Conventional and Emerging Technology Applications for Utilizing Landfill Gas

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On behalf of USEPA LMOP

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Methane to Markets Ministerial Meeting

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Possible Uses

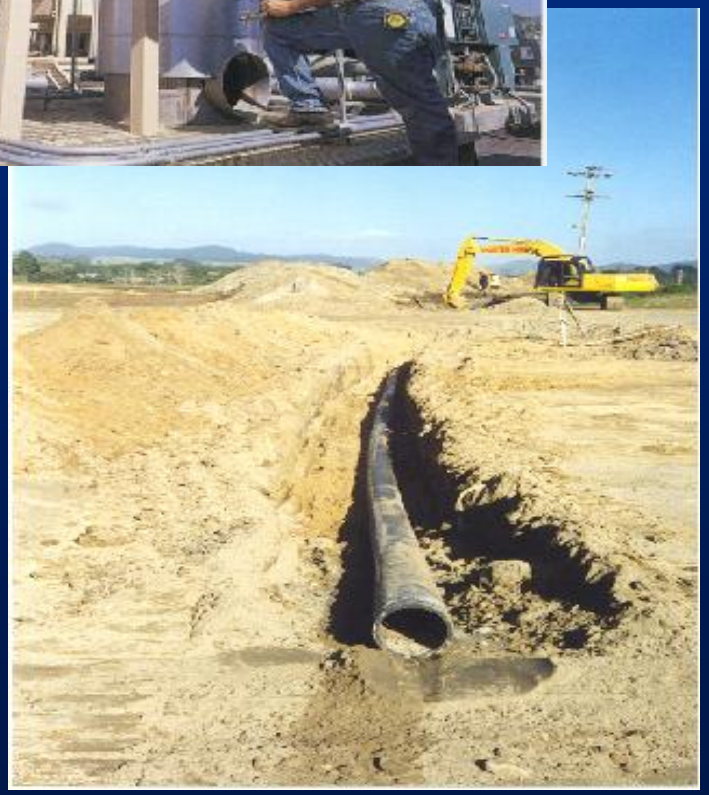
- Direct Use
- Combined Heat and Power
- Electricity Production
- Alternate Fuels

Direct Gas Utilization

- **Boilers**
- **Direct thermal 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 1/3 to 11 miles
  - less than 3 miles is most feasible
- Gas used on-site



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

- **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

Direct Use: Thermal Applications- Greenhouses

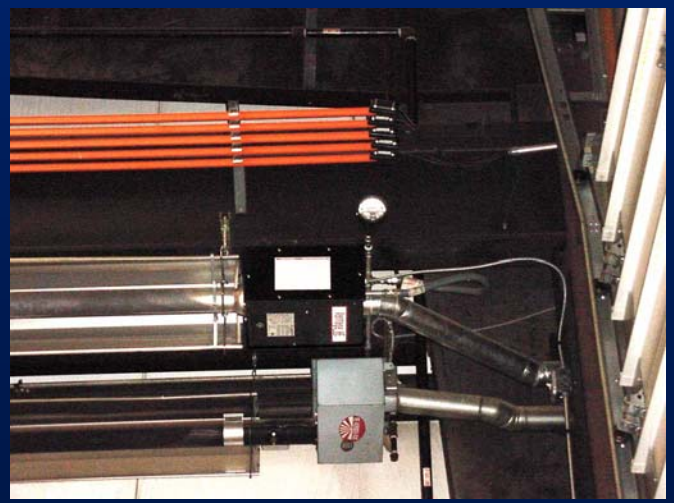
- Applicable to smaller landfills
- Produce high purity carbon dioxide that is used to grow greenhouse plants
- 5 operational greenhouse projects in the U.S.

