Renewable LNG
Update on the world’s largest landfill gas to LNG plant

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Head of Government Affairs
Linde NA, Inc.

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The Linde Group worldwide: Global presence in more than 100 countries

$18.3 billion global sales
A leading gases and engineering company
$2.3 billion in gases sales revenue in North America in 2011
5,000 employees throughout the U.S., Canada and the Caribbean
Supplier of compressed and cryogenic gases and technology
  Atmospheric gases – oxygen, nitrogen, argon
  Helium         LNG and LPG
  Hydrogen       Rare gases
Plant engineering and supply
  LNG            Petrochemicals
  Natural gas processing Atmospheric gases
Linde’s alternative fuels portfolio

Renewable liquefied natural gas production - Altamont, CA

Green hydrogen production - Magog, Quebec

Biogas fueling, LNG import terminal - Sweden

Hydrogen fueling for cars, buses & fork lift trucks
Project introduction

Linde and Waste Management 50/50 JV
Linde brings liquefaction, purification, operations, and logistics expertise
WM brings landfill management and gas collection expertise

JV part of WM comprehensive focus on the environment
Increase renewable energy production
Increase recycling
Improve fleet fuel efficiency

Altamont Landfill & Resource Recovery Facility
Located near Livermore, CA
7,000 tpd refuse from the Bay Area
Existing 8.5 MW electric generation
Altamont landfill gas to LNG project
The largest of its kind in the world

LNG production plant
  13,000 gpd LNG capacity
  Mixed refrigerant liquefaction process
  Purification: compression, chilling, adsorption & membranes
    Designed to remove all potential contaminants

Environmental benefits
  Reduces nearly 30,000 tons CO2 annually
  Uses renewable feedgas and electricity
  Supplies 300 WM refuse trucks

Financials
  $15.5 m total capital
  About $2 m in funding from multiple agencies:
    CIWMB, CARB, CEC, SCAQMD
Plant Schematic

-Incoming landfill gas
-Compression
-NMOC removal
-H2S removal
-CO2, N2 removal
-Purified bio-methane
-Compression and expansion
-Heat Exchanger
-LNG Storage
-Filling
LFG Constituent & Contaminant Summary

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Average Conc, %</th>
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<tbody>
<tr>
<td>Methane</td>
<td>CH4</td>
<td>46</td>
</tr>
<tr>
<td>CO2</td>
<td>CO2</td>
<td>38</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N2</td>
<td>14</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O2</td>
<td>1</td>
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</tbody>
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Uncertainty in accepted LFG composition:
• >100 components present
• Published info not indicative of all components
• Variation in LFG composition

→ Analysis was a challenge
Successful Commissioning & On-going Operations

- Key dates:
  - July 6: Flare commissioning began
  - August 3: Landfill gas introduced to purification system
  - September 16: Methane introduced to liquefier
  - September 19: First LNG trailer loaded
  - October 14: Unattended plant operation
  - February 16: Half million gallons produced

- Performance Update
  - Maximum sustained production: 14,300 gpd
  - Plant operates unattended nights and weekends
<table>
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<tr>
<th>CHALLENGES</th>
<th>SOLUTIONS</th>
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<tr>
<td>Aligning operation of multiple unit operations in purification system</td>
<td>Robust design and commissioning plans</td>
</tr>
<tr>
<td>Going from 48% CH4 → 96%+ CH4</td>
<td>Polishing using Molecular Gate adsorbent</td>
</tr>
<tr>
<td>Reducing CO2 from ~35% to &lt; 50 ppm</td>
<td>Multi-stage design to handle varying levels.</td>
</tr>
<tr>
<td>Multiple NMOC species and amounts</td>
<td>Mixed refrigerant liquefier based on Gas Technology Institute design and heat</td>
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<tr>
<td>Efficiently liquefying natural gas on a small scale</td>
<td>exchanger developed by Linde Engineering</td>
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Awards for the Altamont project

EPA Landfill Methane Outreach Project of the Year

East Bay (CA) Clean Cities Clean Air Champion Award

Climate Change Business Journal Business Achievement Award

2010 – Compressed Gas Association Environmental Recognition Program Award
Status Update

Second site identified by JV & awarded $11MM in funding from CEC - Simi Valley, CA

Would utilize advanced purification system

Would have capacity of 18k gpd of RLNG

Evaluating commercial viability in context of low natural gas prices

Develop mechanisms to “de-risk” RINs, low carbon credits, etc.
Conclusions

Biogas to transportation fuels is technically and economically challenging

But it can be done!!

Significant progress made in moving the technology forward

Commissioning successfully completed

Reliable performance and operation proven

Improvements to purification system will enhance performance/reduce costs

Economic challenges remain

Improve capital and operating efficiencies for future plants

Current low natural gas prices

Minimal & uncertain market valuation for renewable aspect of product

Continued government support is required to

Reduce risks

Enable acceleration of technology and market development

De-risk renewable credits
Thank-you

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