



# Conventional and Emerging Technology Applications for Utilizing Landfill Gas

*Presented by:*

**Rachel Goldstein**

**US EPA LMOP**

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# Agenda

- Uses of Landfill Gas
- Technologies- advantages and disadvantages
  - Direct Use
  - Electric
  - CHP
  - Microtubines
  - Vehicle Fuel

# EPA's Landfill Methane Outreach Program



- Established in 1994
- Voluntary program that creates alliances among states, energy users/providers, the landfill gas industry, and communities

*Mission: To reduce methane emissions by lowering barriers and promoting the development of cost-effective and environmentally beneficial landfill gas energy (LFGGE) projects.*



# Why Use Landfill Gas?

- 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 - >90% up time
- Uses a source of energy that otherwise would have been wasted
- Helps the environment by reducing uncontrolled emissions of landfill gas

# Possible Uses



- **Direct Use**
- **Combined Heat and Power**
- **Electricity Production**
- **Alternate Fuels**



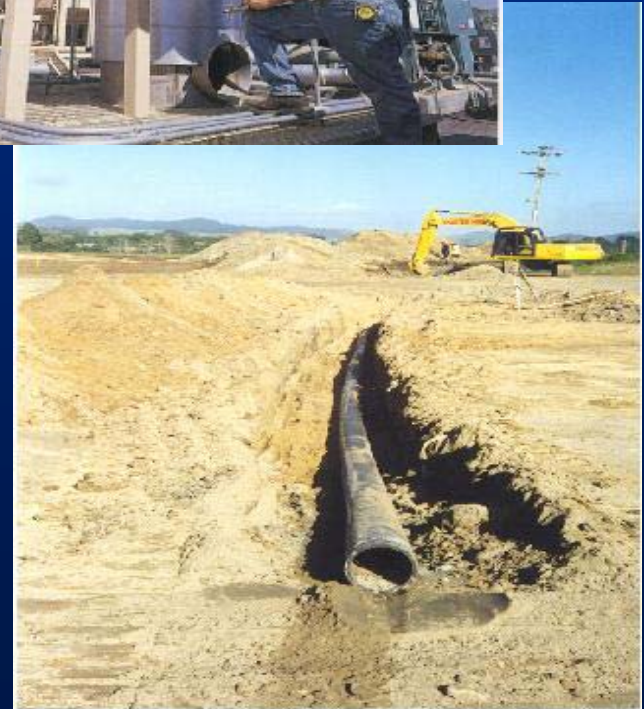
# Direct Gas Utilization

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

# Direct Gas Utilization



- Gas piped to a nearby customer for use in boiler or in industrial process
- 100 projects in the US
- Pipeline length range from half mile to 23 miles
- Gas used on-site





# Direct Use: Boilers

- **Advantages**

- Can be used either in industrial process or for electricity generation in steam turbine
- Mature technology

- **Disadvantages**

- Need large landfill size
- End use facility may require boiler retrofits which can be expensive
- Need high pressure for steam turbine use





# Direct Use: Boilers

- **Sizing**

- Generally require larger landfill size, 3-5 million tons of waste in place

- **Costs**

- \$1.50 to \$3.50 per MMBtu, depending on
  - ◆ Need for boiler retrofits
  - ◆ Whether for use in industrial process or in steam turbine

# Direct Use: Thermal Applications



- **Advantages**

- Simple technology
- Minimal processing requirements
- Most cost effective

- **Disadvantages**

- Need energy user to be sited in close proximity to the landfill
- Right of way permits
- Local terrain may not be conducive to pipeline installation

# Direct Use: Thermal Applications



- **Sizing**

- Applicable to wide variety of landfill sizes

- **Costs**

- \$1.50 to \$3.50 per MMBtu, depending on
  - ◆ Pipeline length
  - ◆ Collection system in-place at landfill
  - ◆ Terrain

# Combined Heat and Power



- Large Industrial
- Microturbine Applications

# Combined Heat and Power: Industrial



## ● 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

- Additional cost associated with electricity generation component

# Combined Heat and Power: Industrial



- **Sizing**

- Generally applicable to mid to larger size landfills

- **Costs**

- Available information indicate overall costs in the \$1200-\$2000 per kWh range.