Direct Use: Thermal Applications- Greenhouses

- **Sizing**
  - Depends on greenhouse size - generally require relatively low LFG volume
- **Costs**
  - Limited cost information available; one project in the U.S. estimated costs to be around $4.80 per MMBtu

Direct Use: Thermal Applications- Infrared Heaters

- Applicable to smaller landfills
- Infrared rays directly heat
- Facilities with space heating needs near or at landfill
- 2 operational infrared heater projects in the U.S.



Direct Use: Thermal Applications- Infrared Heaters

- **Sizing**
  - Depends on facility size - generally require relatively low LFG volume (i.e., 30 cfm for 6500 sq. ft.)
- **Costs**
  - Limited cost information available; two projects in the U.S. estimated costs to be around $10.80 per building sq. ft.

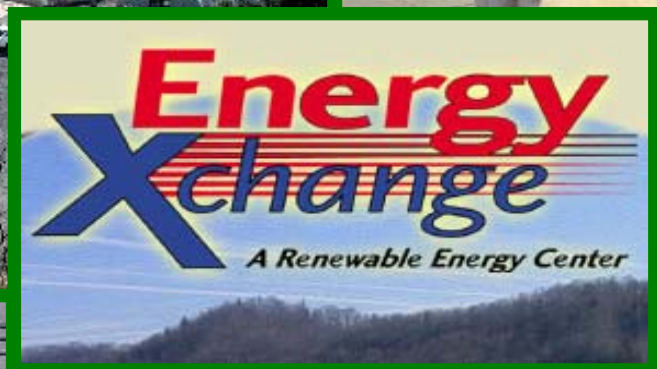
Direct Use: Thermal Applications- Pottery Kilns

- Applicable to smaller landfills
- LFG used in kilns instead of natural gas
- Projects to date are located at landfill

