Seasonal and Lifecycle Cost Considerations in Evaluating Beneficial Utilization of Digester Gas

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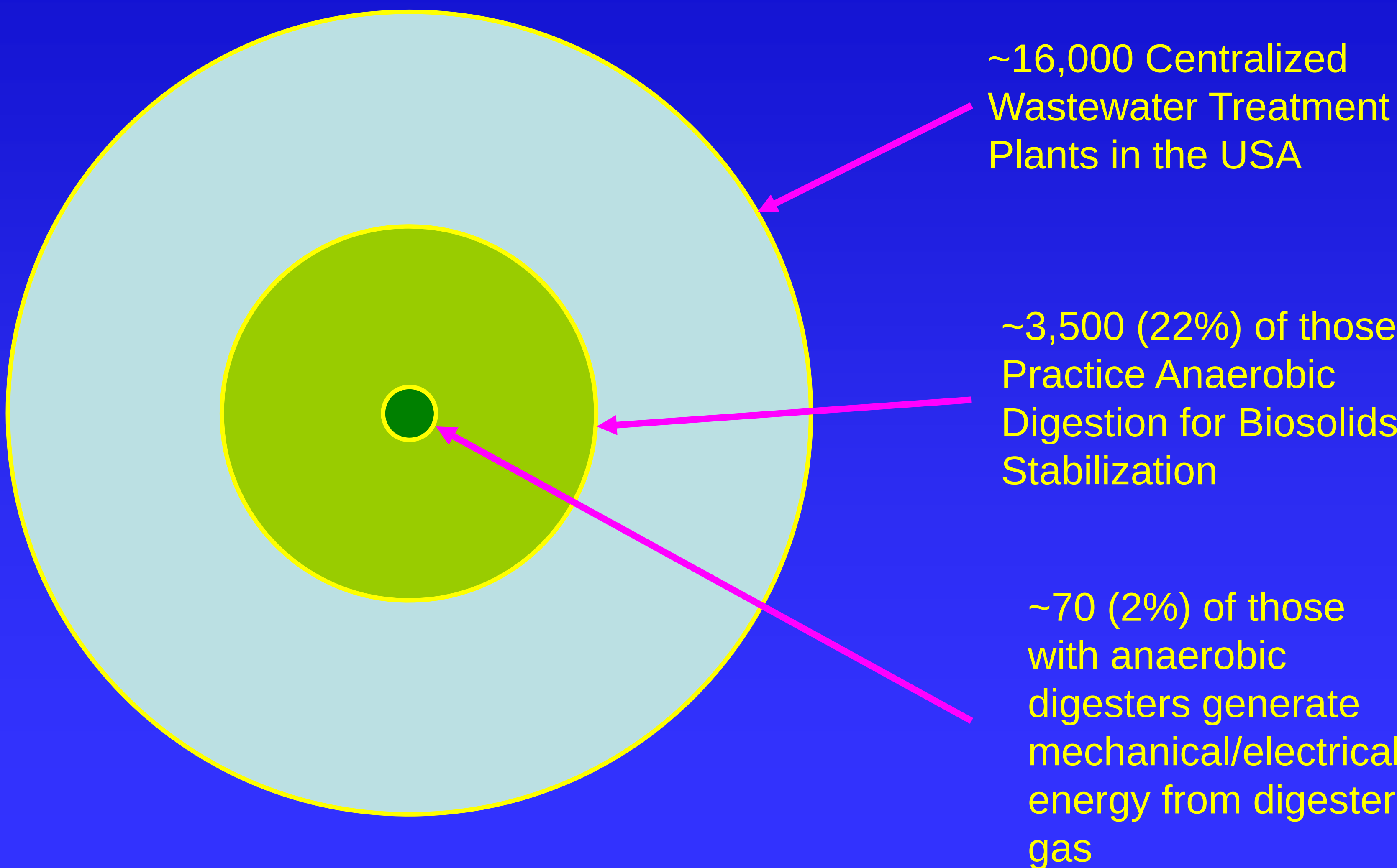
HAZEN AND SAWYER
Environmental Engineers & Scientists

Where are we going…

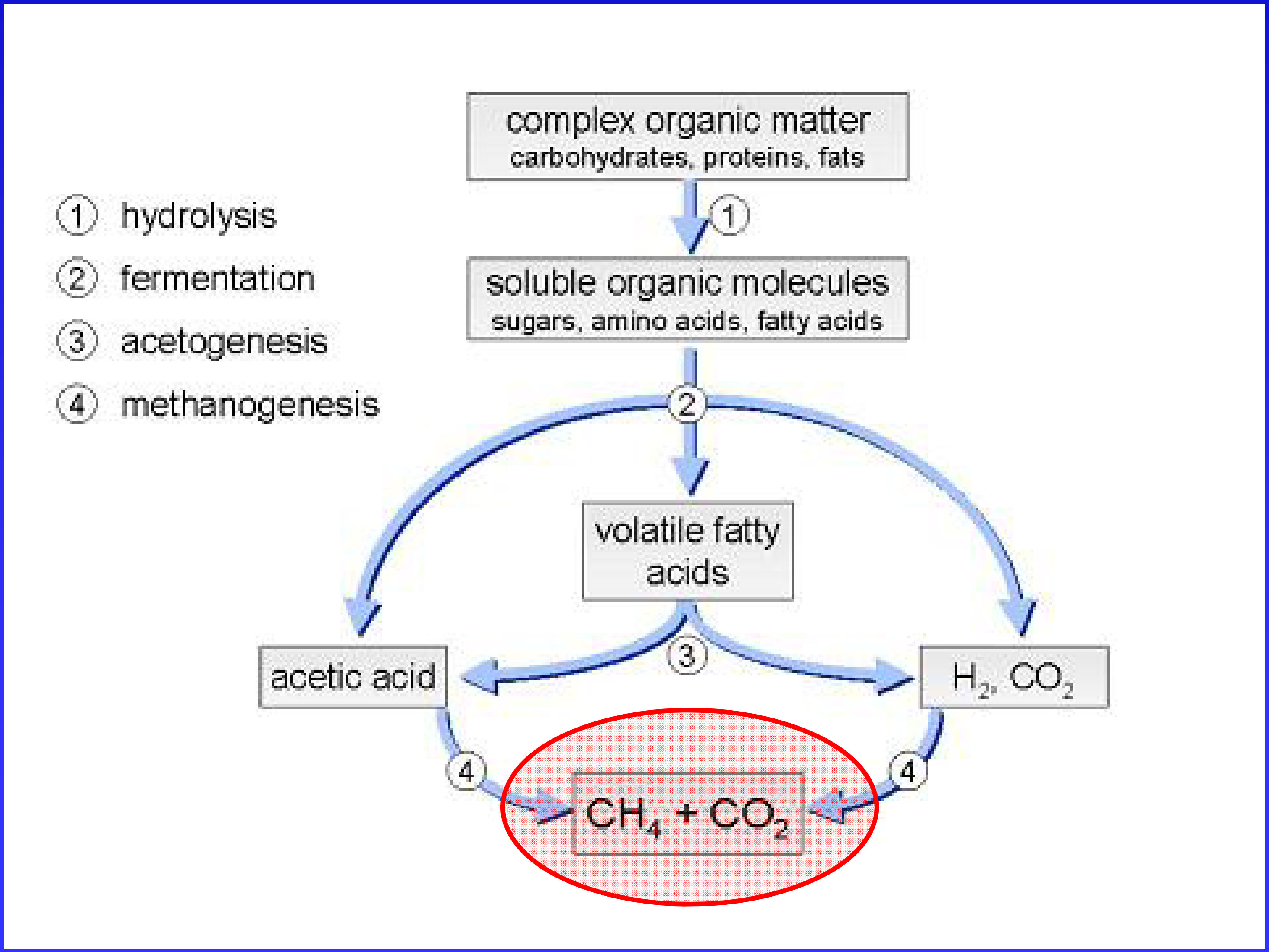
- Anaerobic Digestion and Site Specific Considerations
- Biogas-to-Energy Technologies
- Case Study on Biogas Utilization

