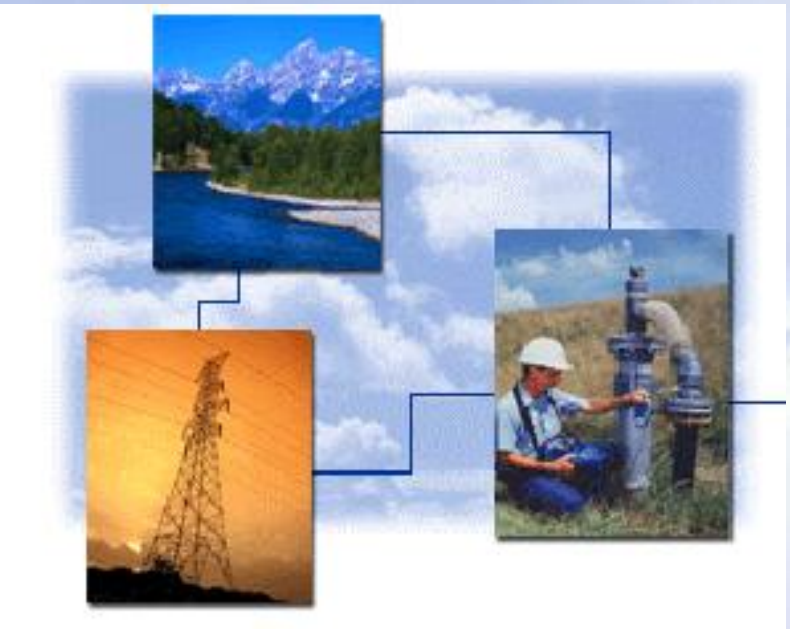
An Overview of Landfill Gas Energy in the United States



Environmental, Energy, & Technical Committee Meetings
Council of Industrial Boiler Operators
September 15-16, 2009

Rachel Goldstein
U.S. Environmental Protection Agency
Landfill Methane Outreach Program (LMOP)

LANDFILL METHANE OUTREACH PROGRAM

Agenda

- LMOP/ LFG 101
- Project Costs and Examples
- GHG reductions
- LMOP Tools/ Services
- International

Why EPA is Concerned about Landfill Gas

- Why is methane a greenhouse gas?
  - Methane absorbs terrestrial infrared radiation (heat) that would otherwise escape to space (GHG characteristic)
- Methane as GHG is over 20x more potent by weight than CO_2
- Methane is more abundant in the atmosphere now than anytime in the past 400,000 years and 150% higher than in the year 1750
- Landfills were the second largest human-made source of methane in the United States in 2007, accounting for 22.7% generated

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

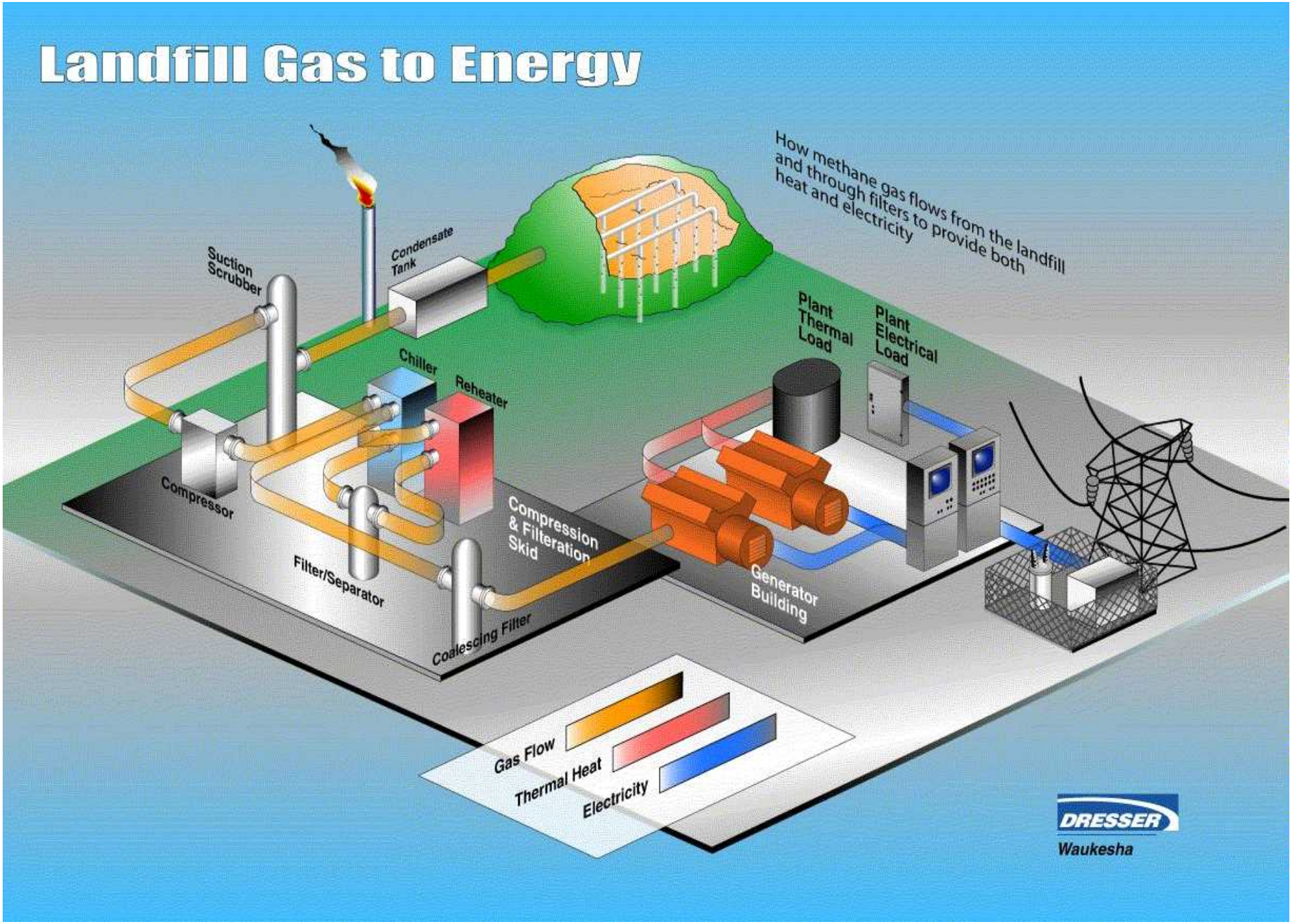
Mission: To reduce methane emissions by lowering barriers and promoting the development of cost-effective and environmentally beneficial landfill gas energy (LFGE) projects.

