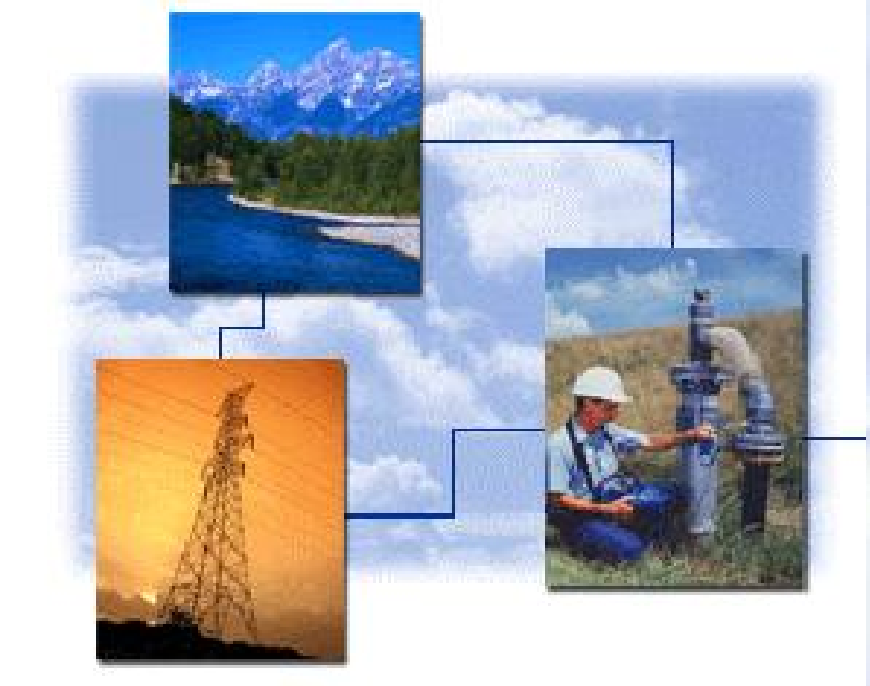
An Overview of Landfill Gas Energy in the U.S.



Chris Voell, Program Manager
U.S. Environmental Protection Agency
Landfill Methane Outreach Program (LMOP)

LANDFILL METHANE OUTREACH PROGRAM

May 2005

Why Does EPA Care About LFG?

- Methane is a potent heat-trapping gas: landfills largest human-made source in US
- Distributed generation opportunity
- Promotes energy independence - local, renewable energy source
- Use an otherwise wasted resource
- Promote jobs, economic development and cost savings
- There are many cost effective options for reducing methane emissions while generating energy
- Projects reduce local air pollution

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 (LFGE) projects.

Modern Municipal Solid Waste Landfill

Landfill Gas 101

- Landfill gas (LFG) is a by-product of the decomposition of municipal solid waste (MSW).
  - It is extracted from the landfill through a series of horizontal and vertical wells and a vacuum
- LFG:
  - ~ 50% methane (CH_4).
  - ~ 50% carbon dioxide (CO_2).
  - <1% non-methane organic compounds (NMOCs).
- For every 1 million tons of MSW:
  - ~ 0.8 MW of electricity
  - ~ 400,000 cubic feet per day of landfill gas
- If uncontrolled, LFG may contribute to smog, global warming, and health and safety concerns.

LFG Energy Emission Reduction Benefits (lbs/MWh)

- As a general rule, landfill gas burned in a boiler as a substitute for natural gas will reduce NOx emissions

Emission Type (LFG from AP-42; others from eGRID)	NO_x	SO_2	Mercury
Weighted Average for all LFG Electricity Generating Technologies	2.05	0.17	3.4×10^{-6}
National Grid Average – Emitting Sources Only	4.09	8.48	37.0×10^{-6}
National Grid Average – All Sources	2.96	6.04	27.2×10^{-6}

LFGE Projects Provide Dual Benefits

- Destroys methane and other organic compounds in LFG
- Offsets use of nonrenewable resources (coal, oil, gas) reducing emissions of:
  - SO_2 contributes to acid rain
  - NO_x contributes to ozone formation and smog
  - CO_2 is a global warming gas
- Each 1 MW of generation capacity:
  - Annual environmental equivalent to planting 12,000 acres 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

