WWTP Cogeneration
Biogas Case Studies

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Presentation Outline

- Cogeneration – Background and Application
  - Historical Perspectives
  - Current Drivers
  - Cogeneration Systems & Considerations
- Cogeneration Case Studies
  - Fond du Lac, Wisconsin
  - Kankakee River Metropolitan Agency, Illinois
  - Dubuque, Iowa

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Definitions & Clarifications

- Cogeneration in this Discussion:
  - Using biogas to produce electricity and recovering waste heat.
  - Assumes internal combustion engines or microturbines.
  - Others not considered: Stirling engines, fuel cells, organic Rankine cycle systems, etc.

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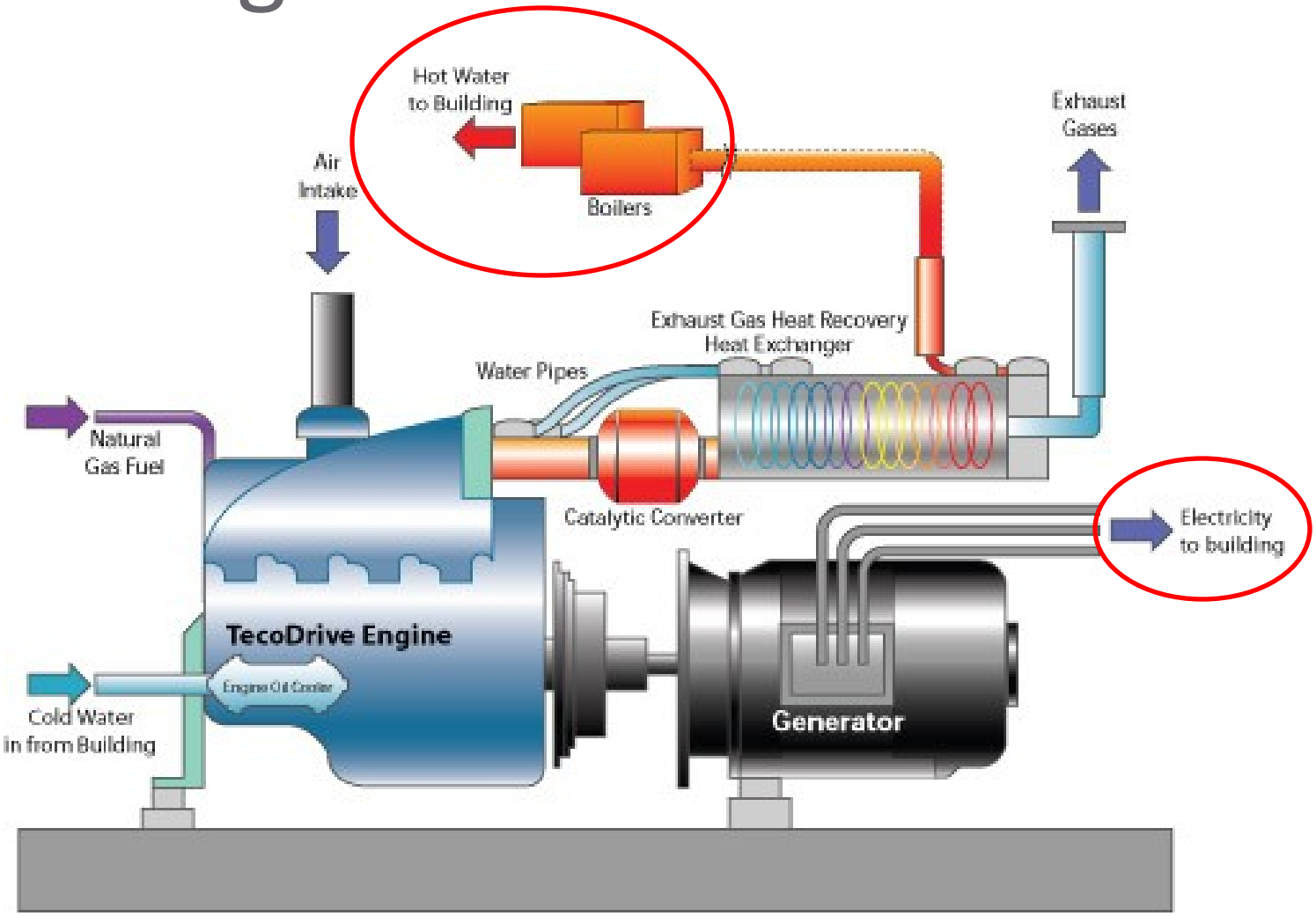
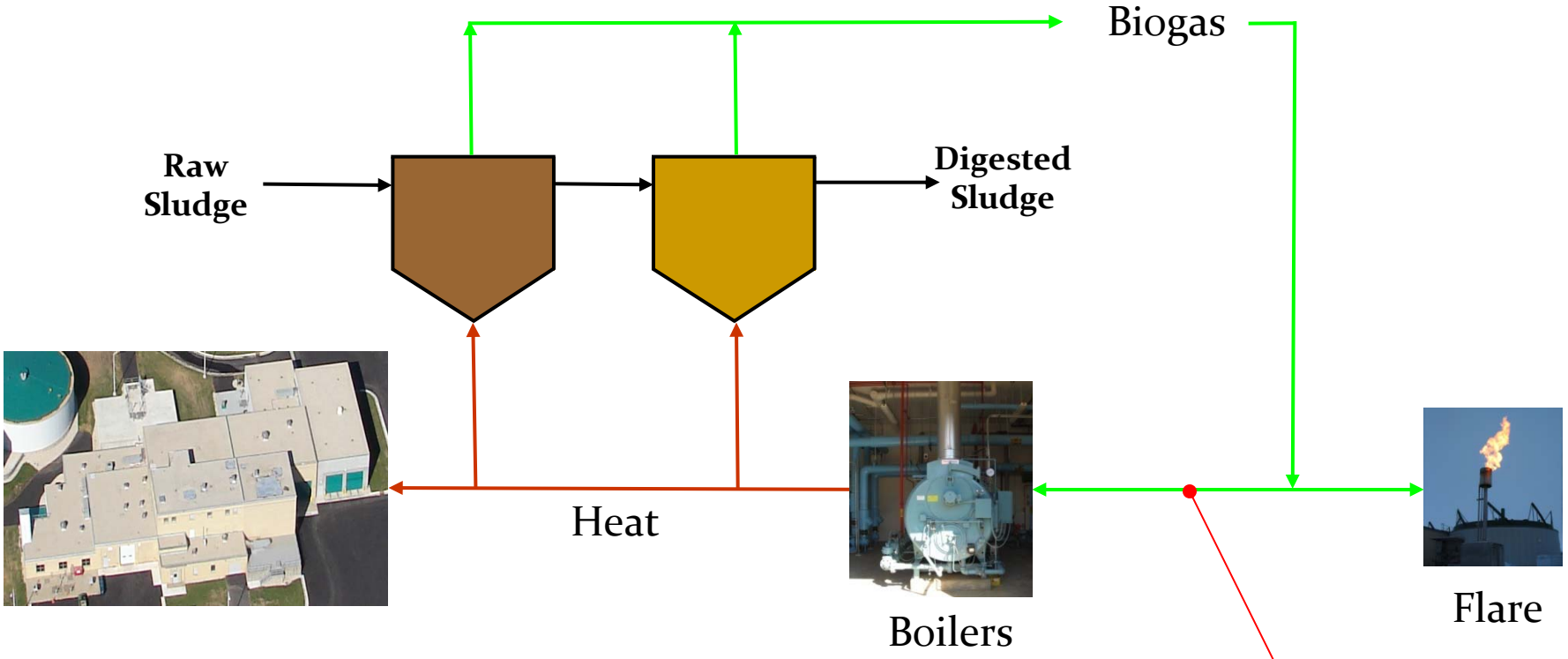
Cogeneration Schematic



