2004 Energy

The Solutions Network

Rochester, New York

Welcome to BIOMASS TO ENERGY: DON'T WASTE THE OPPORTUNITY

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Feasibility Assessment of Power Production at Rural Utilities Using Forest Thinnings and Commercially Available Biomass Power Technologies

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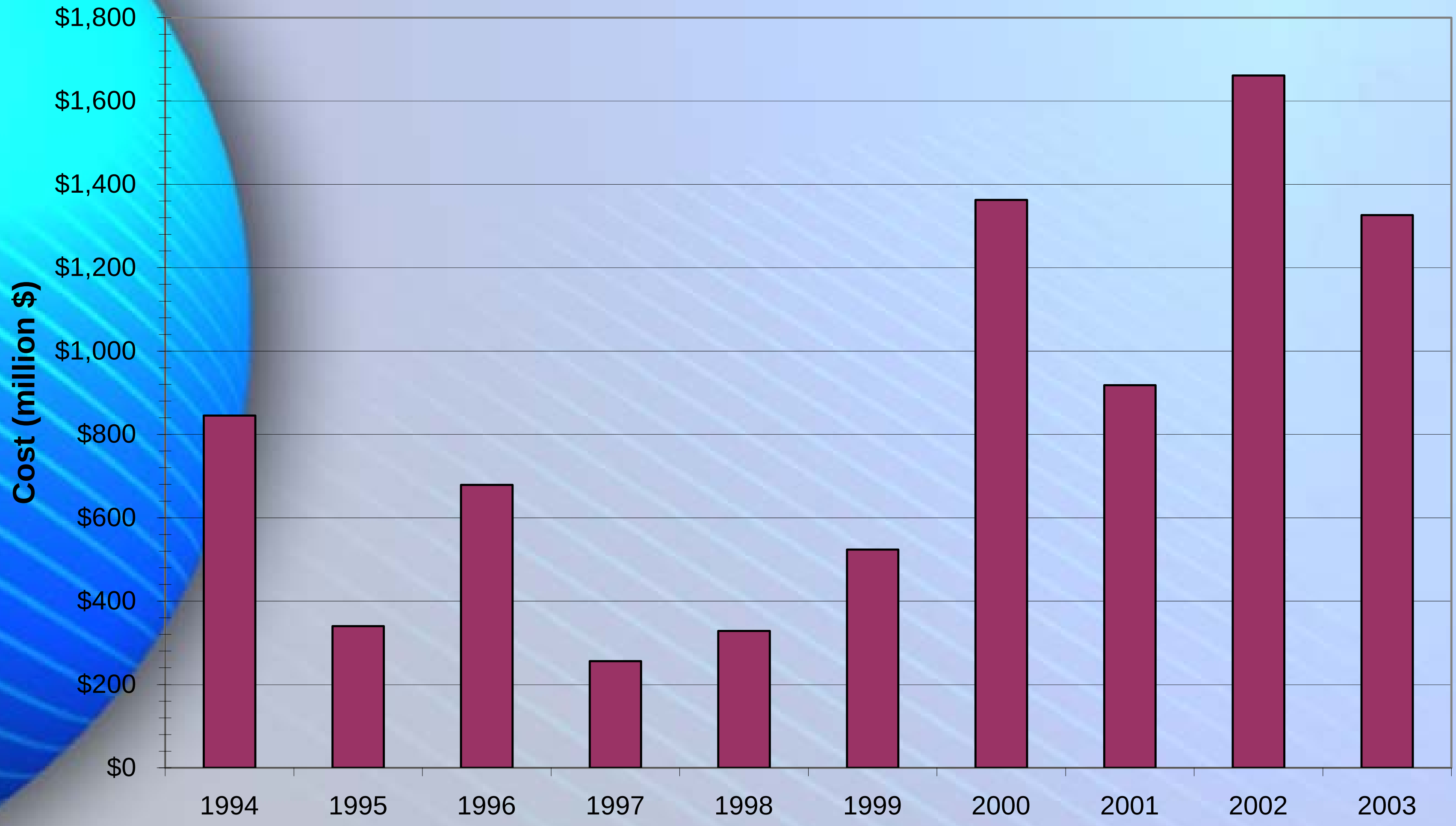
Acknowledgements

- Government Agencies:
  - USDOE, Office of Biomass Energy
  - NREL
  - USDA, RUS & NFS
  - USDoI, BLM
- Industry
  - NRECA
  - EPI, Lurgi, Foster Wheeler, & McBurney
  - Dresser Rand
  - Caterpillar, GE Jenbacher, Wartsila, Waukesha
  - Continental Biomass Industries

Political Rationale for Report

- Record high levels of wildfires in 2002
  - 88,458 wildfires
  - 6.9 million acres burned
  - $1.66 billion spent to suppress fires
- MOU between signed by USDOE, USDA, and USDoI on 6/16/2003
- Healthy Forest Restoration Act of 2003 signed into law on 12/3/2003, P.L. 108-148

Public Funds Spent on Wildfire Suppression
(Total spent by USDA NFS, NPS, FWS, BLM, & BIA)



Agency Motivation

- USDA RUS – Low cost renewable fuels for the rural electric utilities
- USDA FS / DoI BLM – Create markets for forest thinnings (ladder fuels) to reduce wildfire intensity and frequency
- USDOE – Promote advanced conversion technology for biomass

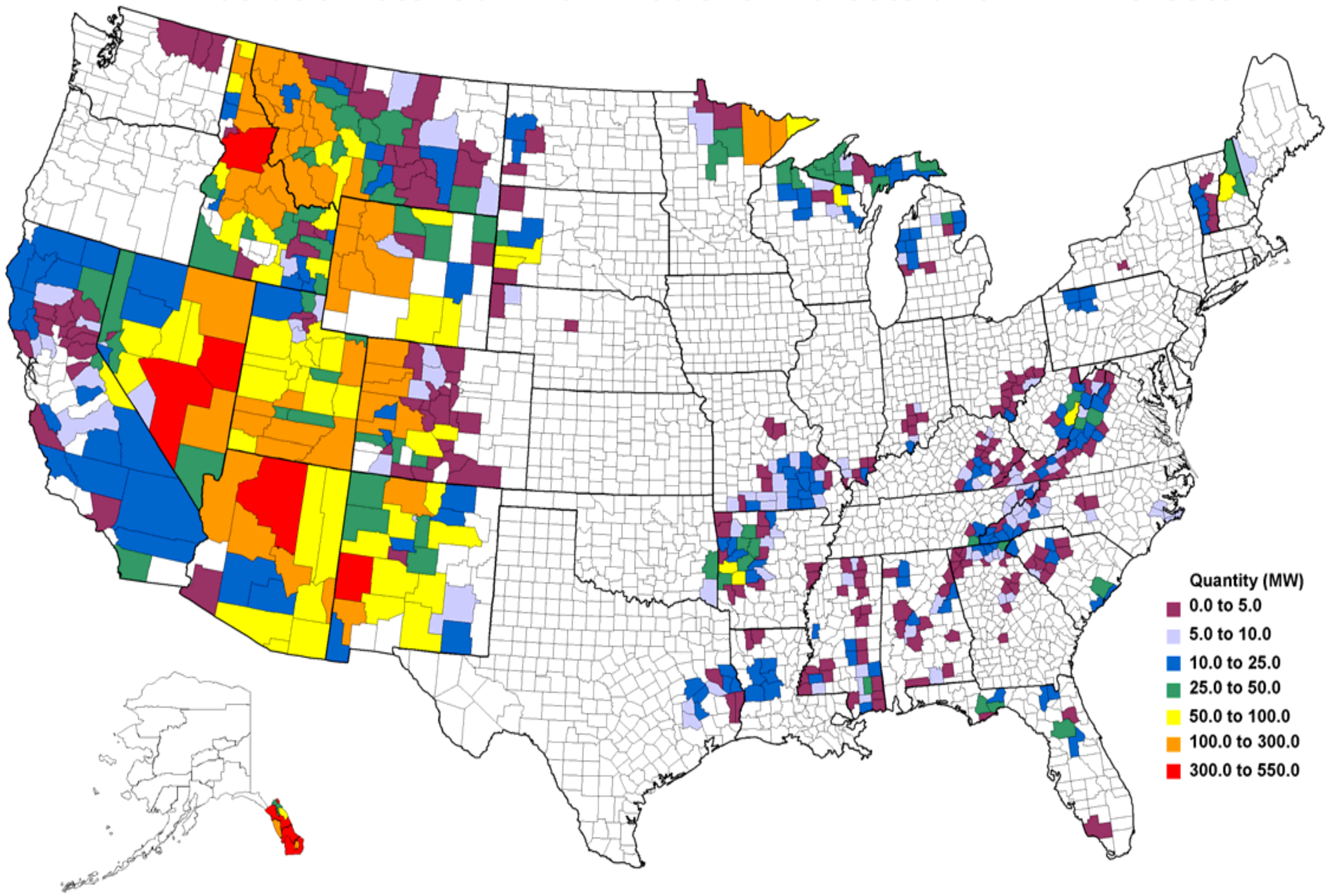
Topics Covered in Report

- Quantified forest thinning availability
- Quantified other biomass resources (wood residues, agricultural residues, energy crops, etc.)
- Located all existing rural utilities
- Characterized eight biomass power production technologies
- Conclusions on commercially available biopower technologies

