Energy Audits
Waste Water Treatment Plants

Ohio Water Environment Association Conference

June 20, 2012

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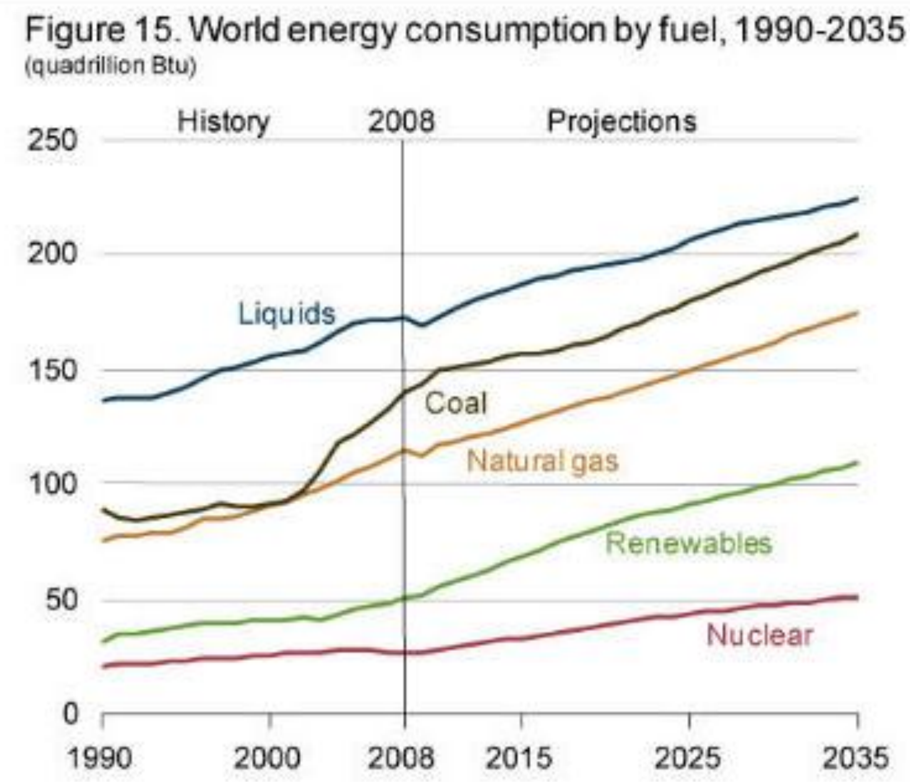
World Energy Trend



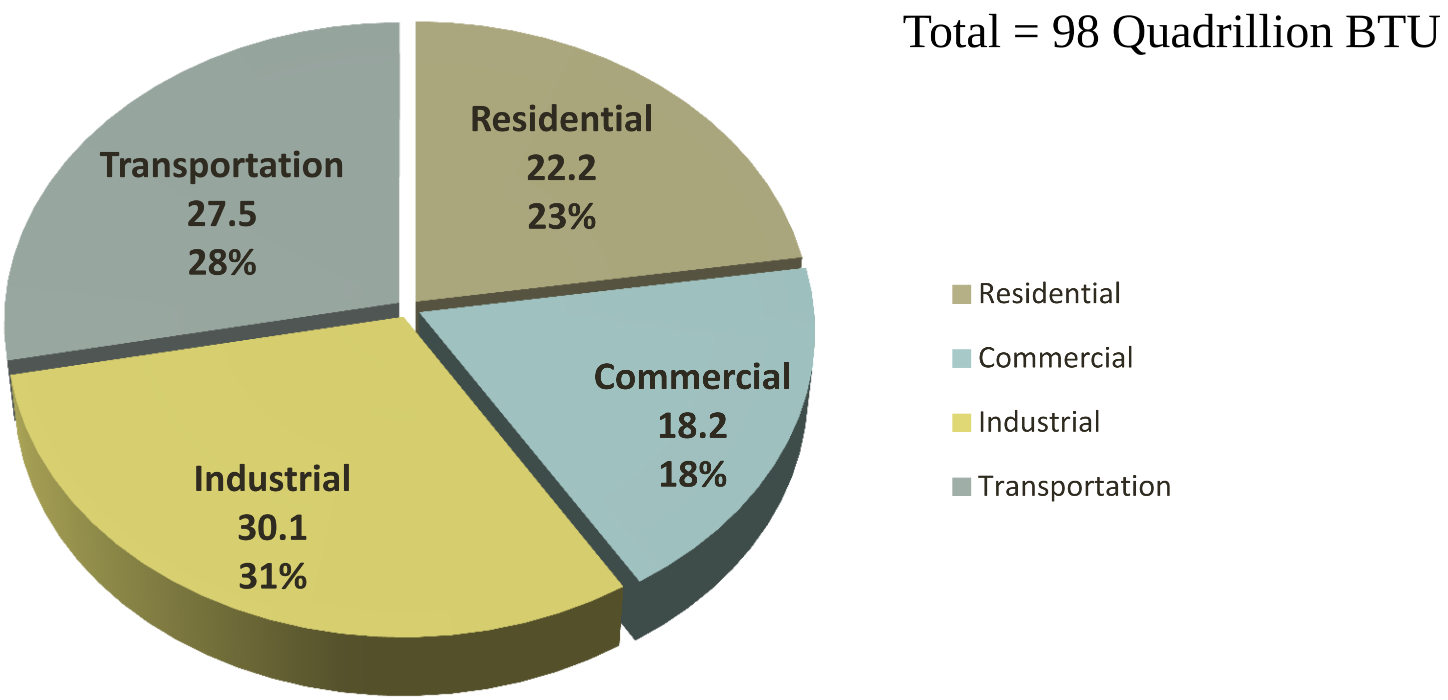
U.S. Energy Information Administration, *International Energy Outlook 2011*, September 19, 2011.