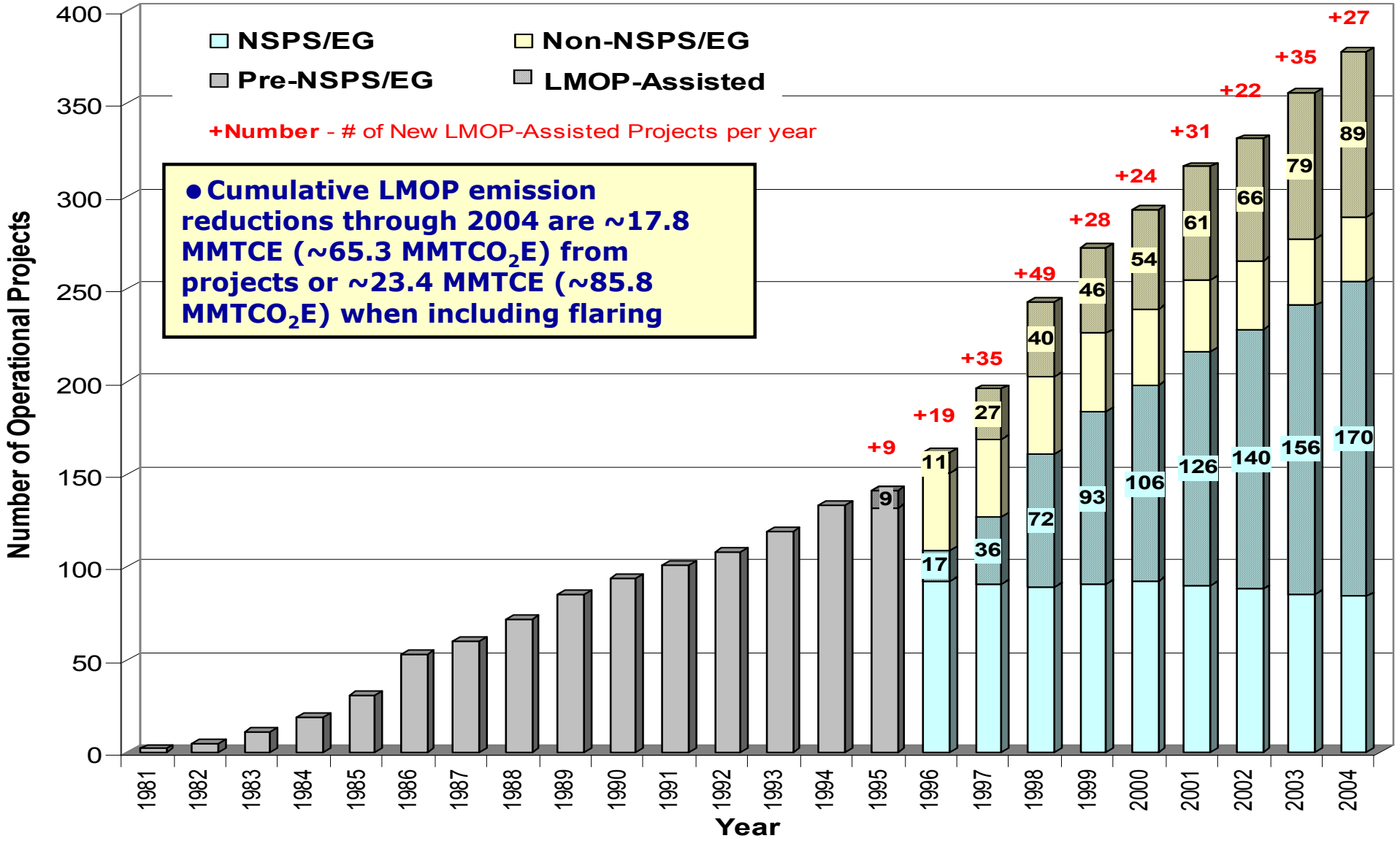
State of the LFGE Industry

- 375 operational projects
  - ~9 billion kWh of electricity produced and ~70 billion cubic feet of gas delivered in '04
- At least 25 projects under construction for 2005 with many more in the advanced planning stages
- Over 600 candidate landfills with 1,500 MW of potential capacity *or* 280 billion cubic feet/yr of LFG for direct use and ~17 MMTCE potential emissions reductions

Environmental Benefits

- Estimated **Annual** Benefits:
  - Planting over **19,000,000 acres of forest**,
  - Preventing the use of over **150,000,000 barrels of oil**,
  - Removing emissions equivalent to over **14,000,000 cars**, or
  - Offsetting the use of **325,000 railcars of coal**.