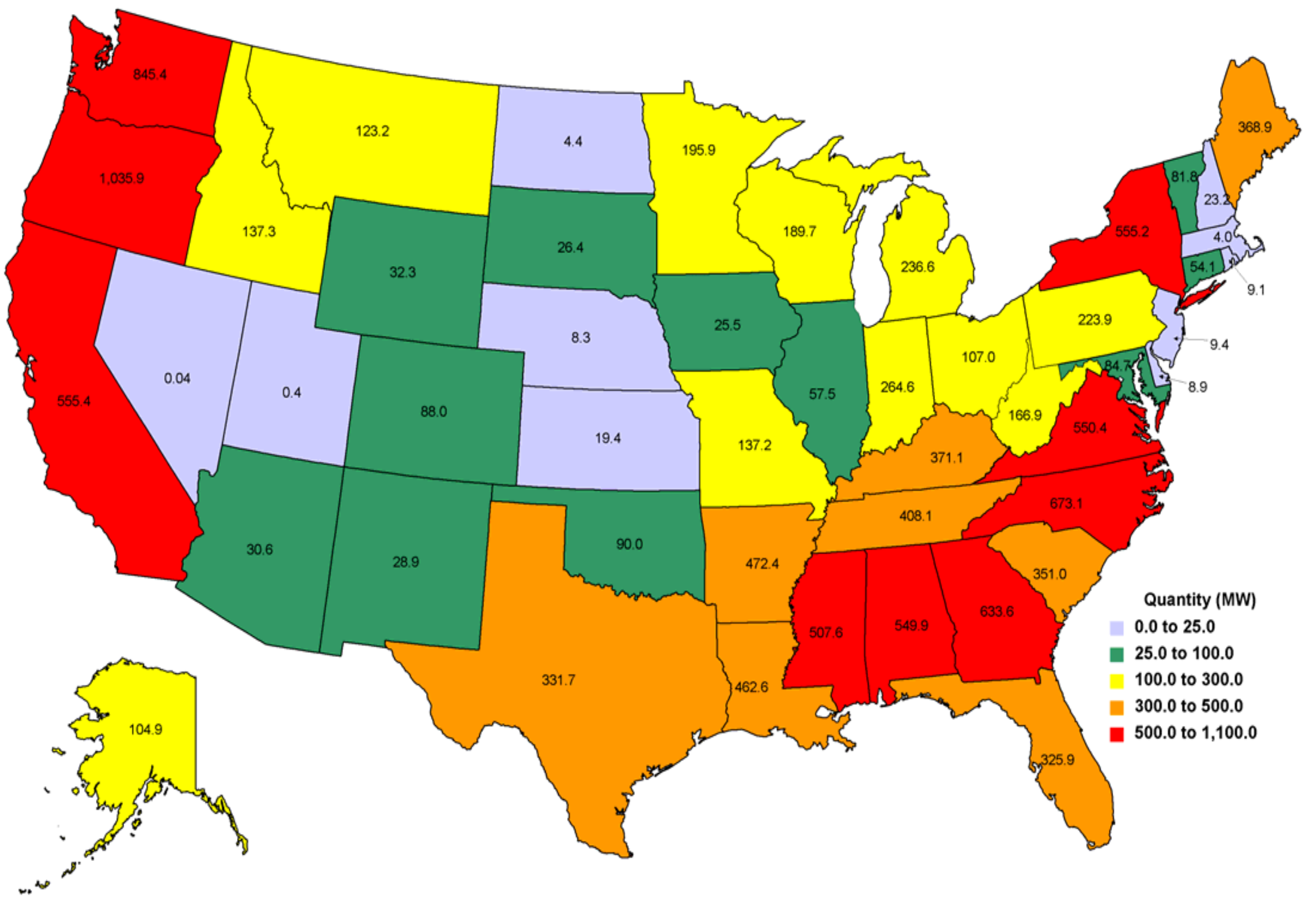
Report Assumptions

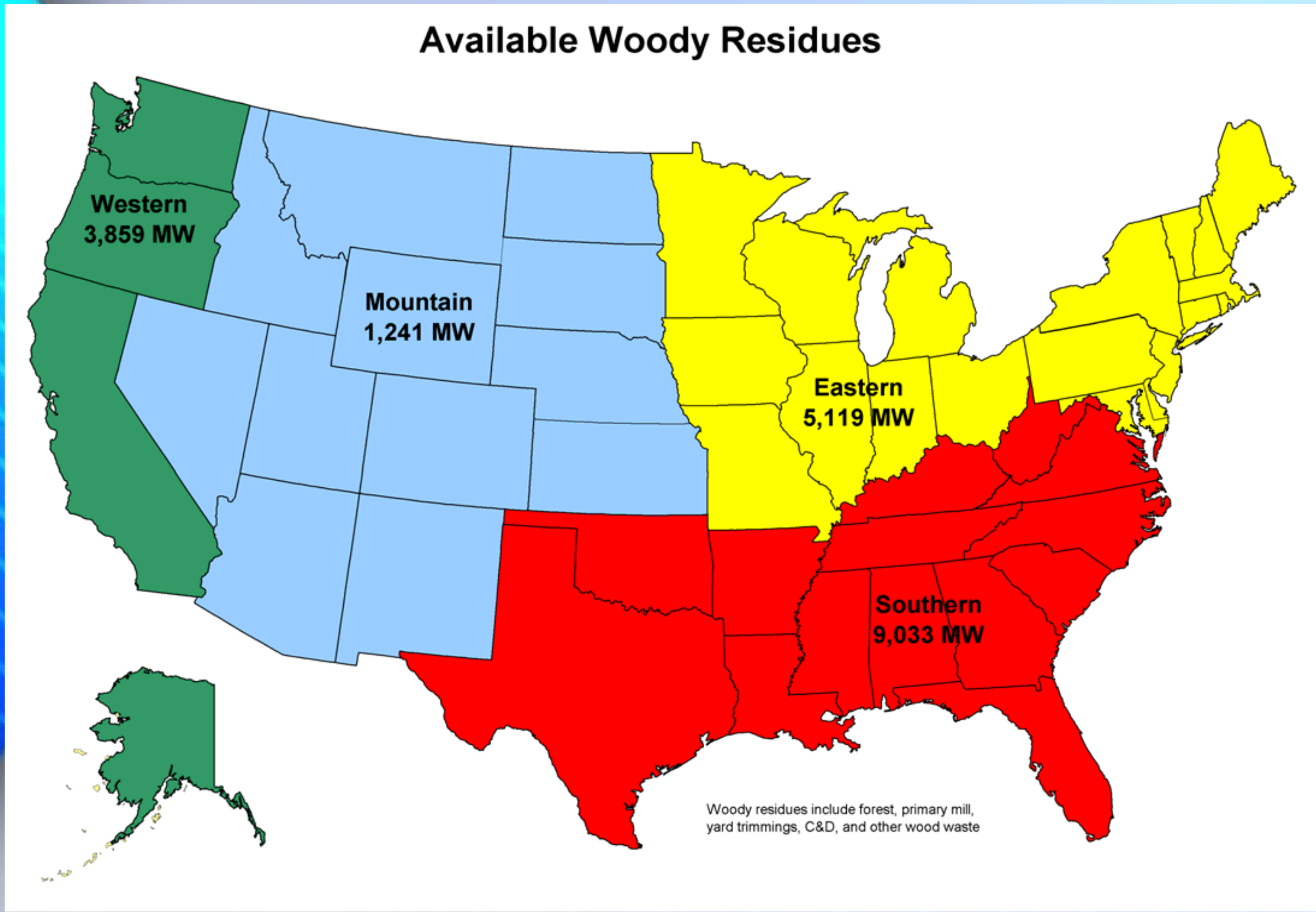
- 100 tons per day of forest thinnings could be made available from FS / BLM property for a biomass project at a Rural Utility (enough to generate 2 MW) at $10 per delivered wet ton
- Other biomass residues could be available for a larger project
- Only commercially available technologies would be assessed

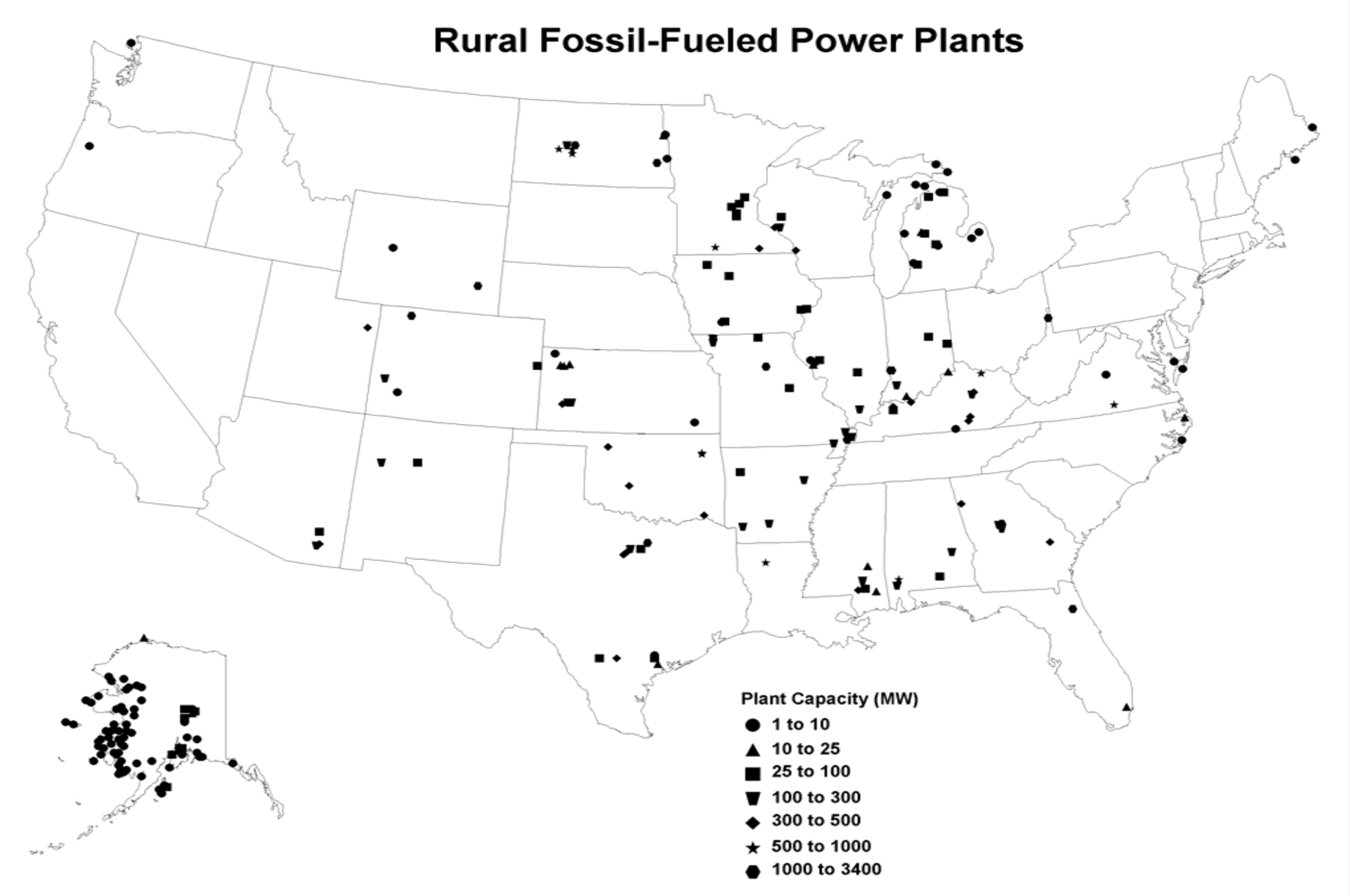
Residue Potential From National Forests and BLM Forests



Available Forest Residues




Available Woody Residues
Western
3,859 MW
Mountain
1,241 MW
Eastern
5,119 MW
Southern
9,033 MW
Woody residues include forest, primary mill,
yard trimmings, C&D, and other wood waste



Rural Fossil-Fueled Power Plants
Plant Capacity (MW)
1 to 10
10 to 25
25 to 100
100 to 300
300 to 500
500 to 1000
1000 to 3400

Technology Evaluation

1. Calculate firing rate or capacity of the low, medium, and high
2. Calculate the preparation yard costs.
3. Calculate the total capital costs. (low, medium, and high cost)
4. Calculate the O&M costs (associated with the three capital costs)
5. Perform preliminary economic evaluation of each technology (burner tip price/cost of electricity).