US Total Energy Usage

	Quadrillion BTU	
Residential	22.2	23%
Commercial	18.2	19%
Industrial	30.1	31%
Transportation	27.5	28%
TOTAL	98.0	

US Total Energy Usage Chart

Quadrillion BTU



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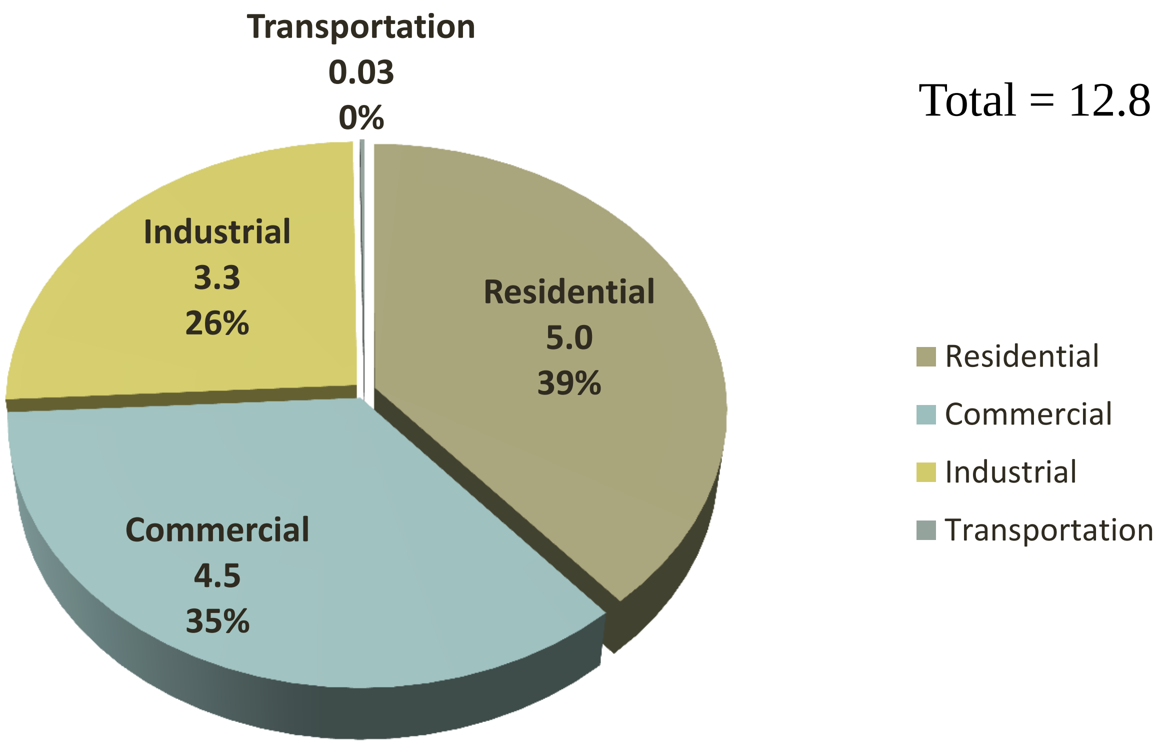
US Electric Energy Usage