Pottery Studio Sugar Grove, NC

Direct Use: Thermal Applications- Pottery Kilns

LANDFILL METHANE OUTREACH PROGRAM

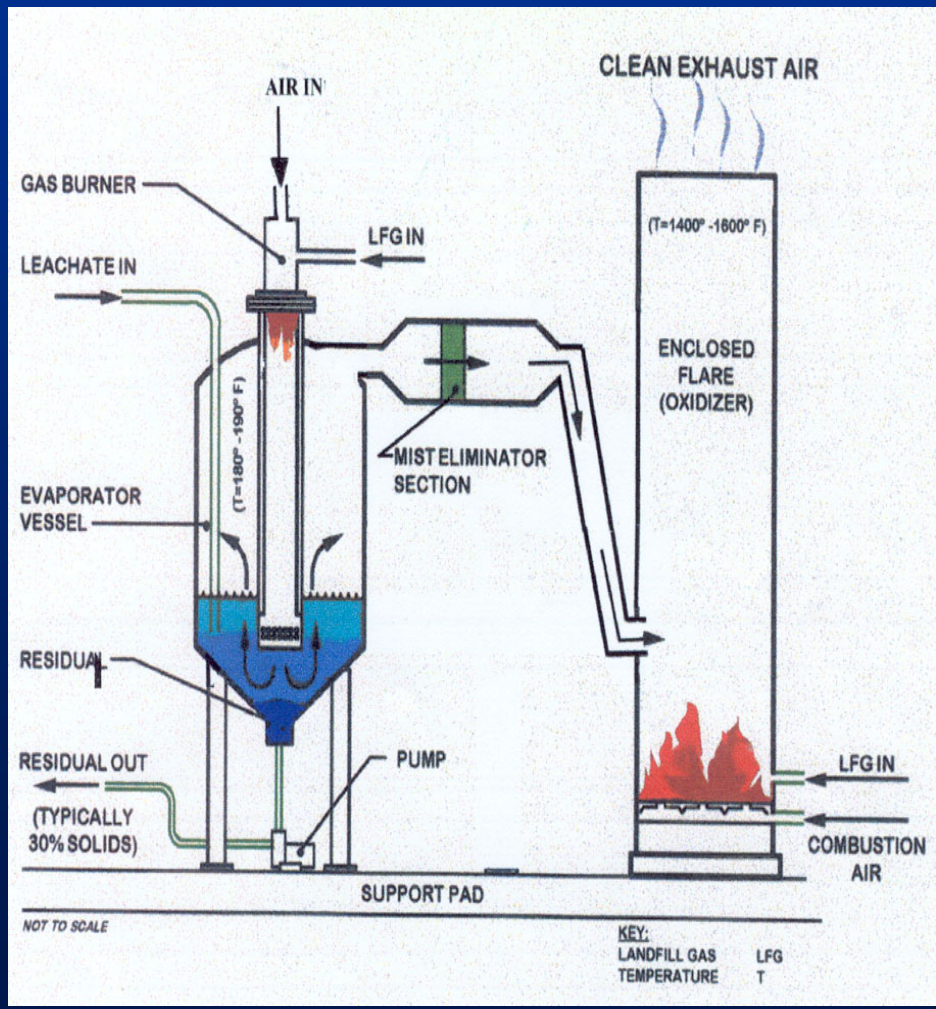


Direct Use: Thermal Applications- Leachate Evaporation

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

Direct Use: Thermal Applications- Leachate Evaporation

- **Sizing**
  - 10,000 to 20,000 gallons per day
- **Costs**
  - Capital Cost - $295,000 (10,000 gpd) to $485,000 (20,000 gpd)
  - Annual O&M Cost - $70,000 to $95,000



Direct Use: Thermal Applications- Other

- Cement Kilns
- Asphalt Plants

Combined Heat and Power

- Large Industrial
- Microturbine Applications

Combined Heat and Power: Industrial

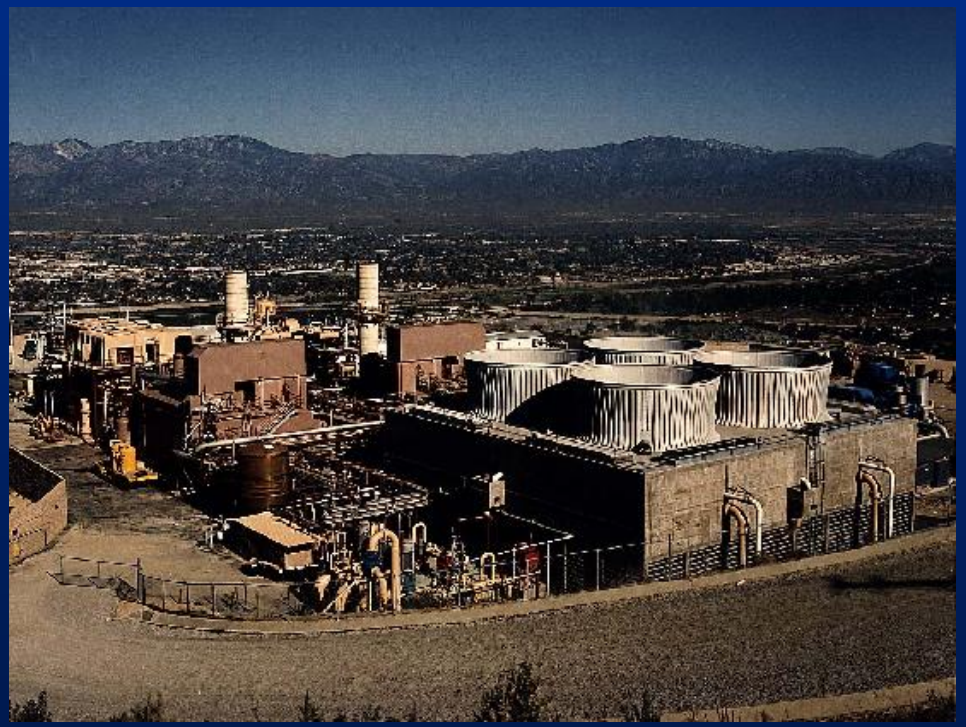
- **Sizing**
  - Generally applicable to mid to larger size landfills
- **Costs**
  - Available information indicate overall costs in the $1200-$2000 per kWh range.