Biomass Power Technologies

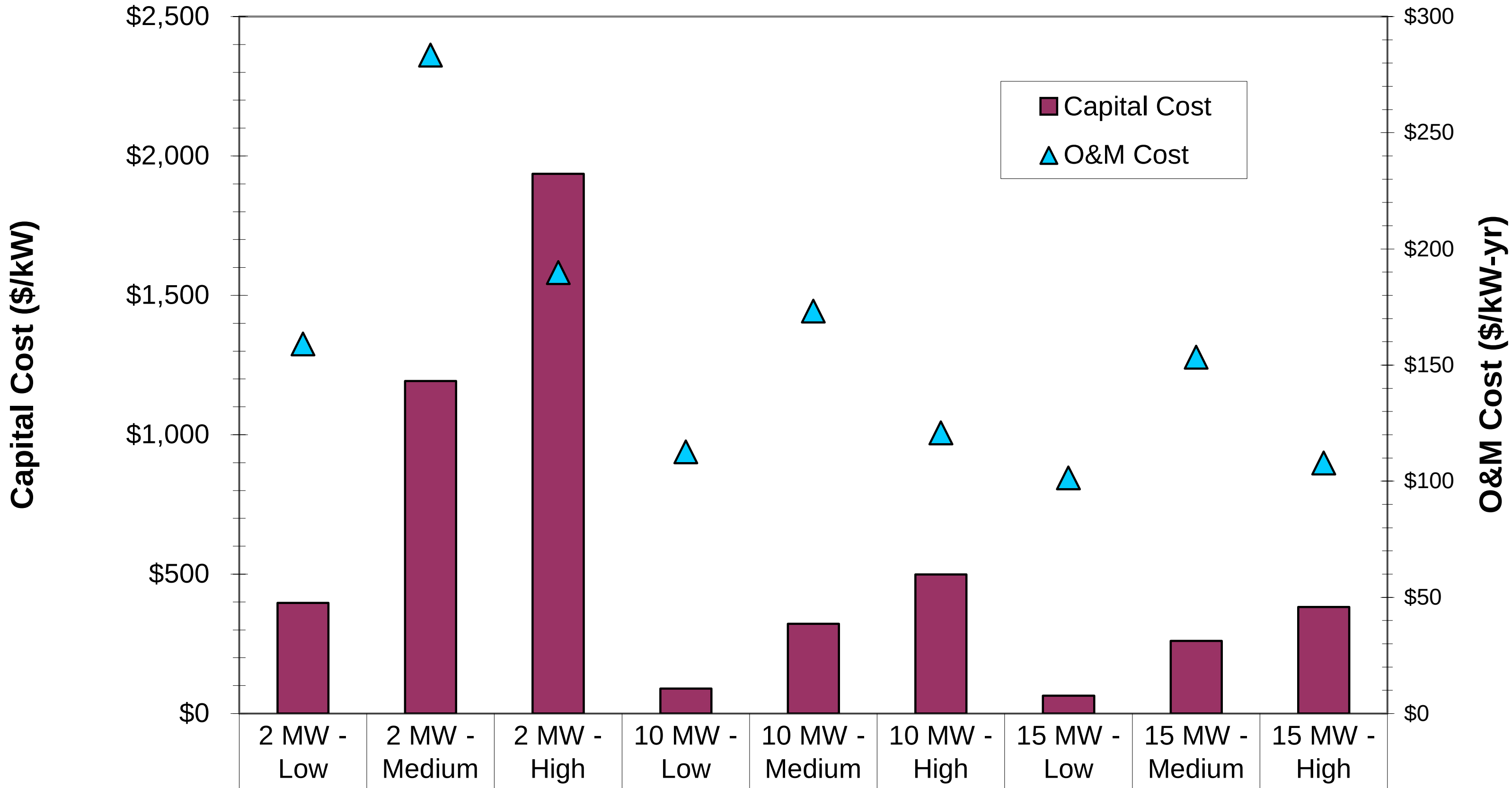
- Cofiring (solid fuel)
- Gasification Cofiring
- Steam Turbine
- CHP via back pressure steam turbine
- Gas Turbine – Simple Cycle
- Gas Turbine – Combined Cycle
- Reciprocating IC Engine
- Feedwater Heater Repowering

Biomass Power Technology	Biopowe Generated (MW) & Required Wood Supply (tpd of x% MC)		
	Low Capacity	**Medium Capacity**	**High Capacity**
Gasification Cofiring	2 MW	10 MW	15 MW
	100 tpd @ 50% MC	**349** tpd @ 30% MC	**523** tpd @ 30% MC
Solid Fuel Cofiring	2 MW	10 MW	15 MW
	100 tpd @ 50% MC	**452** tpd @ 50% MC	**678** tpd @ 50% MC
Steam Turbine	0.7 MW	10 MW	15 MW
	100 tpd @ 50% MC	**598** tpd @ 30% MC	**891** tpd @ 30% MC
Combined Heat and Power (CHP)	0.5 MW_e and 6 MW_{th}	4 MW_e and 48 MW_{th}	6 MW_e and 72 MW_{th}
	100 tpd @ 50% MC	**598** tpd @ 30% MC	**891** tpd @ 30% MC

Biomass Power Technology	Biopower Generated (MW) & Required Wood Supply (tpd of x% MC)		
	Low Capacity	Medium Capacity	High Capacity
Gas Turbine Combined Cycle; Syngas blended w/ Natural Gas	10 MW	15 MW	25 MW
	165 tpd @ 30% MC	**303** tpd @ 30% MC	**493** tpd @ 30% MC
Gas Turbine Combined Cycle; 100% Syngas	10 MW	15 MW	25 MW
	258 tpd @ 30% MC	**474** tpd @ 30% MC	**771** tpd @ 30% MC
Gas Turbine Simple Cycle; Syngas blended w/ Natural Gas	2 MW	10 MW	15 MW
	68 tpd @ 50% MC	**248** tpd @ 30% MC	**397** tpd @ 30% MC
Gas Turbine Simple Cycle; 100% Syngas	2 MW	10 MW	15 MW
	107 tpd @ 50% MC	**388** tpd @ 30% MC	**621** tpd @ 30% MC

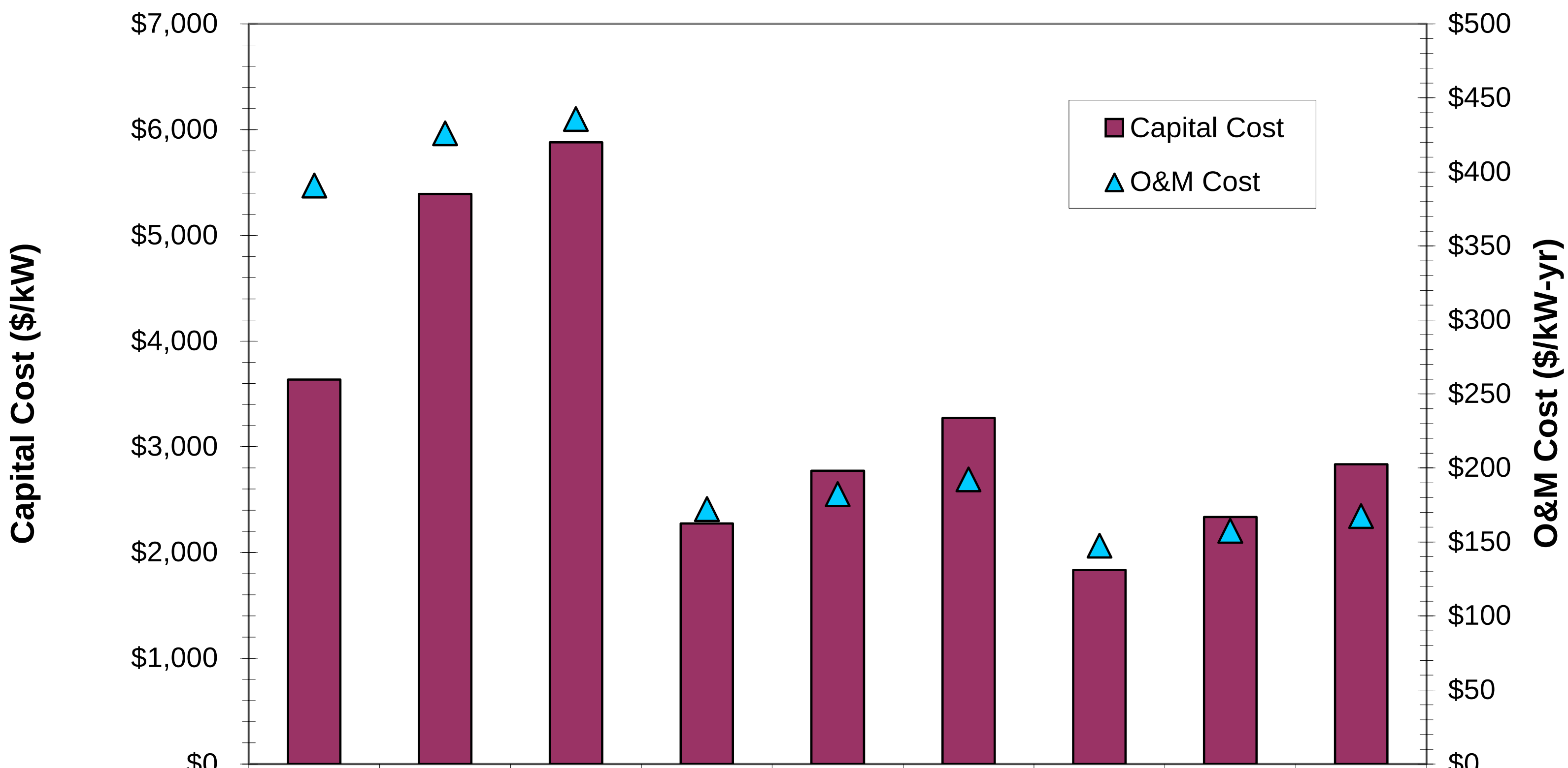
Biomass Power Technology	**Biopower Generated (MW) & Required Wood Supply (tpd of x% MC)**		
	Low Capacity	**Medium Capacity**	**High Capacity**
IC Engine Syngas blended w/ Natural Gas	2 MW	10 MW	15 MW
	19 tpd @ 50% MC	**61** tpd @ 50% MC	**100** tpd @ 50% MC
IC Engine 100% Syngas	2 MW	10 MW	15 MW
	100 tpd @ 50% MC	**333** tpd @ 30% MC	**497** tpd @ 30% MC
Feedwater Heater Repowering	3 MW	13 MW	20 MW
	100 tpd @ 50% MC	**452** tpd @ 50% MC	**678** tpd @ 50% MC