	Quadrillion BTU	
Residential	5.0	39%
Commercial	4.5	35%
Industrial	3.3	26%
Transportation	0.3	0.2%
TOTAL	12.8	

US Electric Energy Usage Chart

Quadrillion BTU



Total = 12.8 Quadrillion BTU

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Energy Benchmarking

- Commercial Buildings
  - Energy Star
  - DOE Commercial Buildings Benchmark
  - LEED
  - USGBC – US Green Building Council
  - ASHRAE
    - 90.1 Defines Minimum Energy Efficiency Standards
    - 189.1 Allows Adoption of LEED as Building Code

Energy Benchmarking

- WWTP – EPA Tools
  - Energy Star EPA Portfolio Manager – WTP & WWTP
  - EPA Energy Management Planning Self Assessment Worksheet
  - EPA Groundwater and Drinking Water Energy Use Assessment Tool

EPA Benchmarking Tools for WWTP

- EPA Energy Star Portfolio Manager
  - Performance Score Based on Energy Use per Unit of Flow / Effluent Quality / Treatment Type
  - Accessed On-line
- EPA Energy Use Assessment Tool
  - Drills Down to Equipment Level
  - Allows Utility Bill Analysis
  - Use Before Full Scale Energy Audit _

Non-EPA Benchmarking Tools

- WERF Carbon Heat Energy Analysis Plant Evaluation Tool (CHEApet) – for WERF Members
  ---- Water Environment Research Foundation ----
- CEE Water and Wastewater Self-Audit Checklists
  ---- Consortium for Energy Efficiency ----
- NYSERDA Water and Wastewater Focus Program
- Various State Specific Measurement Tools

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Electric Usage at WWTP and WTP

- 55 Billion Kilowatt Hours (kWh)
- $4 Billion Annual Energy Cost
- Equivalent to 45 Million Tons of Greenhouse Gas
- Represents 3% of US Electricity Use
- Accounts for 35% of Municipal Electric Use
- Preliminary Savings Estimates = 15% - 30% _

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WWTP Energy Use

- Over 15,000 Wastewater Treatment Plants
- Over 50,000 Water Treatment Plants
- WWTP Energy = 25% – 35% of Total Plant O&M _

Why Reduce?

- Reduced Energy Costs
- Lower Operating Costs
- Save Water
- Reduced Carbon Footprint
  - Lower Greenhouse Gas Emissions

