Methane to Markets

Landfill Biogas (LFG) Technology Applications

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Agenda

- LFG Utilization - General
- Direct Use – Medium BTU
- Direct Use – High BTU
- Electricity Production
- Combined Heat and Power

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Why Use Biogas (LFG)?

- Local, available fuel source
- Easy to capture and use
- Source of renewable energy
- Constant supply - 24 hours a day, 7 days a week
- Reliable technologies exist for using landfill gas
- Uses a source of energy that otherwise would have been wasted
- Helps the environment by reducing uncontrolled emissions of landfill gas

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Modern Municipal Solid Waste Landfill

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LFGE Project Benefits

- Destroys methane and other organic compounds in LFG
- Offsets use of nonrenewable resources
- Potential benefits for the landfill;
  - Another source of income
  - Local
- Potential benefits for the End User
  - Reduces fuel costs
  - Win through the use of renewable sources
  - Supports the strategy of being a “green” and/or sustainable company

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LFGE Project Benefits

- Each 1 MW of generation capacity o direct use of 615 m3/h is equivalent to:
  - Annual environmental equivalent to planting 4,900 hectare of trees or removing the CO2 emissions of 9,000 cars
  - Annual energy equivalent to preventing the use of 99,000 barrels of oil, offsetting the use of 200 railcars of coal, or powering more than 650 homes

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Landfill Gas has been used to help produce…?

- Flowers and tomatoes
- Pottery and glass
- Cars and trucks
- Pharmaceuticals
- Bricks and concrete
- Steel
- Orange and apple juice
- Biodiesel, LNG and ethanol
- Consumer goods and containers
- Fiberglass, nylon and paper
- Denim
- Electronics
- Chemicals
- Chocolate
- Dried wastewater sludge
- Soy-based products
- Carpet
- Infrared heat
- Green power
- Cost savings
- Increased sustainability

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Landfill Gas Utilization Options

- Medium BTU fuel. Used directly or with little treatment for commercial, institutional, and industrial use to supply water heaters, furnaces, aggregate dryers and conventional power generators. Typically contains 50% methane.
  - Leachate Evaporation. Landfill gas is used as fuel for the evaporation of leachate, thus reducing treatment costs.
- High BTU Fuel. Landfill gas is purified to levels of 92 to 99 percent methane by removing the carbon dioxide. End-use is Natural Gas or Compressed Natural Gas.
- Electricity. Landfill gas is used as fuel for internal combustion engines and turbines for the generation of energy to be send to the grid.

Landfill Gas 101 (Project Type)

"Sanitary Landfill" "Energy Delivery" "End-User" (MBTU)

"Pipeline"

High BTU Project

- Require high capital investments
- Requires at least 95% methane to sell to the Natural Gas company.

Electricity Generation

- Requires interconnection to the local electric grid.
- In the long term, it is economically dependent on the price of kWh

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Who uses Landfill Gas?

The Ultimate Driving Machine

INTERNATIONAL PAPER
From innovation to results.

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Landfill Gas Utilization

Direct Use:

Medium BTU Fuel

Direct Gas Utilization

- **Boilers**
- **Direct thermal applications**
  - **Kilns**
  - **furnaces**
- **Innovative applications**
  - Greenhouses
  - Infrared heaters
  - Pottery kilns
  - Leachate evaporation

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Direct Gas Utilization

- More than 100 projects in the US
- Pipeline length range from 0.6 to 15 kilometers
  - less than 10 kilometers is most feasible
- Gas used at off-site end user
- Gas piped to a nearby customer for use in boiler, kiln or other process

Three Rivers Solid Waste Authority
Kimberly Clark/Siemens - Aiken, South Carolina

Compression and Dehydration Plant

- 3390 M^3/hr Flow
- 25.6 km
- Compression to 40 $lb/pulg^2$
- Remote communications
- integration with the automated burner
- Compliance with specific design standards

Capital Costs

- ~$2.0 Million Dollars

Terms

- Design and Installation : 8 months

Compression Station

Jenkins Brick
Moody, Alabama

- 11 km pipeline
- Start-up in 2006
- Landfill supplies 1015 m3/hr to the brick kilns
  - Equivalent to 18 mmBtu/hr
- LFG is 45% of plants energy needs
- Benefits
  - Savings of more than $600,000 in seven years
  - Good public relations
  - Local economic development.

