Side Stream Treatment and Advanced Stabilization Technologies

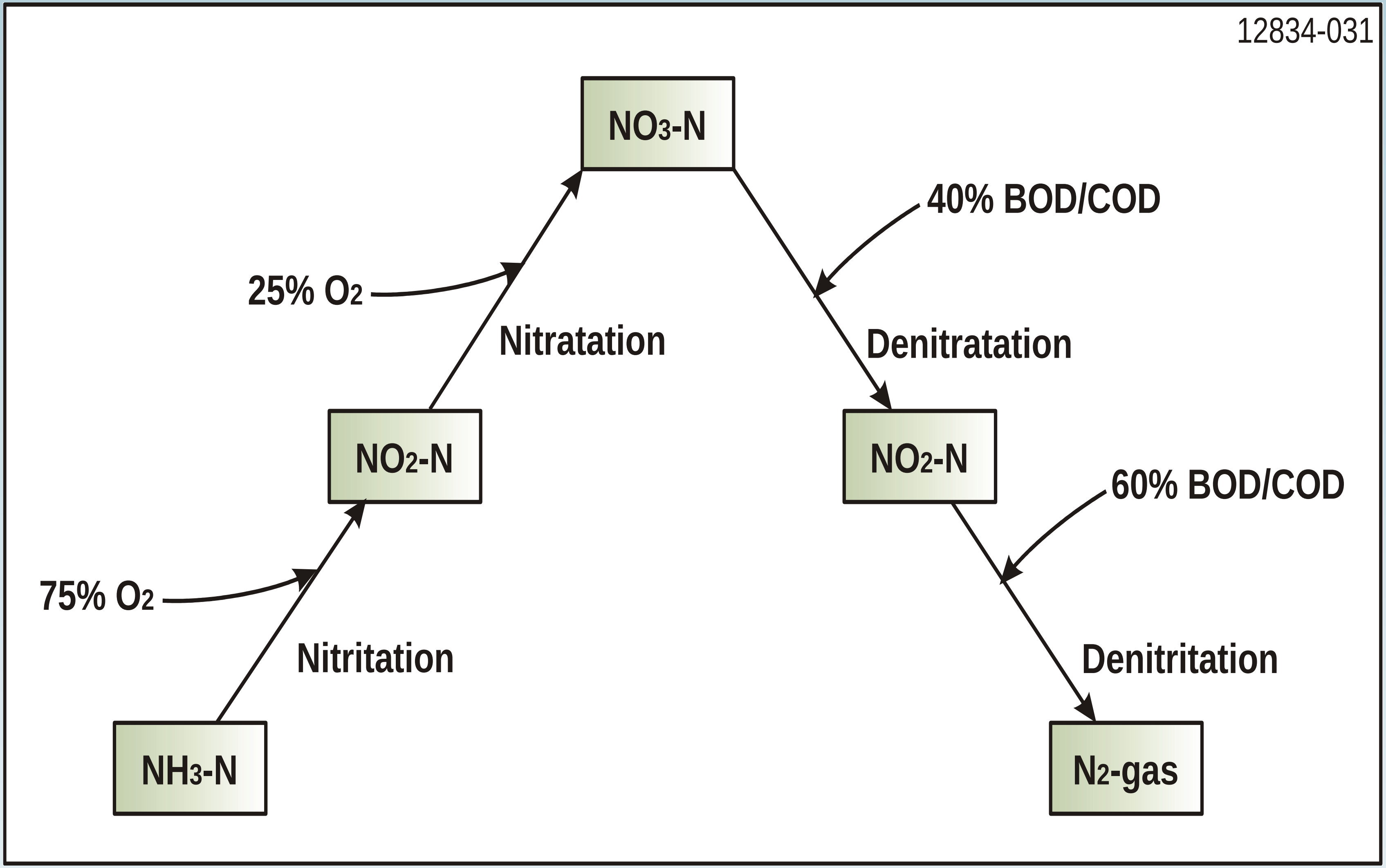
HAZEN AND SAWYER
Environmental Engineers & Scientists

Overall Program Agenda

Time	Program Item
9:30 – 10:20	Biosolids Management / Regulatory Framework
10:20 – 10:30	Break
10:30 – 12:00	Biosolids Treatment Technologies
12:00 – 13:00	Lunch
13:00 – 13:30	Sidestream Treatment and Advanced Stabilization
13:30 – 14:30	Energy Management
14:30	Workshop Closure

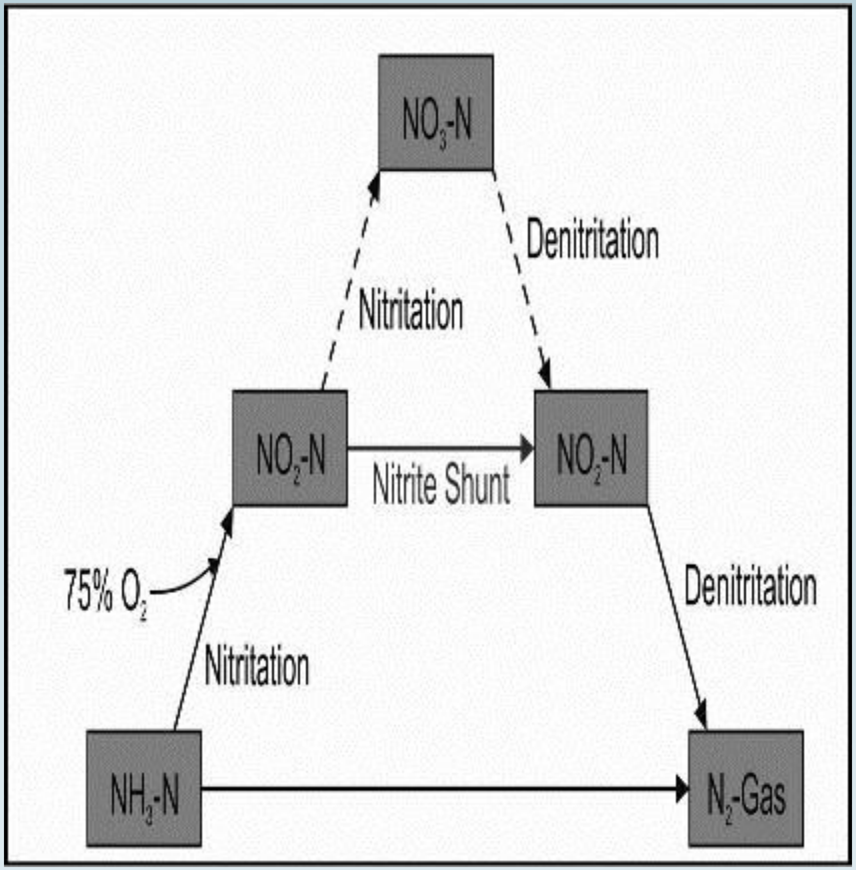
SIDESTREAM TREATMENT NITROGEN REMOVAL

Conventional nitrogen removal pathway is energy and carbon “intensive”



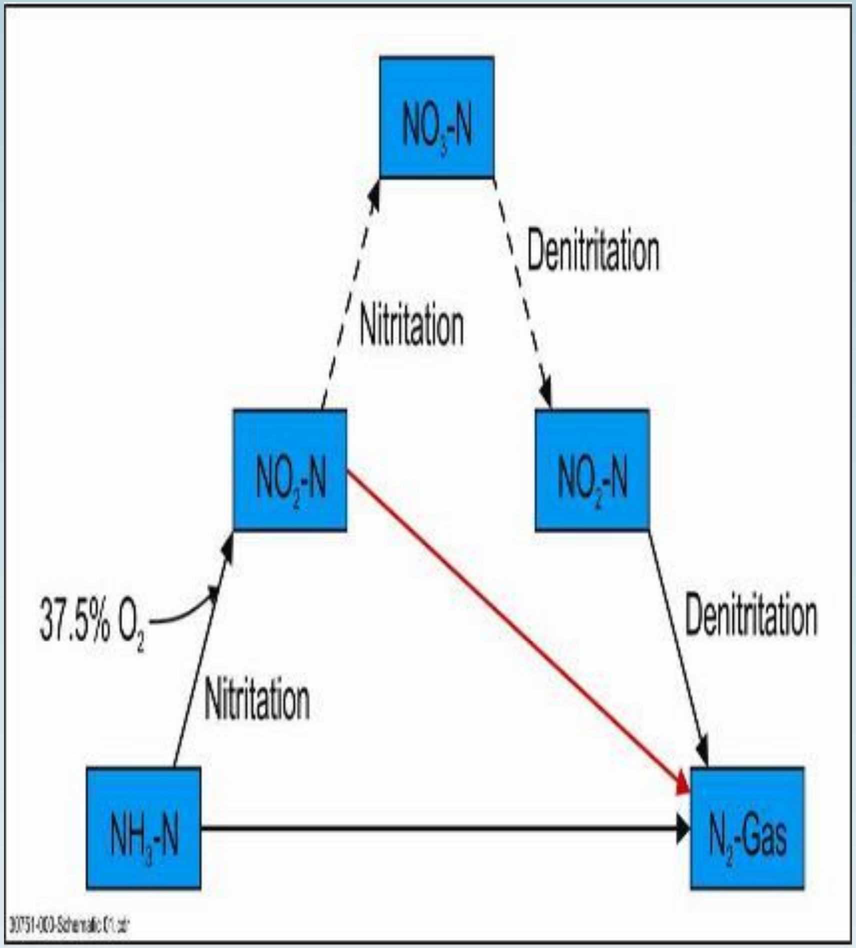
There are more energy and carbon efficient pathways for nitrogen removal.