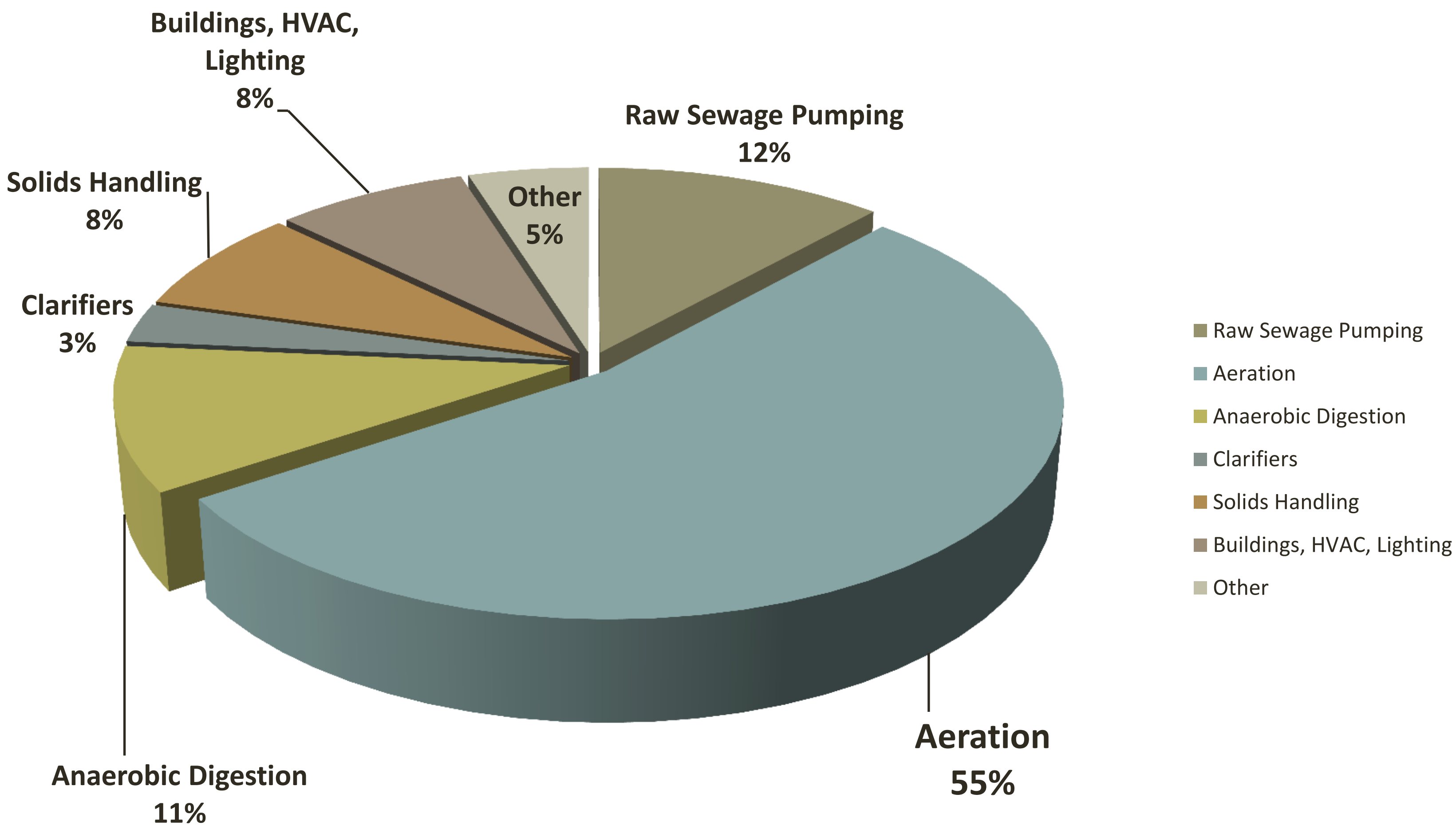
Reduce Carbon Footprint

- Saving 25% of WWTP Energy Equals
  - 9,500,000 Tons CO_2
  - 3,300,000 Tons Recycled Waste Instead of Landfill
  - 22,000,000 Million Barrels of Oil
  - 51,500 Rail Cars of Coal
  - 1,180,000 Homes
  - Carbon sequestered by 2,000,000 Acres Pine Forest

Where Does the Energy Go

End Use	% of Total
Raw Sewage Pumping	12%
Aeration	55%
Anaerobic Digestion	11%
Clarifiers	3%
Solids Handling	8%
Buildings, HVAC, Lighting	6%
Other	5%

WWTP Energy Usage



Types of Energy Audits

- Varying Level of Detail
- Varying Level of Costs
- ASHRAE Tiered Levels
  - Level 1 – Walk-Through Analysis, Low or No Cost
  - Level 2 – Energy Survey Req'd, Identifies Energy Conservation Measures with Cost Estimate & Payback
  - Level 3 – Detailed Analysis of Capital Intensive Improvements _

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Types of Energy Audits

- ASHRAE Level I
  - Walk-through Analysis Identifies Areas of Potential Energy Savings
  - Usually ½ Day or Less
  - Suggestions for Quick Payback Projects
  - Suggestions for Areas Needing Further Study
  - Often Performed for Little or No Cost _

Types of Energy Audits

- ASHRAE Level II
  - May Require One or Two Days at Plant
  - Includes Interviews with Plant Personnel
  - May Require Two or More Weeks to Analyze Utility Data, Pump Curves, Aeration Processes, Other Processes
  - Identify Projects With Short Payback
  - Determine Savings, Costs and Payback Period _

Types of Energy Audits

- ASHRAE Level III
  - May Require Three or More Days at Plant
  - Examines Energy Use in All Processes
  - Proposes Possible Design Modifications
  - Emphasis on Optimization
  - Detailed Cost Est. Often with Significant Investment
  - May Result in Major Energy Savings _

Elements of Level II & III Energy Audit

- Examine and Analyze Utility Bill / Rate Structure
  - Electric, Gas and Water
  - Allocate Usage to Major Processes – *Energy Balance*
- Identify Cost Effective Equipment Efficiency Improvements
- Identify Cost Effective Operational Improvements
  - Often Find Controls Related Improvements (e.g. DO)
- Develop Cost Estimate and Energy Savings
- Determine Payback in Years