SOLAE - South Shelby Landfill Memphis, Tennessee

- Biggest renewable energy project in Tennessee.
- Capacity 8.475 m^3/hra.
- Constructed in 150 days.
- Combustion system was modified and the automated systems were integrated to optimize landfill gas use
- Design and construction of the flares and of the automated systems.
- Reduction of more than 65% of the emissions of NG
- 5 mile pipeline
- Reduction of NOx emissions greater than 75%

Landfill Gas Retrofit
Ocean Spray Corporation

- Systems design and integration to take the landfill gas to two new boilers
- Controls designed to operate without personnel
- Optimized to use the fuel with the least operational cost
- Remote monitoring and diagnostic system

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Greenhouses

- Use both electricity and heat.
- Carbon dioxide can be used to grow greenhouse plants.
- 6 operational greenhouse projects in the U.S.

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Energy Center

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Leachate Evaporation

- Utilize LFG to treat leachate
- Commercially available technology
- Units operating in the U.S. and internationally; 20 operational in the U.S.

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Landfill gas Utilization

Direct Use:

High BTU Fuel

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High-Btu Upgrade

- **Technology**
  - Gas is purified from 50% to 97- 99% methane
  - Removal of carbon dioxide is primary step
- **Advantages**
  - Inject treated product into pipeline
  - Methane can be used as raw material
  - Reduction in use of fossil fuels
- **Disadvantages**
  - Must meet strict standards of pipeline
  - Costly technology
  - Economical for large scale only

High BTU Fuel – Montauk Energy - Valley & Monroeville, PA

- Started operations in 2006.
- Landfill gas to high btu, pipeline quality (two plants)
  - Membrane technology
- Landfill gas delivered to:
  - Low pressure pipeline for local distribution
  - High pressure to national level pipeline

Photos courtesy of Montauk Energy

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LFG for Vehicle Fuel

- Compressed natural gas (CNG) to fuel landfill equipment and fleet vehicles
- CNG to fuel buses
- Diesel from LFG
- Methanol to biodiesel
- Ethanol production

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LFG Utilization

Electricity Generation

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Electricity Generation

- **Most prevalent type of project in the US**
  - In US, 1100 MW of capacity from over 250 operational projects
- **Sale of Electricity to**
  - Utility
  - Cooperative or industries enabled to buy directly
  - Nearby large customer
  - Auto generation or net metering
- **Average project size: 4 MW (500 kW - 50 MW)**

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Electricity Generation

- Internal Combustion Engines
- Turbines
- Microturbines
- New technologies
  - Fuel Cell

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Internal Combustion Engine

- **Sizing:** 350 kW - 3 MWs
- **Advantages**
  - Proven and reliable
  - Efficient
  - High availability > 92%
  - Do not require LFG pretreatment
- **Disadvantages**
  - High O&M costs
  - High NOx and CO emissions

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Turbines: Gas, Steam, and Combined Cycle

- **Sizing:** 1- 6 MWs
- **Advantages**
  - Corrosion resistant
  - Low O&M costs
  - Small physical size
  - Lower NOx emissions
- **Disadvantages**
  - Inefficient at partial load
  - High parasitic loads, due to high gas compression requirements
  - Require LFG pre-treatment

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Microturbines

- **Sizing:** 30-200 kW
- **Advantages**
  - Low emissions
  - Multiple fuel capability
  - Light weight/small size
  - Fuel pretreatment not required
  - Lower maintenance costs
- **Disadvantages**
  - Inefficient
  - High installed capital cost $/kW