- Shortcuts traditional nitrification and /denitrification
- Stopping at nitrite rather than nitrate.
- Uses 25% less oxygen (theoretical)
- Uses 40% less carbon (theoretical)



Nitritation and Deammonification is an even more efficient N removal pathway.

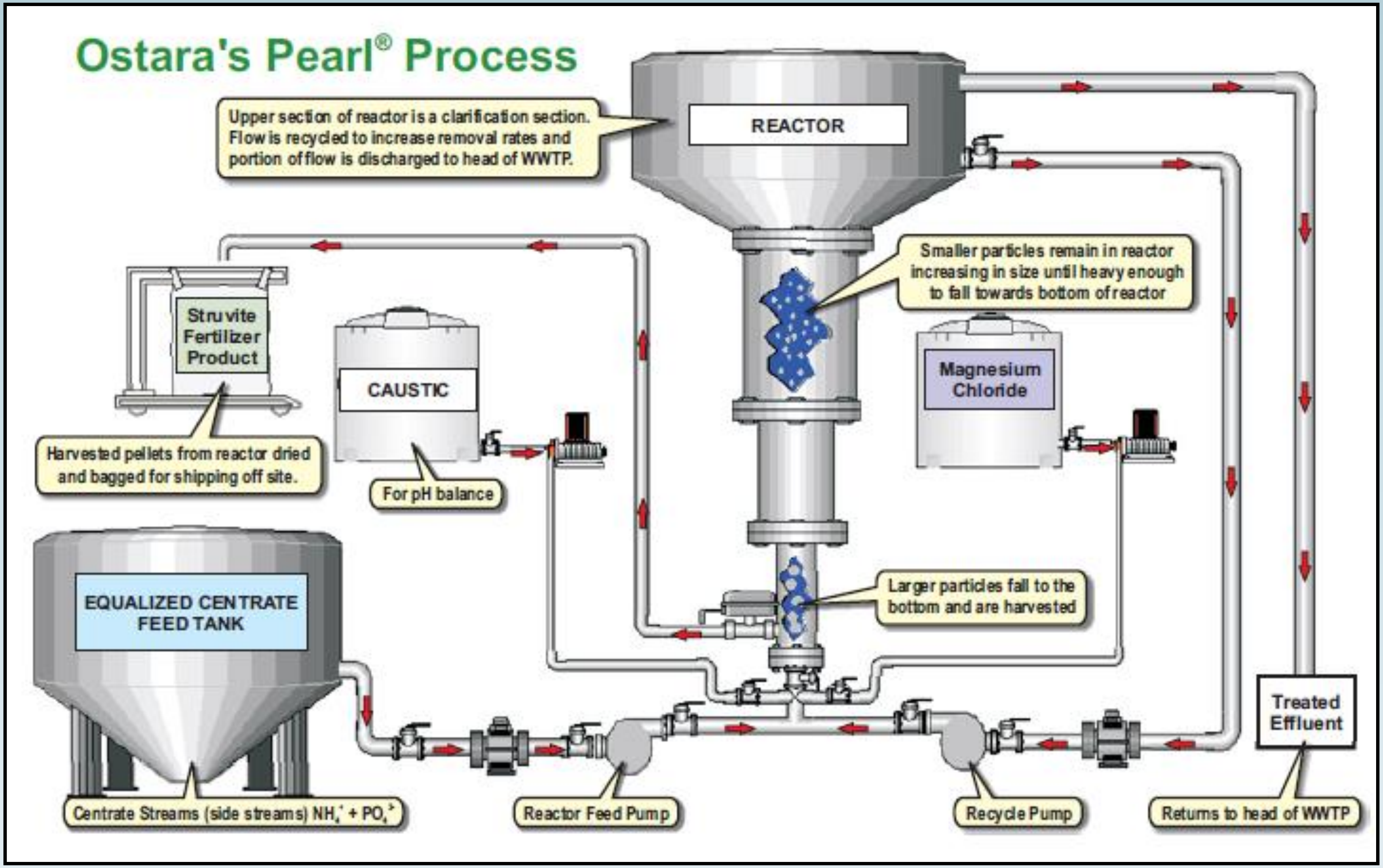
- The most energy-efficient and low cost way to remove nitrogen
- Uses 62.5% less oxygen
- Does not require any supplemental carbon
- Utilizes annamox bacteria



SIDESTREAM TREATMENT PHOSPHORUS REMOVAL

Uncontrolled Struvite formation after anaerobic digestion can be a problem

OSTARA offers a “controlled” struvite recovery reactor system



Upper section of reactor is a clarification section. Flow is recycled to increase removal rates and portion of flow is discharged to head of WWTP.

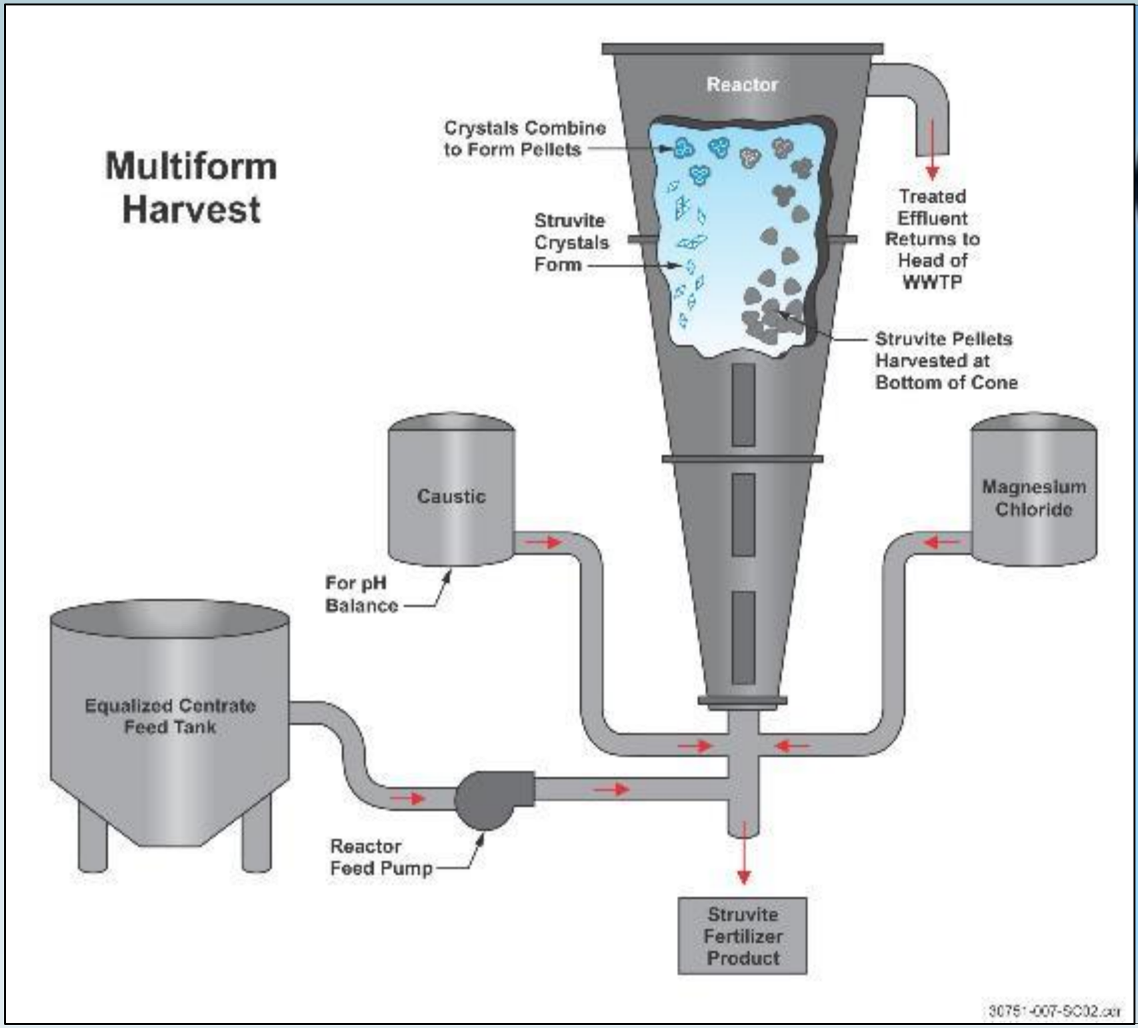
Smaller particles remain in reactor increasing in size until heavy enough to fall towards bottom of reactor

Harvested pellets from reactor dried and bagged for shipping off site.