Solid Fuel Cofiring Costs



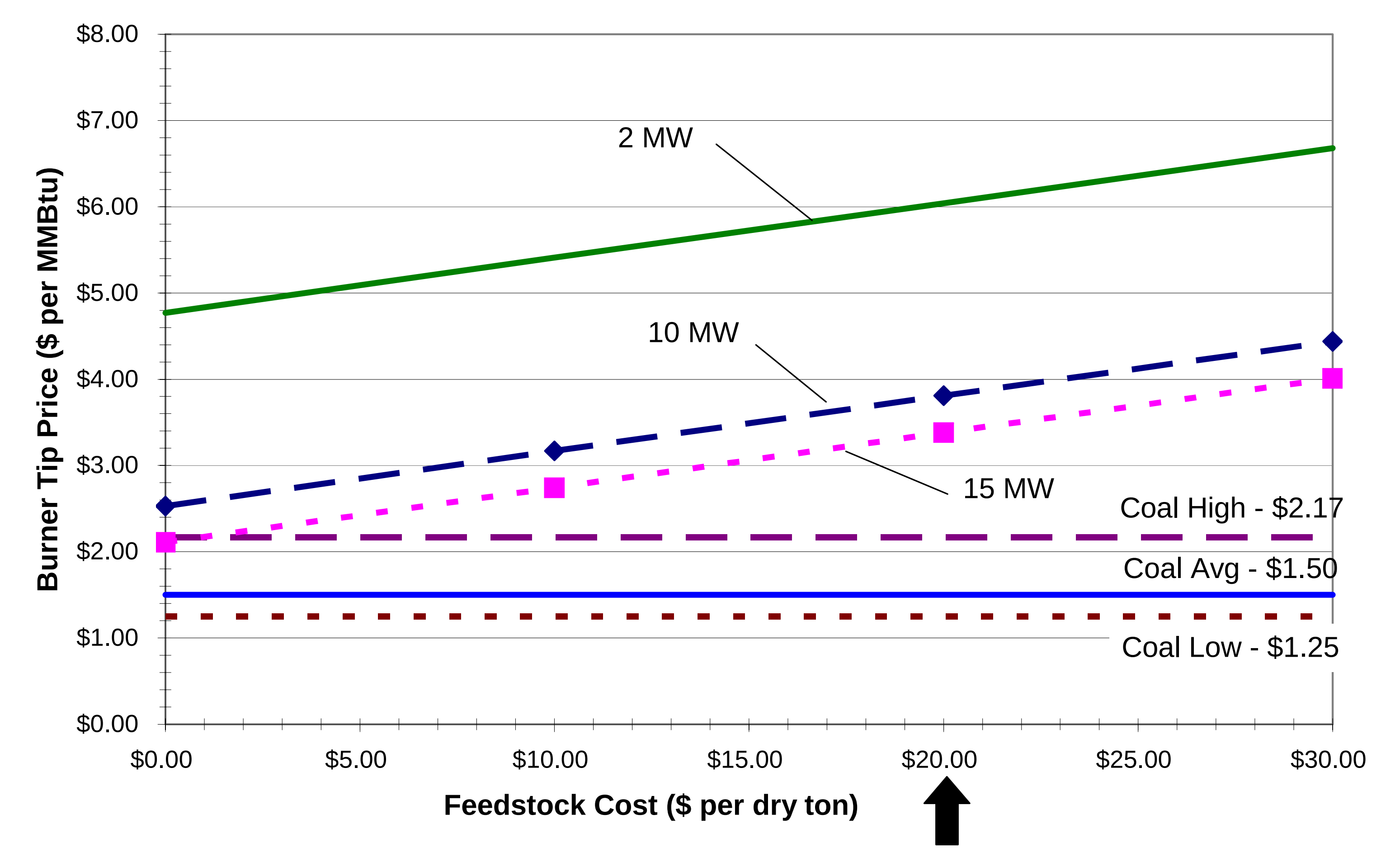
	2 MW - Low	2 MW - Medium	2 MW - High	10 MW - Low	10 MW - Medium	10 MW - High	15 MW - Low	15 MW - Medium	15 MW - High
Capital Cost	$397	$1,193	$1,936	$89	$322	$499	$64	$261	$382
O&M Cost	$159	$283	$190	$113	$173	$121	$101	$153	$108

Gasification Cofiring Costs

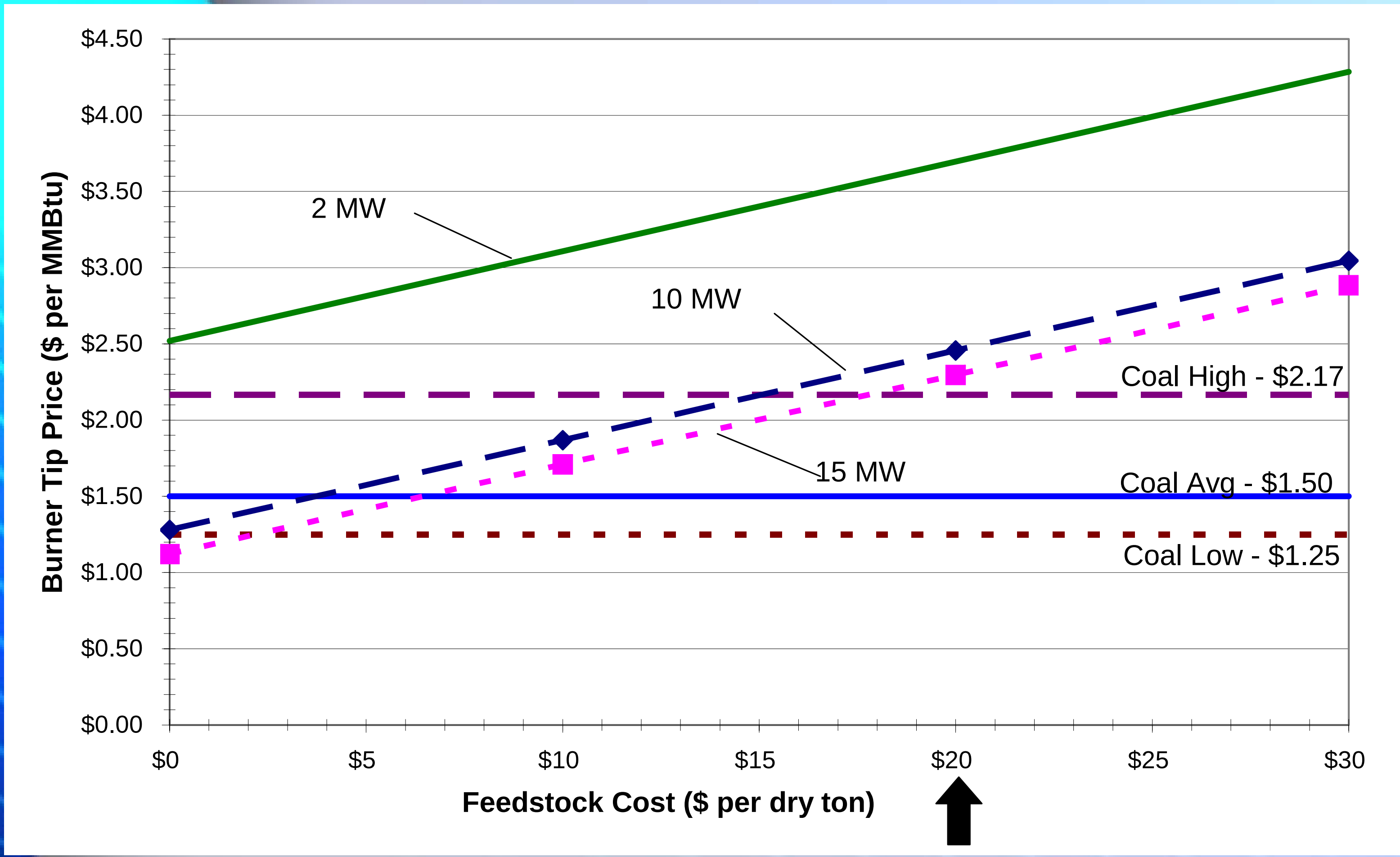


	2 MW - Low	2 MW - Medium	2 MW - High	10 MW - Low	10 MW - Medium	10 MW - High	15 MW - Low	15 MW - Medium	15 MW - High
Capital Cost	$3,635	$5,392	$5,881	$2,274	$2,774	$3,274	$1,836	$2,336	$2,836
O&M Cost	$391	$426	$436	$172	$182	$192	$148	$158	$168

Gasification Cofiring Results



Solid Fuel Cofiring Results



Conclusions

Technology	Technical Feasibility	Cost Feasibility	Commercial Experience
Gasification cofiring	Demonstrated	Not competitive	Two European sites
Solid fuel cofiring	Proven	Competitive at avg coal prices and <$15/dt biomass	On going at 8 plants in the USA
Steam turbine	Proven	Not competitive with grid power in <=15 MW capacities	Many plants worldwide
Combined Heat and Power (CHP)	Proven	Can be very competitive	Many plants worldwide

Conclusions

Technology	Technical Feasibility	Cost Feasibility	Commercial Experience
Gasification Combined Cycle	Under development	Not competitive	None
Gasification Simple Cycle	Under development	Could be competitive with high cost natural gas DG plants	None
Internal Combustion Engine	Proven	Could be competitive with high cost natural gas DG plants	Some in Europe. None in the USA.
Feedwater Preheating	Marginal	Modest	None

Conclusions

- Regardless of technology, no biomass power plants are competitive with coal at 2 MW capacity
  - More than 100 tpd of thinnings will be needed to support a larger unit.
- Regardless of technology, the delivered cost of biomass can be, at most $10/ton to be competitive
- CHP, solid fuel cofiring, and feedwater heating have best chance to be competitive

More Information

- Download the DOE RUS report:
  - **http://www.antaresgroupinc.com/DOERUSreport.htm**
- Download the Federal Technology Alert: Biomass Cofiring:
  - **http://www.antaresgroupinc.com/fta_biomass_cofiring.htm**
- Information on Healthy Forests
  - **http://healthyforests.gov**
- Download the MOU between Agencies:
  - **http://www.fs.fed.us/fmsc/ftp/sdu/docs/BiomassMOU_060303_final_web.pdf**

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Opportunities for LFG Energy

LANDFILL METHANE OUTREACH PROGRAM

Chris Voell

Environmental Protection Agency

Landfill Methane Outreach Program

Why does EPA care?

- Methane is a potent heat-trapping gas.
- Landfills are the largest human-made source of methane in the US.
- There are many cost effective options for reducing methane emissions while generating energy.
- Projects reduce local air pollution.
- Projects create jobs, revenues, and cost savings.

EPA LMOP

- 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.*

Landfill Gas 101

- Landfill gas (LFG) is a by-product of the decomposition of municipal solid waste (MSW).
- LFG:
  - ~ 50% methane (CH_4).
  - ~ 50% carbon dioxide (CO_2).
  - <1% non-methane organic compounds (NMOCs).
- For every 1 million tons of MSW:
  - ~ 1.0 MW of electricity
  - ~ 550,000 cubic feet per day of landfill gas.
- If uncontrolled, LFG contributes to smog and global warming, and may cause health and safety concerns.

LFG Energy Emission Reduction Benefits (lbs/MWh)

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 Project Benefits

- Destroys methane and other organic compounds in LFG
  - Each 1 MW of generation = planting ~12,000 acres of trees per year, removing the emissions of ~8,800 cars per year, or preventing the use of ~93,000 barrels of oil per year
- 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
  - PM is a respiratory health concern
  - CO_2 is a global warming gas

Jobs and Revenue

- A typical 3 MW LFG electricity project is estimated to have the following national benefits (direct, indirect, and induced) during the construction year:
  - Increase the output of the US economy by $14 million
  - Increase US employee earnings by $3.5 million (wages, salaries, etc.)
  - Employ 90 people (expressed in full-time equivalents per year)

Industry Status

- More than 365 projects in 39 states supplying:
  - 8,000,000,000 kilowatt hours of electricity per year
  - 75,000,000,000 cubic feet per year of landfill gas to direct use applications

