Renewable, Green LNG

Update on the world's largest landfill gas to LNG plant

Linde Gas

17 November 2009

Steve Eckhardt

Linde's profile

Linde Gas



- Linde North America revenues of nearly $2 billion and 3800 employees
- Linde operates in over 100 countries generating over $17 billion in revenues
- Supplier of compressed and cryogenic gases
  - Atmospheric gases - O2, N2, Ar
  - Helium
  - Hydrogen
  - LNG and LPG
  - Rare gases
- Engineering and equipment
  - LNG
  - Natural gas processing
  - Petrochemicals
  - Atmospheric gases

Linde's alternative fuels portfolio

Linde Gas

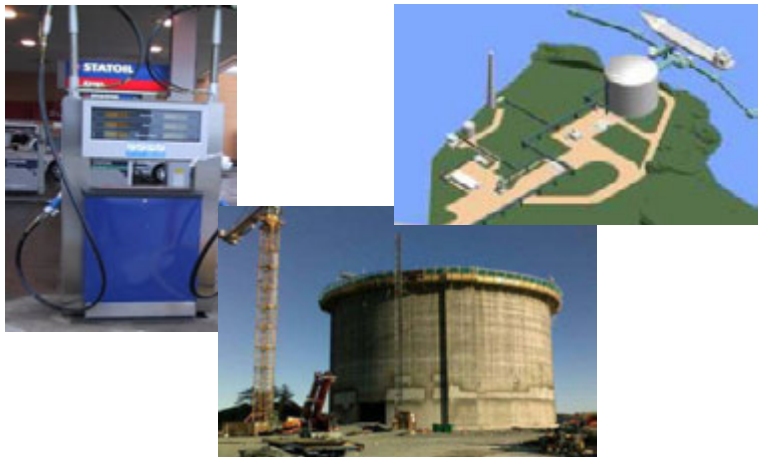
Renewable liquefied natural gas production - Altamont, CA



Green hydrogen production - Magog, Quebec



Biogas fueling, LNG import terminal - Sweden



Hydrogen fueling for cars, buses & fork lifts

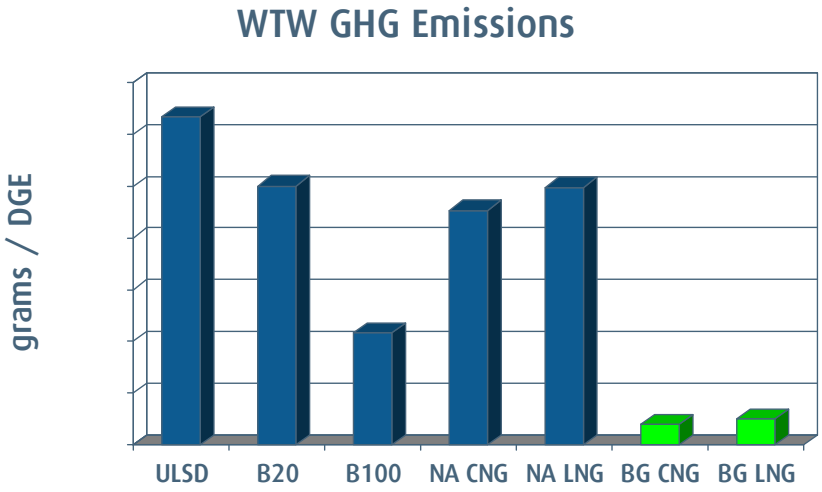


Why consider biogas?

