CHP Application:
  - Thermal Management of Digester
  - Hot water for wash down
- Deployment: mid-2012



### Cal-Denier Dairy in Galt, CA

- Site specifics:
  - 800 head
  - Currently installed digester
  - Producing ~65kW of electricity
- CHP Application:
  - Hot water for on-site laundry facility
- Deployment: early-2013





# Contact Info



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