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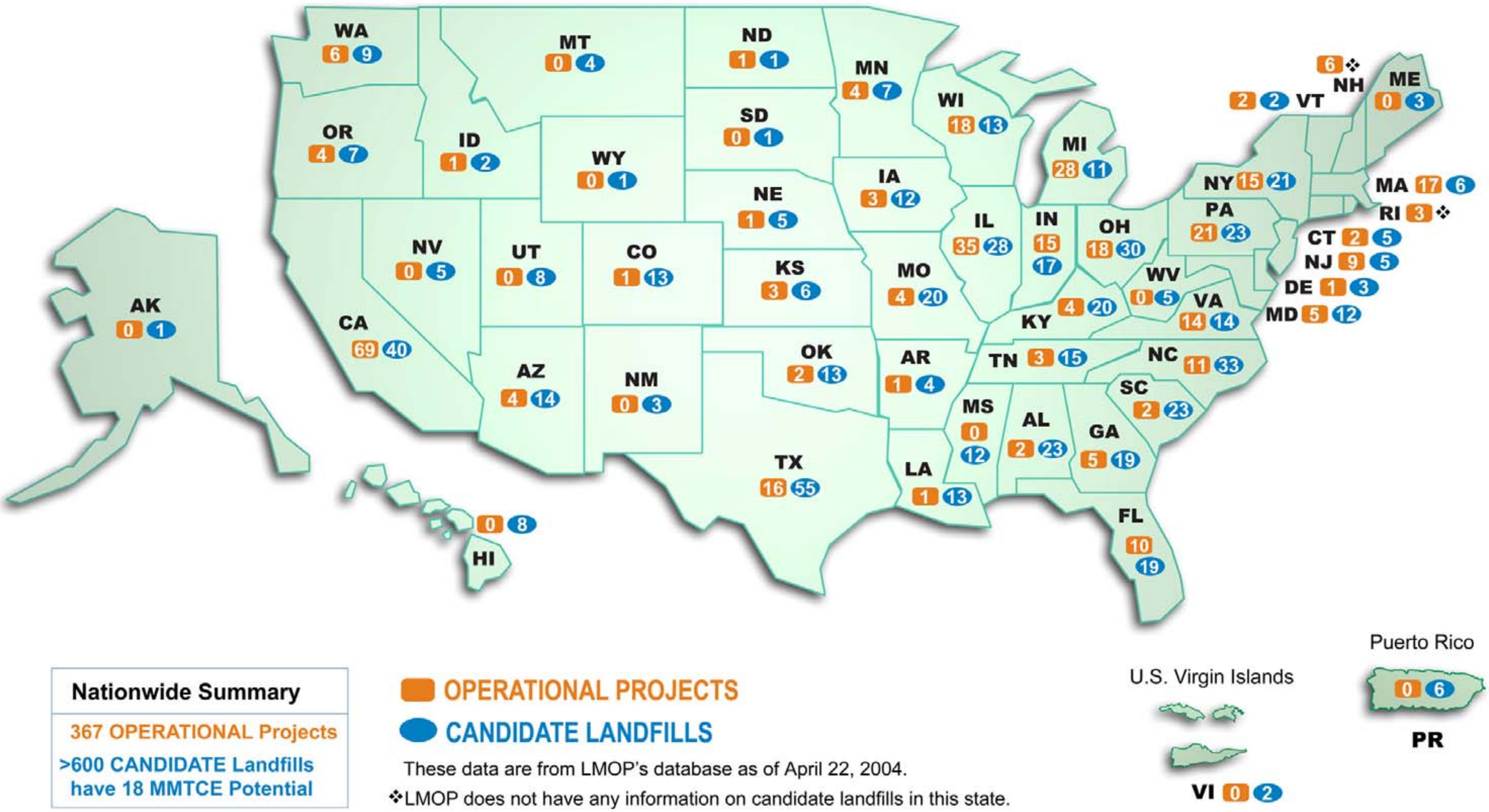
Project Status



Environmental Benefits

- Estimated Annual Benefits:
  - Planting 18,000,000 acres of forest,
  - Preventing the use of 140,000,000 barrels of oil,
  - Removing emissions equivalent to 13,000,000 cars, or
  - Offsetting the use of 295,000 railcars of coal.

LFGE and Green Power

- LFGE is a recognized renewable energy resource (*Green-e*, EPA Green Power Partnership).
- LFGE Serves as the "baseload renewable" for many green power programs.
- LFG is generated 24/7 and available over 90% of the time.
- LFG can act as a long-term price and volatility hedge against fossil fuels.
- Utilities are already using LFGE.

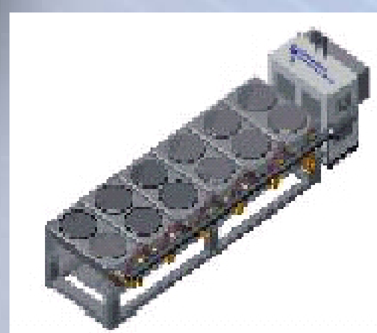
Electricity

Internal Combustion Engine

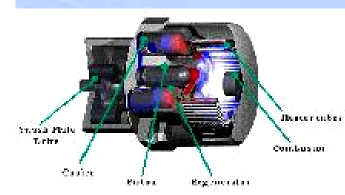
Gas Turbine

Emerging Technologies

Microturbine



Organic Rankine Cycle Engine



Stirling "External Combustion" Engine

Antioch Community H.S.

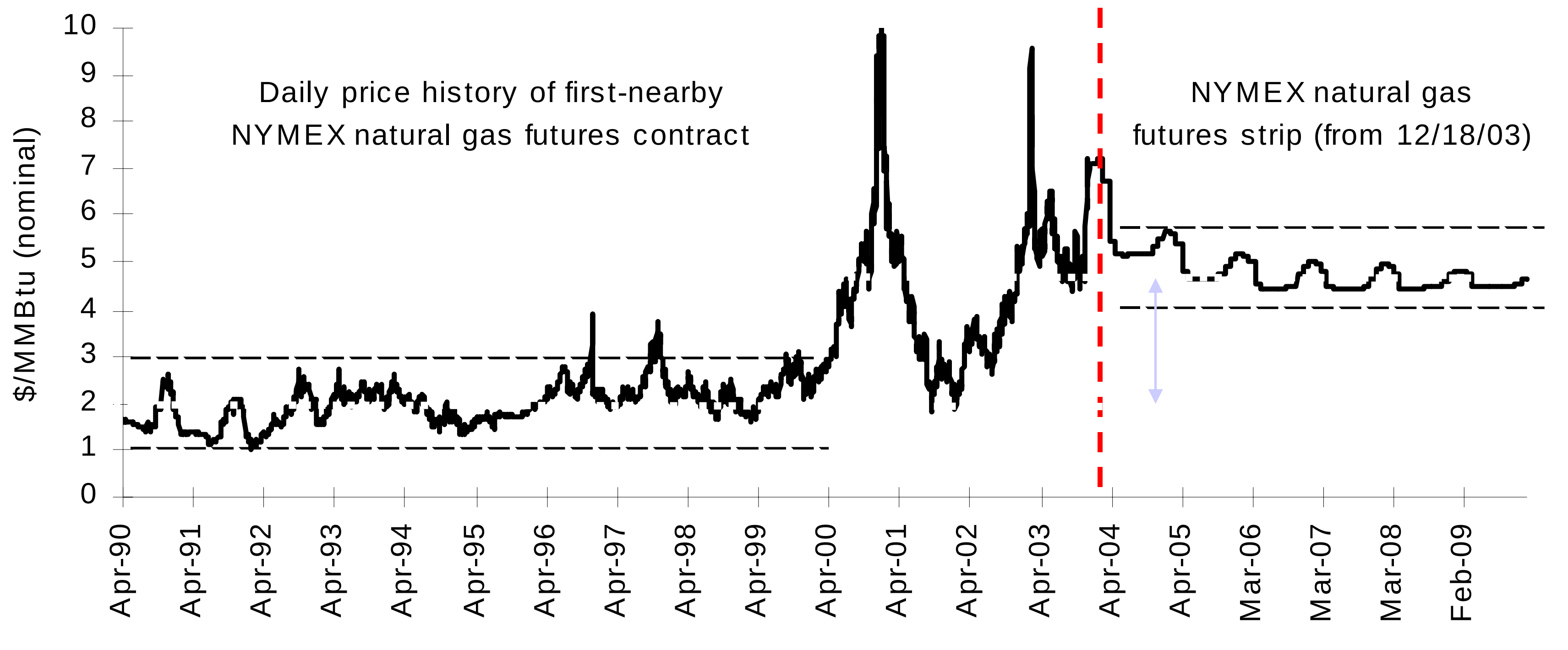
- First school co-generation (CHP) project on LFG
- Landfill former Superfund site
- 12 microturbines with 360 kW capacity
- Exhaust energy produces 290,000 BTUs/hour at 550°
- School expects to save $100,000/year

Direct Use

- 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 and Aquaculture

Pottery Studio Sugar Grove, NC

Natural Gas Prices



Source: NYMEX

EnergyXchange, NC

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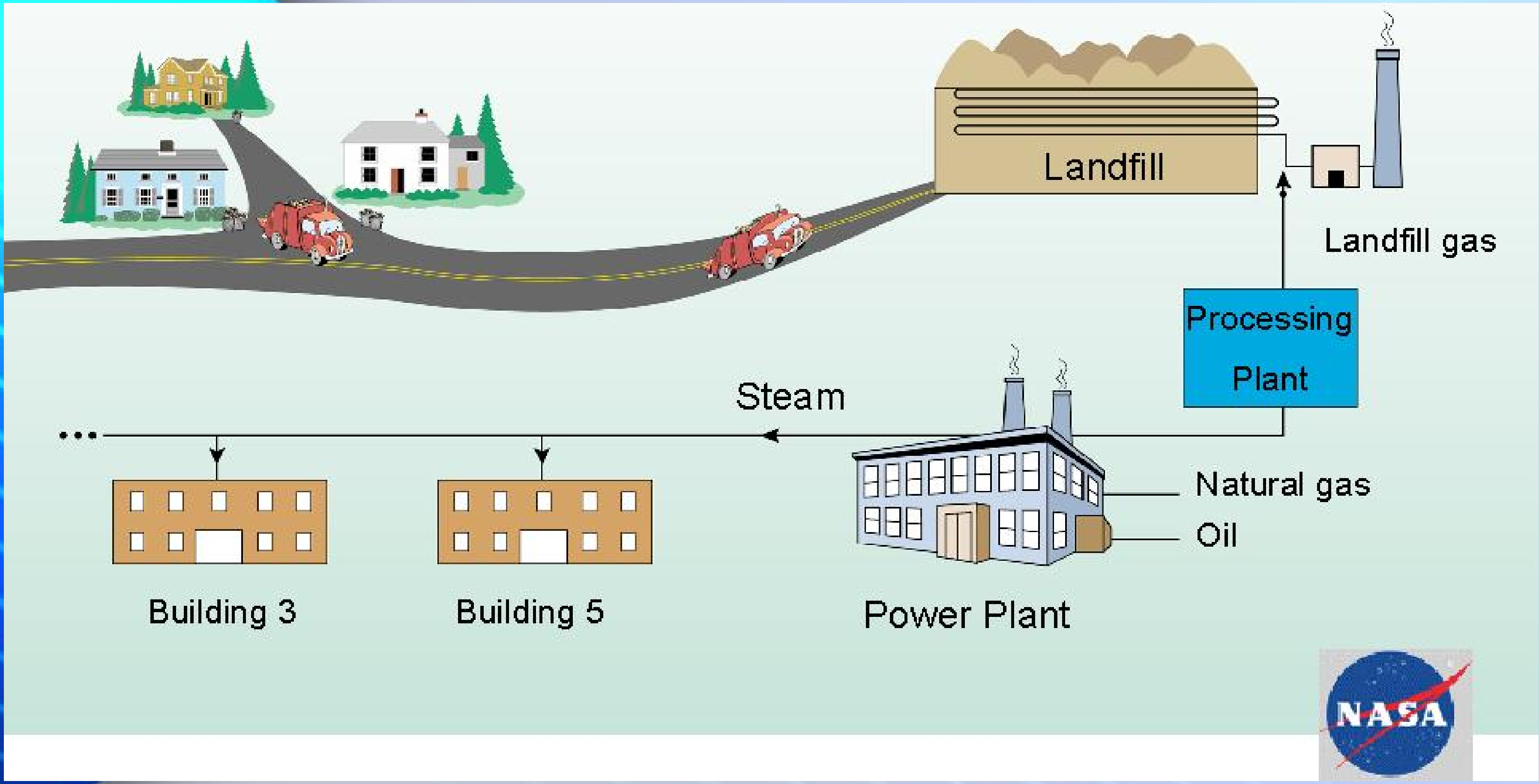
LFG Users

- CONE corporatedenimfinishingjacquards
- MALLINCKRODT
- Cargill
- AJINOMOTO
- SENECA Foods.com "A World Leader In Agribusiness"
- Honeywell
- Owens Corning
- LAFARGE
- INTERNATIONAL
- Nestlé Makes the Very Best
- GE
- NASA
- Rolls-Royce
- SC Johnson
- Ford
- SUNOCO
- Lucent Technologies Bell Labs Innovations
- GM
- Frito Lay
- BMW The Ultimate Driving Machine
- INTERNATIONAL PAPER From innovation to results.
- DAIMLERCHRYSLER

"This LFG energy project allows BMW to take a wasted source of energy and use it to generate electricity, which benefits the environment and area residents through lower emissions."