Work Product - Level II & III Audit

- Whole Plant Benchmark
- Energy Balance
  - Allocate Electric, Gas and Water to End Use
  - Include 24 Months Usage -- 12 Months Minimum
- Energy Conservation Measures
  - Cost of Implementation -- Level II vs. Level III
  - Energy Savings – Include Methods / Calculations
  - Calculate Payback
- Recommendations for Future Study

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Energy Audit Focus

- HVAC / Mechanical Systems
  - Mainly in Administrative Buildings
- Electrical Systems
  - Lighting in All Buildings – Examine Efficiency / Consider Occupancy Sensors
  - Motor Efficiency (Premium Motor Efficiency Savings)
  - VFD's (Frequent Savings Opportunities)

Energy Audit Focus

- Aeration Systems
  - Blower Efficiency
  - Blower Controls
  - Constant Speed, Throttling, VFD's
  - Diffusers – Fine Bubble vs. Coarse Bubble

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Energy Audit Focus

- Pumping Systems
  - Premium Motor Efficiency
  - Sizing
  - VFD's

- Solids Handling
  - Varies by Plant

Energy Audit Focus - Equipment

- Equipment Assessment
  - Tour Facility
  - Review Plans & Specs
  - Meet with Operating Personnel
  - Understand Current Conditions
  - Discuss Alternatives to be Considered
  - Develop Payback for Each Alternative

Energy Audit Focus - Process

- Process Optimization
  - Review O&M Manual
  - Discuss Operating Techniques
  - Review / Discuss Regulatory Status
  - Consider Present & Future NPDES Discharge Limits
  - Examine Plant Loadings vs. Future Expansion
  - May Develop Computer Model - Benchmarking

Energy Audit Focus - Process

- Process Optimization Continued
  - Explore Revising Basic Plant Operating Methods
  - Analyze Process Configuration Changes
  - Calculate Capital Improvement Costs
  - Calculate Energy Savings
  - Determine Payback Period
  - Identify Other Benefits – Chemical Reduction, Sludge Removal, etc.

Energy Audit Focus – Utility Optimize

- Utility Optimization
  - Examine Utility Rate(s)
    - Consider Alternative Rate Structures - *Case Study 2*
  - Perform Energy Balance – End Use Allocation
  - Examine Incentives to Reduce Peak Demand
  - Evaluate Opportunities to Reduce Peak Demand

Energy Audit Focus – Buildings

- Building Auditing
  - Allocate Energy to End Use
  - HVAC
  - HVAC Controls
  - Lighting
  - Envelope

Auditor's Tools

- eQuest
- Air Master +
- Motor Master +
- Pumping Assessment Tool (PSAT)
- Numerous Others

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Analysis of Implementation Costs

- Auditor Must Help Explore Funding Opportunities
- Identify All Utility Incentive Programs
- Factor External Funding and Utility Incentives into Financial Analysis
- Consider Remaining Useful Life
  - Sometimes Overlooked in Energy Audit
  - Include in Capital Replacement Program

Best Savings Opportunities

- Aeration Blower Optimization
  - Control DO to Minimum Practical Value
  - Match Energy Input to DO – Via Throttling, Timers, Speed Control
  - Change Diffusers from Coarse Bubble to Fine

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Best Savings Opportunities

- Plant Pumping Systems
  - Size for Efficient Operation at Average Conditions
  - Consider Entire System Design
    - Big Pipes and Small Motors - Not the opposite
- Motors
  - Premium Efficiency Motors
  - Apply Variable Speed Drives

Best Savings Opportunities

- Plant Anaerobic Digestion
  - Can Usually Reduce Mixing
  - Run Mechanical Mixers Intermittently
  - Consider Running Heater Recirculation Pumps Intermittently
  - Replace Recessed Biosolids Pumps with Semi-open Impeller Non-clogging Pumps
  - Shift Operations to Off-peak Times Where Possible

Best Savings Opportunities

- Lighting
  - Replace T12 Fluorescent and Incandescent
  - Add Occupancy Sensors
- HVAC in Administrative Buildings
- Water Heating

Case Study 1 – City of Canton Water Reclamation Facility

Case Study 1

Canton Water Reclamation Facility

- De-nitrification Activated Sludge Process
- 39 MGD
- Major Facility Improvement Project
- Install New MBR - Membrane Bioreactor System
- Convert Blowers From Activated Sludge Aeration to MBR Scour Operation

Case Study 1

Canton Water Reclamation Facility Aeration

- 4 – 800 hp Blowers and 1 – 500 hp Blower
- Centrifugal Blowers
- 4160 Volt Motors
- Common Air Header
- Inlet Valve Throttling
- Controlled by Header Pressure