Larger particles fall to the bottom and are harvested

Centrate Streams (side streams) NH_4^+ + PO_4^{3-}

Multiform Harvest offers a competing controlled struvite recovery reactor



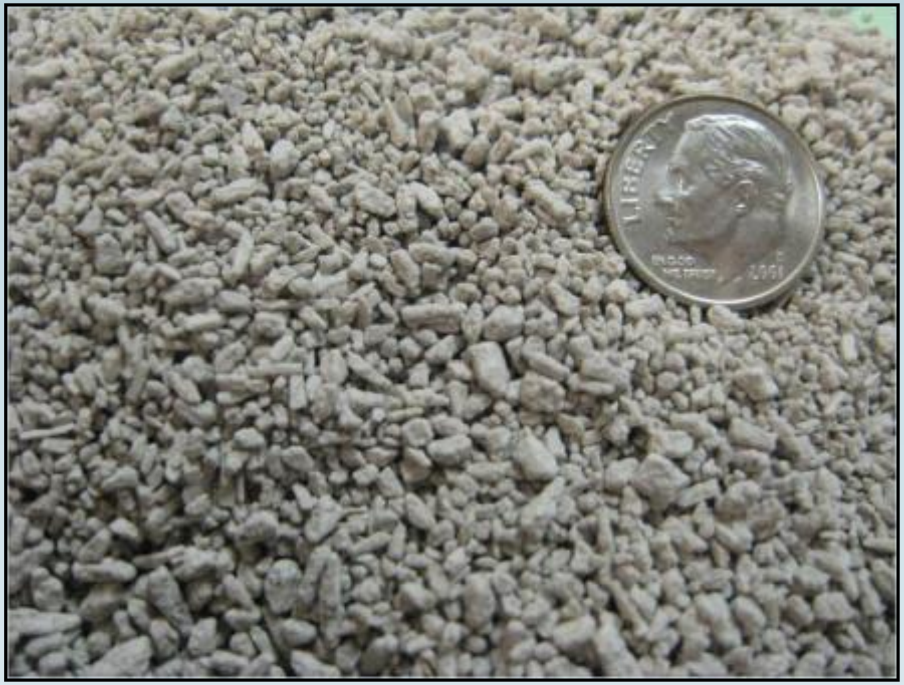
OSTARA struvite recovery reactor system at the Nansemond WWTP.

OSTARA struvite recovery reactor system at the Nansemond WWTP.

Product quality can vary depending on the struvite recovery system installed.

OSTARA CrystalGreen Product

Multiform Harvest Product



Active learning exercise…

The two major constituents of concern in side stream from dewatering anaerobically digested sludge are:

1. ____________________
2. ____________________

Active learning exercise…

What are the five chemical elements found in struvite:

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

POST-DEWATERING TREATMENT TECHNOLOGIES

Composting can be utilized to achieve 40 CFR 503 “Class A” standards.

- Space intensive
- High odor potential
- Labor and equipment intensive for material handling
- Seasonal product demand
- Unique marketing and distribution challenges

Basic process configuration for composting unit treatment process.

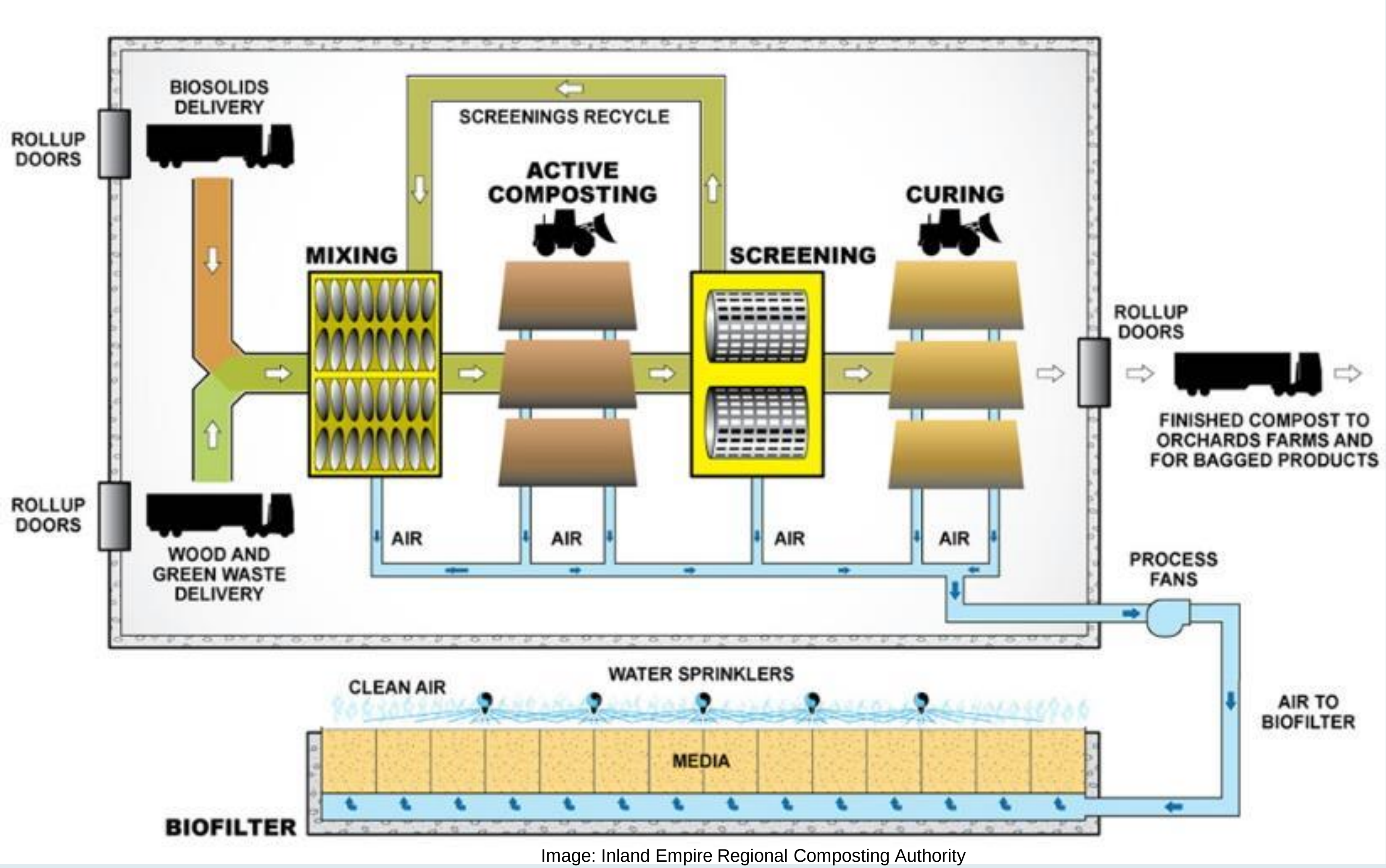


Image: Inland Empire Regional Composting Authority
(http://www.ierca.org/process/compostprocess.html)

Alkaline stabilization can meet both "Class A" or "Class B" standards

- Calcium Oxide (Lime) is blended with dewatered cake
- Elevated pH can result in high ammonia odors release
- "Class A" achieved by:
    - pH + Temperature
    - Time + Temperature
- Finish Product used as Soil Conditioner