Biogas Historically Fired in Boilers and/or Flared



Biogas Cogeneration

Raw Sludge

Digested Sludge

Biogas

Electricity

Waste Heat Recovery

Engine/Microturbine

Flare

Boilers

Typically Significant Conditioning Required

- **Moisture**
- **Hydrogen Sulfide**
- **Siloxanes**

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Historical Biogas Cogeneration

- Pre-1970s:
  - Electrical production typical only at large plants
- 1970 & early 1980s
  - Grants + high energy costs
  - Cogeneration installed at many small WWTPs
  - Systems often not used because of high maintenance and operational costs
- 1990s:
  - Low energy costs
  - Fewer cogeneration projects, except at larger plants

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Current Biogas/COGEN Drivers

- High Energy Costs
- Potential Revenue from High-Strength Wastes
  - Additional biogas
  - Tipping fees
- Carbon Footprint/Green Considerations
- Improved Biogas Conditioning Systems
- “It’s the Right Thing To Do”

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Keys For Cogen Viability

- Plant Size
- Plant Energy Balance – Heat Recovery
- Local Energy Costs
- Local Renewable Energy Value
- Local High-Strength Waste Availability/Ability to Receive
- Biogas Quality

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Generalized Cogen Viability

(Assuming biogas quality is not significantly worse than typical)

Plant Size	Cogen Viable (Typically)	Cogen w/ Supplemental Feed Stock
< 5 mgd	No	Possible
5-15 mgd	Possible/Likely	Yes
> 15 mgd	Yes	Yes

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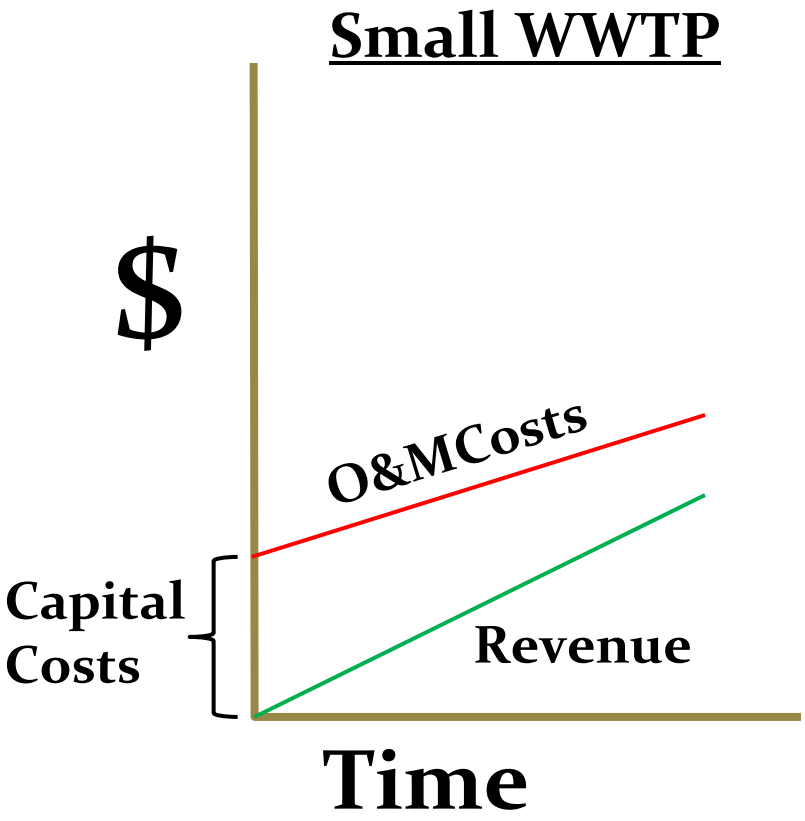
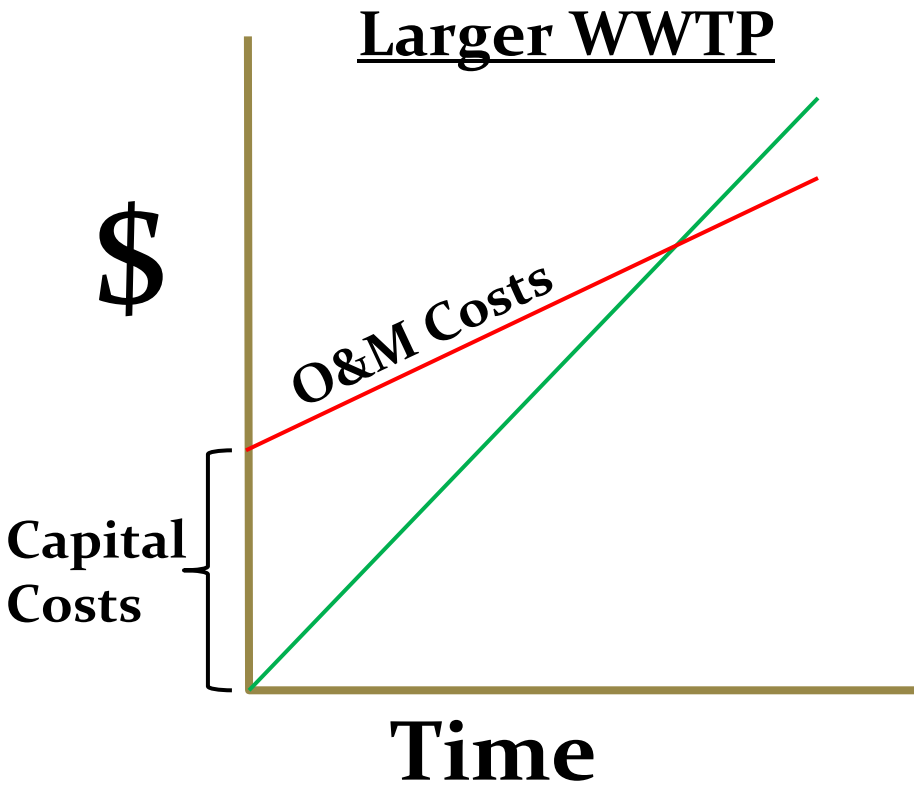
COGEN Viability – Size Matters





