Best Practices to Select Internal Combustion Engines and Maximize the Success of Methane to Electricity Projects

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Objective

• This presentation is an add-on companion to GMI’s Best Practices.

• Provides four additional practices for better decisions in methane to electricity projects.

• Applies to all segments (Ag, Waste Water, etc.)
Agenda

1. Engine Technology
2. Gas Contamination
3. Engine Installation
1. Engine Technology

High Efficiency v. High Robustness
Internal Combustion Engine

• Invented by N. Otto, 1876
  – Traditional four-stroke cycle
• Improved by R. Miller, 1957
  – Changes valve timing, fuel mixture ‘supercharged’
  – Manages higher pressure inside the cylinders
  – Inherently more efficient
  – Requires closer control of air inlet temperature, fuel contamination, tolerances.
Which Technical Design Is Better?

It depends ....
Engine Design Trade-Off

High Robustness Engines (Traditional *Otto, non-Miller*)

- **CAPEX** ↓ **OPEX** ↑
- Accept higher siloxane and H2S contamination
- Efficiency below 40%
- Dirty gas forces more oil changes, higher M&O cost
- Excellent for: ‘dirty’ gas, worst-case ambient swings & quicker load response

High Efficiency Engines (*Miller* Cycle)

- **CAPEX** ↑ **OPEX** ↓
- Usually require costly siloxane & H2S removal
- Efficiency above 40%
- Lower M&O costs due to cleaner gas
- Excellent for: ‘clean’ gas, controlled environments, average load demands
Engine Technology Best Practice

• Run two separate economic evaluations of your methane to electricity project:
  – Scenario A: high efficiency engine (Miller)
  – Scenario B: high robustness engine (non-Miller)

• Include in your evaluation:
  – CAPEX: cost of siloxane and H2S removal equipment required by high efficiency engine
  – OPEX: additional M&O for siloxane/H2S removal units
  – Risk Factors: if cleaning equipment fails or under-perform, high efficiency engine will be quickly damaged
2. Gas Contamination

Removing Siloxanes and H2S
Why Siloxane and H2S?

• Siloxanes
  – Present in cosmetics, shampoo, detergents
  – Transform during combustion to SiO2. Sand in the engine!

• H2S (Hydrogen Sulphide)
  – Combusts to SO2 and H2O. Further transform to sulphurous/sulphuric acid.
  – Corrosion
Fuel Specification Guidelines

• All Manufacturers have guidelines for maximum fuel contamination. Warranty depends on compliance.
• Miller engine users strongly advised to stay within the limits of the ‘clean biogas’ definition

Sample Recommendation for Optimal Engine Application

*Based on 500 Btu/scf Fuel

<table>
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<tr>
<th>Fuel Contaminant</th>
<th>µg/Btu of Fuel</th>
<th>Approx. PPM*</th>
<th>µg/Btu of Fuel</th>
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Economics of Siloxane Removal

• Recent 12MW LFGE project (6 engines)
  - Siloxane removal unit added 25% extra cost
• Recent 1-2MW quotes
  – 50-100% added cost.
• 1 MW and below
  – Siloxane removal costs as much as the engine!
• Cost becomes manageable if project is very large
3. Engine Installation Options

Building v. Container
Engine Installation Trade-Off

**Building Installation**
- Ample space for service personnel, cranes for safe lifting of heavy parts, controls & storage rooms
- Economies of scale for multi-engine buildings
- Easier to manage dust contamination and air inlet temperatures

**Container Installation**
- Restricted access and work space, more time & money on service steps
- Fast deployment, easier to quickly add or remove units
- Easier to obtain bank loans
- High reliability: complex systems integrated by engine manufacturer
4. Better Estimation of M&O Costs
Estimating Maintenance & Operation Costs

• Most financial evaluation tools use just one number for the M&O cost of a generator set
• Comparison of costs may not be appropriate without knowing the different elements that went into the M&O number
• Potential customers need to request separate estimates for different combinations of service
  – Window of time used for calculations is critical
  – Gas type used for calculations also critical
Cost per kWh, Cost per Running Hour

- L1-L7 are lists of different service alternatives
# Need to Break Down O&M Elements

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- Included in cost?
  - Lube oil?
  - Major Overhaul?
  - Electrical Items?
  - Unscheduled Maintenance?
  - System Auxiliaries?
Thank You For Your Attention!

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