Fluid bed thermal oxidation is the current "standard" in incineration

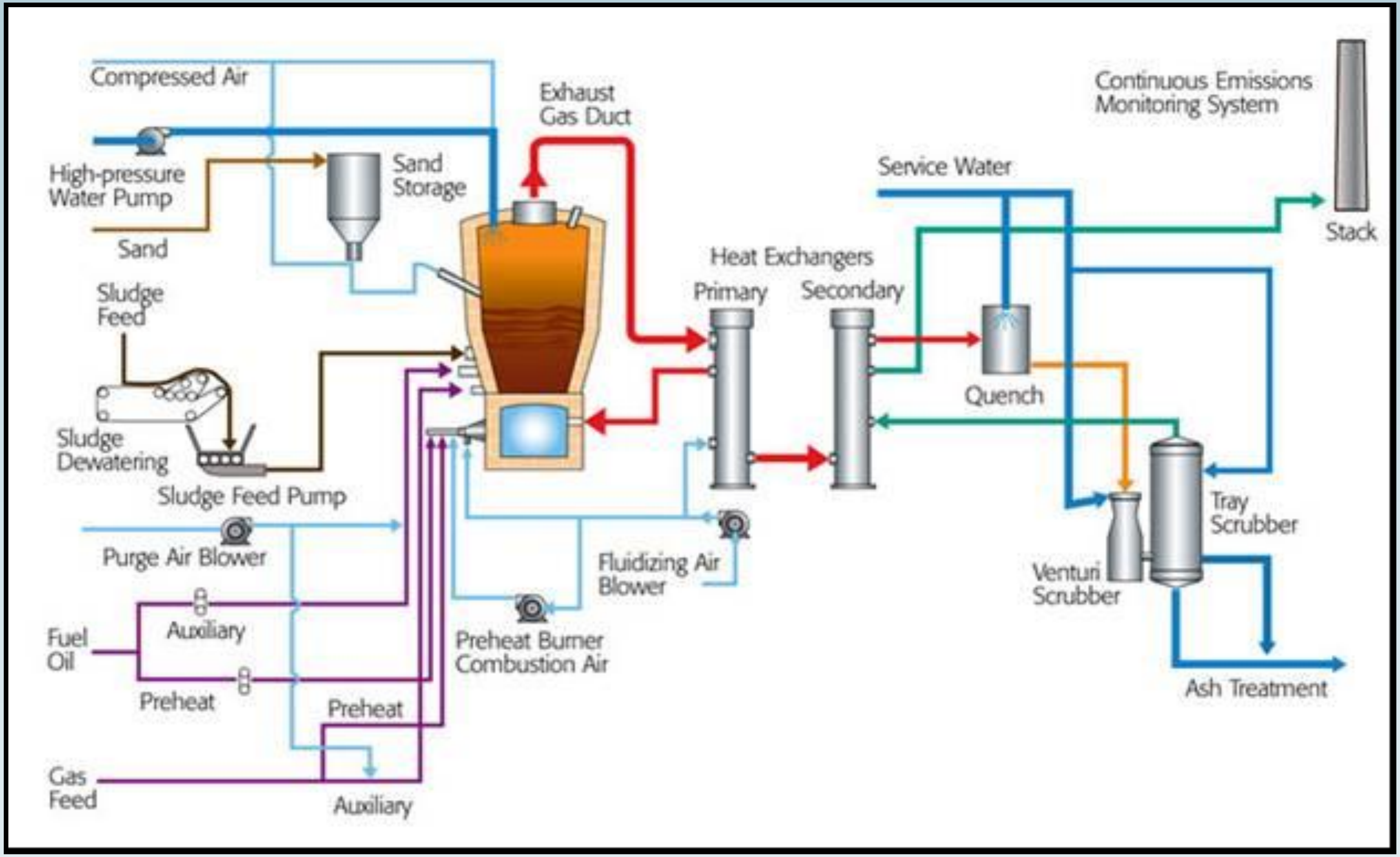
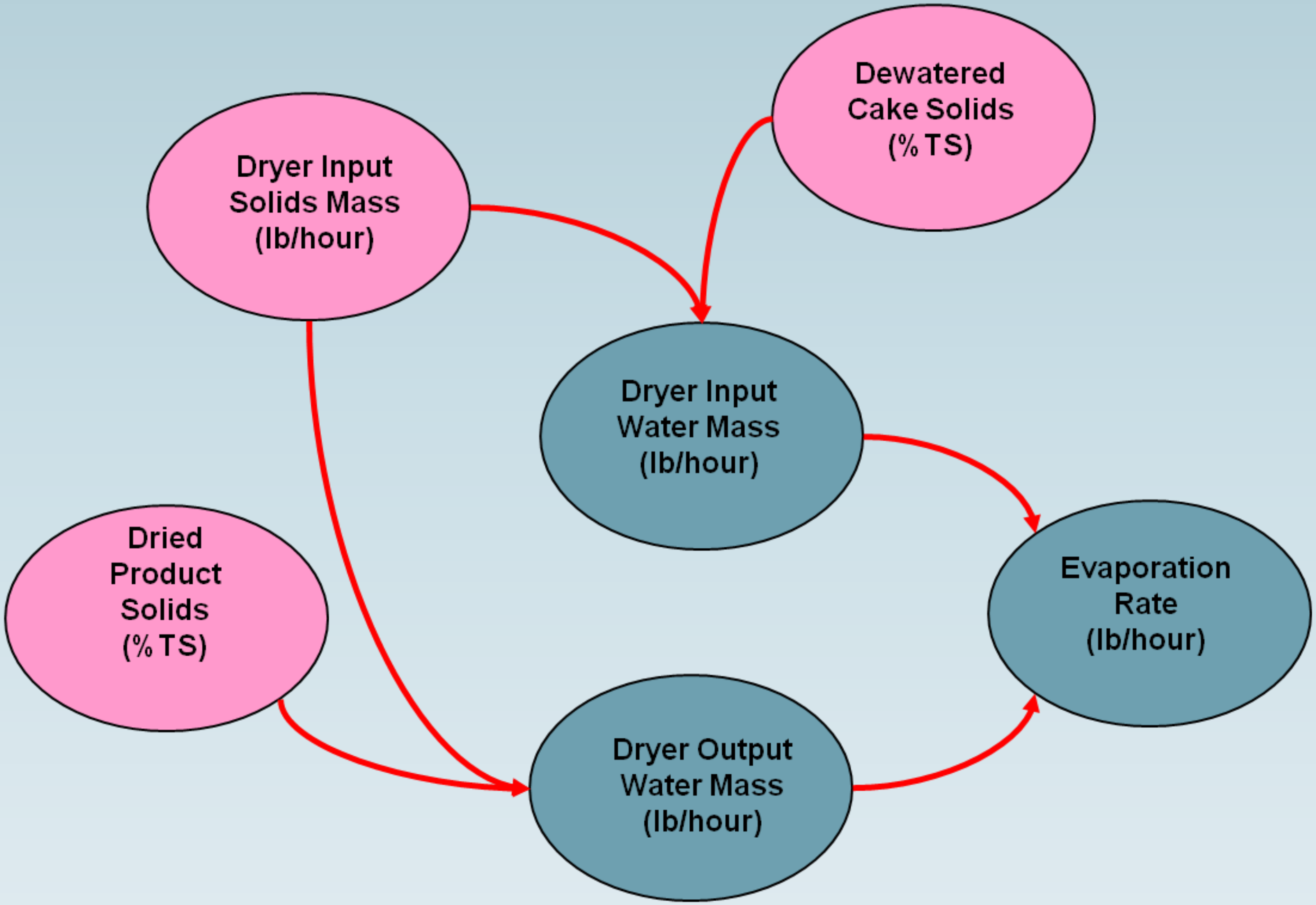
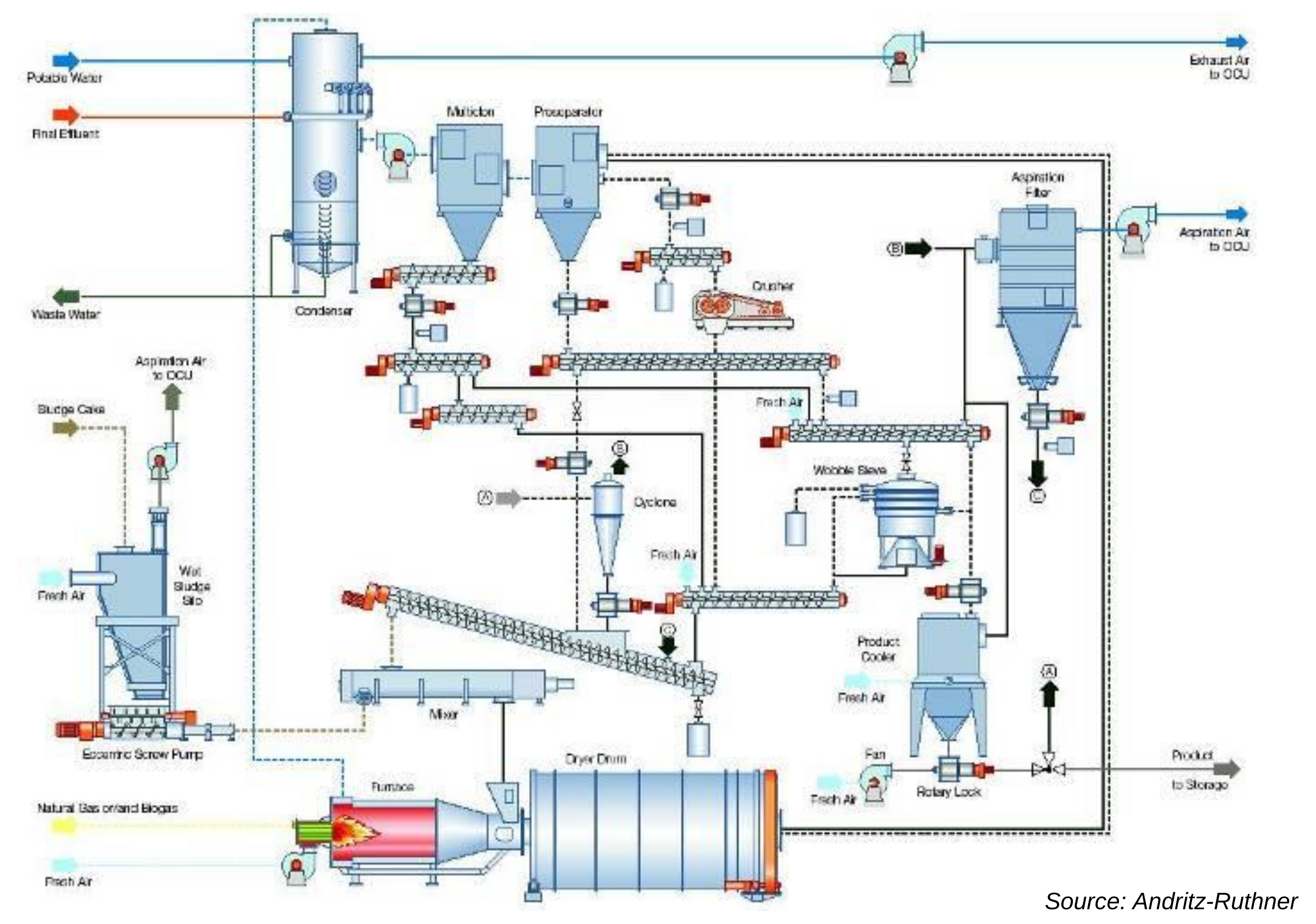