# Combined Heat and Power: Microturbines



## ● Advantages

- Greater overall energy recovery efficiency from waste heat recovery - up to 75%
- Specialized CHP systems available
- Flexible - hot water or steam generation from recovered heat
- Low emissions and noise

## ● Disadvantages

- Additional cost associated with electricity generation component
- Cost of gas conditioning to remove Siloxane

# Combined Heat and Power: Microturbines



- **Sizing**

- Generally applicable to small to mid size landfills

- **Costs**

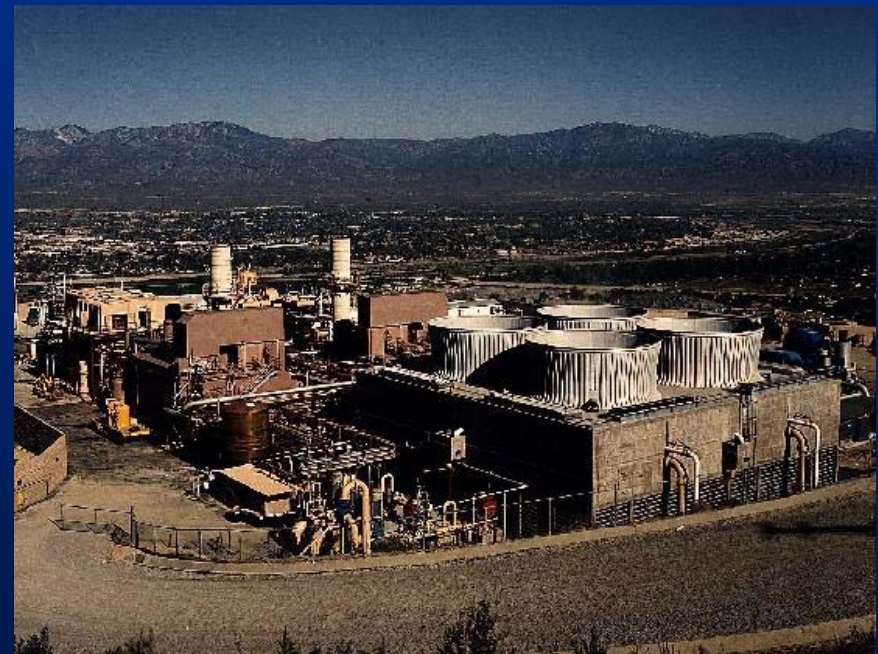
- Available information indicate overall installed costs in the \$1800-\$3000 per kWh range.



# Electricity Generation



- **Most prevalent type of project in the US**
  - In US, 1000 MW of capacity from over 200 operational projects
- **Electricity sold to utility, cooperative or nearby customer**
- **Average project size: 3 MW (500 kW - 50 MW)**



50 MW Steam Turbine, Puente Hills LF, CA

# Electricity Generation



- **Internal Combustion Engines**
- **Turbines**
- **Microturbines**
- **Emerging Technologies**
  - Stirling Engine
  - Organic Rankine Cycle Engine

# Internal Combustion Engine



- **Advantages**

- Low cost, high efficiency and reliability
- Most common technology

- **Disadvantages**

- Problems due to particulate matter buildup
- Corrosion of engine parts and catalysts
- High NO<sub>x</sub> emissions

# Internal Combustion Engine



- **Sizing**
  - 1-3 MWs
- **Costs**
  - \$1,100-1,300 (\$/kW)
- **Major suppliers**
  - Cat, Jenbacher, Waukesha, Deutz



# Small Internal Combustion Engine



- **Advantages**

- Function on low input landfill gas pressure (<1 psig)



Man EO826E, Lean Burn, 55kW

- **Disadvantages**

- Similar to larger IC engines



MAN E2842 LE302 Lean Burn, 315 kW

# Small Internal Combustion Engine



- **Sizing**
  - 55-800 kW
- **Costs**
  - Not easily available, expected to be lower than microturbine capital and O&M costs
- **Major suppliers**
  - MAN, LFG Specialties

# Turbines: Gas, Steam, and Combined Cycle



- **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



# Turbines: Gas, Steam, and Combined Cycle



- **Sizing**
  - 1-10MWs
- **Costs**
  - \$1,200-1,700 (\$/kW)
- **Major suppliers: Cat, Fairbanks-Morse**





# Microturbines



- **Advantages**

- Low emissions
- Multiple fuel capability
- Light weight/small size
- Fuel pretreatment not required
- Lower maintenance costs

- **Disadvantages**

- Low efficiencies
- Primarily tested for natural gas applications
- Less proven technology



# Microturbines

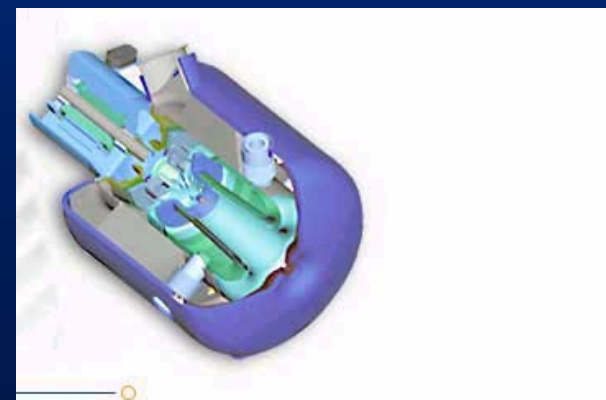


- **Sizing**

- 30-250 kW

- **Costs**

- Equipment Costs:  
\$1,200-\$2,000 (\$/kW)
- Installed Costs:  
\$2,200 - \$3,500 (\$/kW)
- Maintenance Costs:  
\$0.01-0.015 (\$/kW)