Anaerobic Digestion
and
Site Specific Considerations

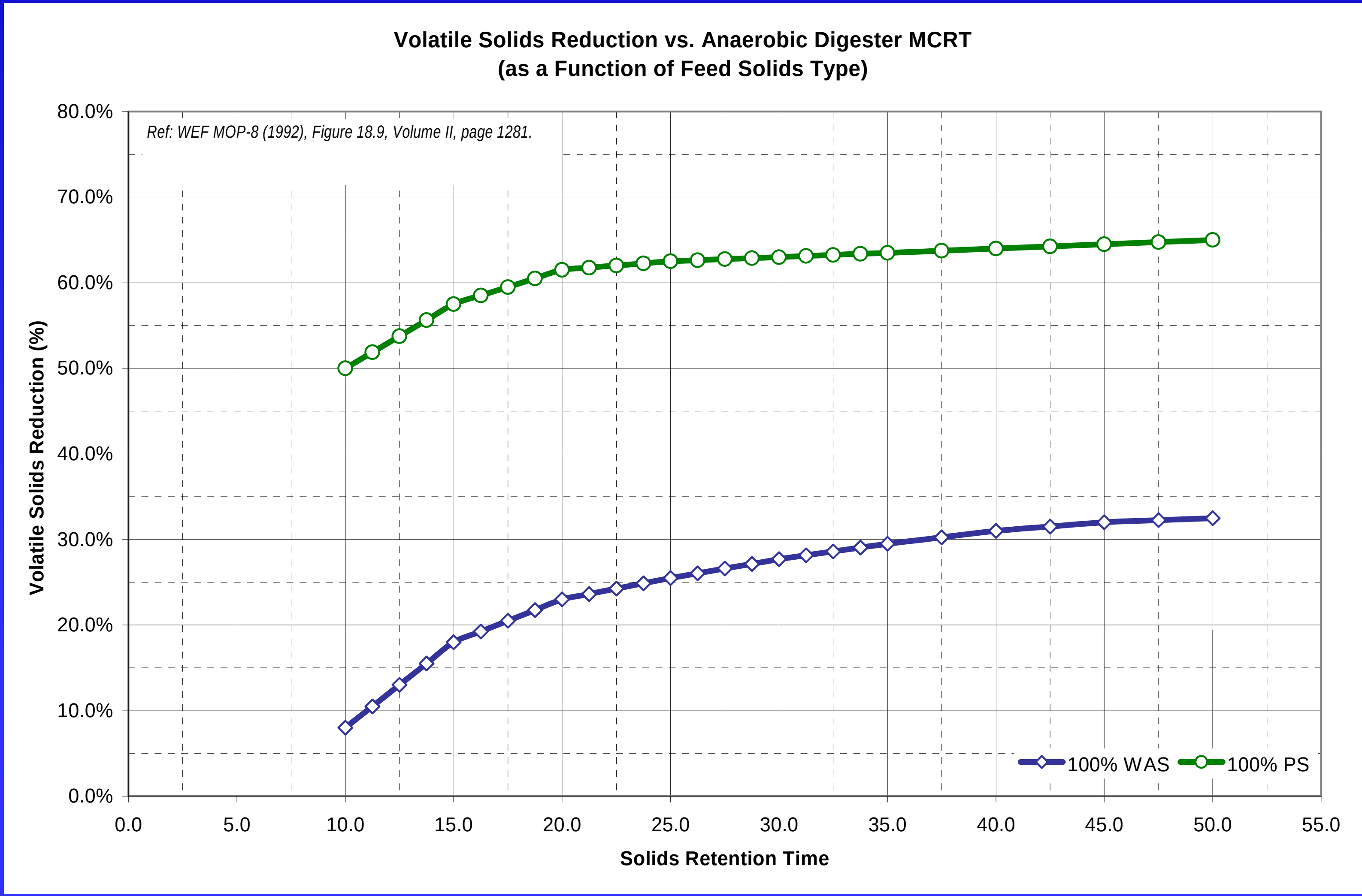
Energy production from digester gas represents an untapped energy resource.



Anaerobic digestion converts complex organic material into gaseous byproducts



Not all "complex organic matter" is created equal in the anaerobic digester



Practical implications…what does it mean if you don't have a primary sludge feedstock…

Primary + WAS Feedstock

- **DG = 9,360 CFT/MG**
- **Heat = 6.08 MMBTU/MG**

- **Sufficient excess DG heat is generated, even in winter, to cover anticipated heating demands and provide heat for other uses.**

100% WAS Feedstock

- **DG = 3,390 CFT/MG**
- **Heat = 2.20 MMBTU/MG**

- **Heat generation, particularly under winter conditions, is marginal and excess heat availability for other uses may only be seasonal**

Digester gas quality also must be considered in a beneficial use system

Constituent	WILM NS	WILM SS	ND DG	IC #1 DG	RWSA DG	ROAN DG
CH_4 (%)	66.2	61.7	71.5	60.4	58.7	61.2
CO_2 (%)	31.5	29.6	25.5	32.9	38.3	30.8
Nitrogen (%)	2.0	5.1	2.3	3.8	1.6	7.4
Oxygen (%)	0.3	1.7	0.7	0.9	0.4	0.6
Heat Value (BTU/CFT)	670	620	720	610	595	620