Image Courtesy IDI Technologies

Thermal drying systems are “rated” by evaporation rate capacity



Rotary drum thermal drying is the most prominent technology for “large” systems.



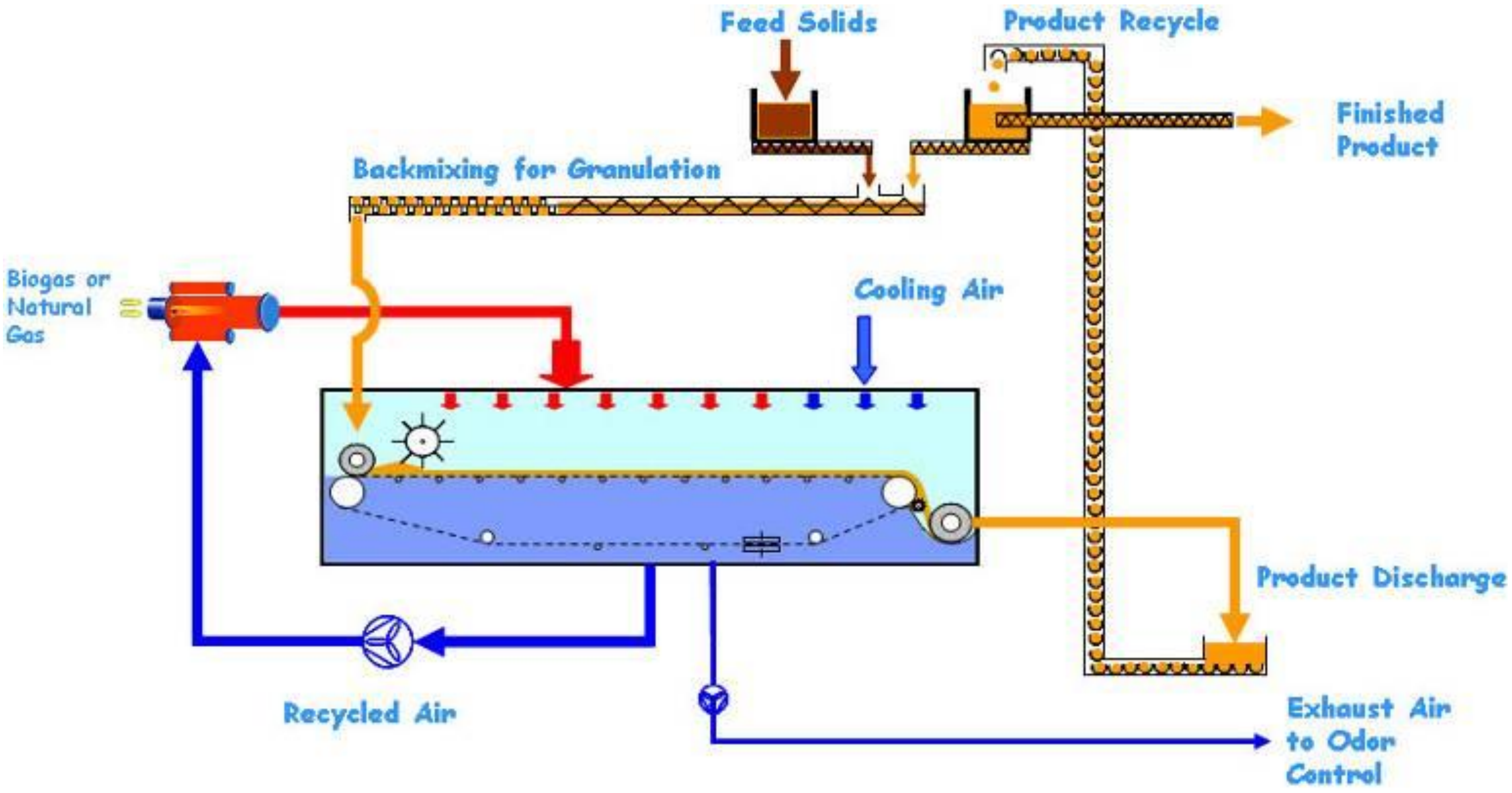
Source: Andritz-Ruthner

South Cary WRF thermal drying facility 8,800 lb/hour evaporation rate capacity.

Compact rotary drum drying systems are available for "smaller" size systems.

Photo Courtesy: Andritz-Ruthner

Belt drying systems are a more recent addition to the sludge drying market.