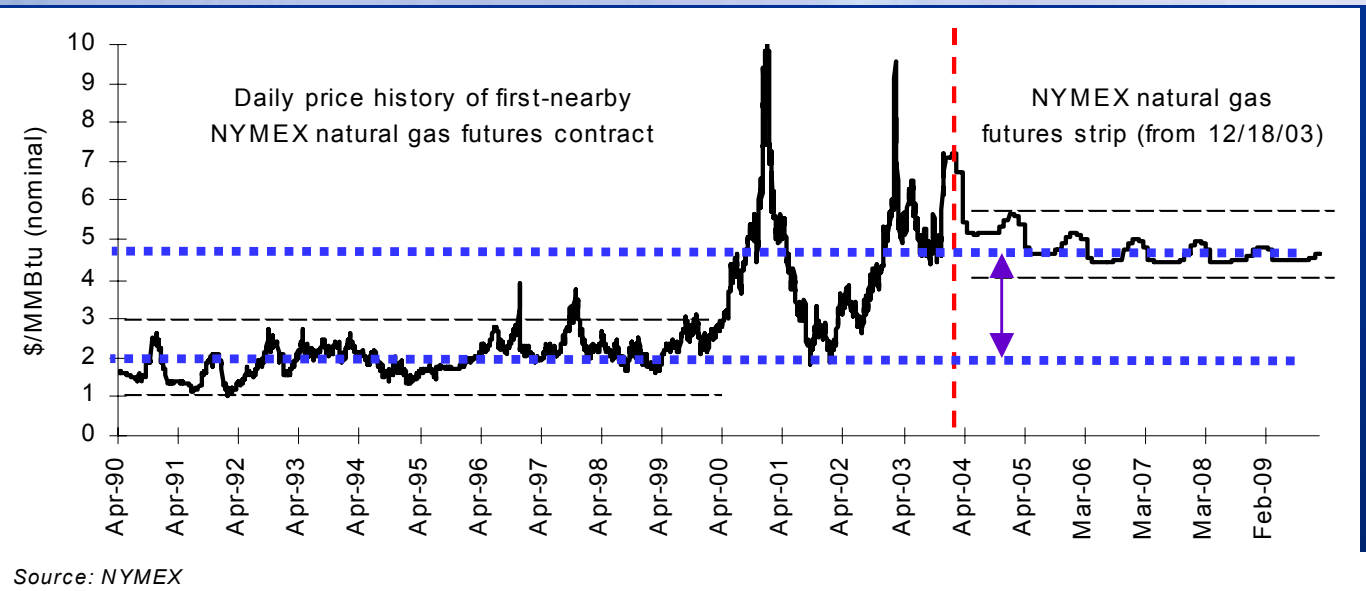
Growth in Landfill Gas Utilization Project Development



Landfill Gas and Green Power
A Winning Combination

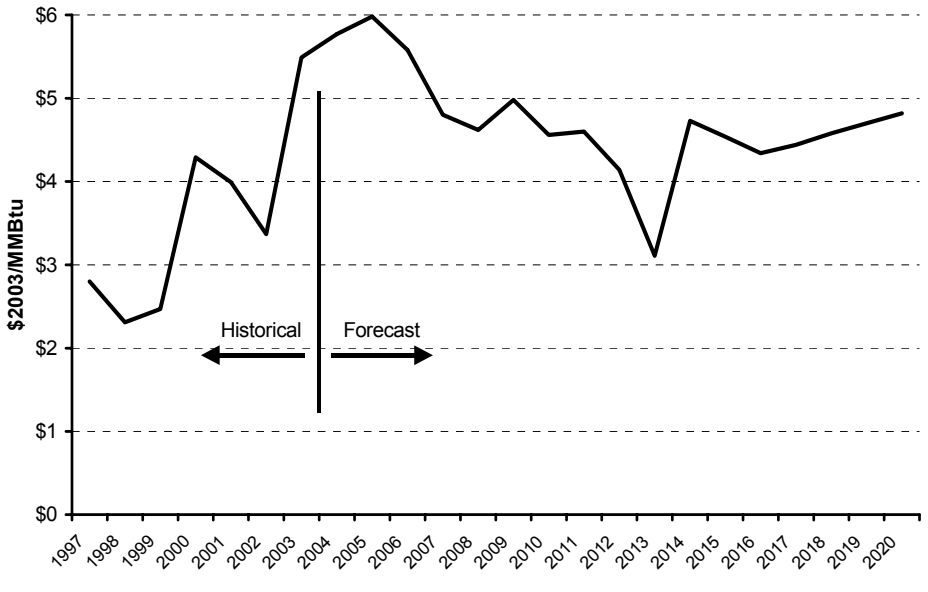
- LFGE is a recognized renewable energy resource
  - *Green-e*, EPA Green Power Partnership, Sierra Club
- LFG is generated 24/7 and projects have on-line reliability over 90%
- Serves as the "baseload renewable" for many green power programs
- Levelized cost of 4–6 cents per kWh for new electricity projects
- LFG can act as a long-term price and volatility hedge against fossil fuels
- Coops/Munis/Utilities are already using LFGE
  - over 50 green power programs currently have LFG in portfolio