Recent Climate Change Activities

- **Waxman-Markey discussion draft "The American Clean Energy and Security Act of 2009" released March 31, 2009**
  - EPA's preliminary economic analysis available at epa.gov/climatechange/economics/economicanalyses.html#wax
- **Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act signed by the EPA Administrator on April 17, 2009.**
  - Additional information available at epa.gov/climatechange/endangerment.html
- **EPA Mandatory Greenhouse Gas Reporting Rule published in the Federal Registrar on April 10, 2009, 60 day comment period open until June 9, 2009.**

Landfill Gas 101

- Landfill gas (LFG) is a by-product of the decomposition of municipal solid waste (MSW):
  - ~50% methane (CH_4)
  - ~50% carbon dioxide (CO_2)
  - <1% non-methane organic compounds (NMOCs)
- For every 1 million tons of MSW:
  - ~0.8 megawatts (MW) of electricity
  - ~432,000 cubic feet per day of LFG
- If uncontrolled, LFG contributes to smog and global warming, and may cause health and safety concerns

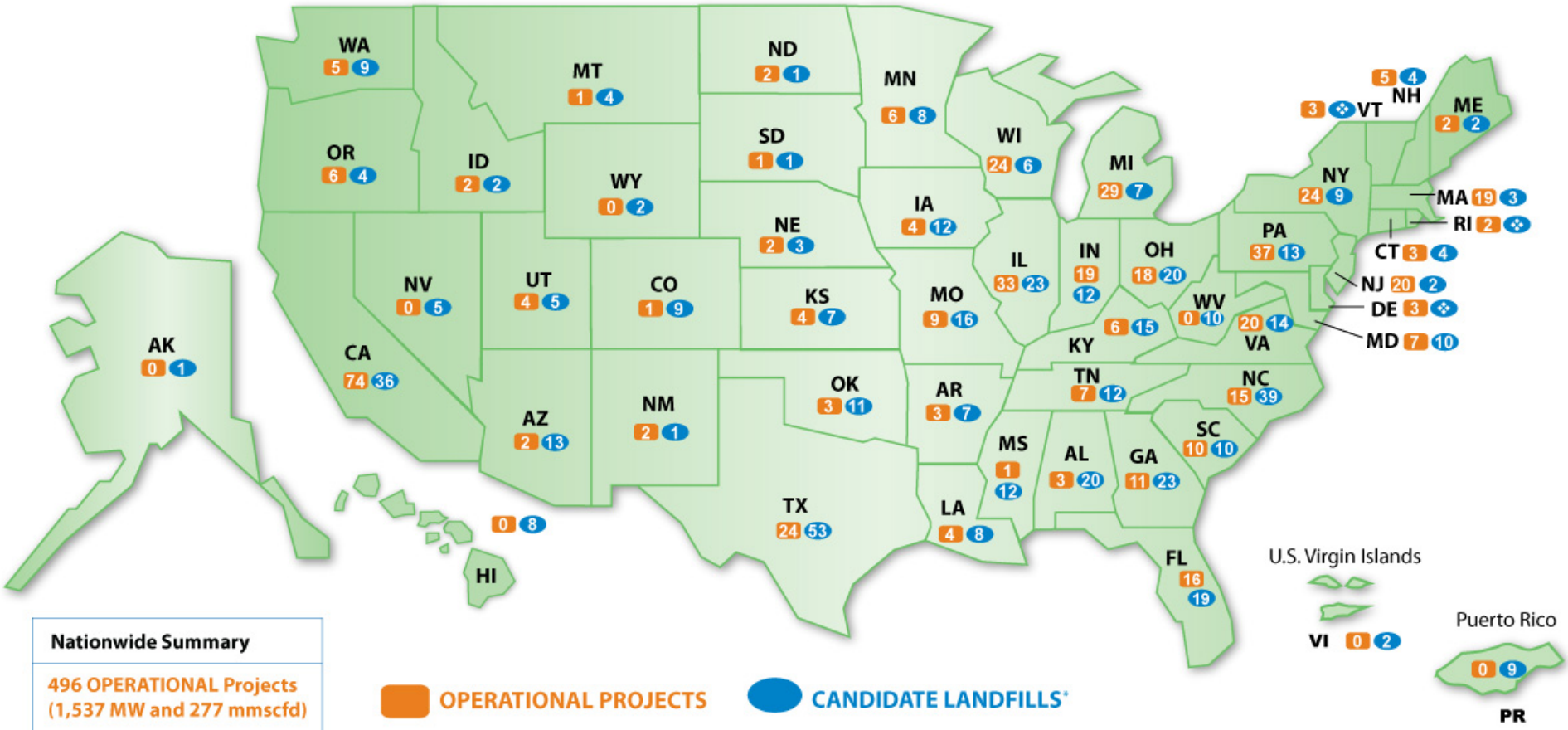

Landfill Gas to Energy
How methane gas flows from the landfill and through filters to provide both heat and electricity
Suction Scrubber
Condensate Tank
Chiller
Reheater
Compressor
Filter/Separator
Compression & Filteration Skid
Coalescing Filter
Plant Thermal Load
Plant Electrical Load
Generator Building
Gas Flow
Thermal Heat
Electricity
DRESSER
Waukesha

State of the National LFG Industry (July 2009)

- At least 496 operational projects in 44 states supplying:
  - 12 billion kilowatt-hours of electricity and 85 billion cubic feet of LFG to direct-use applications annually
- Estimated '09 **Annual** Environmental Benefits
  - Carbon sequestered annually by **~19,500,000 acres of pine or fir forests**, or
  - CO_2 emissions from **~199,000,000 barrels of oil consumed**, or
  - Annual greenhouse gas emissions from **~15,700,000 passenger vehicles**
- Estimated **Annual** Energy Benefit
  - Powering more than **889,000 homes** and heating nearly **614,000 homes**

LANDFILL METHANE OUTREACH PROGRAM

LFG Energy Projects and Candidate Landfills



Nationwide Summary

496 OPERATIONAL Projects (1,537 MW and 277 mmscfd)

~ 525 CANDIDATE Landfills (1,180 MW or 620 mmscfd, 13.5 MMTCE Potential)

* Landfill is accepting waste or has been closed for 5 years or less and has at least 1 mmtons of waste and does not have an operational/under construction LFGE project; or is designated based on actual interest/planning.

These data are from LMOP's database as of July 1, 2009.
❖LMOP does not have any information on candidate landfills in this state.