Dr. Helmut Leube, President, BMW Manufacturing Corp.

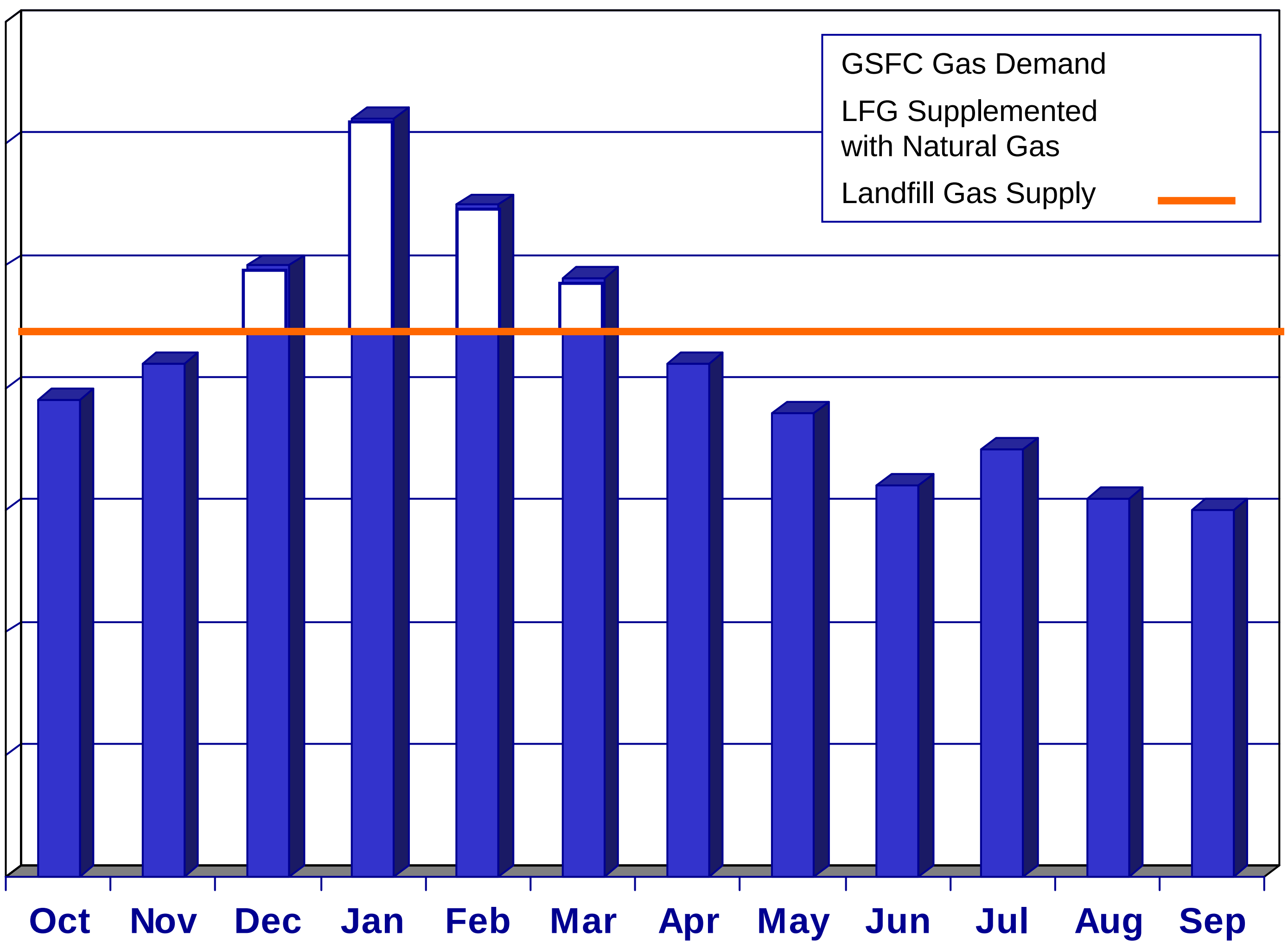
NASA GSFC, MD


Landfill
Landfill gas
Processing Plant
Steam
Natural gas
Oil
Building 3
Building 5
Power Plant
NASA

Hill AFB, Utah

- Using the FEMP ESPC BAMF contract
  - Exelon Federal Services (Ameresco)
- Hill AFB < 1 mile from Davis County LF
- LFG will be piped to Hill AFB, where engine generators will be located (1 MW)
- Selling electricity to Utah Power
  - Results in $300,000-$400,000 credit per year on utility bill
- Expected on-line in fall 2004

Supply/Demand at GSFC



GSFC Project Benefits

- ✓ NASA wins by saving $350K/year on fuel cost, and no cost to the government
- ✓ NASA increases energy reliability
- ✓ Public and Private Partnerships
  - ✓ Developers win by making a profit
  - ✓ County wins by sharing the LFG fee
- ✓ Reduced local emissions
- ✓ Sustainability goals - 80% of NASA's renewable energy source goal met through this project
- ✓ Offset fossil fuel usage

Untapped Potential

- Currently over 600 candidate landfills and a total potential of over 1,700 MW.
- Total expected annual environmental benefits if all projects were developed:
  - 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.

LMOP Services

- Partnerships and networking (over 365)
- Newsletter and listserv
- Direct Project Assistance
  - Feasibility studies, end user searches
- Technical Assistance Resource
- LFG Advocate
- PR/Ribbon Cuttings

LMOP Services

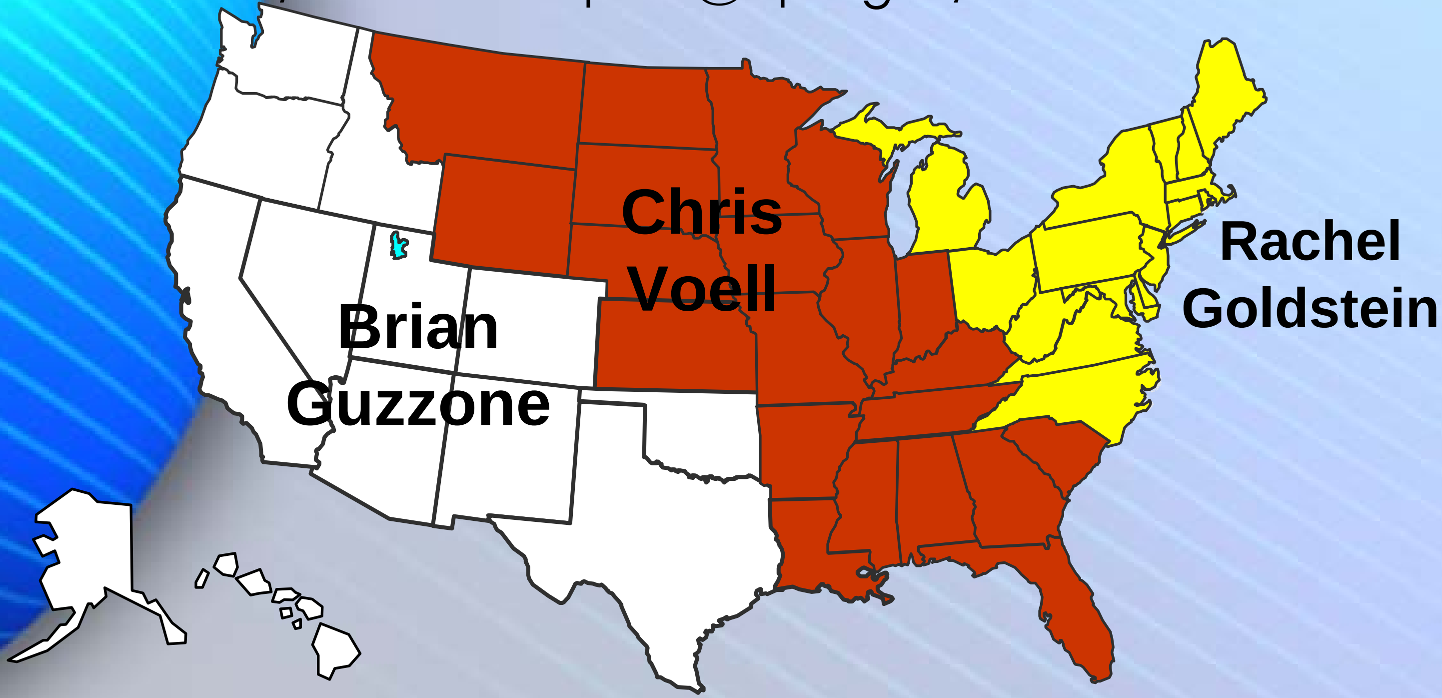
- ❖Project and Candidate Database
- ❖Green Pricing Accreditation
- ❖State Workshops/Conferences
- ❖Peer Matching
- ❖Web Site (e.g., publications, database)

❖*Annual LMOP Conference, Project Expo, and Partner Awards - January 10-11 2005 in Baltimore!*

For more information

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

- Brian Guzzone, guzzone.brian@epa.gov, 202-343-9248
- Rachel Goldstein, goldstein.rachel@epa.gov, 202-343-9391
- Chris Voell, voell.christopher@epa.gov, 202-343-9406