Natural Gas Prices Continue to Rise and Remain Volatile



Source: NYMEX

EEA Forecast of Natural Gas Price at Henry Hub



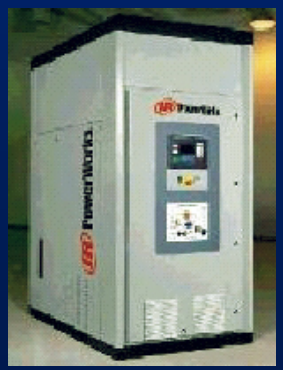
Diversity of Project Types
Electricity Generation

LANDFILL METHANE OUTREACH PROGRAM

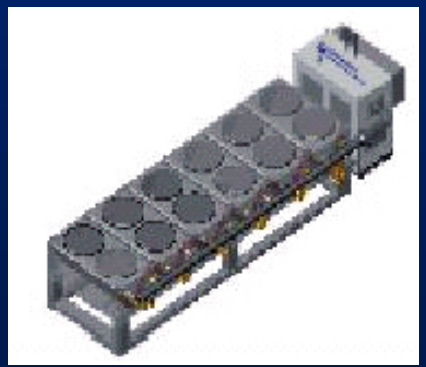
Internal Combustion Engine

Gas Turbine

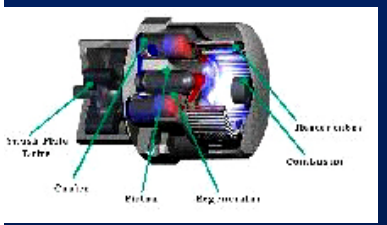
Emerging Technologies



Microturbine



Organic Rankine Cycle Engine



Stirling "External Combustion" Engine

Diversity of Project Types
Direct Use of LFG

- Direct-use projects are growing!
  - Boiler applications - replace natural gas, coal, fuel oil
  - Combined heat & power (CHP)
  - Direct thermal (dryers, kilns)
  - Natural gas pipeline injection
    - Medium and high-Btu
  - Greenhouse
  - Leachate evaporation
  - Vehicle fuel (LNG)
  - Artist studios
  - Hydroponics
  - Aquaculture (fish farming)

Greenhouse Burlington, NJ

Pottery Studio Sugar Grove, NC

LFG-fired Boiler Ft. Wayne, IN

Look Who's Using Landfill Gas

Honeywell

DAIRYLAND POWER COOPERATIVE

NUCOR

The Solae Company

Owens Corning

CONE corporatedenimfinishingjacquards

HILL AIR FORCE BASE, Utah
OGDEN AIR LOGISTICS CENTER

GE

Frito Lay

Cargill

Rolls-Royce

SENECA Foods.com "A World Leader In Agribusiness"

SC Johnson

International

Ford

SUNOCO

LAFARGE

MALLINCKRODT

AJINOMOTO

NASA

Nestlé Makes the Very Best

Lucent Technologies Bell Labs Innovations

GM

BMW The Ultimate Driving Machine

INTERNATIONAL PAPER From innovation to results.

DAIMLERCHRYSLER

"It's a clean-burning fuel and makes a perfect power source for the plant's boilers. It's reduced our dependence on coal."