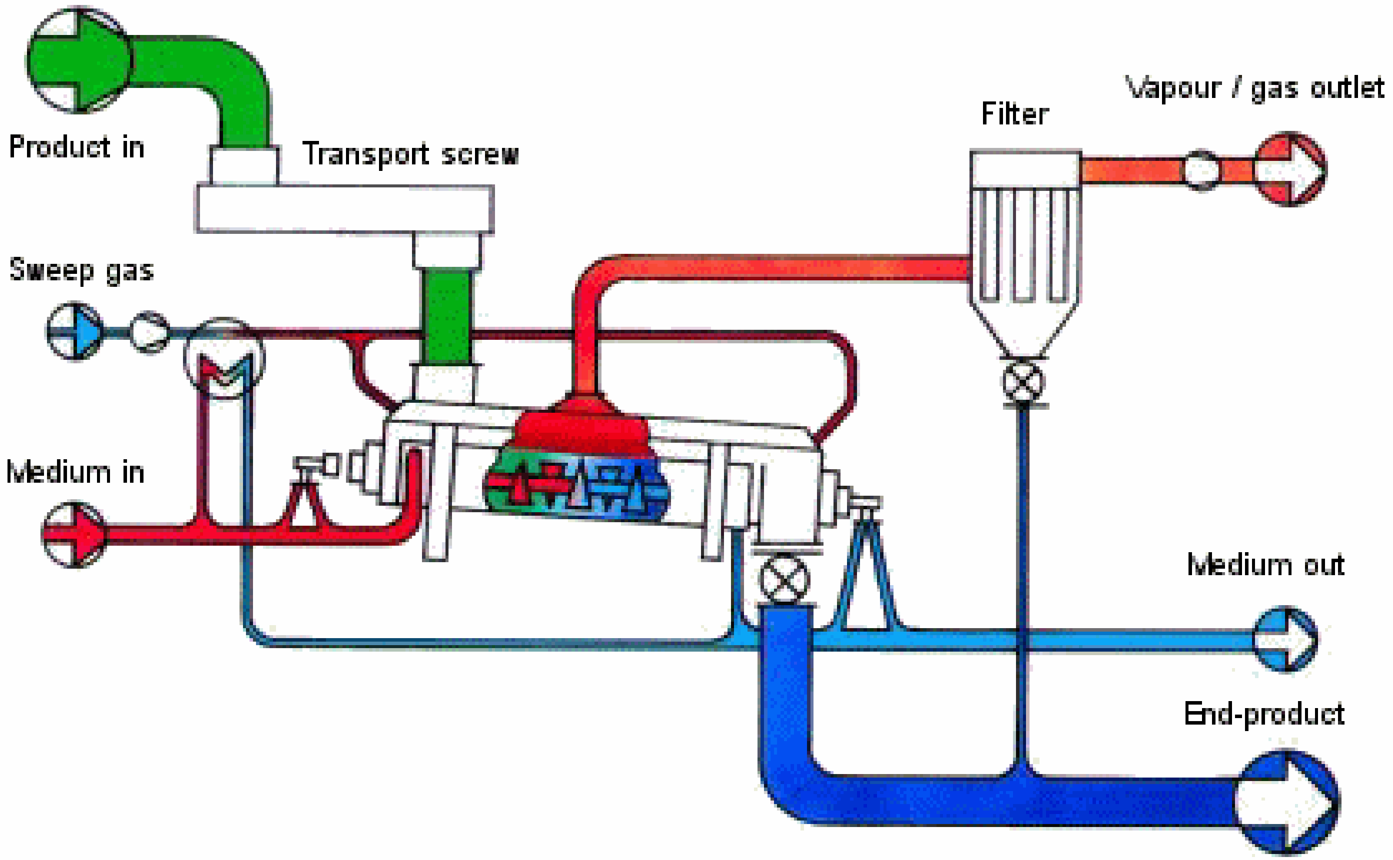


Source: Andritz-Ruthner

Belt dryer installation in Biel, Switzerland with an evaporation rate 2,900 lb/hour.

Image: Andrtiz-Ruthner

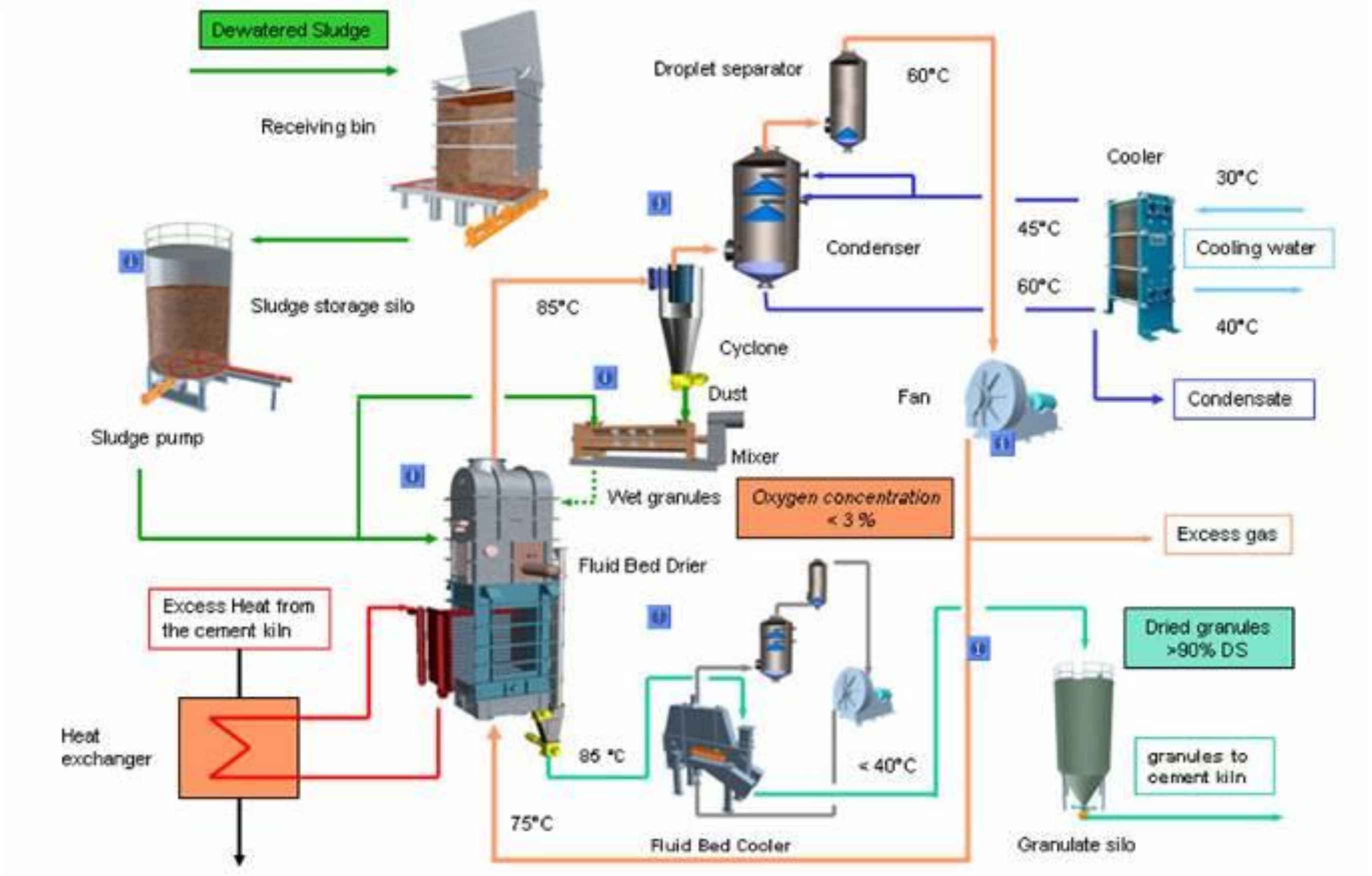
Paddle dryers are the most common of the “indirect” dryer systems.



Source: Komline-Sanderson

Paddle drying system in Mason, OH with 6,500 lb/hour evaporation rate capacity.

Fluid bed dryers are not common in the North American market.

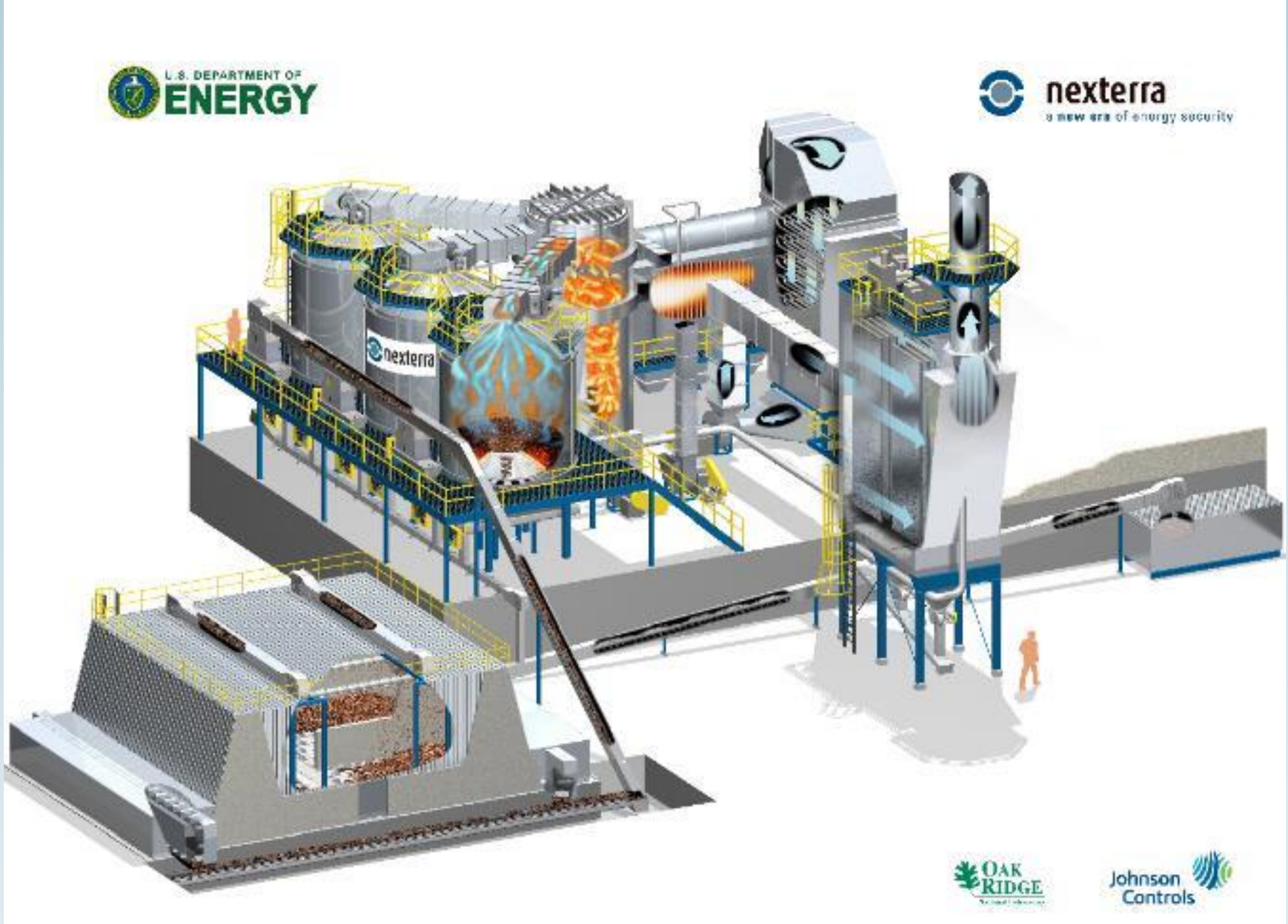


Source: Andritz-Ruthner

Fluid bed dryer in Houthalen, Belgium with evaporative capacity 8,000 lb/hour.