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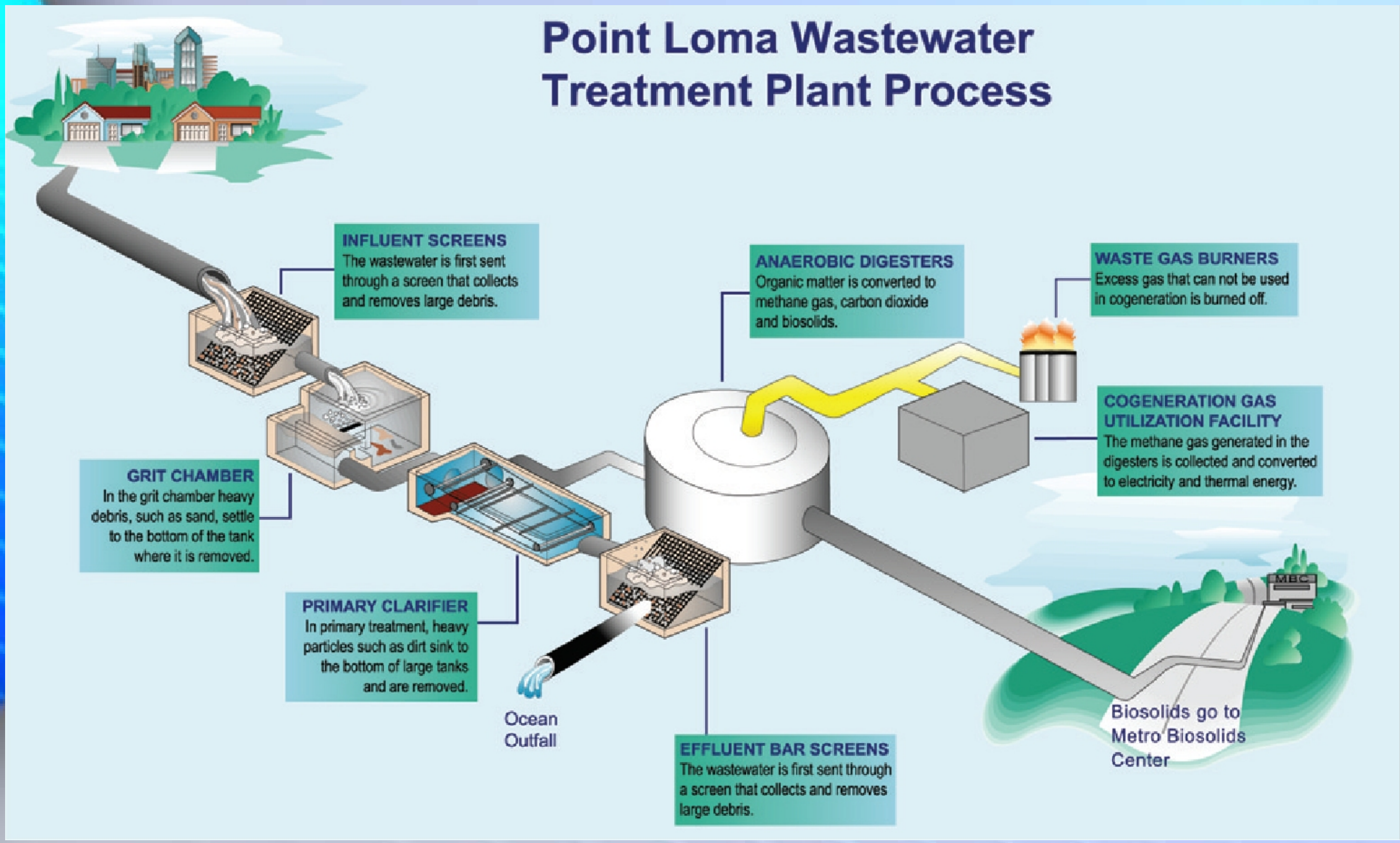
Use of WWTP Digester Gas to Generate Power

Craig Hustwit
Edd Bills
Chuck White
National Energy Technology Laboratory

Overview

- What is WWTP Digester Gas?
- Applications
- Process Issues
- WWTP Gas to Power

Wastewater Treatment Plant



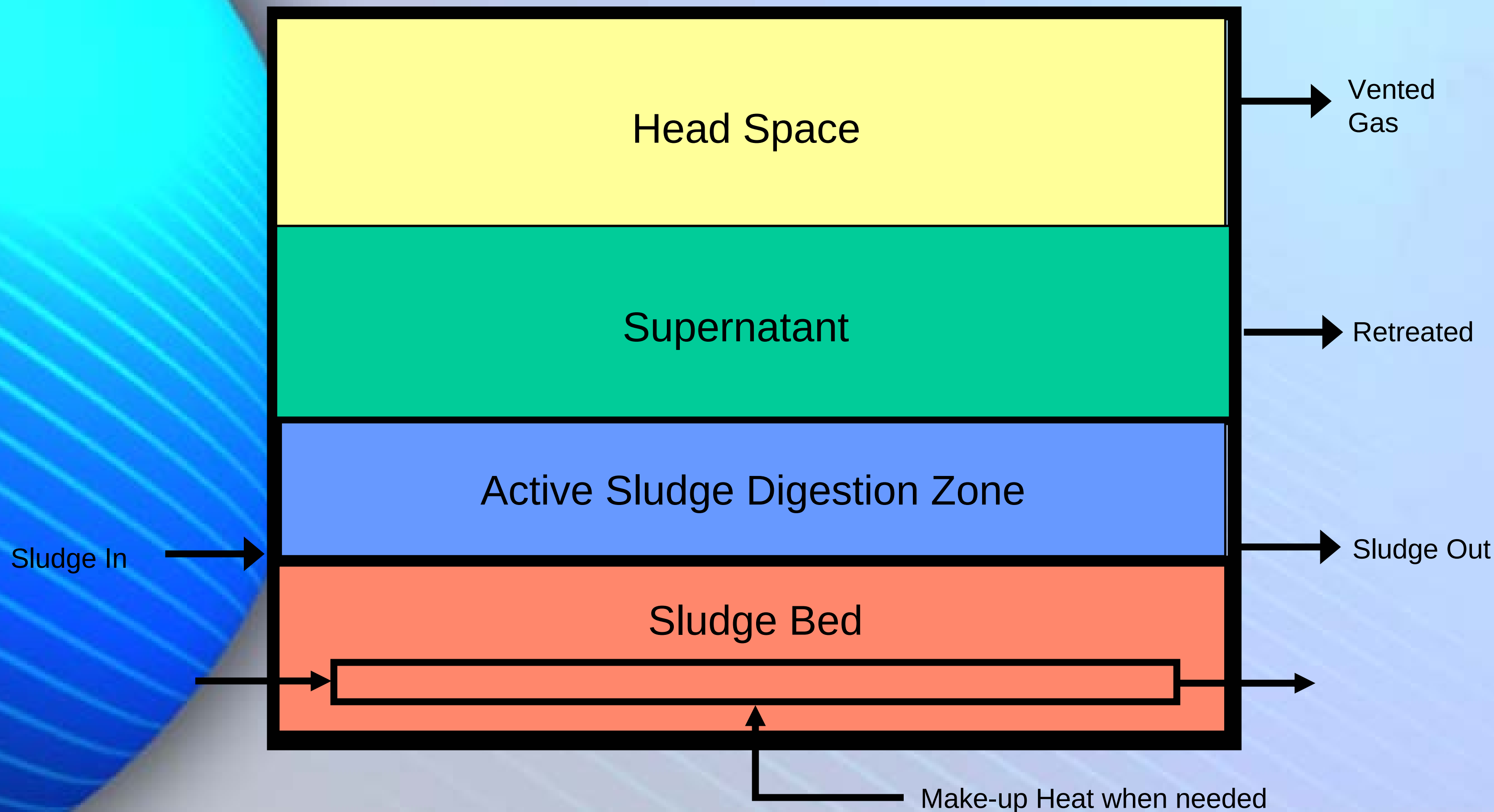
Wastewater Treatment Process

- Preliminary Treatment
- Primary Treatment
- Secondary Treatment
- Tertiary Treatment
- Sludge Thickening
- Sludge Dewatering
- Digestion and Stabilization

Anaerobic Digestion

- Sludge & resident anaerobic bacteria pumped into large covered tank, anaerobic conditions
- Temperature 90 - 95 °F, pH circum-neutral
- Supernatant and scum periodically returned to beginning of the treatment process
- Sludge allowed to sit for 1 – 3 months

Anaerobic Digester



Anaerobic Digestion

- Bacteria (methanogens, SRB) metabolize complex hydrocarbons in the sludge

$$(CH_2O)_x \rightarrow (CH_2O)_y + H_2O + CO_2 + H_2S + CH_4$$

- Gas collects in head space, periodically drawn off (Typical production = 1 scf / capita / day)

- Even small concentration of H_2S problematic
  - Odor
  - Corrosive properties

Anaerobic Digestion

Optimum Temperature	95 - 98 °F
Optimum pH	6.7 - 7.8
Gas production	7-10 ft^3/lb volatile solids
Gas composition	64% CH_4, 35% CO_2, trace H_2S
Gas heating value	600 Btu/ft^3
Retention time	30 – 90 days
Typical tank diameter	20 – 115 ft

Digester Gas to Power

- Substitute for natural gas
- Internal combustion (IC) engines
- Small gas turbines & Microturbines
- Sterling engines
- Fuel cells

Reciprocating Engines

- Most common choice for DG applications
- Wide capacity range (1kw – 6 MW)
- Wide range of fuels (liquid and gaseous)
- Feed rates from under 5,000 scf/day
- Can utilize low BTU gas – some models as low as 300 Btu/scf

Reciprocating Engines

- Proven and reliable technology
- Tolerate H_2S in the 200 ppm range
- Generally more emissions problems than other types of equipment but cleanup is understood
- Heat from exhaust can be used to heat digester
- Lowest capital cost at 300 – 500 $/kW

Microturbines

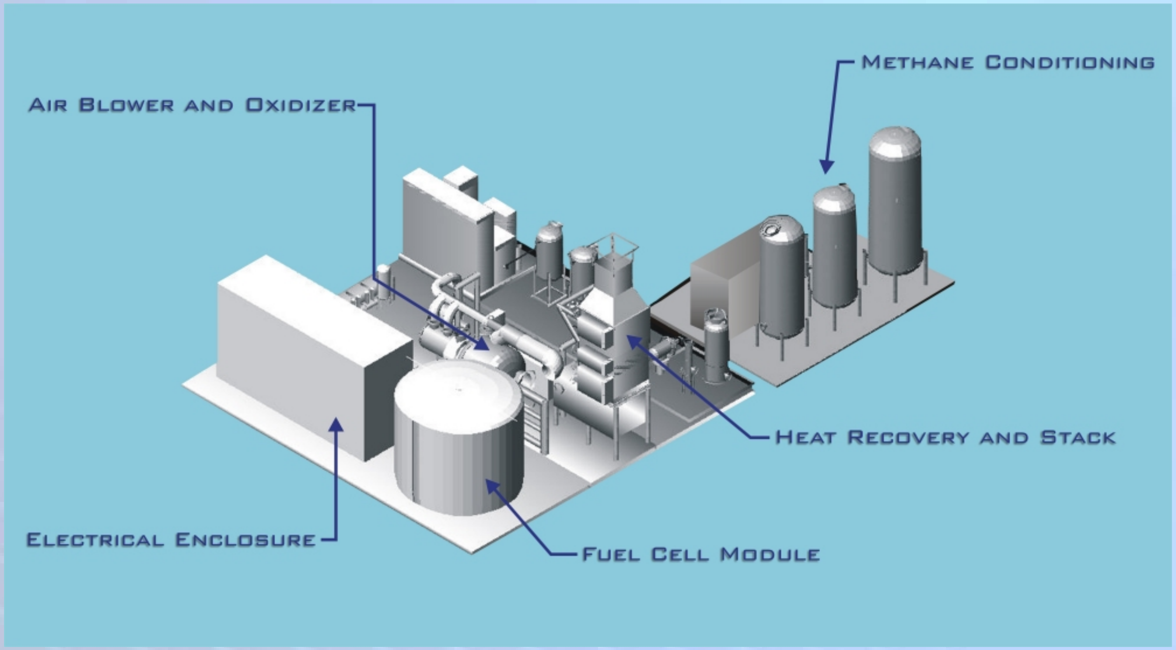
- Better for smaller operations – "plug and play" for pipeline quality gas
- Small "modular" units available: 30 – 100 kW
- Inlet pressures from 0.2 to 55 psi
- Inlet temperatures from – 20 to 50 °C
- Feed rates from 10,000 – 40,000 scf/day
- Some models tolerate high levels (7%) H_2S

Microturbines

- Heat from exhaust can be used to heat digester
- Low NOx (< 9 ppm – most models)
- Most run on air bearings having only one moving part (the central shaft with turbine) → less maintenance than reciprocating engines
- Cost is 1,000 -1,500 $/kW
- For large plants good strategy to use recips for bulk of power and use microturbines for peaking power

Fuel Cells

- Low Emissions
  - H_2O
  - Heat
- Heat used for digesters



- Low O&M costs – no moving parts
- High capital cost > 2,000 $/kW

Success Story 1

- Point Loma, San Diego Metropolitan WWT Dept.