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Biogas Likely Requires Cleaning

Comparison of Digester Gases					
Parameters	**TCB, IL**	**Fond du Lac, WI**	**Stevens Point, WI**	**Glenbard, IL**	**KRMA, IL**
H_2S (ppm_v)	6,100	2,400	800	302	2,800
Siloxanes (µg/BTU)	1.6	2.4	1.3	0.6	0.2

Cogeneration Thresholds:

H_2S: ***< 500 ppm preferred***

<1,000 ppm for some equipment

Siloxanes: ***~ 0.1 – 0.6 µg/BTU***

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Case Study Locations

Fond du Lac, WI

Dubuque, IA

Kankakee River Metropolitan Agency (KRMA), IL

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Fond du Lac WPCP - Background

- New WPCP in 2008
  - 9.84 mgd & 21,600 lb BOD/day
  - Converted from Zimpro to Anaerobic Digestion (TPAD)
  - Construction costs = $57 million
  - Project did not include cogeneration

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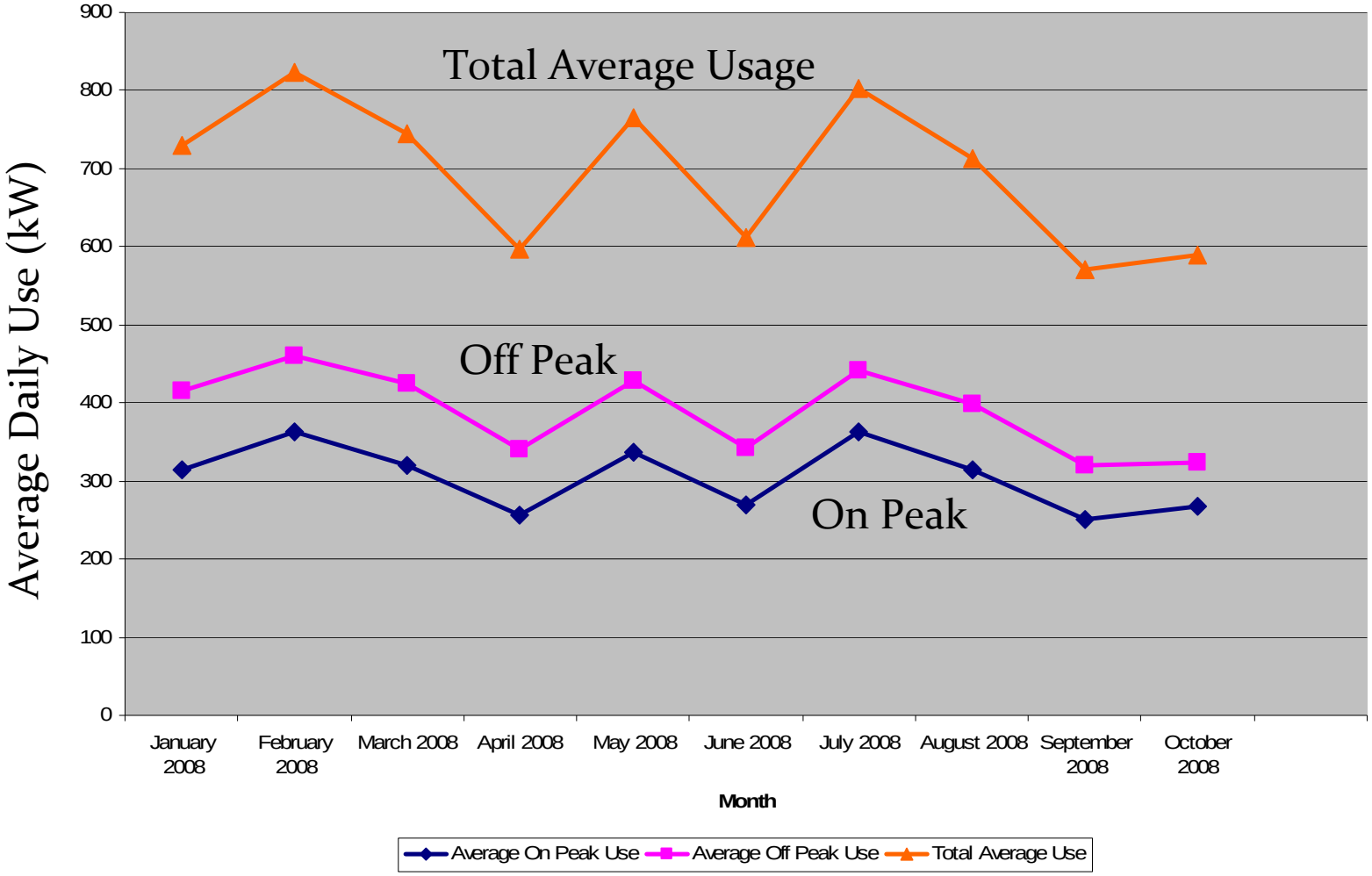
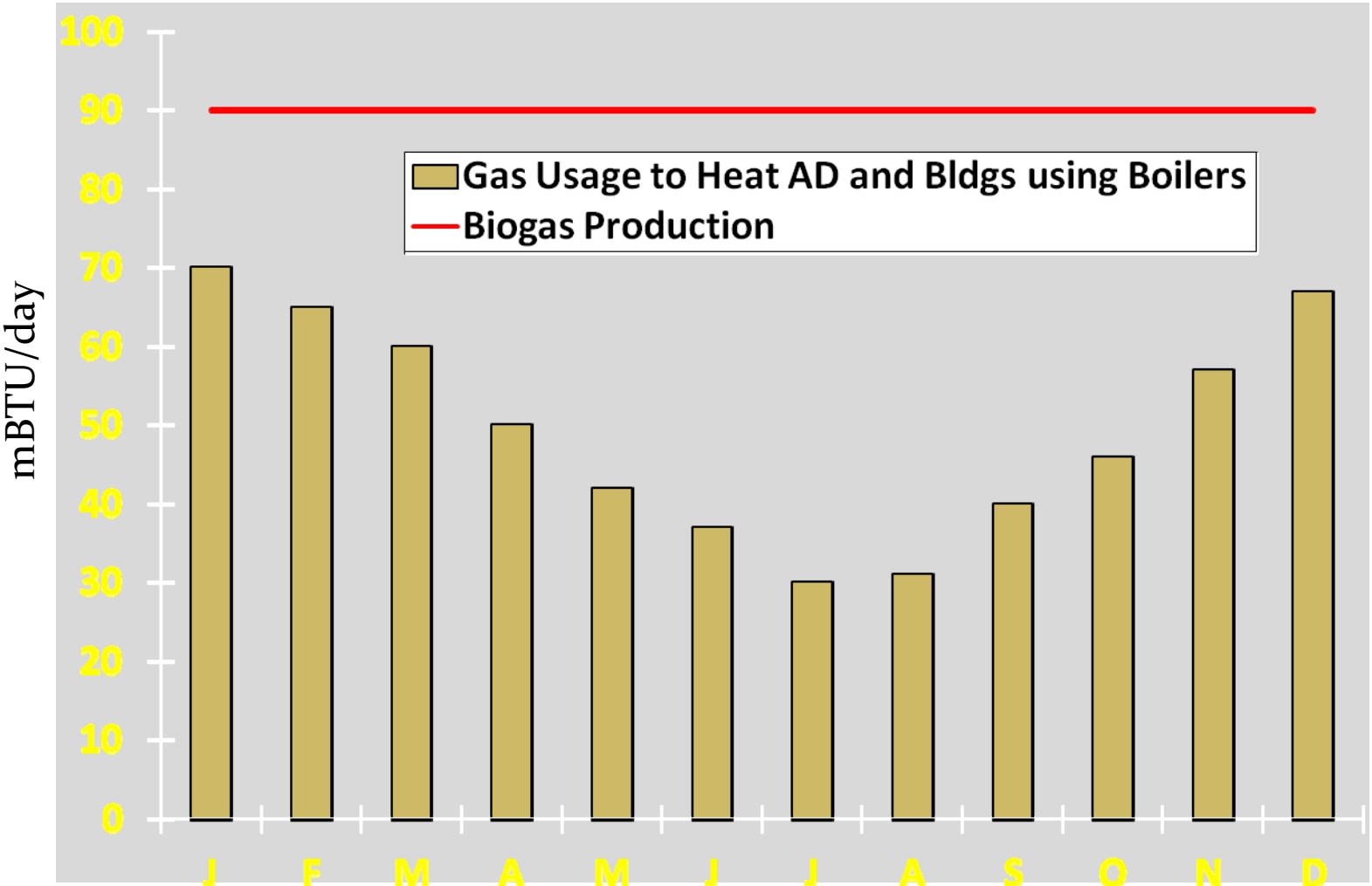
Fond du Lac TPAD System