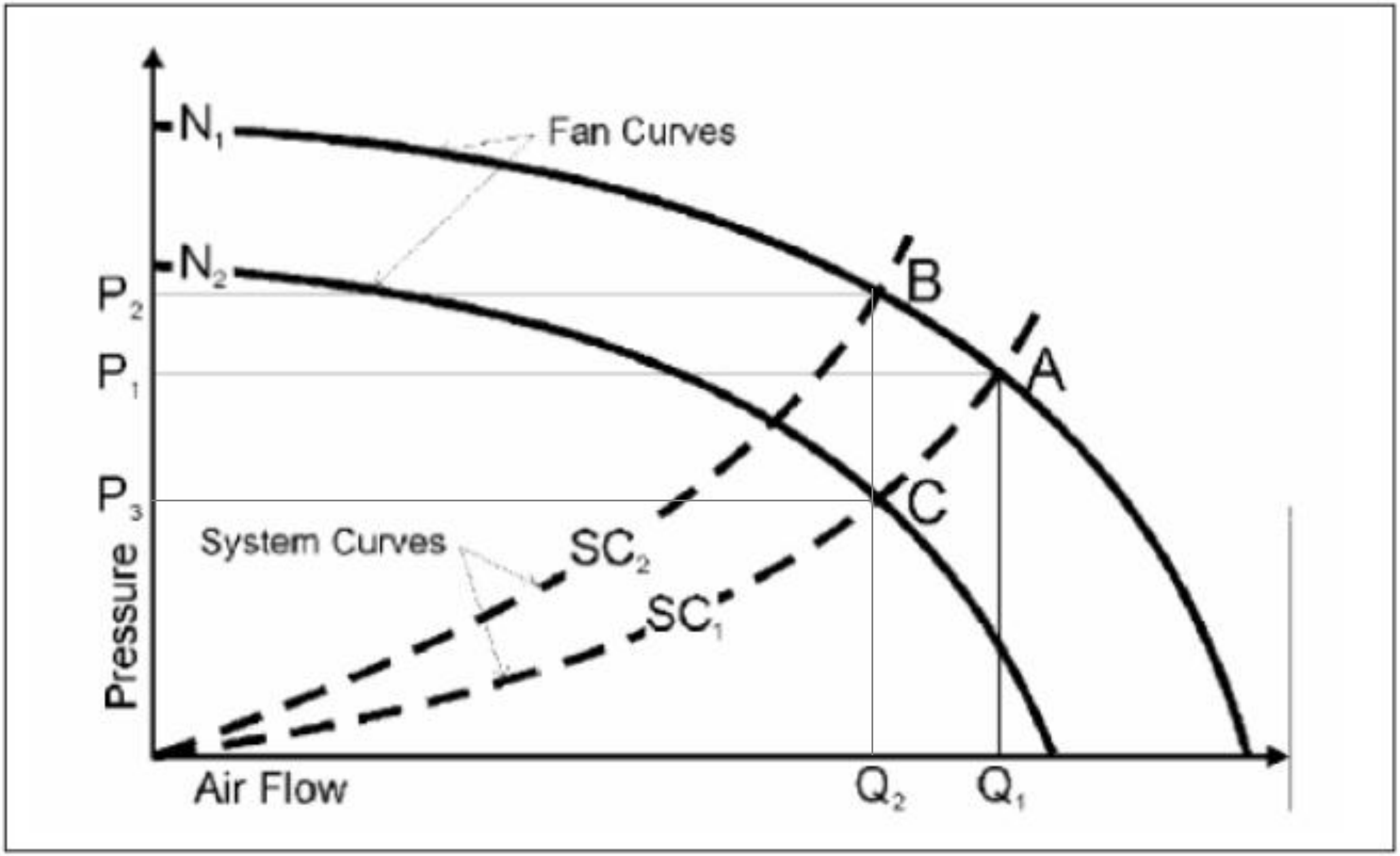
Case Study 1 - VFD's vs. Throttling

- Should VFD's be Added?
- If Yes, How Many VFD's? (1, 2, 3, 4 or 5)
- Blower Type: Centrifugal
- Blower Motors: 4160 VAC, 3570 RPM
- Blower HP: 4 – 800 hp + 1 – 500 hp
- VFD's at 4160 volts Are Very Costly
- Involve Blower Manufacturer in Analysis