Michael Schafran, Environmental Engineer,
General Motors Orion Assembly Plant

Direct Use Case Study

GM Truck Assembly Plant Fort Wayne, Indiana

LFG-fired Boiler Ft. Wayne, IN

- Direct use of LFG in boiler since Feb '02. Replaces fuel oil.
  - 9-mile pipeline.
  - Produces steam to heat assembly plant and process equipment, and to drive turbines to produce chilled water and to pump water.
  - Positive public reaction.
- One of five GM projects estimated to save in excess of $5 million annually (2000 billion BTU/year fossil fuels savings).

"The greenhouse gases we save through this LFG energy project will be equivalent to keeping 3,200 cars off the road per year. That's right for SCJ, our community and our planet today – and even more important, it's right for the generations of tomorrow."

Dr. H. Fisk Johnson, Chairman of SC Johnson and Sons

Direct Use Case Study

SC Johnson & Son, Inc. Waxdale Plant Racine, Wisconsin

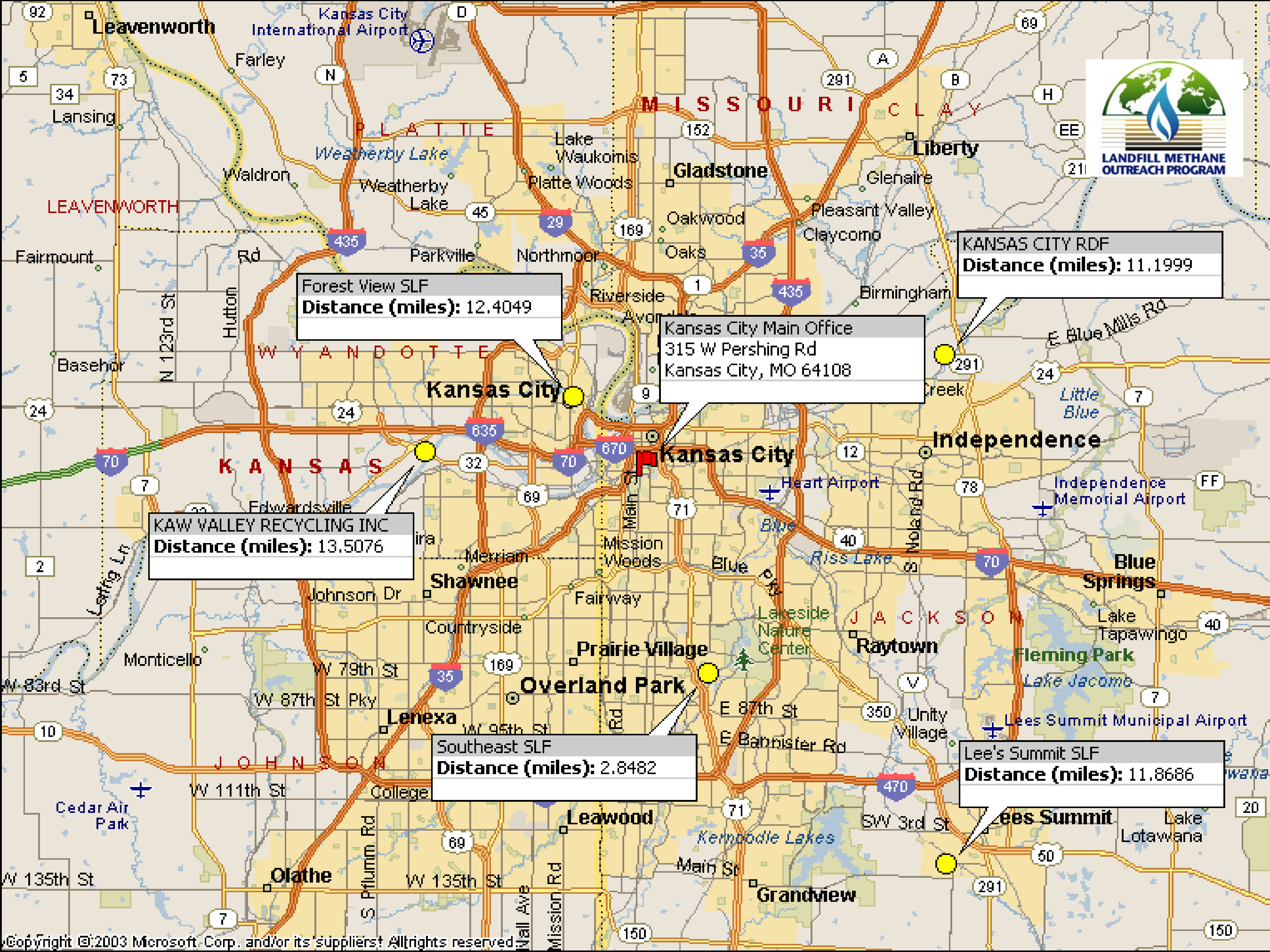
- Have used LFG in boilers for 14 years.
- Changed to a combined heat and power (CHP) LFG turbine project.
- Will produce 3.2 MW of electricity. Recover waste heat to produce 17,000 lb/hr steam.
- Reduce plant fossil fuel use by 50%. Reduce plant GHG emissions by 47%.
- Projected gross energy savings $2.4 million/yr (net - $1 million/yr).