- 4 Digesters Constructed: 2 thermophilic, 2 mesophilic
- Conservative design to accept high-strength industrial wastes.
- Cogeneration was not included; City elected to measure biogas quantity and quality for ~ 2 years before starting design.

Determine Facility Electrical Requirements



Biogas Use and Production



Fond du Lac - Cogen Design

- **130,000 ft^3/day from sludge digestion**
- **60,000 ft^3/day from high-strength wastes**
- **New silo and pumping system for high-strength wastes**

Fond du Lac – Generation Equipment

- **Heat is recovered from the engine jacket water and exhaust.**
- **Can burn digester gas or natural gas to shave peak electric demand.**
- **450 kW unit selected (CAT).**
- **~50% turn down ability.**

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Fond du Lac Digester Gas Quality

- Siloxanes:
  - Siloxane build-up in boilers became an issue
  - 2.4 µg/BTU measured in gas
  - Threshold ~ 0.1 – 0.6 µg/BTU
  - Siloxane removal required
- Hydrogen Sulfide:
  - Industry/dairies
  - 2,340 ppm_v measured in gas
  - Threshold ~ 500 – 1,000 ppm_v
  - H_2S removal required
- Moisture – very high; typical of thermophilic biogas

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Fond du Lac – Gas Conditioning

Biogas

Biological Scrubber
Hydrogen Sulfide Removal

GAC Filter
Siloxane Removal

To Genset

Compression; moisture removal/drying

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Fond du Lac – Costs and Financials

Parameter	Value without High-Strength Wastes (current conditions)	Value with High-Strength Wastes (future conditions)
Total Capital Cost	$3,173,000	$3,363,500
Energy Recovery Costs*	$1,854,000	$2,044,500
Annual Savings	$188,000	$248,000
Direct Payback	9.9 yrs	8.2 yrs
Estimated ROI (20 year)	9.1%	17.8%

* ***Biogas cleaning was also required for boiler-only option.***

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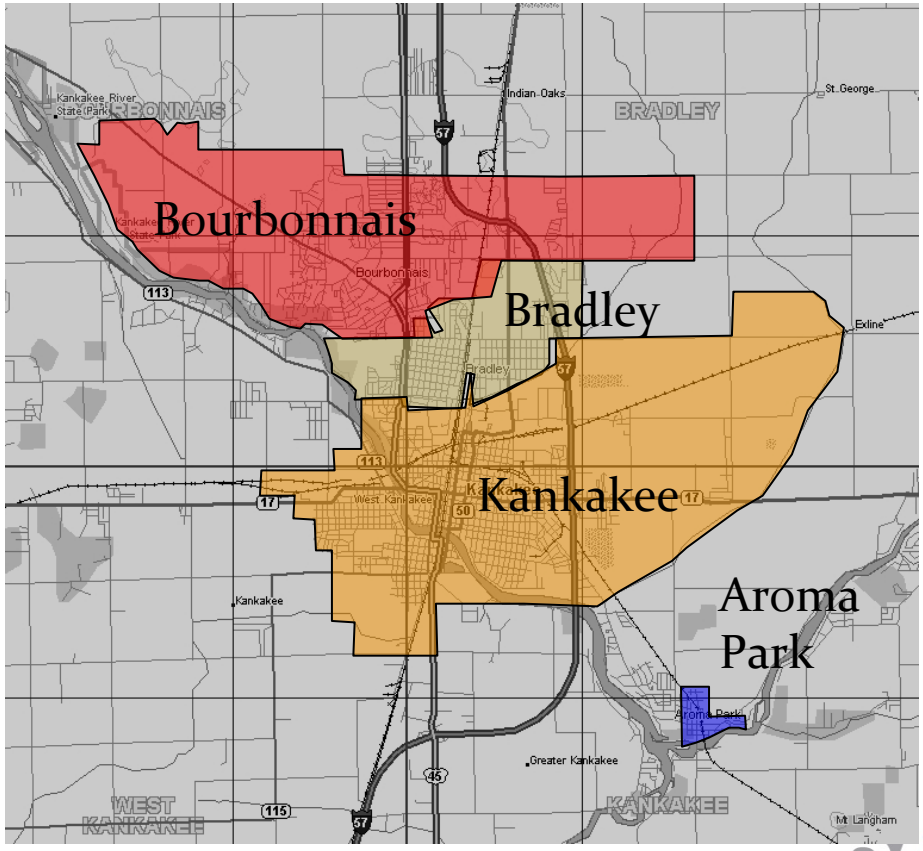
Kankakee River Metropolitan Agency (KRMA)

- **Service Population: 75,000**
- **Design Avg. Flow: 25 mgd**
- **Design Peak Flow: 85 mgd**
- **BOD Load: 40,000 lb/d**



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Existing KRMA Biogas Utilization

- **Conventional anaerobic digestion with COGEN since 1986**
- **Two 250-kW Waukesha engine generators**
- **Hot water heat recovery to process and building heat**
- **No biogas conditioning**

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KRMA Cogen Design

- **220,000 ft^3/day of biogas from sludge digestion**
- **No receiving facilities for high-strength wastes**
- **450 kW unit selected (CAT)**

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KRMA Digester Gas Evaluation