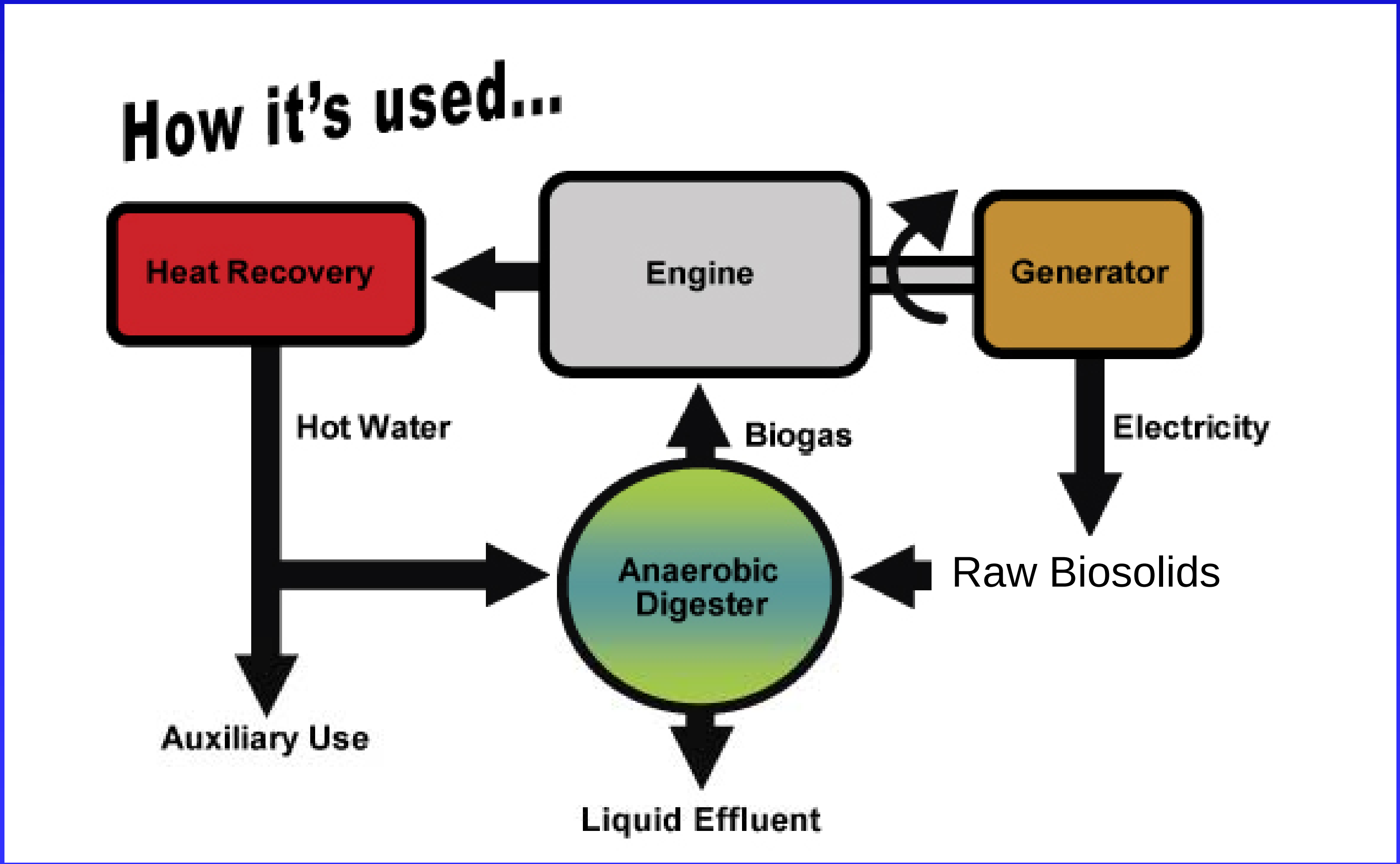
Micro-constituents in digester gas can not be ignored in the decision making process

Constituent	WILM NS	WILM SS	ND DG	IC #1 DG	RWSA DG	ROAN DG
Specific Gravity (relative to air)	0.81	0.88	0.85	0.88	0.94	0.89
H_2S (ppmV)	550	250	690	53	118	ND
Total Siloxane (ppbV)	1,045	2,246	3,103	360	2,569	3,477