Combined Heat and Power: Microturbines

- **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: 4 MW (500 kW - 50 MW)**



50 MW Steam Turbine, Puente Hills LF, CA

Electricity Generation

- **Internal Combustion Engines**
- **Turbines**
- **Microturbines**
- **Emerging Technologies**
  - Stirling Engine

Internal Combustion Engine

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

Small Internal Combustion Engine

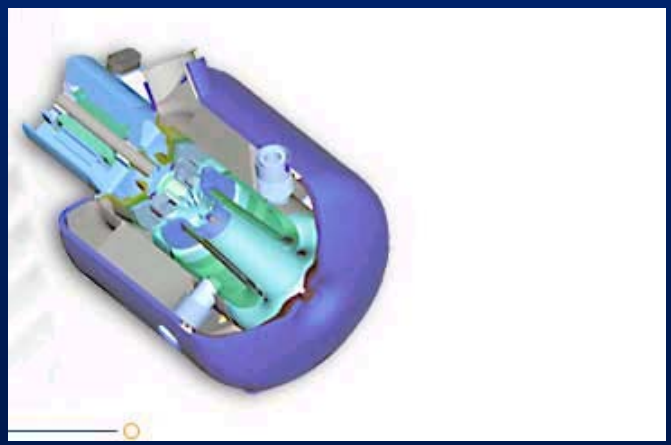
- **Sizing**
  - 55-800 kW
- **Costs**
  - Not easily available, expected to be lower than microturbine capital and O&M costs
- **Major suppliers**
  - MAN, LFG Specialties

Turbines: Gas, Steam, and Combined Cycle

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

Microturbines

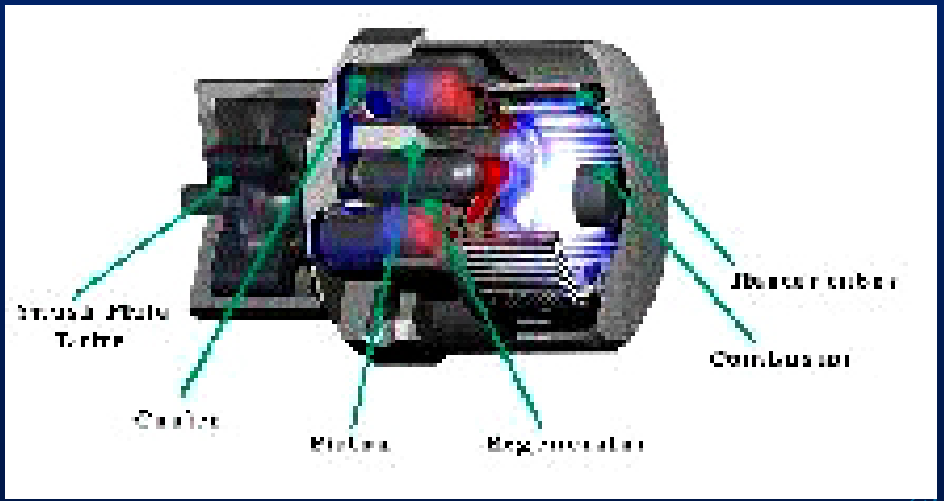
- **Sizing**
  - 30-200 kW
- **Costs**
  - $1,200-2,000 ($/kW)



Allied Signal Parallon 75

Emerging Technologies

- **Stirling External Combustion Engine**
  - Sizing
    - 25 - 55 kW
  - Costs
    - O&M approximately 0.8 cents/kW
    - Capital Cost - limited information – just in production



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

Alternate Fuels – High-Btu Upgrades

Sizing

- Economical for large scale only

Costs

- Capital Costs for 2,000 cfm 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®
- Early stages of commercial development

Alternate Fuels- Vehicle Fuel

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

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