There Are Still Many Untapped LFG Resources

- Currently over 600 candidate landfills and a total MW potential of over 1,700 MW.
- Total expected annual environmental benefits if all projects were developed/ producing power:
  - **Planting over 20 million acres of forest, or**
  - **Removing the emissions from over 14.6 million cars on the road, or**
  - **Powering over 1 million homes per year.**

How can we work together?

- Assess landfill and end user facilities
- Identify potential matches
- Analyze landfill resource
- Look at project possibilities
- Initial feasibility analyses
- Facilitate networking


LANDFILL METHANE OUTREACH PROGRAM
Kansas City Main Office
315 W Pershing Rd
Kansas City, MO 64108
Forest View SLF
Distance (miles): 12.4049
KANSAS CITY RDF
Distance (miles): 11.1999
KAW VALLEY RECYCLING INC
Distance (miles): 13.5076
Southeast SLF
Distance (miles): 2.8482
Lee's Summit SLF
Distance (miles): 11.8686
Leavenworth
Kansas City International Airport
Farley
Lansing
MISSOURI
PLATTE
CLAY
Liberty
Weatherby Lake
Waldron
LEAVENWORTH
Lake Waukomis
Platte Woods
Gladstone
Glenaire
Pleasant Valley
Oakwood
Claycomo
Oaks
Parkville
Northmoor
Fairmount
Riverside
Birmingham
Basehor
WYANDOTTE
Kansas City
E. Blue Mills Rd
Little Blue
Independence
KANSAS
Edwardsville
Heart Airport
Independence Memorial Airport
Merriam
Mission Woods
Shawnee
Riss Lake
Blue Springs
Johnson Dr
Fairway
Countryside
JACKSON
Lake Tapawingo
Lakeside Nature Center
Raytown
Fleming Park
Monticello
Prairie Village
W 79th St
Overland Park
Lake Jacomo
W 83rd St
W 87th St Pky
Lenexa
E 87th St
Unity Village
Lees Summit Municipal Airport
W 95th St
E Bannister Rd
JOHNSON
Cedar Air Park
W 111th St
College
Leawood
Kemoodle Lakes
SW 3rd St
Lees Summit
Lake Lotawana
Olathe
W 135th St
Main St
Grandview
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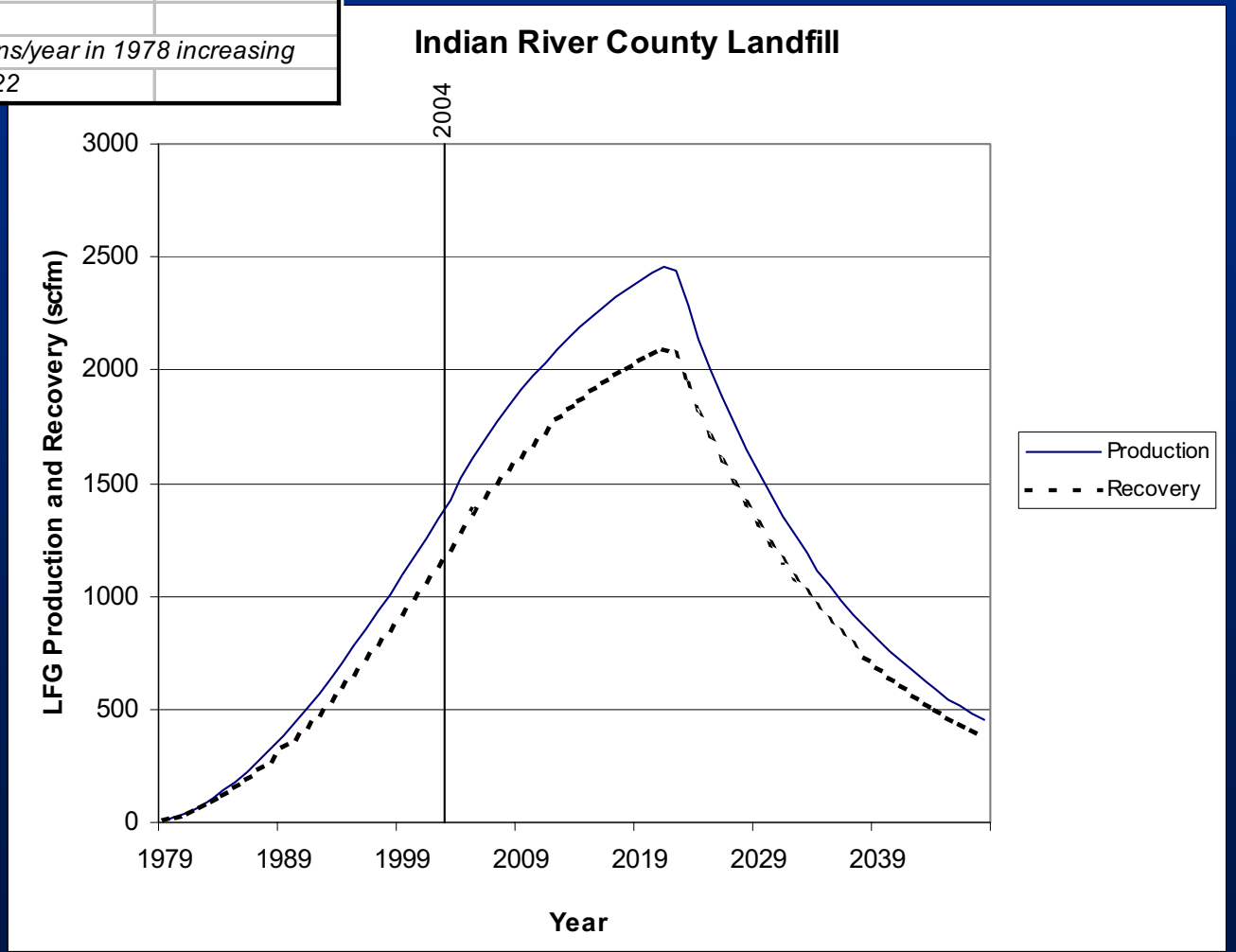
Analyze Landfill Resource