Biogas-to-Energy Technologies

Conventional digester gas utilization equipment as a bare minimum…

Gas utilization in a combined heat and power cycle system increases efficiency



Typical Combined Heat and Power (CHP) Technologies

- Gas Driven
  Internal Combustion Engines

- Microturbines

- Stirling Engines

Internal Combustion Gas Driven Engine

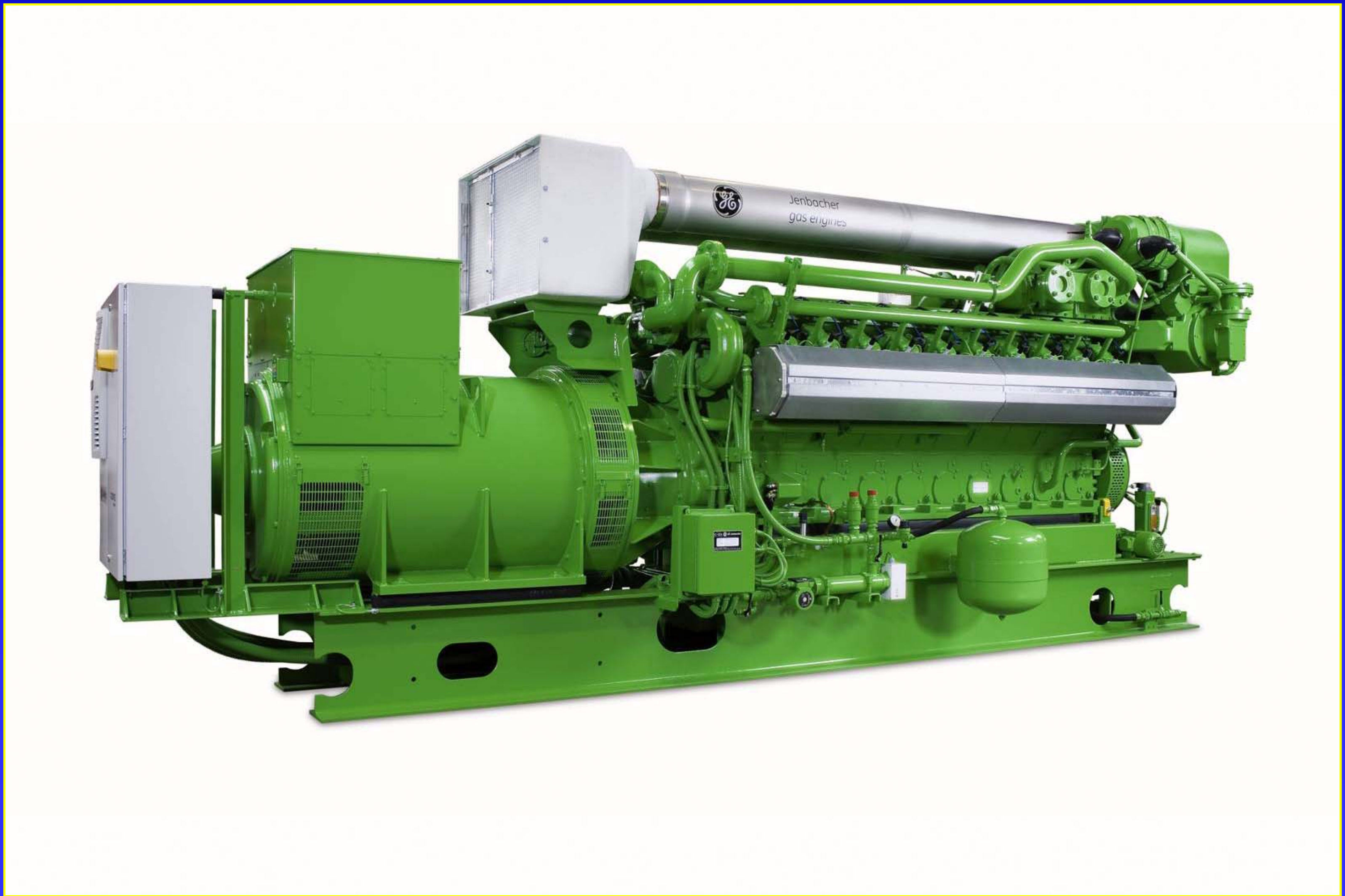
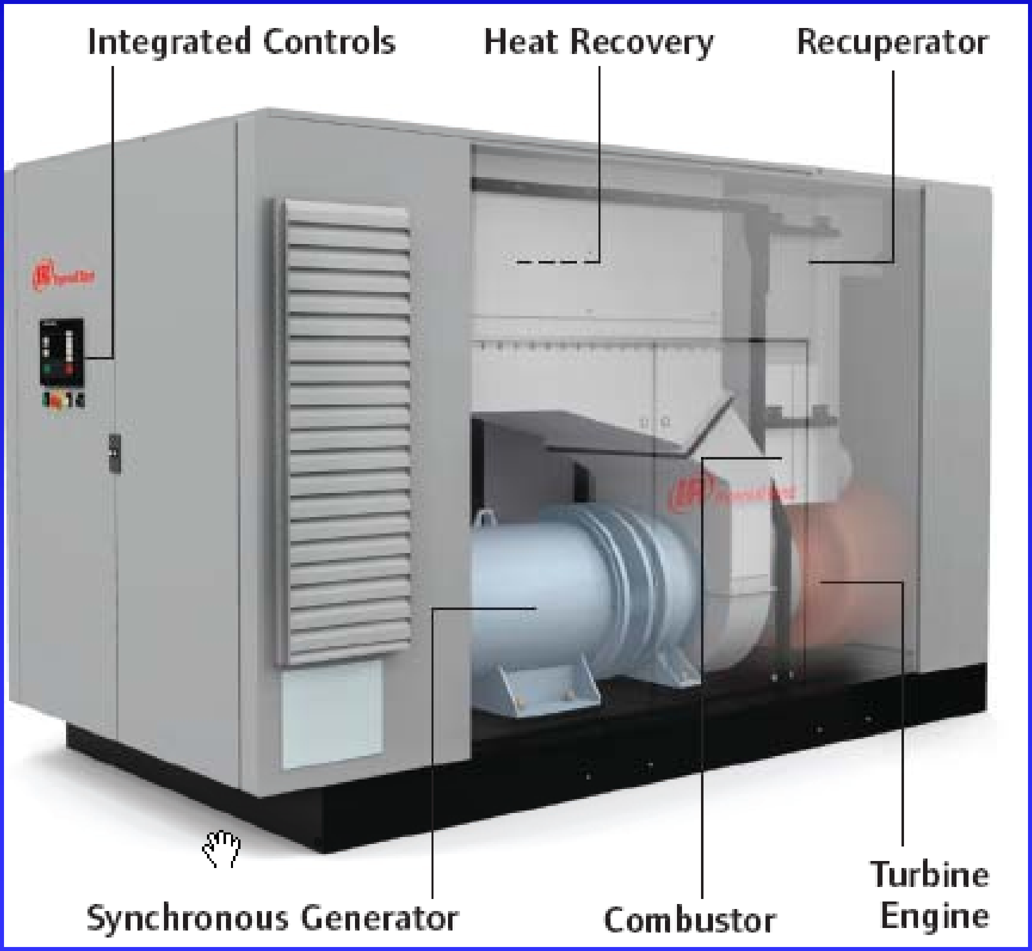
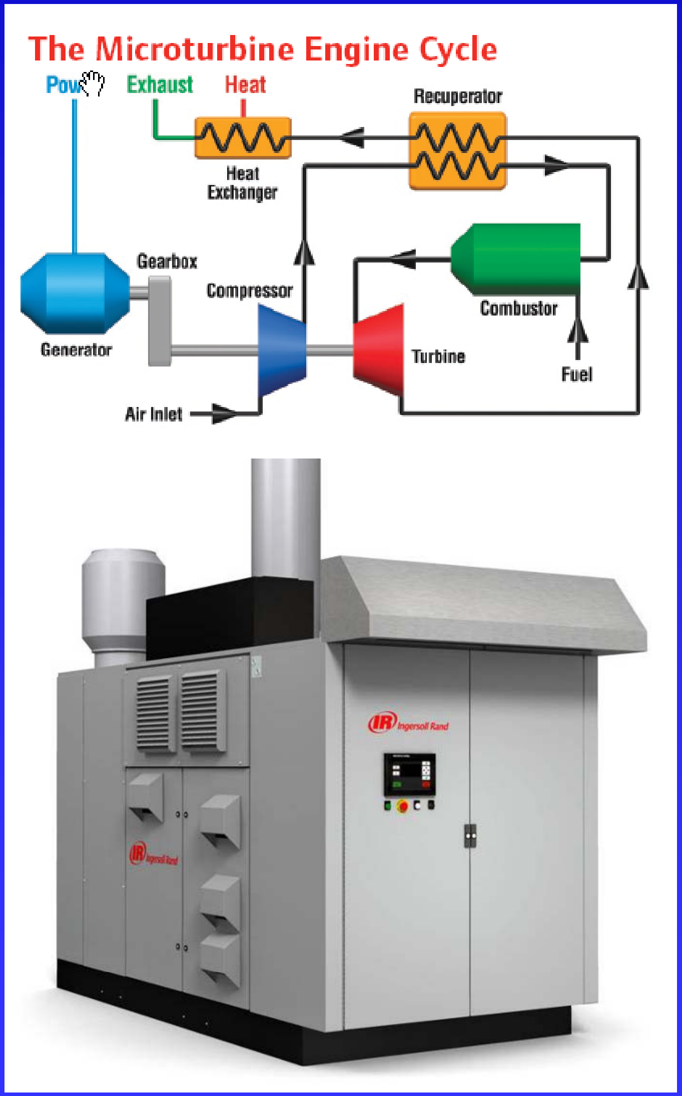