- **Sulfur compounds exceeded permissible concentration**
  - **Measured 2,800 ppm_v vs 1,000 ppm_v allowed**
  - **H_2S removal required**

- **Siloxane concentrations:**
  - **Measured at ~0.2 µg/BTU vs. allowable 0.1 – 0.6 µg/BTU**
  - **Siloxane removal not required**

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KRMA – Gas Conditioning

Biogas →  → To Genset

Moisture removal

Biological Scrubber Hydrogen Sulfide Removal

Benefits:

- **Bio-H_2S Removal has low O&M costs**
- **No siloxane removal = additional O&M cost savings**

KRMA – Costs and Financials

Parameter	Value without High-Strength Wastes (current conditions)
Total Capital Cost	$1,724,000
Annual Savings	> $175,000
Direct Payback	< 10 yrs

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City of Dubuque

THE CITY OF DUBUQUE

Masterpiece on the Mississippi

SUSTAINABLE DUBUQUE

viable • livable • equitable

- **Service Population: 68,000**
- **Design Avg. Flow: 10.9 mgd**
- **Design Peak Flow: 41 mgd**
- **BOD Load: 37,000 lb/d**

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Dubuque Operations - Background

- **Raw sludge dewatering and incineration since the 1960s**
- **Fluid bed incinerators operating well beyond their useful life**
- **Facilities planning resulted in new direction - conversion to anaerobic digestion with land application of biosolids**

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Major Project

- **Design 2009; Construction 2010 - 2013**
  - **Bid costs = $50 million**
  - **Major portion is biosolids digestion**
  - **Project did not include cogeneration, but did include biogas cleaning for boiler use**

Dubuque Biogas Projections

- **Current Conditions:** **165,000 ft^3/day**
  ~ 390 kW
- **Future Design:** **303,000 ft^3/day**
  ~ 715 kW
- **Future Design w/ High-Strength:** **380,000 ft^3/day**
  ~ 900 kW

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Dubuque – High-Strength Wastes

- **Facility constructed to receive and screen septage and trucked in liquid wastes**
- **Additional facilities planned to accept high-solids food residuals**
- **Hauled materials can be pumped directly to digesters, sludge storage, or the head of the plant**

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Dubuque – COGEN Analyses

- **Compared multiple types of engine generators with Capstone microturbines (MTs)**

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Dubuque – COGEN Analyses

- **Capstone MTs selected because of:**
  - **Modularity for increasing capacity**
  - **Available building space better fit for MTs**
  - **Local Capstone service available in Dubuque**
  - **Costs and financials were similar to ICEs, mainly because gas cleaning was already included**

Dubuque – COGEN Design

- **Initial Installation: 400 kW**

- **Future Build-Out: 1,000 kW (increments of 200 kW)**

Dubuque Digester Gas Evaluation

- **Biogas cleaning installed as part of major (current) project for boiler use**
- **No Gas to Evaluate!**
- **H_2S projections based on influent sulfate data, understanding of local industries, etc.**
- **Siloxane removal assumed to be required**

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Dubuque – Gas Conditioning

Biogas

Sulfa-Treat Media
H_2S Removal

GAC Filter
Siloxane Removal

High Compression Skid
Heat Exchanger

To MTs

Compression; moisture removal/drying

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Dubuque – Costs and Financials

Parameter	Value (current conditions)	Value (future conditions)
Total Capital Cost	$1,921,000	$2,700,000
Annual O&M	$87,000	$150,000
Annual Electricity Value	($223,000)	($450,000)
Annual Savings	$136,000	$300,000
Direct Payback	14 years	9 years
Return on Investment (20 yrs)	3.6%	9.2%

Dubuque will likely receive 20% grant for the project, which is not reflected in the analyses above.

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Lessons Learned

- **Biogas quality drives economics:**
  - **Capital costs**
  - **O&M costs**
- **Supplemental feed stocks help, but be careful.**
- **The energy balance is the key!**
  - **Waste heat recovery from cogen should meet process and some building heating demands.**
- **Air permitting is becoming a big issue, and has been a big issue in some states for years.**

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Questions & Thank You!

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