Landfill Gas and Green Power A Winning Combination

- Dual benefit ➔ destroys methane and other organic compounds in LFG
- Offsets use of nonrenewable resources (coal, oil, gas) reducing emissions of SO_2, NO_X, PM, CO_2
  - LFG is a recognized renewable energy resource (Green-e, EPA Green Power Partnership, 33 states, NRDC)
  - LFG is generated 24/7 and projects have online reliability over 90%
  - LFG can act as a long-term price and volatility hedge against fossil fuels

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 & high Btu
  - Greenhouse
  - Leachate evaporation
  - Vehicle fuel (LNG, CNG)
  - Artist studio
  - Hydroponics
  - Aquaculture (fish farming)

Greenhouse Burlington, NJ

Pottery Studio Sugar Grove, NC

LFG-fired Boiler Ft. Wayne, IN

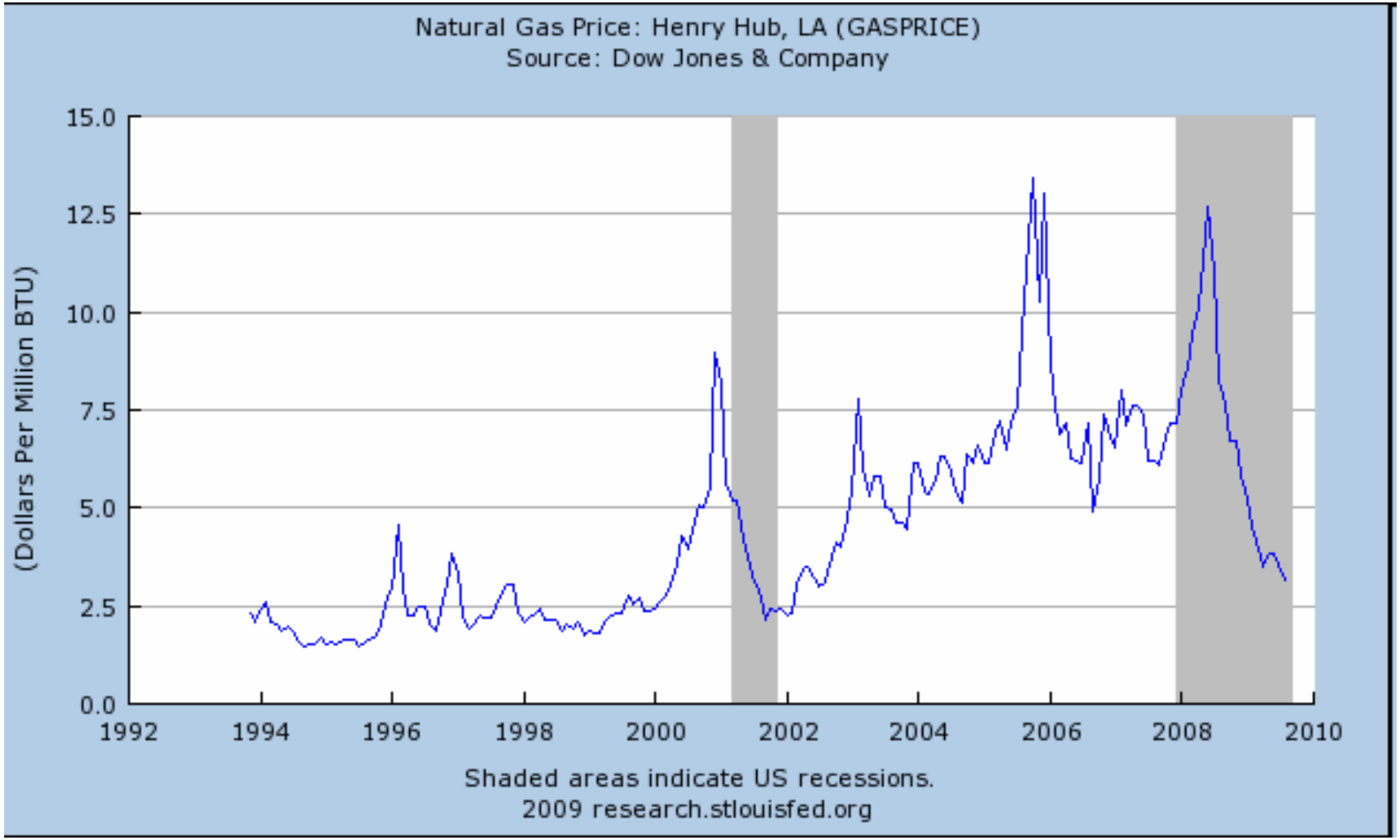
LFG Has Helped Produce…

- Aluminum
- Alternative fuels (biodiesel, CNG, ethanol, and LNG)
- Aquaculture (e.g., tilapia)
- Arts & crafts (blacksmithing, ceramics, glass)
- Biosolids (drying)
- Bricks, cement, concrete
- Carpet
- Cars and trucks
- Chemicals
- Chocolate
- Consumer goods and containers
- Denim
- Electronics
- Fiberglass, nylon, and paper
- Furthering space exploration
- Garden plants
- Green power
- Ice cream, milk, and tea
- Infrared heat
- Juice (apple, cranberry, orange)
- Pet food
- Pharmaceuticals
- Pierogies and snack food
- Soy-based products
- Steel
- Tomatoes (hydroponic)
- **Taxpayer savings and increased sustainability!**

Corporate Interest in LFG Energy

- Pipelines stretching – Honeywell connected to WM landfill by 23-mile pipeline
- LFG a cheaper fuel source and long term hedge against energy price volatility
  - BMW expanded its project based on success and is saving over $1 million/yr
  - NASA saving taxpayers more than $350,000/yr
  - MARS saves $600,000/yr using LFG in Waco, TX
  - Reduction of fossil fuel use by 50% at SC Johnson & Son site in WI saves $1 million/yr
- Requests from >20 large, national companies to identify landfill opportunities
- Siting new facilities near landfills
  - Multiple requests received to find appropriate sites for NEW brick plants, greenhouses, etc.

History of Natural Gas Prices




CHRYSLER
HILL AIR FORCE BASE, Utah
OGDEN AIR LOGISTICS CENTER
DART
NASA
GEO SPECIALTY CHEMICALS
Ford
Kimberly-Clark
GM
SUNOCO
NUCOR
Honeywell
NEW HOLLAND CONCRETE
A Better Building Partner
Rolls-Royce
Stouffer's
FritoLay
LAFARGE
H.R. EWELL INC.
INTERFACE
The Solae Company
CYTEC
Look Who's Using Landfill Gas!
CONE
corporatedenimfinishingjacquards
INTERNATIONAL
Cargill
AJINOMOTO
DOW
Tropicana
DUPONT
The miracles of science
BMW
The Ultimate Driving Machine
FP
advanced food products llc
MARS
snackfood
MALLINCKRODT
TURKEY HILL
Jenkins Brick Company
Tyson
BORAL
SC Johnson
Lucent Technologies
Bell Labs Innovations
L&S SWEETENERS
CNH

Typical Direct-Use Project Components & Costs

800 scfm, 5-mi pipeline, 15-yr project:

- Total capital cost = ~$2.7 million
  - Gas compression & treatment = ~$1.1 million
  - Pipeline = ~$1.6 million
  - (Plus end-of-pipe combustion equipment retrofits, if needed)
- Annual operation & maintenance cost = ~$120,000/year

Typical Electric Project Components & Costs

- 3 MW engine project for 15 years:
  - Gas compression & treatment, engine, & generator
    - Installed capital cost = ~$3.5 million
  - Annual operation & maintenance
    - Cost = ~$570,000/year
  - Interconnect equipment = ~$260,000
- Total capital cost = ~$3.76 million
- Total annual cost = ~$570,000