Image Courtesy GE/Jenbacher Engines

Microturbine





Images: Courtesy Ingersoll-Rand

Comparative performance and gas quality requirements between options

	Internal Combustion Gas Engine	Microturbine
Electrical Power Conversion Efficiency	31.1% to 32.9%	26.1% to 27.0%
Hydrogen Sulfide Concentration (ppmV)	< 1,000	< 25
Siloxane Content	< 1,800 ppbV < 25 ug/L	< 60 ppbV < 0.83 ug/L
Inlet Gas Pressure (psig)	> 1.0	> 100.0
Electrical Power Output Capacity	300kW to 3,000kW	30kW to 250kW

A Detailed Case Study

Cape Fear Public Utility Authority
Wilmington, North Carolina - Northside WWTP

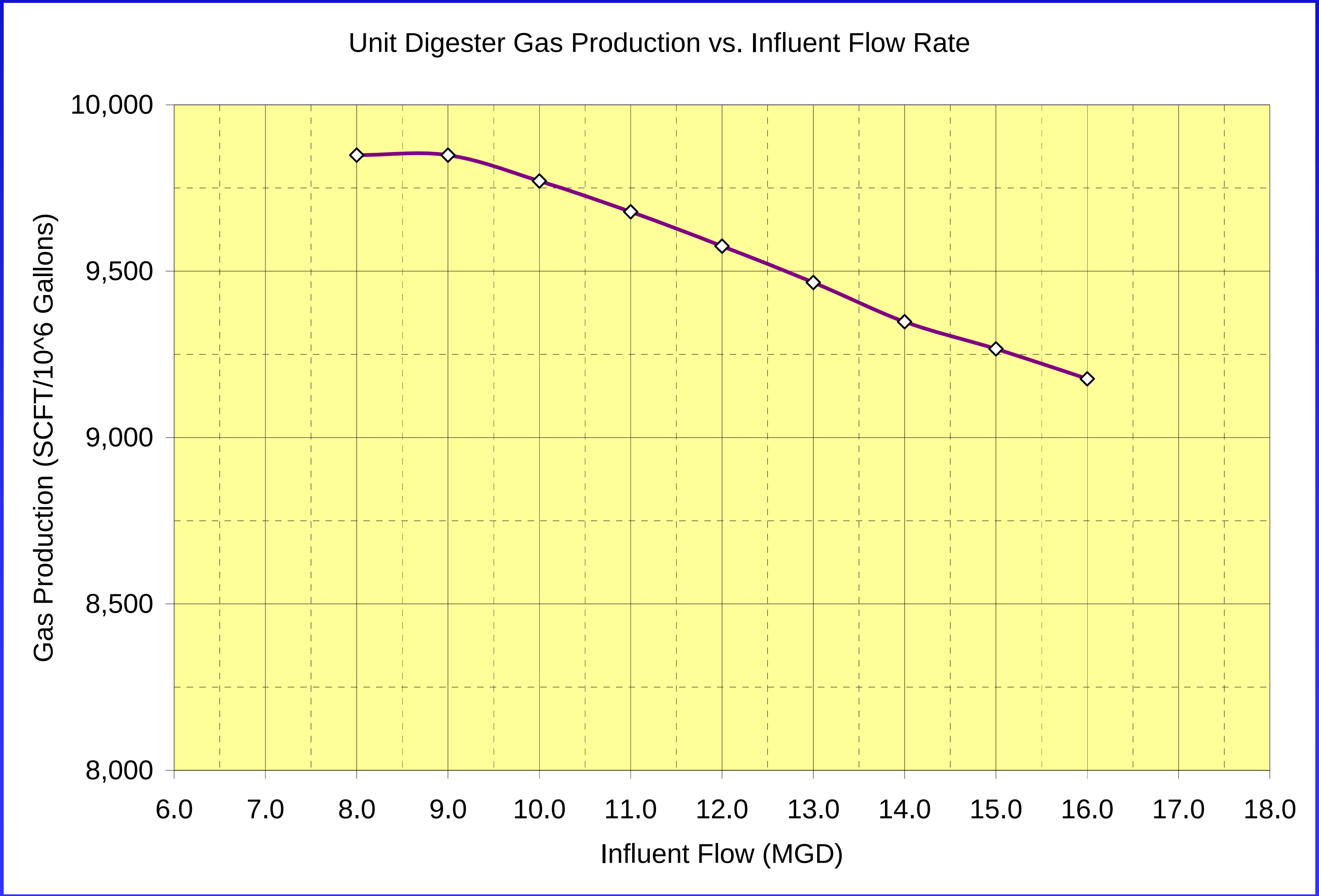
Design Basis

- 16-MGD Permitted Flow
- Primary Clarification
- Nitrification Activated Sludge

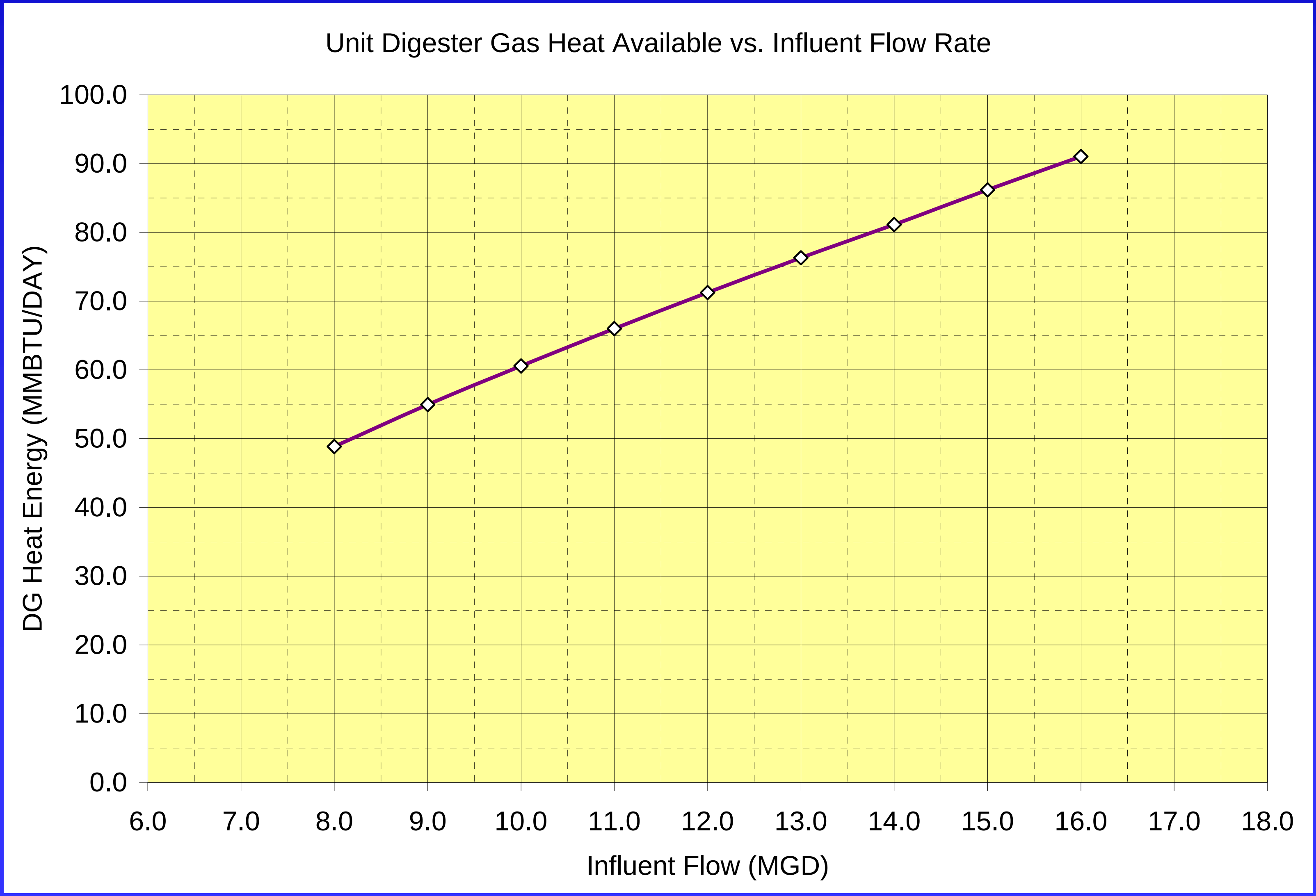
Anaerobic Digestion

- 3 @ 0.380 MG each
- 2 @ 0.695 MG each
- Total = 2.53 MG

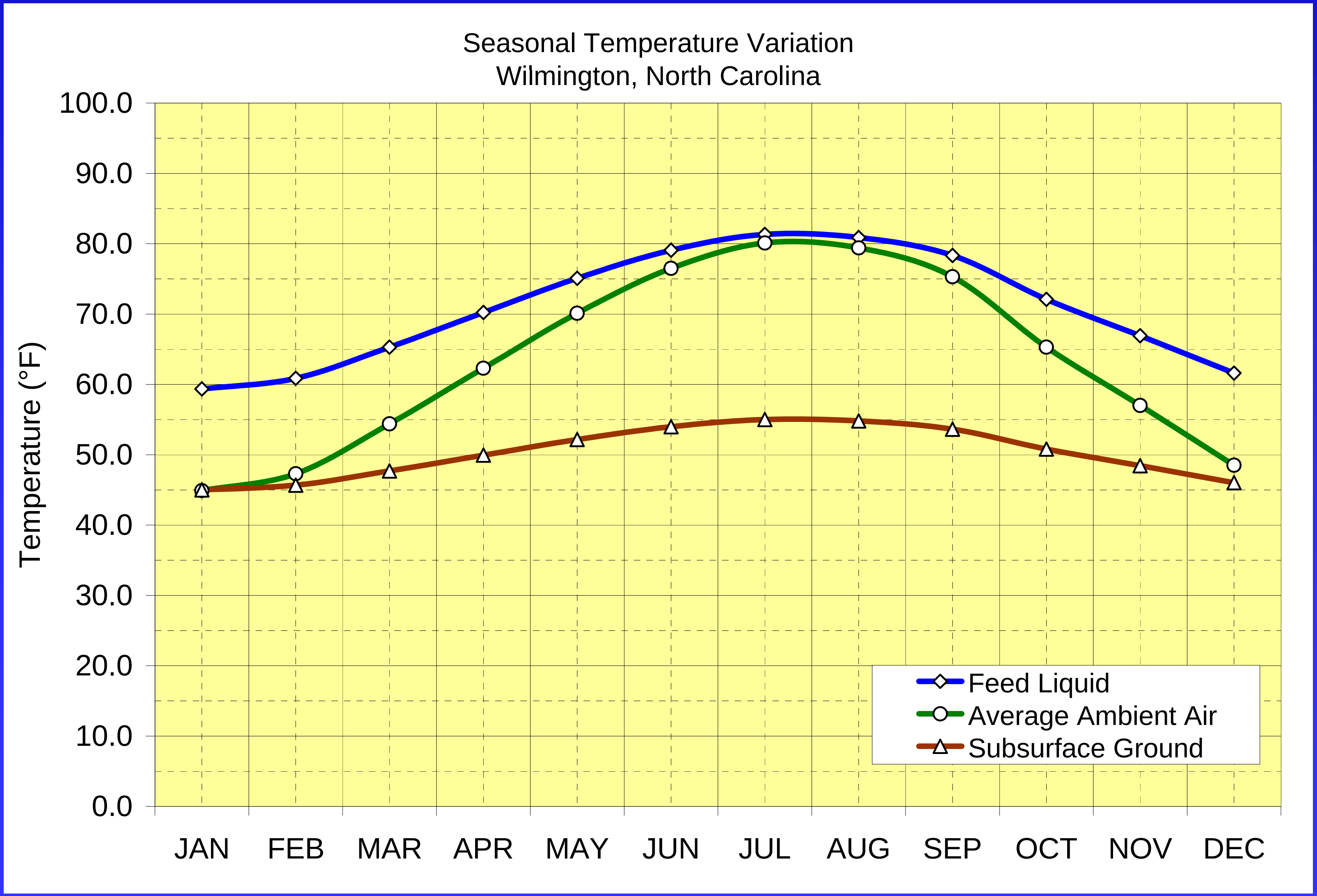
The unit gas production rate falls as the plant approaches design capacity…



… but the overall heat energy production continues to increase



Seasonal temperature variation impacts digester process heating requirements.