Linde Gas

- Readily available resource
  - Produced naturally in landfills
  - Produced from anaerobic digestion - animal & food waste, sewage, crop waste
- Can be upgraded to high purity bio-methane
- DOE estimates potential is 10 billion gasoline gallon-equivalents per year
  - reduce GHG emissions by 500 million tons annually
  - Take 90 million light-duty gasoline vehicles off the road

Source: NGVAmerica.org





Project introduction

A Renewable Fuel Joint Venture Company

- **Linde and Waste Management 50/50 JV**
  - Linde brings liquefaction, purification skills
  - WM brings landfill management and gas collection skills
- **JV part of WM comprehensive focus on the environment**
  - Increase renewable energy production
  - Increase volume of recyclable materials processed
  - Improve fleet fuel efficiency
  - Preserve and restore wildlife habitat
- **Altamont Landfill & Resource Recovery Facility**
  - Located near Livermore, CA
  - 7,000 tpd refuse from the Bay Area
  - Existing 8.5 MW electric generation





Trailer loading and storage

Altamont landfill gas to LNG project

The largest of its kind in the world

A Renewable Fuel Joint Venture Company

- 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



LNG Cold Box



Purification system and flare

Commissioning and Start-up

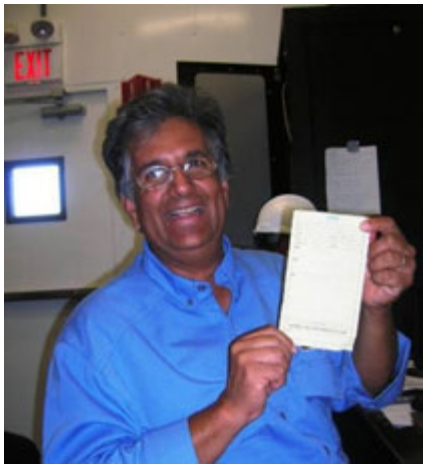
A Renewable Fuel Joint Venture Company

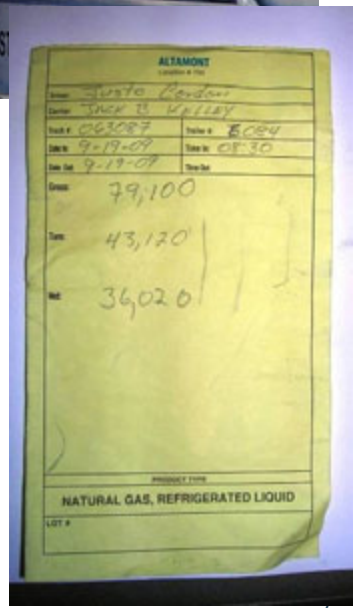
- Key dates:
  - July 6: Flare commissioning began
  - August 3: landfill gas introduced to purification system
  - September 16: Methane introduced to liquefier
  - September 19: First LNG trailer loaded
  - October 14: Unattended plant operation

- Performance through mid November
  - Over 250,000 gallons produced
  - Maximum sustained production: 13,000 gpd
  - Number of LNG trailers delivered: 25
  - Plant operates unattended nights and weekends

1st trailer loading – Sept 19







Challenges, next steps

WASTE MANAGEMENT

THE LINDE GROUP

Linde

A Renewable Fuel Joint Venture Company

- Key challenges
  - Flare & purification system interaction
    - *integrating flare, which likes steady state, and a dynamic purification system*
  - Aligning operation of multiple unit operations in purification system
    - *Going from 48% CH4 → 96%+ CH4*



- Next steps
  - Plant performance test: production and efficiency
  - Liquefier and purification system optimization
  - Purification system pilot testing for future plants



Conclusions





A Renewable Fuel Joint Venture Company

- Biogas to transportation fuels is technically and economically challenging
  - *But it can be done!!*
- We are moving down the path in meeting the technical challenges
  - But let's remember, the plant has only run for 2 months!
  - Need to optimize plant and run longer term
  - Improve capital and operating efficiencies on future plants
- The economic challenges
  - Codes for a new product and industry
  - Low natural gas prices
  - No market valuation for green, renewable aspect
- Finally……continued Government support is required
  - Reduce risks
  - Enables acceleration of technology and market development

Video: From Refuse to Refueling

Linde Gas

Go to:

http://www.youtube.com/watch?v=SjCjWVY3MOw

Thank-you

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