Potential LFG Revenue

Potential Revenue Source	Electric	Direct-Use
Sale of electricity (6 – 11 cents/kWh)	X	
Sale of Renewable Energy Certificates (RECs)	X	
Premium pricing for renewables through RPS/RPG or voluntary green power markets	X	
Tax credits or incentives	X	
Clean Renewable Energy Bonds (CREBs)	X	
Sale of LFG (~$8.00 per MMBtu)		X
Greenhouse gas reduction credits	X	X
Energy cost savings	X	X

Federal Financial Incentives

- Section 45 Production Tax Credit (PTC)
  - Electricity generation – 1.0 cent/kWh
  - Placed in service by 12/31/13
  - 10-year window for credits
  - Under Economic Stimulus Bill: Short-term option to select a one time 30% investment tax credit (Section 48) or convert into a 30% cash grant
- Clean Renewable Energy Bonds (CREBs)
  - National allocation of $2.4 billion
  - In 2008, IRS granted issuance of 45 bonds for LFGE projects
- Renewable Energy Production Incentive (REPI)
  - Local/state government or non-profit electric co-op facilities
  - Online by 10/1/16
  - Payment for first 10 years of operation

Methane Home

LMOP Home
Basic Information
Accomplishments
Energy Projects and Candidate Landfills
Benefits of LFG Energy
Partners
Join the Program
Documents, Tools & Resources
Newsroom
Workshops/ Conferences
International Activities
Frequent Questions
Green Power

Funding Landfill Gas Energy Projects: State, Federal, and Foundation Resources

How to Use this Guide

State Resources | State Renewable Portfolio Standards (RPS) | Federal Resources

Purposes of this Funding Guide

Through the over 400 operational landfill gas energy (LFGE) projects, communities, landfill owners and operators, and state officials across the United States have learned that landfill gas is an important local and regional resource. To develop LFGE projects, landfill owners and operators capture landfill gas and convert it into renewable energy. Converting landfill gas into energy reduces odors and hazards associated with landfill gas emissions and helps reduce reliance on fossil fuel-based energy. Landfill gas is also a valuable renewable resource that, when used, helps prevent landfill methane from migrating into the atmosphere and contributing to local smog and global climate change.

While landfill gas recovery offers significant environmental, energy, and economic benefits to the public and private sector, there are still barriers to project development. This funding guide focuses on one barrier in particular-financing for landfill gas project development.

Included in this funding guide are many innovative funding programs and strategies that can help developers overcome financial barriers. These programs and strategies include, among other things, loans, grants, renewable portfolio standards, renewable energy trust funds, and property, sales, and use tax exemptions. Whether you are a state agency official, a landfill owner or operator, or a developer, the programs described in this guidebook will provide you with important information as you consider ways to facilitate and/or develop successful LFGE projects.

Benefits from LFGE Use in Boilers

- Reduced fuel costs
  - At least 50 LFG-fired boiler project in operation.
  - Given the lack of State and Federal incentives, majority have been developed on their own economic merits (e.g., reduced fuel costs).
- Reduction in GHG emissions through displacement of fossil fuel use
  - GHG reduction = Btu's of LFG used * CO_2 emission factor of offset fuel (e.g., coal, oil, NG)
- Reduction in GHG emissions through voluntary destruction of methane in LFG
  - Not applicable at all locations. Use of LFG from small to mid-sized landfills (non-NSPS).

GHG Reduction Opportunities

- Voluntary control of landfill gas (including beneficial use projects) is a desired GHG reduction project and is a net supplier of greenhouse gas credits to various markets:
  - Climate Action Reserve (CAR)
  - Chicago Climate Exchange (CCX)
  - Voluntary Carbon Standard (VCS)
- Volume-weighted average price per metric ton (MT) of CO_2e in 2008 was $4.10
- CCX current price at $0.25/MT$CO_2e$
- CAR credits valued between $6 - 7/MT$CO_2e$

Potential GHG Reduction and Market Value from 15 MMBtu/hr Project

- ~ 500 cfm of LFG
- Direct reduction of methane
  - Applicable only if LFG collected "voluntarily", annual CO_2e reduction of ~ 50,000 metric tons
  - @ $5.00/MT ~ $250,000/yr in market value (avoided cost?)
- Displacement of fossil fuels
  - Always applicable regardless of LF NSPS status
  - If displacing natural gas use, annual CO_2e reduction of ~ 6,200 metric tons
  - @ $5.00/MT ~ $31,000/yr in market value (avoided cost?)

NASA Goddard Space Flight Center Greenbelt, Maryland

- Start-up in 2003. First LFG project at a Federal facility
- Sandy Hill Landfill in Bowie, MD with a 5.5 mile pipeline to the NASA Space Center
- Project highlights:
  - The LFG fuels 3 boilers and provides 100% of the facilities heating needs 95% of the time, saving taxpayers more than $ 3.5 million in energy costs over the next decade.
  - Sophisticated control system to allow the boilers to burn fuel oil, natural gas, or LFG.
  - LFG produces steam to heat 31 buildings on the 1,270-acre NASA campus.

James A Quillen VA Hospital, E. Tennessee State University, Johnson City, Tennessee

- Start-up in 2007
- Iris Glen Landfill, 4.5 million tons WIP in 2009
- Direct use of LFG for boilers and reciprocating engine
- Project highlights:
  - 4 mile LFG transmission pipeline.
  - Supplies 100,000 lbs/hr of steam, 7.5 MW of power, and chilled water to the VA hospital and East Tennessee State University.
  - Saves the hospital thousands of dollars plus $500,000 annually in revenue to the City.
  - Pipeline quality LFG, so no boiler modifications were required.

LMOP 2007
Project of the Year

Kimberly-Clark Case Study

- Kimberly-Clark and LMOP began discussions in 2005 after meeting at a conference
- LMOP searched for landfills proximate to over 30 KC facilities
- Identified one opportunity in South Carolina
- Conducted preliminary *pro-forma*
- Assisted KC in understanding LFGE projects

Kimberly-Clark Case Study (cont.)

Contract Structure

- A Win-Win agreement for both parties:
- Three Rivers gets:
  - Guaranteed outlet with Take or pay
  - Minimum take of 1440 DT/day at full output
- K-C in return gets:
  - A cap reducing exposure to very high gas costs
  - Project to replace 80% of baseline fuel use in boiler

WORLD-CLASS MANUFACTURING
Kimberly-Clark Corporation
Beech Island

Kimberly-Clark Case Study (cont.)