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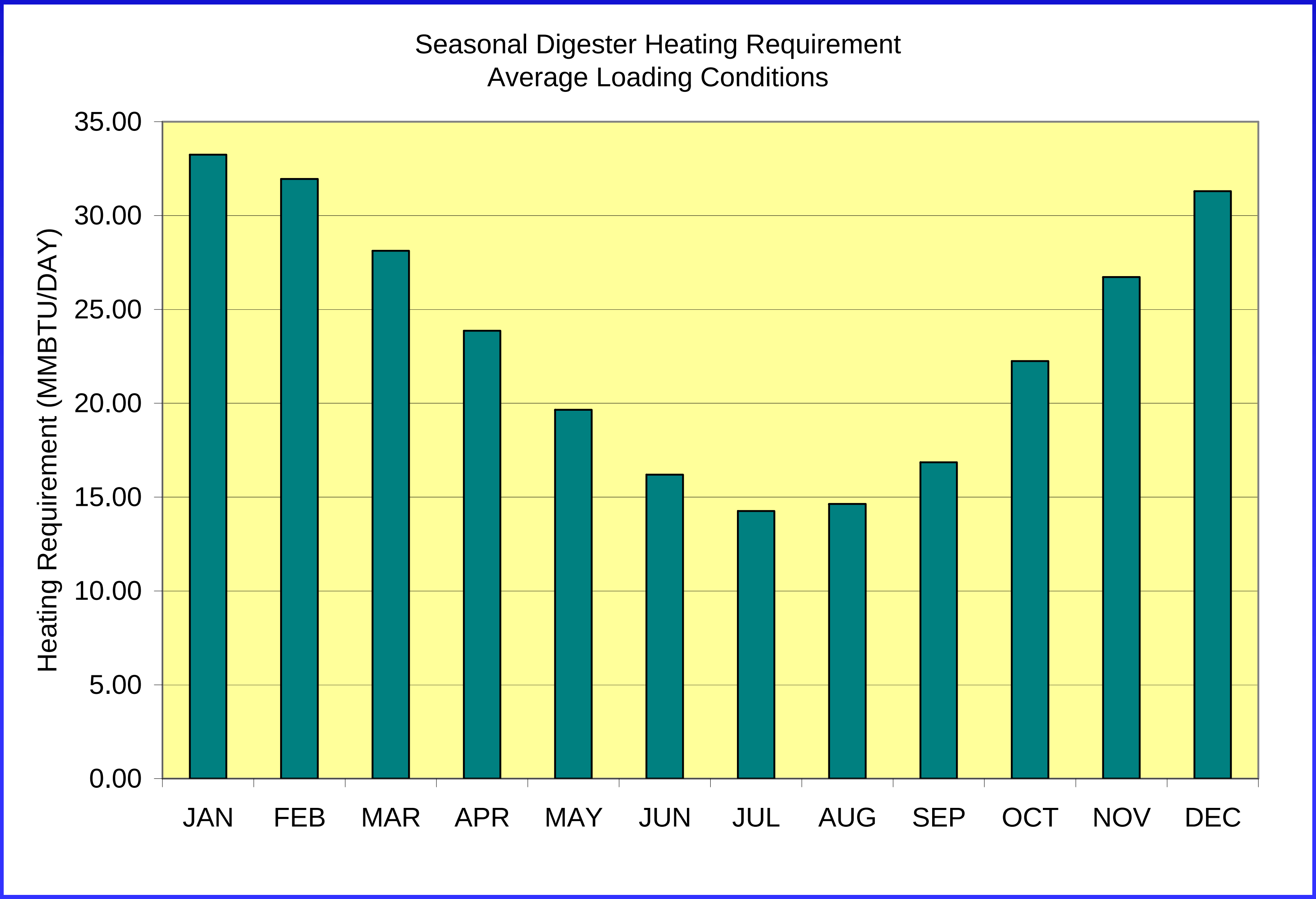
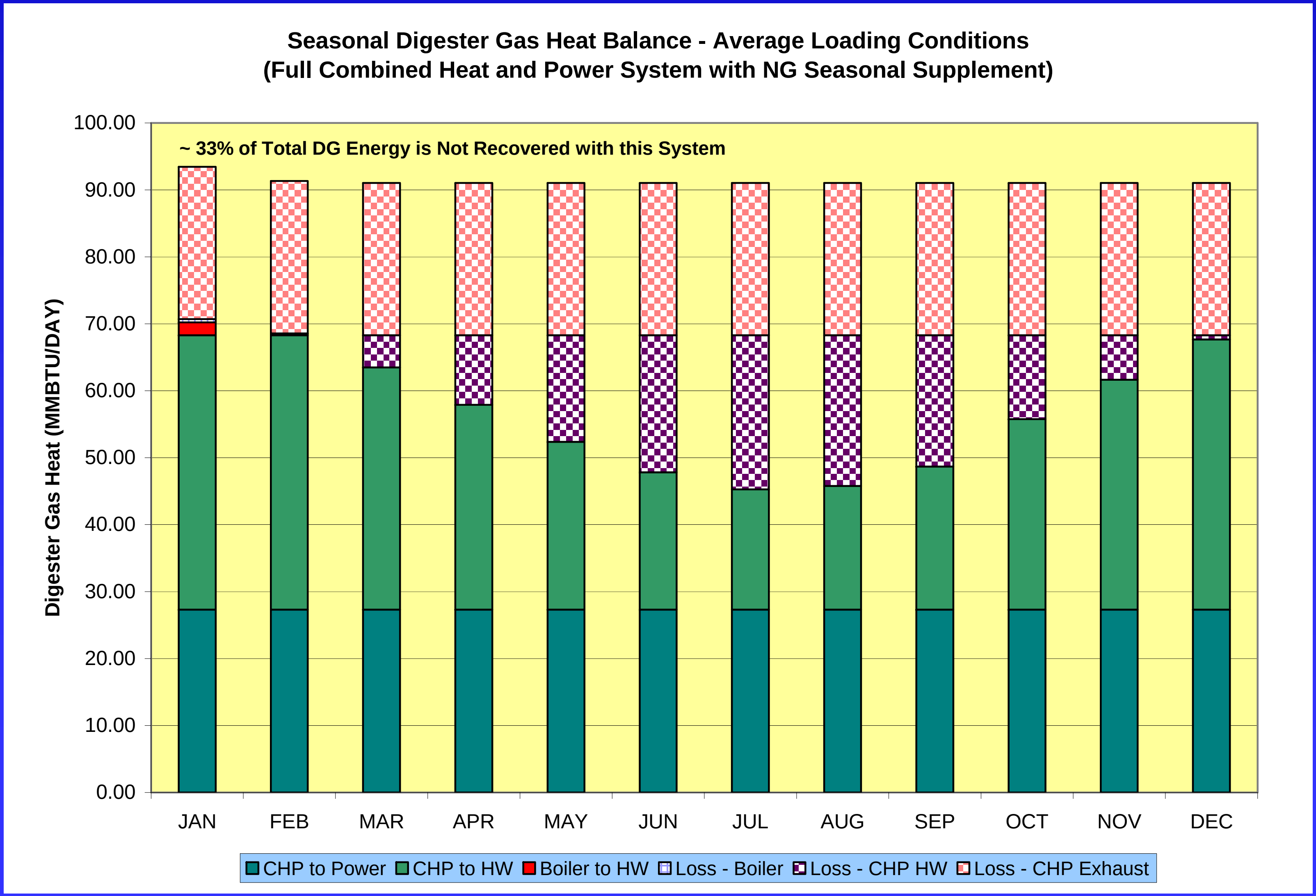


Multiple digester gas energy recovery configurations were evaluated…

Plant Operating Flow (mgd)	Hot Water Boiler Only	Hot Water Boiler + ICGE Generator without CHP	Hot Water Boiler + ICGE Generator with CHP
10-mgd (Current)			
16-mgd (Future)			

Seasonal heating demands and energy capture effectiveness were evaluated.



Beneficial energy recovery varied depending on flow and process configuration.