Case Study 1 – VFD's vs. Throttling

- Required SCFM Based on Total Plant Flow (Q)
- Q - Determines Number of MBR Basins
- MBR Basins – 5 Minimum, 12 Maximum
- Developed Hourly SCFM Requirements
- 12,000 – 48,000 SCFM @Outlet Pressure = 7.1 psi
- Derived Number of Blowers for Each Air Flow
- Could Reach All Operating Points with 2 VFD's

Case Study 1 – Fan Performance



Case Study 1 – Fan Laws

- Fan Air Flow Rate Varies with Fan Speed Ratio
  - $Q2 = Q1 \times (N2 / N1)$
- Fan Pressure Varies with Square of Speed Ratio
  - $P2 = P1 \times (N2 / N1)^2$
- Fan Input Power Varies with Cube of Speed Ratio
  - **$H2 = H1 \times (N2 / N1)^3$** ←
  - This 3rd Law Answers Why Speed Control Saves So Much Energy

Case Study 1 – HP vs. Blower Speed

SCFM	RPM	HP	% Full RPM	% Full HP
16,900	**3,357**	**571**	**100%**	**100%**
14,002	3,300	511	92%	90%
12,402	3,170	441	89%	77%
10,950	3,090	393	87%	69%
9,662	3,025	351	85%	62%
7,754	2,960	298	83%	52%
4,696	2,925	225	82%	39%
Source = Gardner Denver Fan Curves				7.1 psi

Case Study 1 – Air Demand Profile

Hours / Day	SCFM	Blower RPM			
		VFD's		Constant Speed	
		Blower 1	Blower 2	Blower 3	Blower 4
3	12,084	3150	----	----	----
2	22,472	3150	3150	----	----
7	31,270	3225	----	3570	----
12	48,336	2925	2925	3570	3570
0.7	72,504	3560	3560	3570	3570
500 HP Blower Not Shown					

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Case Study 1 – Air Demand vs. HP

Hours / Day	SCFM	HP per Blower				Total HP
		VFD's		Constant Speed		
		Blower 1	Blower 2	Blower 3	Blower 4	
3	12,084	430	--	--	--	430
2	22,472	402	402	--	--	804
7	31,270	471	--	675	--	1,146
12	48,336	255	255	675	675	1,800
0.7	72,504	670	670	675	675	2,690
500 HP Blower Not Shown						

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Case Study 1 – Annual Energy Cost

Month	kWh	Energy Cost	kWh	Energy Cost
	Inlet Valve Throttling		2 VFD's	
January	807,025	$ 60,285	736,681	$ 55,030
February	727,650	$ 54,355	663,726	$ 49,580
March	807,814	$ 60,344	737,711	$ 55,107
April	779,434	$ 58,224	710,886	$ 53,103
May	879,286	$ 65,683	709,436	$ 52,995
June	851,698	$ 63,622	688,436	$ 51,426
July	880,038	$ 65,739	711,262	$ 53,131
August	878,834	$ 65,649	708,340	$ 52,913
September	851,071	$ 63,575	686,914	$ 51,312
October	878,784	$ 65,645	708,218	$ 52,904
November	778,714	$ 58,170	709,946	$ 53,033
December	804,657	$ 60,108	733,593	$ 54,799
TOTALS	**9,925,005**	**$ 741,398**	**8,505,147**	**$ 635,334**
Annual Savings with 2 VFD's			**1,419,858**	**$ 106,063**

Case Study 1 – Study Results

Blower Curves Defined Operating hp and kW	
Cost per kWh	$0.075
Energy Cost Inflation	4%
Install Cost of Two VFD's	$497,000
Annual kWh with Throttling	9,946,000
1st Year Energy Cost with Throttling	$742,000
Annual kWh with Two VFD's	8,512,000
1st Year Energy Cost with Two VFD's	$635,000

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Case Study 1 – Study Results

- 1st Year Gross Energy Savings Using 2 VFD's
  - 1,434,000 kWh
  - $106,000
  - 14% Reduction
- VFD Rejected Heat at Full Load = 63 mBTU
- 1st Year Cooling Costs for VFD's
  - 107,015 kWh
  - $8,782

Case Study 1 – VFD's vs. Throttling

- 1st Year Net Savings
  - 1,326,985 kWh
  - $97,218
  - 13% Reduction
  - Equivalent to 915 Metric Tons of CO_2 Emissions _

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Case Study 1 – Payback Calculation