SIEMENS

Project History and Timeline

Three Rivers Began investigation late 2005
Issued RFQ for partner 1st Quarter 2006
Selected Siemens 2nd quarter 2006
Direct Use Project with KC selected Oct 2006
Detailed Engineering and contracts completed April 07
Financial Closure Sep 07
Construction began Oct. 07
Construction to be completed April 08

Two year development and construction schedule

CHP and Direct-Use Case Study

BMW Manufacturing Greer, SC

LMOP 2003
Project of the Year

- 9.5-mile pipeline from Palmetto Landfill to BMW
- 2003 – 4 KG2 gas turbines retrofitted to burn LFG
  - 4.8 MW of electricity generated and 72 MMBtu/hr of heat recovery
- 2006 – Converted paint shop to utilize LFG in oven burners & for indirect heating
- LFG accounts for nearly 70% of BMW's energy needs
- To date, LFG has saved BMW an annual average of $5 million in energy costs
- 2009/2010 – 2 new gas turbines will replace 4 older ones & generate 11 MW

LMOP 2006
Energy End User Partner of the Year

CHP and Direct-Use Case Study

BMW Manufacturing Greer, SC

LMOP 2003
Project of the Year

- 9.5-mile pipeline from Palmetto Landfill to BMW
- 2003 – 4 KG2 gas turbines retrofitted to burn LFG
  - 4.8 MW of electricity generated and 72 million Btu/hr of heat recovered
- 2006 – Converted paint shop to utilize LFG in oven burners and for indirect heating
- BMW saves at least $1 million/yr

LMOP 2006
Energy End User Partner of the Year

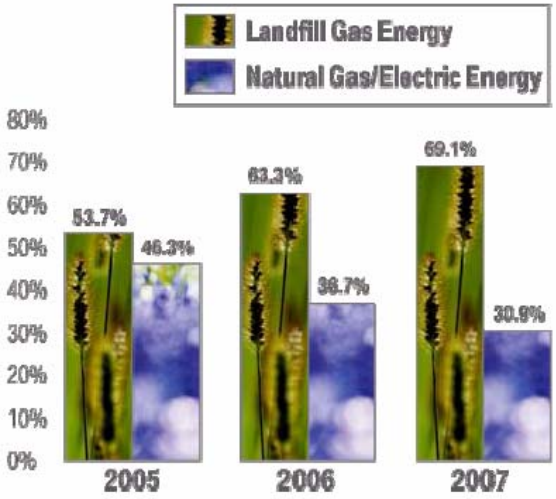
LANDFILL METHANE OUTREACH PROGRAM

BMW Case Study (cont.)

The Greenest Automotive Paint Shop

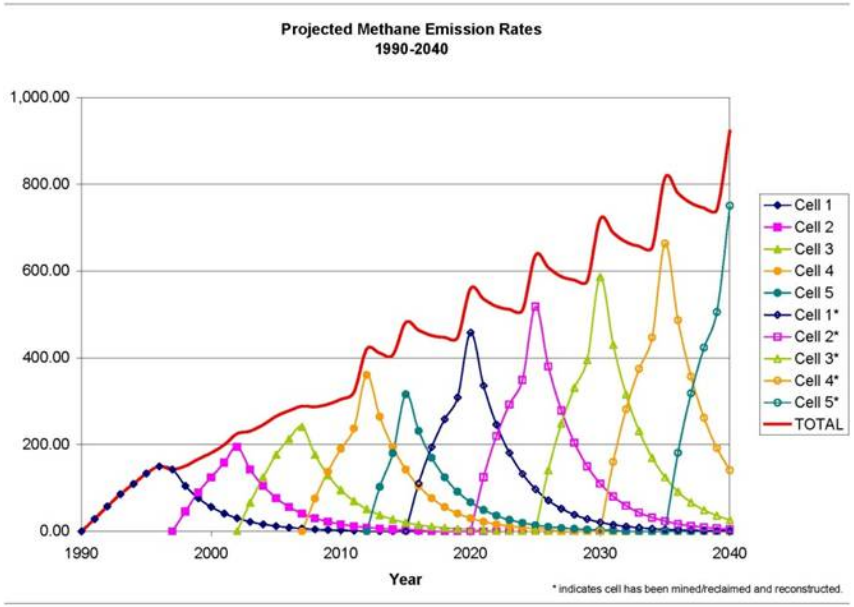
DÜRR

In 2006 @ BMW Spartanburg in S. Carolina, 63% of Energy consumed in operation comes from Landfill Gas Methane



Central Landfill, Worcester County, MD

- Recirculating leachate – using leachate recharge wells for gas extraction (dual-use wellheads)
- Only **three** new dedicated gas wells needed – capital savings

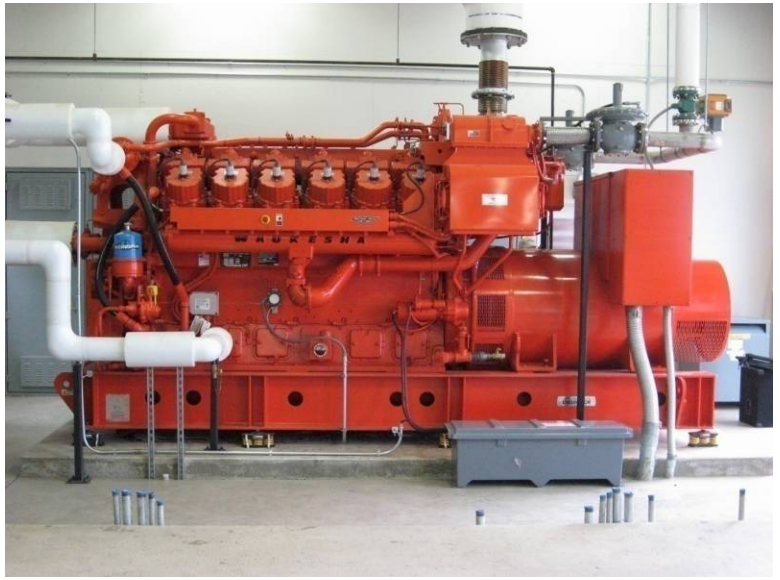


- Cell mining & reconstruction (extraction of humic material for soil amendment use)
- Will cycle through the cells – virtual indefinite use of space & slowly increasing gas supply

Central Landfill, Worcester County, MD (cont.)

- Provided business opportunities for local consultants, engineers, and construction contractors
- County will receive royalty payments for LFG
- Two 1-MW engines installed with third engine planned

- Selling: electricity (to Old Dominion Electric Coop), carbon credits (thru TerraPass) & RECs (to Pepco Holdings)
- Carbon credits verified by Voluntary Carbon Standard
- Estimated total value of renewable energy: $100/MWh



Many Untapped LFG Resources

- Currently ~520 candidate landfills with a total gas generation potential of 200 billion cubic feet per year (~12,000 MMBtu/hr)
- If projects were developed at all these landfills, estimated
  - **Annual** Environmental Benefit =

    Carbon sequestered annually by ~11.5 million acres of pine or fir forests OR annual greenhouse gas emissions from ~9.2 million passenger vehicles, AND
  - **Annual** Energy Benefit =

    Powering 698,000 homes OR heating 1.4 million homes per year

Many Untapped LFG Resources (cont.)