Point Loma

- Treats up to 240 MGD
- Two reciprocating engine generators – 4.5 MWe
- Exhaust heat – heats digesters
- Dual fuel recip. engine generator – 1.2 MWe
- In 2000:
  - saved $3 million energy costs
  - sold $1.4 million to grid

Success Story 2

- South Treatment Plant – King County (Seattle) Washington

South Treatment Plant

- Uses a Binax scrubber to remove CO_2, H_2S and Siloxanes
- Scrubber produces pipeline quality gas, sold to Puget Sound Energy
- Can use two 3.5 MWe Solar turbine/generators (under construction)
- Lessons learned: removing the CO_2 from digester gas is expensive
  - Better to utilize lower Btu gas
  - Occasionally has been cheaper to flare than to run the scrubber

South Treatment Plant

- Alternative Usage of Unscrubbed Gas
  - Can use in 1 MWe molten carbonate FuelCell Energy fuel cell
  - Fuel with CO_2 is preferred
  - H_2S removed with SulfaTreat

Success Story 3

- West Point Treatment Plant King County (Seattle) Washington

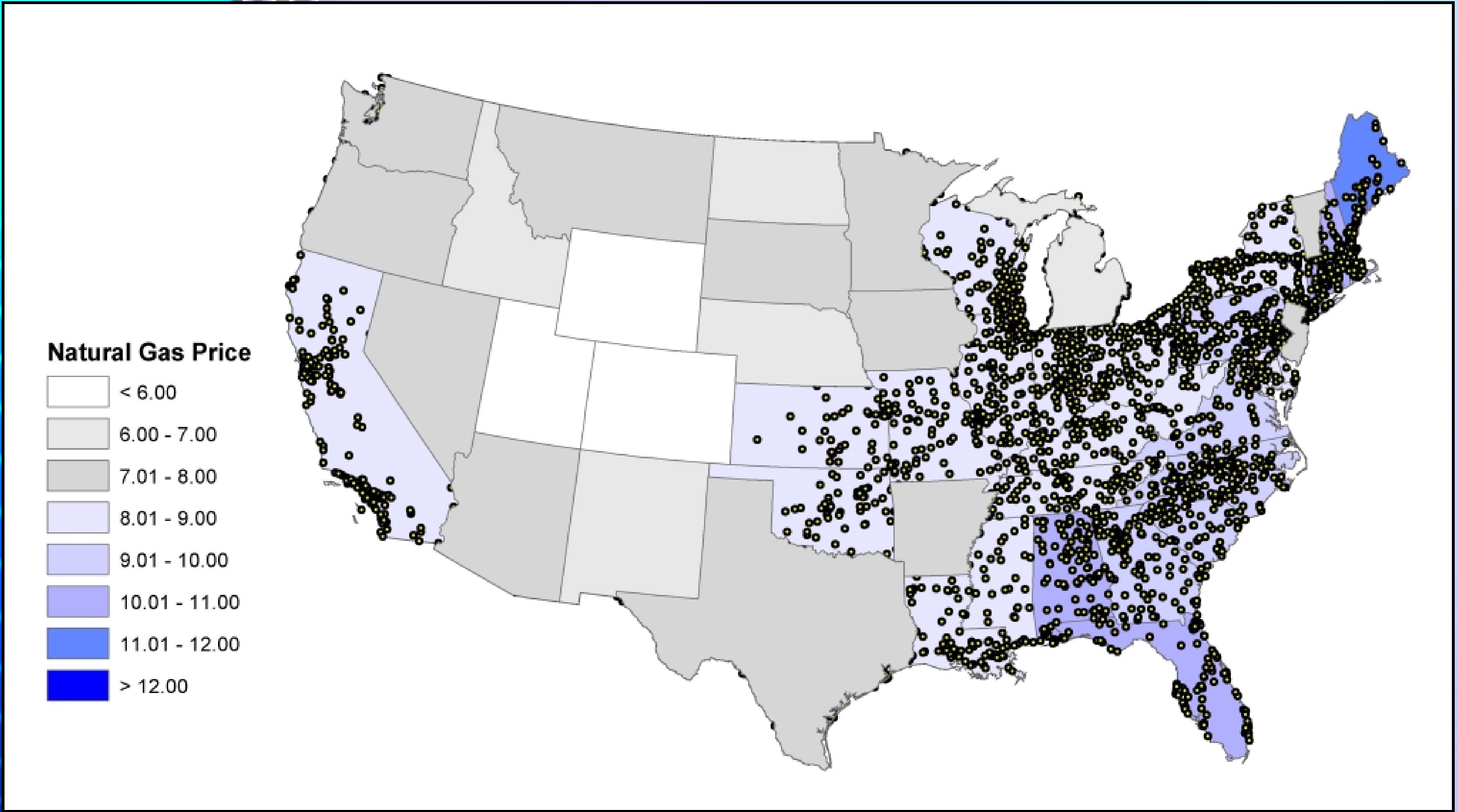
West Point Treatment Plant

- 133 MGD, 1.4 mmscfd digester gas
- Two 1.3 MWe recip. engine generators
- Exhaust heats LP boilers producing steam for digesters
- Engines have modified carburetors to use lower Btu gas

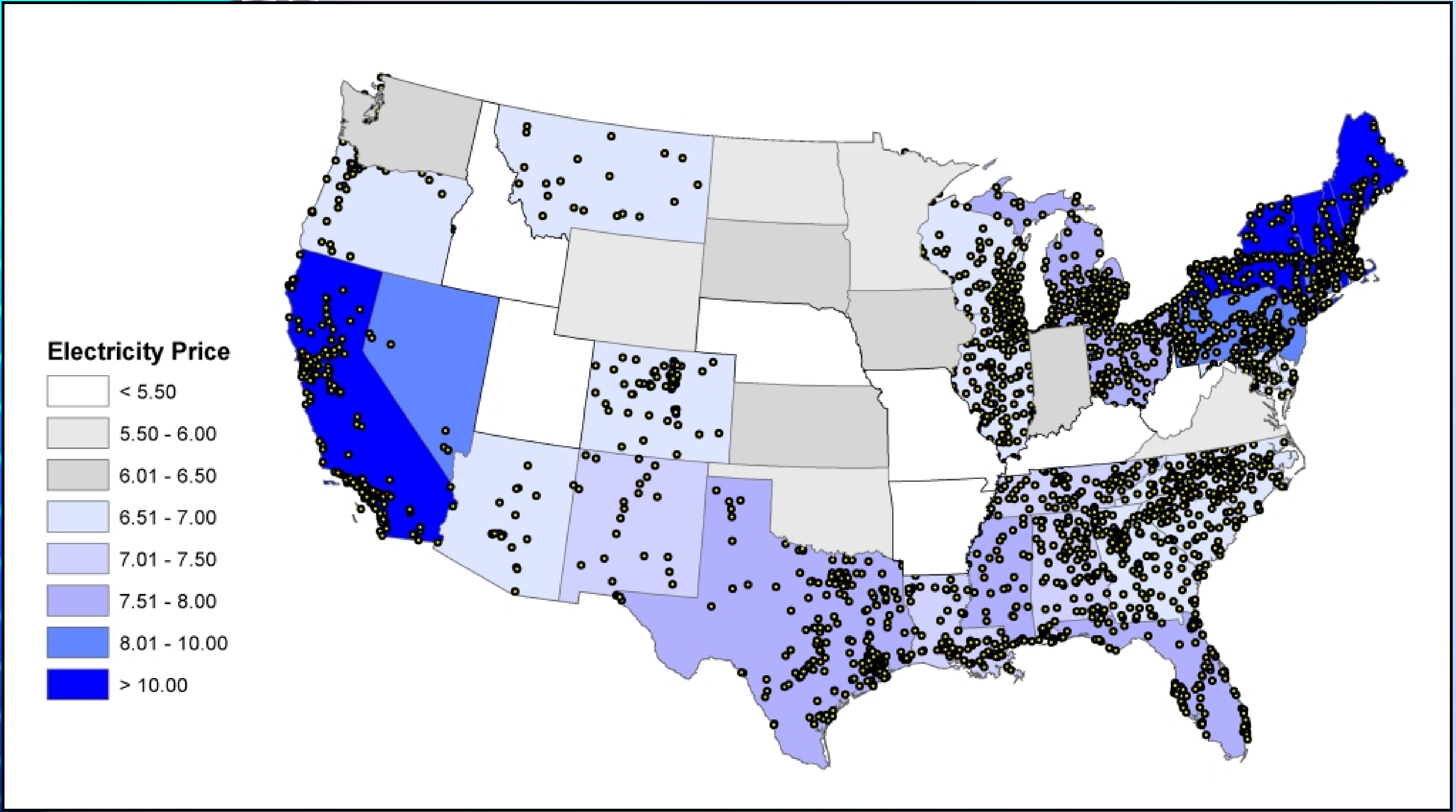
Digester Gas to Power

- Other Issues to Consider:
  - Availability
  - Economics
  - Energy Security
  - Regulations & Environment
  - Contracts

Natural Gas Prices



Electricity Prices



Economic Evaluation

- Digester gas cost includes base price plus:
  - Cost of H_2S and H_2O removal
  - Cost of transportation
    - pipeline construction
    - land right of ways, etc.
  - Cost of gas conditioning (i.e. compressing, etc.)
  - Special adaptation to combustors or engines

Economic Evaluation

- Can be a long-term, low cost renewable fuel source for generating electricity and heat
- Requires in-depth economic comparison to competing fuel and/or energy sources
- Issue is further complicated when digester gas availability fluctuates during the year
- Mitigating factor: digester gas can be burned in combination with natural gas, landfill gas, and other organic waste materials

Economic Evaluation

- Issues to Take into Account
  - Use of certain renewable and alternative fuel sources to generate electricity qualifies for green tax credits
  - The tax credits can be used to improve the financial viability of a project either directly or through their sale

Economic Evaluation

- Issues to Take into Account
  - Explore state incentives for use of green and/or renewable fuel sources to generate power
  - Explore utility company incentives for use of green and/or renewable fuel sources to generate power

Economic Evaluation

- Issues to Take into Account
  - Include avoided costs when performing financial evaluation
  - Consider value to customer of protection from grid outages and volatility of competing fuel costs
  - Consider any potential O&M Savings

Successful Approaches

- Use digester gas in combination with other locally available renewable resources
- Generate as much electricity (or heat) as you can, use what you can at the facility, sell the rest
- When using digester gas and other renewables to generate electricity, capture and use process heat, i.e. CHP

Digester Gas to Power

- Resources are Available:
  - DOE's Office of Energy Efficiency and Renewable Energy
  - Federal Energy Management Program
  - FEMP's Biomass and Alternative Methane Fuels (BAMF) Super ESPC group
  - EPA Office of Wastewater Management (OWM) for general information, laws and regulations, permitting and location data for WWTPs
    - http://www.epa.gov/owm
  - Water Environment Federation (WEF), the national WWTP trade association
    - http://www.wef.org

Digester Gas to Power

- BAMF
  - Streamlined contracting vehicle for federal facilities to utilize digester gas (and other fuels)
  - Financing alternative to Congressional appropriations
  - Trained and experienced technical core team
  - More information available from:
    - NETL booth
    - FEMP booth
    - Workshop "BAMF Baseball"

Conclusion

- Use of digester gas in generating electricity and/or steam can be an attractive approach especially when used in combination with conventional or other renewable fuels

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