Year	Investment Less Savings + 5% / yr.	Electric Savings + 4% / yr.	Balance End of Year
0	$ 497,000	$ 97,282	n/a
1	$ 521,850	$ 101,173	$ 420,677
2	$ 441,711	$ 105,220	$ 336,491
3	$ 353,316	$ 109,429	$ 243,887
4	$ 256,081	$ 113,806	$ 142,275
5	$ 149,389	$ 118,358	$ 31,031
6	$ 32,583	$ 123,092	($ 90,510)

Payback Period is 5.3 Years

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Case Study 1 – Conclusion

- VFD's vs. Inlet Valve Throttling
  - VFD Speed Control is Economically Justified
    Even If Inlet Valve Throttling Already Installed
- Blowers Operate Closer to Surge Line
- Savings Produces $100,000 + Every Year After Year 6
- Savings Calculated Without Utility Incentive

Case Study 2 – City of Willoughby WWTP

- Conventional Activated Sludge Process
- 9 MGD

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Case Study 2 – City of Willoughby WWTP

- Performed a Level 1-1/2 Audit
  - Three Hour On-site Visit
  - No Cost to Client
  - Palmer Conservation Consulting & CT
- Looked for Readily Apparent Savings Opportunities
- Developed Some ECM and Calculated Payback

  Not Normally Part of Level 1 Audit

Case Study 2 - Opportunities

- Savings Opportunities
  - Lighting and Lighting Controls Throughout Plant
  - Administrative Building HVAC Roof Top Units
  - Administrative Building HVAC Controls
  - Power Distribution - Utility Electric Service
    Secondary Metering to Primary Metering
  - Aeration Blower Dispatch with DO Monitoring

Case Study 2 - Lighting

- Lighting Upgrade
  - Plant Previously Replaced 50% of T12 Fluorescent
  - Replace Remaining T12's with T8's
  - Applied Utility Incentive -- Minimal
  - Calculated 6 Year Payback
- Lighting Controls
  - Occupancy Sensors with Manual Override
  - Calculated 6 Year Payback

Case Study 2 - Buildings

- HVAC in Administrative Building
  - Replace Singular RTU with Two Separate Units to Serve Areas of Different Needs
  - Replace Building Controls
  - Approximately $60,000 in Cost
  - Calculated 10 Year Payback

Case Study 2 – Electric Rate Schedule

- Existing Electric Utility Service
  - 13.2 kV Service from Utility
  - 13,200 – 480 volt Transformers
  - Billing Metering CT's on 480 volt Bus (Secondary)
- Proposed Service
  - Purchase Transformer from Utility Company
  - Move Metering to 13.2 kV Bus (Primary Metering)
  - Savings Due to Lower Electric Rate Schedule

Case Study 2 – Electric Rate Schedule

- Primary Metering Rate is Lower but Has Risks
- Cost to Purchase Transformer and Primary Metering CT's & PT's
  - $189,000
- Annual kWh Savings = 0
- Annual Electric Cost Savings = $25,000
- Simple Payback = 7.6 Years

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Case Study 2 – Energy Conservation Measures

Energy Conservation Measures	Cost	Annual Savings	Payback – Yrs.
Lighting	$25,100	$4,200	6.0
HVAC Modifications	$43,200	$4,300	10.0
HVAC Controls	$27,000	$2,500	10.8
Power Distribution	$189,000	$25,000	7.6
Other	$27,000	$1,000	27.0
TOTAL	**$311,300**	**$37,000**	**8.4**
Future Study	DO Controls / Aeration Blower Controls		

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Case Study 2 – Future Study

- Aeration Blower Dispatch Optimization
- 4 – 200 hp Turbo Blowers
- Manual DO Readings
- Manual Dispatch of Blowers
- Question – If 160% of Blower Capacity is Needed, What is Optimum Configuration?
  - 2 Blowers @ 80% or 1 Blower @100% + 1 @ 60%
  - Other Combination(s) ?

Renewable Energy

- Consider Renewable Energy Alternatives
  - Co-Generation
  - Photovoltaic
  - Wind Turbine
- Usually Requires Outside Funding
  - Often Partially Available
- City of Delphos WWTP
  - Installed 83 kW Photovoltaic - 100% Outside Funding

Summary

- Energy Costs Will Continue to Increase
- Perform Level II or Level III Audit
- Make Energy Conservation an Integral Part of Plant Operations and Future Planning
- Select Efficient Equipment
- Install Energy Monitoring Equipment
- Savings Opportunities Exist _

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Thank You

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