- ~500 landfills have a gas collection system but no energy project
  - Potential of 263,000 MMBtu/day
- ~95 landfills have an energy project and excess LFG available
  - Potential of 60,000 MMBtu/day
- ~970 landfills do not have a gas collection system
  - Potential of 206,000 MMBtu/day

LMOP Tools and Services

- Network of 800+ Partner (and growing)
- Newsletter and listserv
- Direct project assistance
- Technical and outreach publications
- Project and candidate landfill database
- Web site (epa.gov/lmop)
- Support for ribbon cuttings/ othe PR
- Presentations at conferences
- State training workshops
- *LMOP 13th Annual Conference, Project Expo & Partner Awards – January 11-13, 2010 Baltimore, MD*

EPA Administrator
Stephen L. Johnson

Keynote Speaker
11th Annual LMOP Conference
Washington, DC

January 9, 2008

Adapting Boilers to Utilize Landfill Gas: An Environmentally and Economically Beneficial Opportunity

Mallinckrodt, Inc. Raleigh, NC

Utilization of landfill gas (LFG) in place of a conventional fuel such as natural gas, fuel oil, or coal in boilers is an established practice with a track record of more than 25 years of success. In the United States, more than 60 organizations have switched to the use of LFG in their industrial, commercial, or institutional boilers, with more than 70 boilers operating with LFG, either alone or co-fired with other fuels. Boilers firing LFG range in size from 2 to more than 150 million British Thermal Units per hour (MMBtu/hr). Companies using LFG are saving money while protecting the environment. General Motors fires LFG in boilers at four of their manufacturing and assembly plants and reports that they have realized energy cost savings of about $500,000 per year at each of the four plants. GM also reported that the total LFG used at the four projects replaces more than 1.6 trillion Btu per year of fossil fuels—enough to heat 45,000 homes for a year.

This fact sheet discusses the technical and engineering issues associated with using LFG in boilers designed to burn other fuels. The equipment and operational changes are relatively simple and use proven technologies, and dozens of firms can engineer and implement a conversion project.

Comparison of Landfill Gas and Natural Gas

Like natural gas, LFG's heating value is derived largely from methane, but unlike natural gas, LFG is comprised about 50 percent by volume of non-combustible gas, mostly carbon dioxide (CO_2). LFG is classified as a "medium Btu gas" with a heating value of about 500 Btu per cubic foot, about half that of natural gas. Therefore, the volume of LFG that must be handled by the fuel train and burner is twice that of natural gas. This means that modifications to the fuel train and burner are usually required to accommodate the higher overall gas flowrate for an equivalent natural gas heating value. The increased gas flow, however, does not have an appreciable effect on the design and operation of boiler components downstream of the burner. The added volume of non-combustible (inert) gas in LFG is equivalent to the inert gas entering a boiler when about six percent of the flue gas is recirculated to the boiler. Flue Gas Recirculation (FGR) is a widely applied technique for reducing NO_x emissions from natural gas-fired industrial and commercial boilers, and boilers can typically operate at recirculation rates of 20-25 percent without adversely affecting boiler heat transfer and efficiency. This comparison illustrates that the increased flow of LFG as compared to natural gas will not adversely affect boiler operation, although the burner, controls, and fuel train will require some modifications.

Mallinckrodt, Inc. Raleigh, NC

Burner, Control, and Fuel Train Modifications

The equipment for retrofitting a boiler to burn LFG is commercially available, proven, and not overly complex. The decisions that must be made during engineering and design are, however, site-specific and may be somewhat involved. For example, some installations have retained the original burner but modified it for LFG (e.g., by installing separate LFG fuel train and gas spuds) while maintaining the existing natural gas fuel train and gas ring to permit LFG/natural gas co-firing. Other installations have replaced the entire burner, controls, and fuel train with a dual-fuel burner and dual-fuel trains specifically designed to handle medium Btu gas. In general, the decision to furnish all new equipment is made based on the owner's preference or because the existing burner and controls are nearing the end of their useful lives. Additional analysis may be required to determine the amount of LFG compression that is provided versus the modifications needed for the burner and gas train.

Because LFG is typically a wet gas often containing trace corrosive compounds, the fuel train and possibly some burner "internals" should be replaced with corrosion-resistant materials. Stainless steel has typically been the material selected.

The controls associated with fuel flow and combustion air flow need to be engineered to cope with the variable heat content of LFG. The complexity of the burner management system will depend upon whether the boiler is to be co-fired with natural gas or oil and whether the boiler is to be co-fired at all times or if there will be times when it will be fired with LFG only. Today's modern controls, fast-responding oxygen analyzers, and responsive flame sensors make it possible to fire LFG with the same level of safety that is characteristic of current natural gas systems.