Indian River County Landfill, Vero Beach, FL				
LMOP Landfill ID #408				
Year Landfill Opened: 1978				
Calculated Landfill Closure: 2022				
Landfill Capacity (MSW): 7,188,000 tons				
Waste-in-place (MSW): 2,842,000 tons (as of 2003)				
Calculated Annual Waste Acceptance Rate (MSW): 11,370 tons/year in 1978 increasing				
	30% yearly to 232,000 tons/yr for 2003 to 2022			



Look at Project Possibilities

- Direct Use
  - boiler, heating, cooling, direct thermal, greenhouses, pottery/glass blowing
- Combined Heat and Power (Co-Generation)
  - engines, turbines, microturbines; hot water and steam; chillers
- Electricity Production
  - internal combustion engine, turbine, microturbine; emerging - Organic Rankine Cycle, Stirling Engine
- Alternate Fuels
  - medium-Btu or high-Btu pipeline injection
  - methanol, compressed NG, liquefied NG

Initial Feasibility Analysis

INPUTS / OUTPUTS

Enter Landfill Name or Identifier: Indian River County Landfill

LANDFILL METHANE OUTREACH PROGRAM

Print Summary Report

Required User Inputs:

Type of Input Required		Input Data
Year landfill opened		1978
Year of landfill closure		2022
Area of landfill waste for LFG to be collected (acres)		72
Method for entering waste acceptance data [CHOOSE ONLY ONE METHOD]:	Average annual waste acceptance rate (tons/yr)	
	Waste acceptance rate calculator (in WASTE worksheet)	Go to WASTE
	Annual waste disposal history (in WASTE worksheet)	Go to WASTE
LFG energy project type: (D)irect use, (T)urbine, (E)ngine, (L)NG, microtu(R)bine, small en(G)ine, or lea(C)hate evaporator?		D
Will LFG energy project cost include collection and flaring costs? (Y)es or (N)o		N
For leachate evaporator projects only: Amount of leachate collected (gal/yr)		
Year LFG energy project begins operation		2005
Expected LFG energy project lifetime (years)		15