Allied Signal Parallon 75

# Emerging Technologies

- **Stirling External Combustion Engine**
  - Advantages
    - ◆ Lower emissions
    - ◆ Reliable, scalable, fewer moving parts
  - Disadvantages
    - ◆ Limited track record of performance



# Emerging Technologies

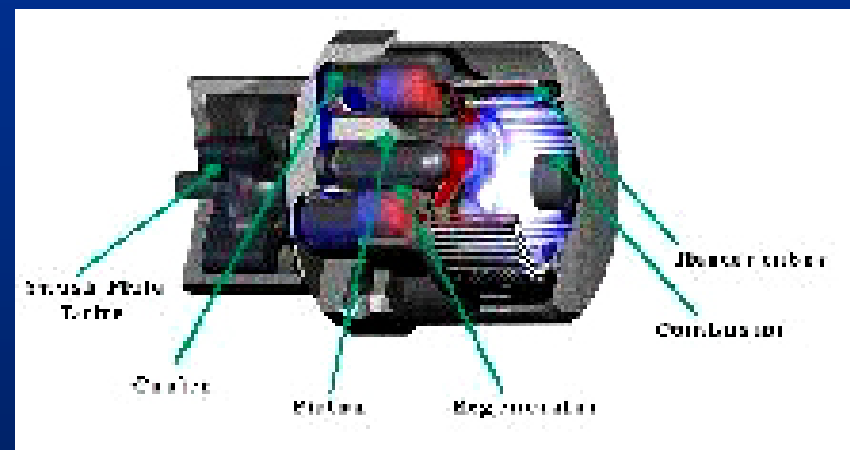
- **Stirling External Combustion Engine (Continued)**

- **Sizing**

- ◆ 25 - 55 kW

- **Costs**

- ◆ O&M approximately 0.8 cents/kW
- ◆ Capital Cost - limited information, demonstration project in Michigan should provide more detailed costs



# Emerging Technologies



- Organic Rankine Cycle Engine
  - Advantages
    - ◆ Provides up to 225 kW electrical power
    - ◆ Free fuel - waste heat powered
    - ◆ No additional emissions
    - ◆ Low life-cycle cost
  - Disadvantages
    - ◆ New unproven technology for LFG



# Alternate Fuels



- **High-Btu Upgrade**
- **Vehicle Fuels LNG/CNG**

# Alternate Fuels – High-Btu Upgrades



- **Technology**

- Gas is purified from 50% to 97% or 99% methane
- Removal of Carbon dioxide is primary step

- **Advantages**

- Inject treated product into pipeline
- Reduction in use of fossil fuels
- Reduce local ozone pollution

- **Disadvantages**

- Must meet strict standards of pipeline
- Costly technology
- Limited track record of performance

# Alternate Fuels – High-Btu Upgrades



## Sizing

- Economical for large scale only

## Costs

- Capital Costs for 2000 cubic ft/min. system range from \$3 million to \$4 million
- O&M costs range from \$0.82 to \$1.12 per MMBtu



# Alternate Fuels - Vehicle Fuel



- **Compressed landfill gas (CNG)**
- **Liquefied landfill gas (LNG) - CryoEnergy®**
- **Bio-Diesel**





# Alternate Fuels- Vehicle Fuel

- **Advantages**

- LNG/CNG price lower than diesel fuel cost
- Reduction in use of fossil fuels
- Reduce local ozone pollution

- **Disadvantages**

- Very small percentage of alternative-fuel vehicles
- Vehicle conversion costs
- Limited track record of performance

- **Costs**

- Retrofit vehicles = \$3,500 to \$4,000 per vehicle
- Fueling station = \$1,000,000
- Fuel price = \$0.48 to \$1.26 per gallon

# California Opportunities



- Currently there are close to 80 landfill gas energy projects operational, with additional 5 projects under construction.
- A total of 280 MW of energy being produced.
- There are an additional 43 candidate landfills around the state with estimated project potential of 50 MWs of energy.
- Microturbines
  - 11 operational projects in California, utilizing over 50 microturbine units
  - Generating 2,710 kW of power

# Summary



- **Many ways to beneficially utilize LFG**
- **Available niche technologies range from research and development stage units to commercially available systems**
- **Technologies exist for low and high volumes of LFG production**
- **Selection of technology is project specific**

# Summary, continued....



- **Key Selection considerations include:**
  - Environmental performance
  - Reliability
  - Accuracy of assumptions
  - Permitting issues – emissions
  - Cost