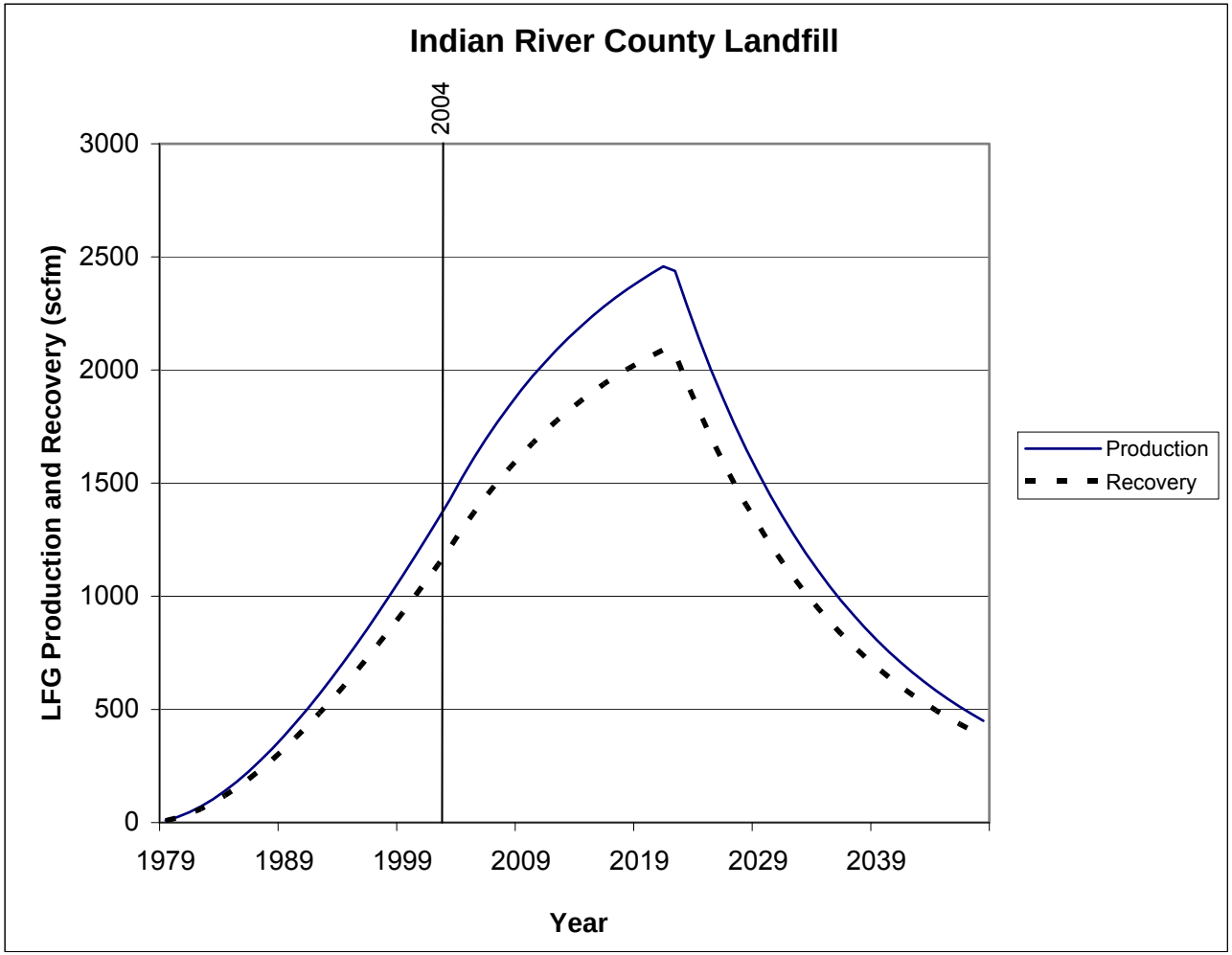
Boiler Deposits and Boiler Cleaning

In recent years, a family of organo-silicon compounds, known as siloxanes, commonly found in detergents, shampoos, deodorants, and cosmetics, have gradually found their way into the solid waste stream and into LFG. Their quantity in LFG is small and varies with the age of the landfilled material. When LFG is burned, the siloxanes are oxidized to silicon oxide—the primary chemical compound in sand. After firing boilers for an extended period with LFG, operators report a thin coating of white powder, described as similar to talcum powder, on some of the boiler tubes and substantial accumulations of the white powder on portions of the boiler floor. Where the material collects and how much of it accumulates is likely to be a function of the velocity patterns in the

How Can We Work Together? Direct Project Assistance

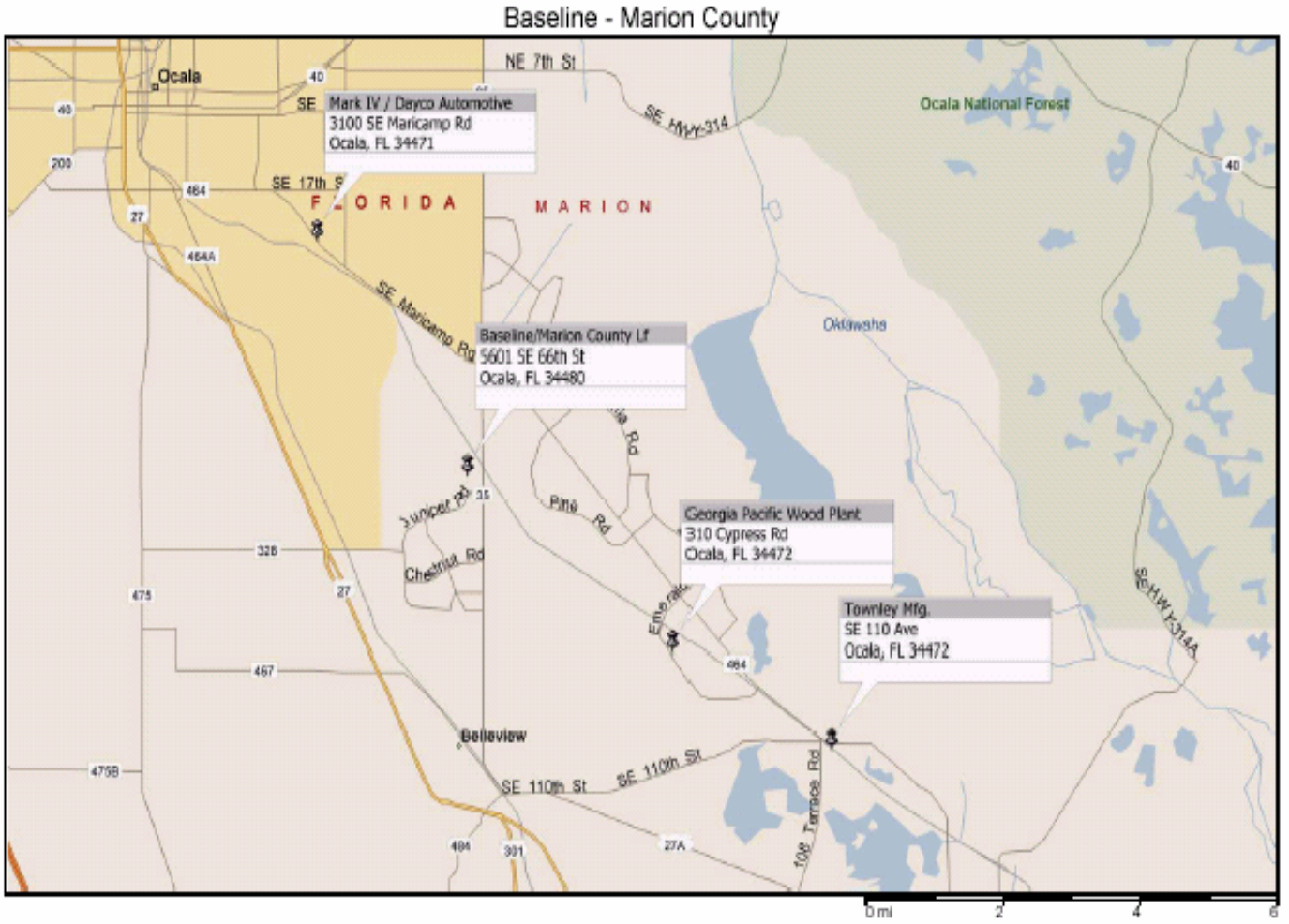
- Analyze landfill resource – gas modeling
- Identify potential matches – *LMOP Locator*
- Assess landfill and end user facilities
- Look at project possibilities
  - Direct-use (boiler, heating, cooling, direct thermal)
  - Combined Heat & Power (engine, turbine, microturbine)
  - Electric (engine, turbine, microturbine)
  - Alternative Fuels (medium or high Btu, LNG, CNG)
- Initial feasibility analyses – *LFGcost*