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LFG Utilization

Combined Heat and Power

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Combined Heat and Power

- **Large Industrial**
- **Microturbine Applications**

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Combined Heat and Power

- **Advantages**
  - Greater overall energy recovery efficiency from waste heat recovery - up to 80%
  - Specialized CHP systems available
  - Flexible - hot water or steam generation from recovered heat
- **Disadvantages**
  - Higher capital costs for the recovery systems

Internal Combustion Generation Greenhouses – Model City, NY

- Developed by Innovative Energy Systems (IES)
- Online June 1, 2001
- 5.6 MW capacity from 7 Caterpillar G3516 engine-generator sets
- Provides all electrical and heating requirements of H_2Gro Greenhouses
- Excess electricity sold to grid
- 7½ acres and produces 10,000 lb/day or 3.5 million lb/yr of tomatoes

CHP
BMW – South Carolina

- 15 km pipeline
- 4 gas turbines retrofitted to burn LFG
- 4.8 MW = 25% energy needs of the plant
- 72 MMBtu/hr = 80% thermal needs of the plant (hot water, heat, cooling)
- BMW saves at least $1 million/yr

Combined Heat and Power Antioch, Illinois

- First school co-generation (CHP) project on LFG
- 12 microturbines with 360 kW capacity
- Exhaust energy produces 306,000 kJ/hour of hot water
- School expects to save $100,000/year

Colombian Electricity Tariffs

Simple Tariff Level 1

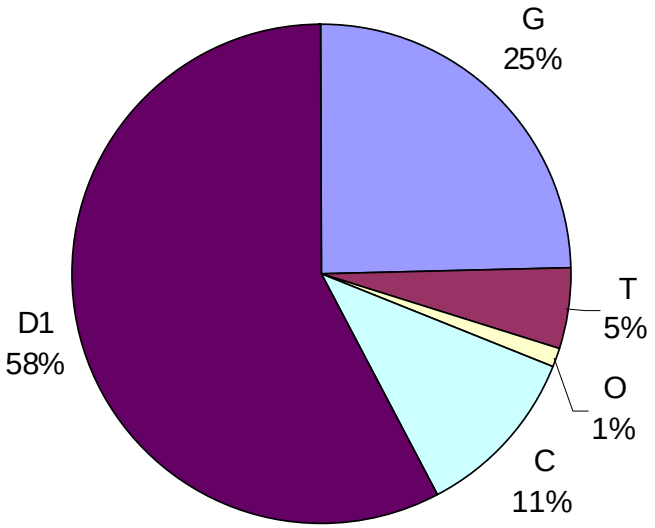
Industrial I = 339.6055 $/Kwh January 2, 2009 Codensa (CREG)

Industrial I = 325.69 December 15 , 2008 EPM (CREG)

EPM Antioquia Unificado (2007)							
G	T	O	C	D1	D2	D3	D4
82.66	17.69	3.57	37.32	194.2	146.79	49.31	15.13

Sell

Buy



Auto-generation and Co-generation

- Autogeneration - Resolution CREG O84 DE 1996
- Cogeneration - Resolution CREG 085 of 1996 modified and CREG-107 de 1998, CREG-032, Y CREG-039 de 2001
- Allows project developer to take advantage of distribution price to offset on-site load
- Does not need to be co-located; can generate on landfill and run a dedicated electricity line or a LFG pipeline and generate at end user
- Difficult to make a electricity project that merely exports to the gird at current wholesale pricing

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Direct Utilization of LFG

- Many times, most economically viable LFG utilization option
- End user must be located nearby (up to ~10 km), depending on LFG pipeline route complexity
- Can sell the LFG with discount off of natural gas distribution tariffs
- Key Point – Projects cannot work if Regulators require that LFG direct pipelines meet same regulations as NG pipelines

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Renewable Energy

- Law 697 de 2001 – Requires the Ministry of Energy and Mines develops a program to use renewable sources of energy
- Law 788 de 2002- Exemption of Taxes for 15 years with two conditions:
  - CDM Project
  - 50% of revenues are reinvested in social projects.
- Decree 2532 of 2001 – Exemption of sale taxes for equipment use on clean power generation
- No additional incentive tariff for renewables

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QUESTIONS

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