Image: Andritz-Ruthner

Biosolids gasification is an emerging technology for energy recovery.



Nexterra Biomass Gasification System for Johnson Controls at DOE's Oak Ridge National Laboratory in Tennessee.

Solar sludge drying beds can be covered to reduce seasonal impacts

Source: Veolia-Water / Kruger

Automation can be applied to increase solids loading rates to reduce footprint.

Source: Veolia-Water / Kruger

Active learning exercise…

What are three major types of processes used for producing a Class A biosolids after dewatering:

1. ______________________
2. ______________________
3. ______________________

Active learning exercise…

What is the primary criteria used for sizing an thermal drying system?

Active learning exercise…

What are the five major types of thermal drying systems on the market:

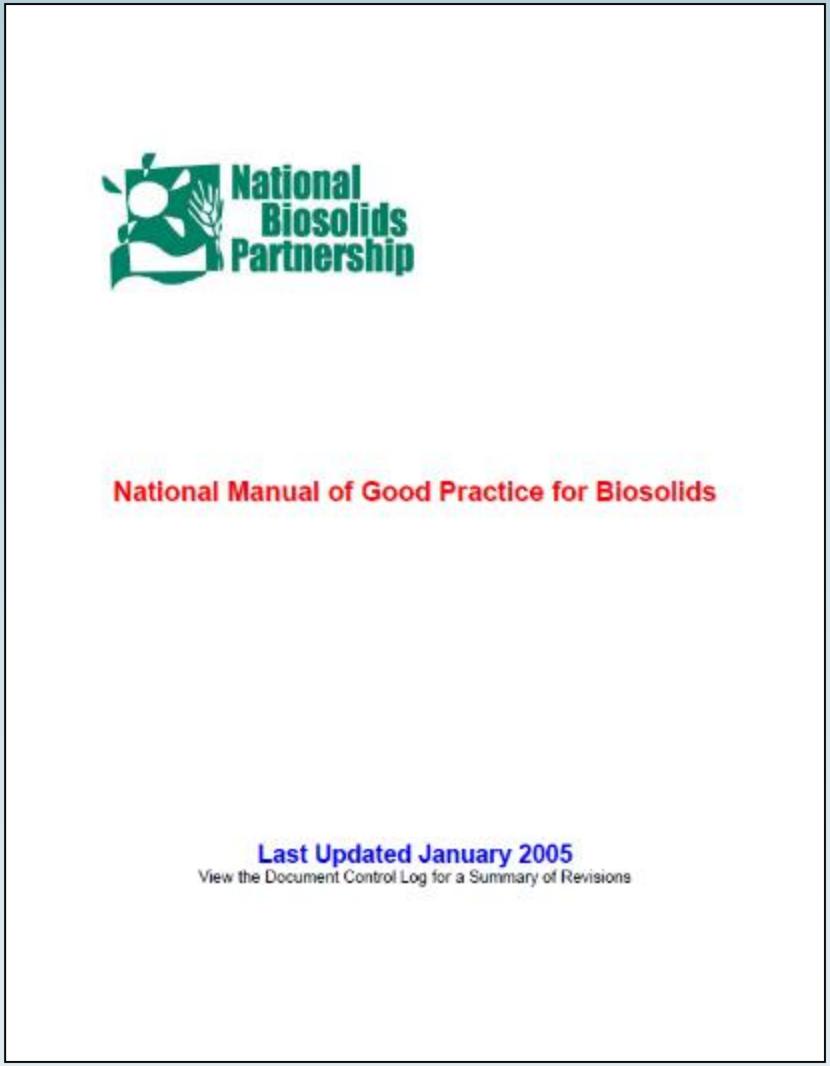
1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

The big picture take away items…

- The “on-site” residuals stabilization and handling requirements are largely governed by the needs of the “off-site” residuals management program.

- Thickening, stabilization, dewatering, and post-dewatering treatment must work together as a system to effectively achieve residuals processing objectives.