Analyze Energy Potential from Landfill



LANDFILL METHANE OUTREACH PROGRAM

Identify Potential End-Use Opportunities

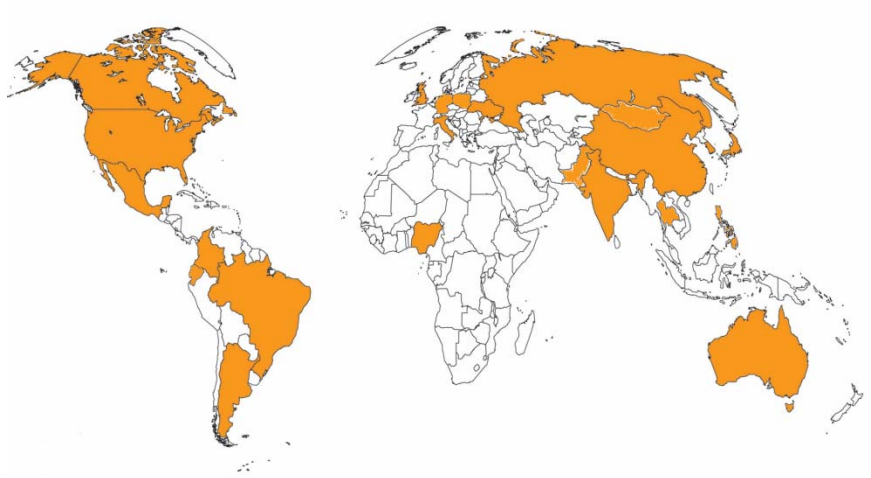


Methane to Markets Partnership

- Encourages development of ***cost-effective*** methane recovery and use opportunities in
  - coal mines
  - landfills
  - oil and gas systems and
  - agriculture (manure waste management)

- Private companies, multilateral development banks and other relevant organizations participate by joining the ***Project Network – over 800 organizations now participating***
- **28 Partner Governments**

Argentina
Australia
Brazil
Canada
Colombia
Chile
China
European Comm.
Ecuador
Finland
Germany
India
Italy
Japan
Kazakhstan
Korea
Mexico
Mongolia
Nigeria
Pakistan
Philippines
Poland
Russia
Thailand
Ukraine
United Kingdom
United States
Vietnam

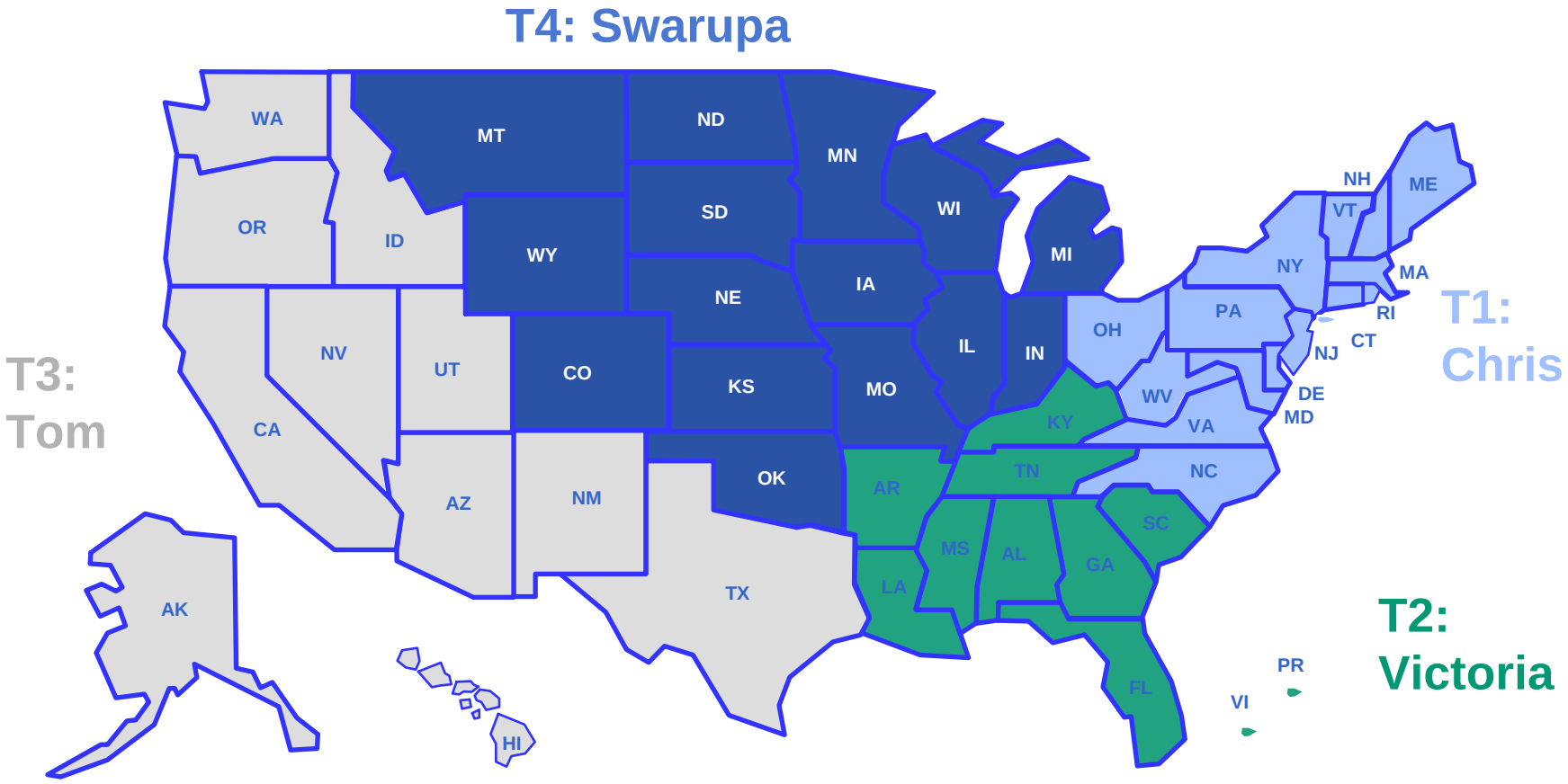


- Premier international forum for promoting methane recovery and use project opportunities and technologies.
- Provides participants with opportunities to:
  - Showcase and learn about methane mitigation projects and technologies.
  - Meet with potential project partners and financiers.
  - Explore key technical, financial, and policy issues.
  - Interact with high-level government agencies from 30 countries.

For more information please visit: www.methanetomarkets.org/expo

For More Information

www.epa.gov/lmop



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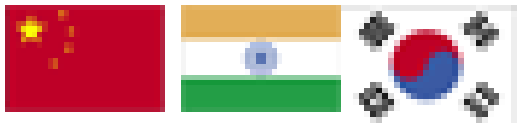

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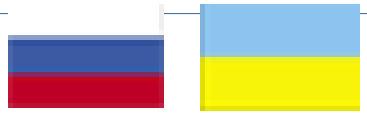

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