Plant Operating Flow (mgd)	Hot Water Boiler Only	Hot Water Boiler + ICGE Generator without CHP	Hot Water Boiler + ICGE Generator with CHP
10-mgd (Current)	38%	54%	66%
16-mgd (Future)	33%	50%	63%

Power production potential varied based on flow and process configuration.

Process Configuration	Plant Average Flow 10-MGD	Plant Average Flow 16-MGD
Conventional Hot Water Boiler + ICGE without CHP	1,013 MWH/YR	1,729 MWH/YR
Conventional Hot Water Boiler + ICGE with CHP	1,944 MWH/YR	2,921 MWH/YR
% Change with CHP Process Configuration	+91.9%	+68.9%

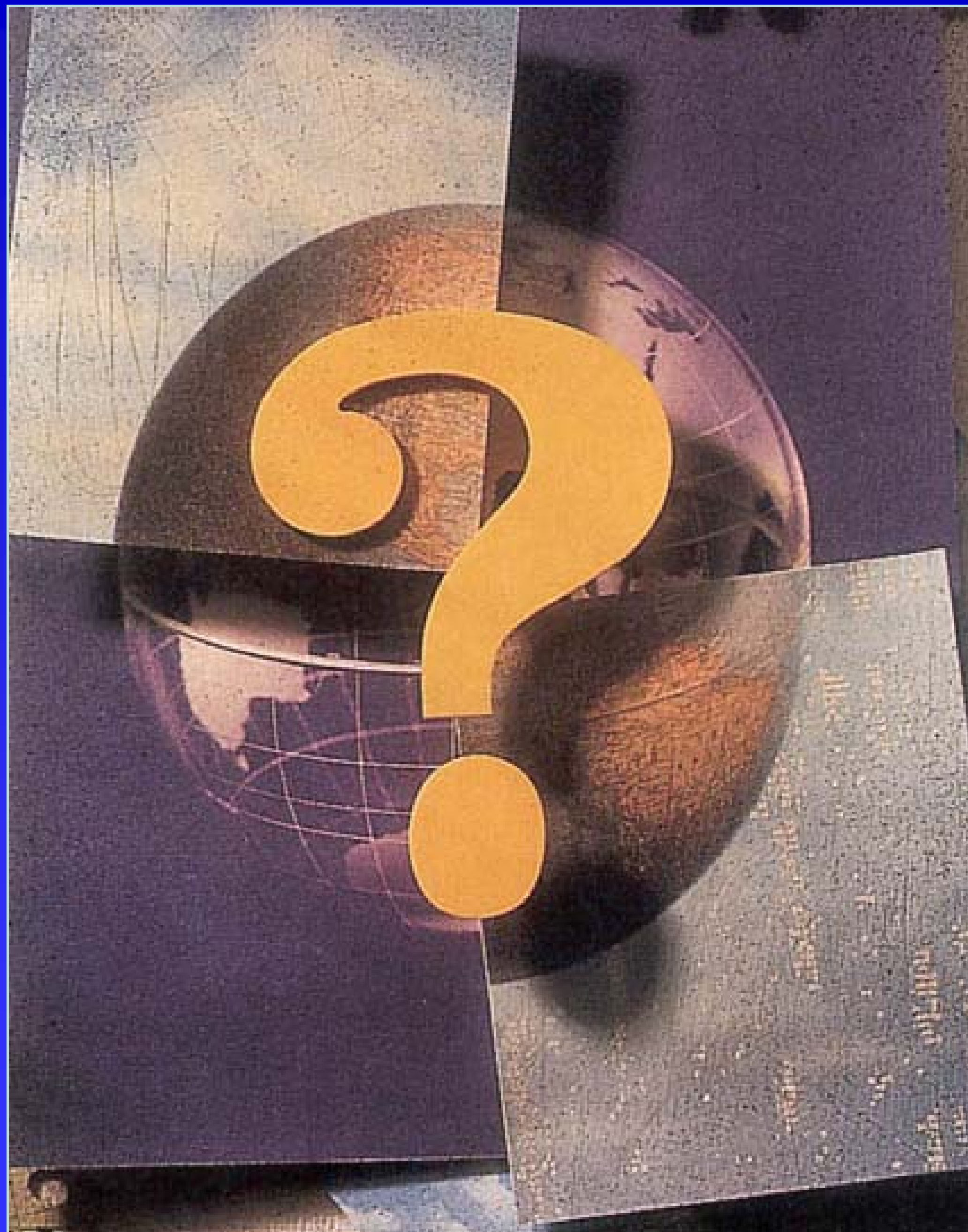
Both energy recovery configuration alternatives were economically attractive.

	ICGE Generator without CHP	ICGE Generator with CHP
Net Present Operating Benefit, $MM	+$1.923	+$3.402
Capital Cost, $MM	-$1.246	-$1.405
Net Value Created, $MM	+$0.677	+$1.997
Benefit-to-Cost Ratio	1.543	2.421

Greenhouse gas reductions are achieved with digester gas-to-energy systems

Process Configuration	Plant Average Flow 10-MGD	Plant Average Flow 16-MGD
Conventional Hot Water Boiler + ICGE without CHP	-890 tCO_{2e}/year	-1,520 tCO_{2e}/year
Conventional Hot Water Boiler + ICGE with CHP	-1,700 tCO_{2e}/year	-2,665 tCO_{2e}/year
% Change with CHP Process Configuration	-91.0%	-75.3%

The day will come where "normal" should be to see a waste gas flare….without a flame.



A Couple More Short Case Studies

Rivanna Water and Sewer Authority Moores Creek WRF

- Multiple Objectives
  - Decouple process air and digester heating
  - Provide beneficial use of digester gas across all seasons
  - Increase reliability in digester heating capacity
  - Reduce overall greenhouse gas production
- Project Components
  - Replace engine driven blowers with high speed turbo blowers.
  - Install new CHP system with new hot water boiler

Reduction in GHG quantities from approximately 765 tCO_{2e}/year to 175 tCO_{2e}/year

Western Virginia Water Authority Roanoke WRF

- Historical Usage
  - Digester gas driven influent pumping system with a combined heat system
  - Gas driven influent pumps replaced with screw pumps in mid 2000’s with a plant upgrade
- Project Components
  - Install new combined heat and power (CHP) system to produce electricity from digester gas and recover heat for digester heat demand
  - Estimated capacity 1,000kW based on current plant influent flow.

Benefit-to-Cost Ratio approximately $3.00 per $1.00 invested with an estimated payback on capital of 7-8 years

Biogas Solutions – Looking beyond the treatment plant and to the landfill.

Generation Capacity (MW)	1.0	2.0
Capital Cost ($MM)	-$4.70	-$7.60
20-year Lifecycle Benefit ($MM)	+$7.50	+$14.14
Total Net Present Value ($MM)	+2.80	+$6.54
Benefit / Cost Ratio (> 1.0 = Good)	1.59	1.86
Payback Period (years)	~12	~9