Outputs:

Type of Output	Output Data
Economic Analysis:	
Average project size for projects NOT generating electricity: (million ft^3/yr)	78.624
[based on actual LFG use] (ft^3/min)	149.589
Average project size for projects generating electricity (kWh/yr)	0
Total installed capital cost for year of construction ($)	$345,814
Annual costs for initial year of operation ($)	$21,531
Internal rate of return (%)	48%
Net present value at year of construction ($)	$353,148
Net present value payback* (years after operation begins)	3
Environmental Benefits:	
Total lifetime amount of methane collected and destroyed (million ft^3)	6,661
Average annual amount of methane collected and destroyed (million ft^3/yr)	444
GHG value of total lifetime amount of methane utilized ($MMTCO_2E$)	2.38E-01
GHG value of average annual amount of methane utilized ($MMTCO_2E$/yr)	1.58E-02
Total lifetime carbon dioxide from avoided energy generation: ($MMTCO_2E$)	3.11E-02
(MMTCE)	8.48E-03
Average annual carbon dioxide from avoided energy generation: ($MMTCO_2E$/yr)	2.07E-03
(MMTCE/yr)	5.65E-04

* "None" = no return on investment or no payback in LFG energy project lifetime

The size of this landfill indicates that it may be subject to EPA's New Source Performance Standards/Emissions Guidelines. Please see 40 CFR part 60 for more information.

Optional User Inputs (User inputs are currently set to suggested default data):

Type of Optional Input		Suggested Default Data
LFG energy project size: Gas rate = (M)inimum, (A)verage, ma(X)imum, or (D)efined by user (must enter design flow rate below)?		M
For user-defined project size only: Design flow rate (ft^3/min)		---
Methane generation rate constant, k (1/yr) [0.04 for typical climates, 0.02 for arid climates, 0.1 for bioreactors or wet landfills]		0.04
Potential methane generation capacity of waste, L_o (ft^3/ton)		3,204
Methane content of landfill gas (%)		50%
Average depth of landfill waste (ft)		50
Landfill gas collection efficiency (%)		85%
Distance between landfill and direct end user (miles)		1.0
Operating schedule: (does not apply to leachate evaporators)	Hours per day	24
	Days per week	7
	Weeks per year	52
Loan lifetime (years)		10
Interest rate (%)		8.0%
General inflation rate (% - applied to O&M costs)		2.5%
Equipment inflation rate (%)		1.0%
Marginal tax rate (%)		35.0%
Discount rate (%)		10.0%
Down payment (%)		20.0%
Energy tax credits:	Landfill gas utilization ($/million Btu)	$0.000
	Electricity generation ($/kWh)	$0.000
	LNG production ($/gal)	$0.000
Direct credits:	Greenhouse gas reduction credit ($/$MMTCO_2E$)	$0.000
	Are direct methane reductions included in GHG credit?	Y
	Renewable electricity credit ($/kWh)	$0.000
	Avoided leachate disposal ($/gal) **	$0.000
	Construction grant ($)	$0
Royalty payment for landfill gas utilization ($/million Btu)		$0.000
Cost uncertainty factor (entered as % adjustment)		0.0%
Initial year product price: *	Landfill gas production ($/million Btu)	$3.50
	Electricity generation ($/kWh)	$0.0450
	LNG production ($/gal)	$0.460
Annual product price escalation rate (%)		2.0%
Electricity purchase price for projects NOT generating electricity ($/kWh) **		$0.075
Annual electricity purchase price escalation rate (%)		2.0%

** Based on initial year of operation

LMOP Partner Recruitment Tools and Services

- Project and Candidate Database
- Green Pricing Accreditation Involvement
- State Workshops/Conferences
  - working with state partners and SWANA
- Peer Matching
- Web Site (e.g., publications, database)
- *Annual LMOP Conference, Project Expo, and Partner Awards - January 18-19, 2006 in Baltimore!*

For More Information

www.epa.gov/lmop - LMOP Hotline: 888-782-7937

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