Reference Materials

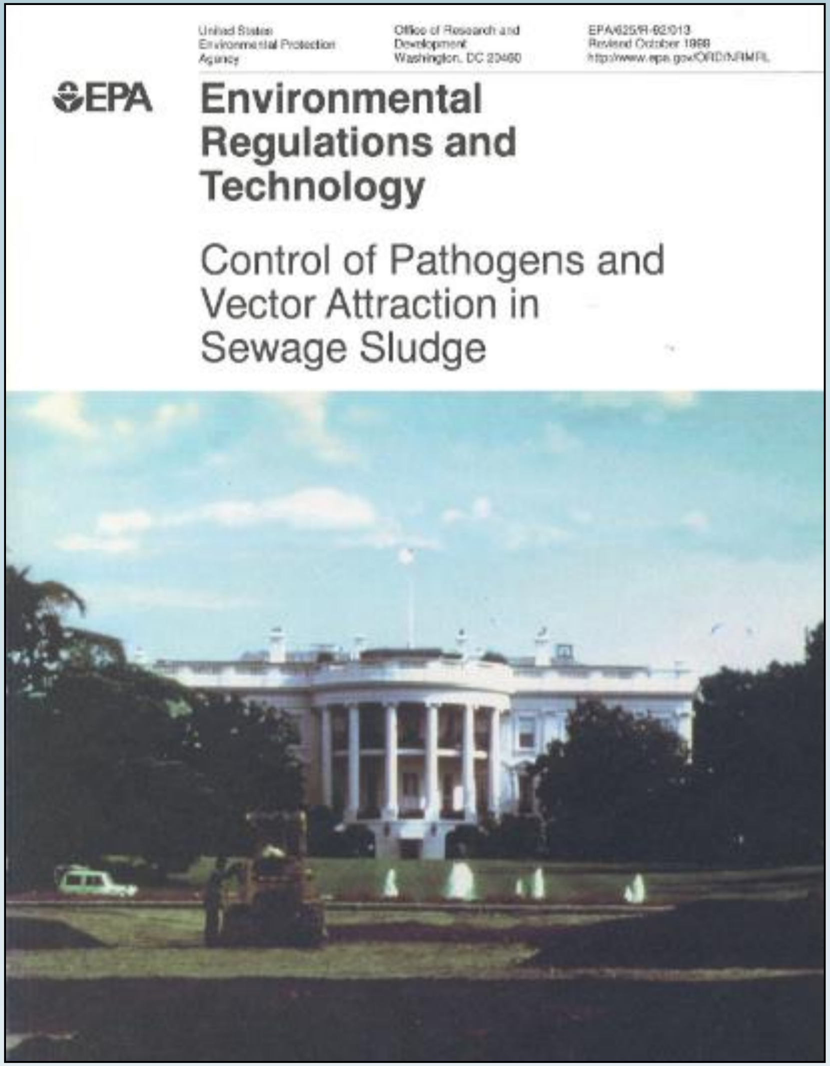


National Biosolids Partnership

National Manual of Good Practice for Biosolids

Last Updated January 2005

View the Document Control Log for a Summary of Revisions



United States Environmental Protection Agency

Office of Research and Development
Washington, DC 20460

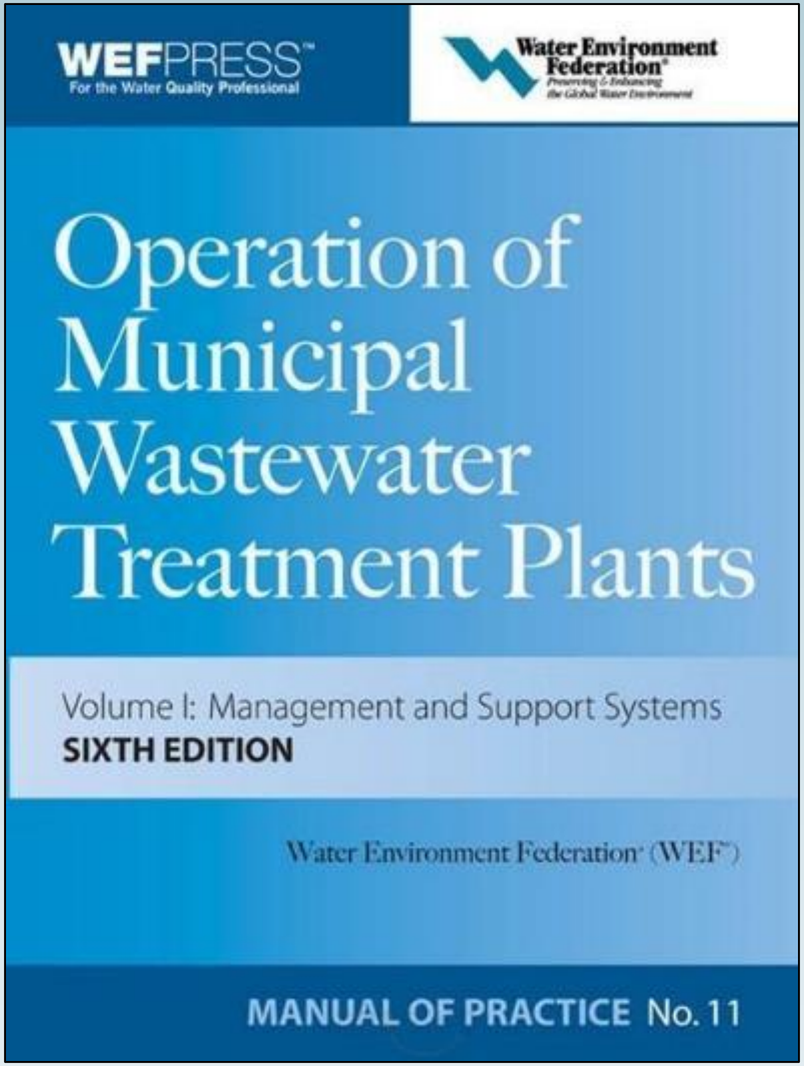
EPA/625/R-92/013
Revised October 1999
http://www.epa.gov/ORD/NRMRL

EPA

Environmental Regulations and Technology

Control of Pathogens and Vector Attraction in Sewage Sludge

Reference Materials



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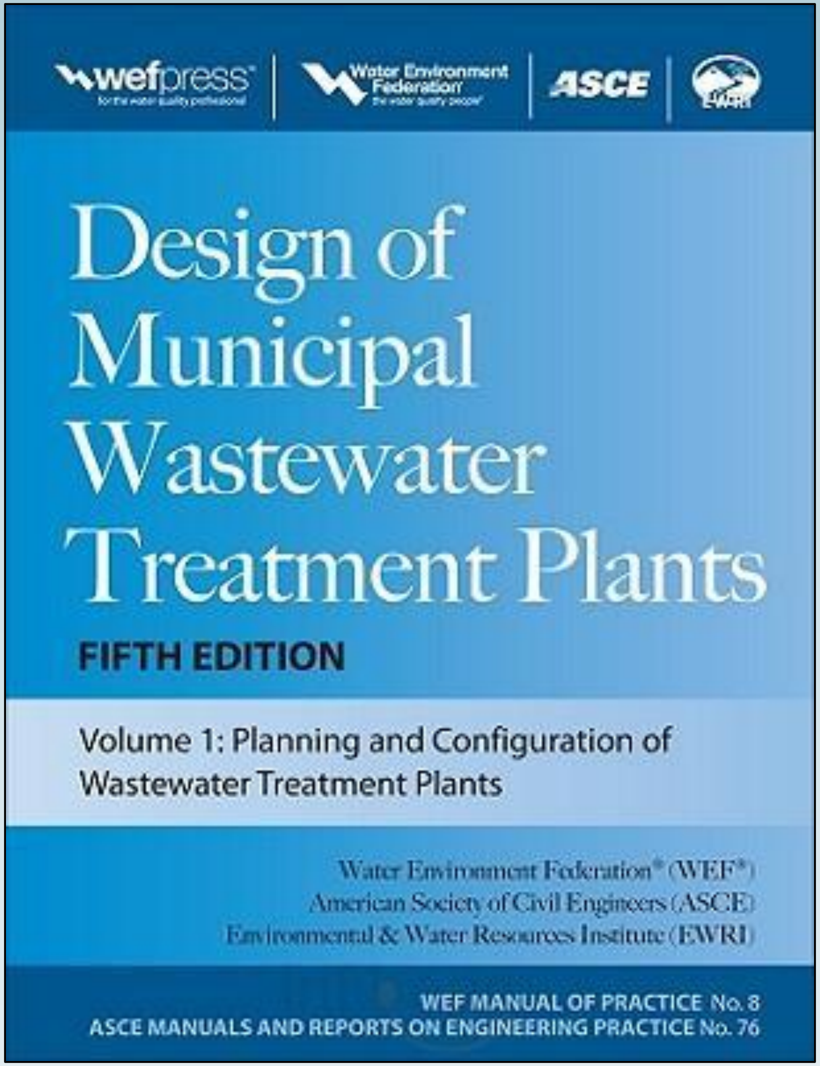

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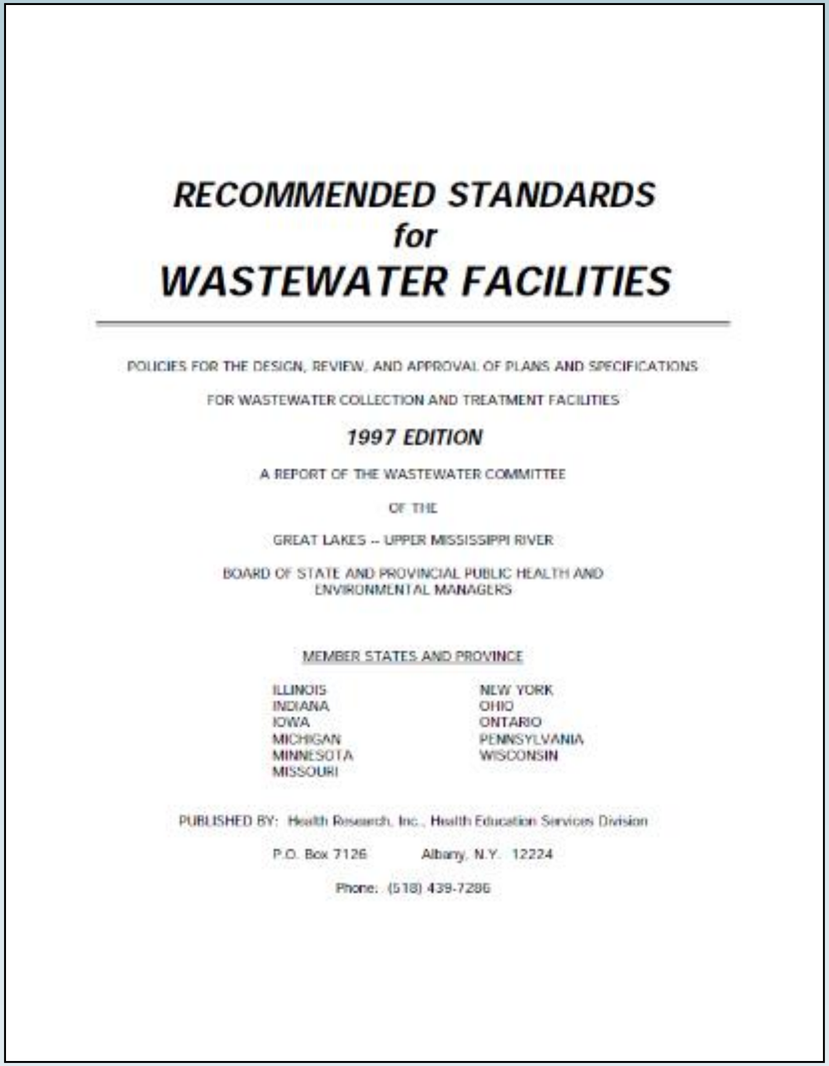

RECOMMENDED STANDARDS
for
WASTEWATER FACILITIES

POLICIES FOR THE DESIGN, REVIEW, AND APPROVAL OF PLANS AND SPECIFICATIONS

FOR WASTEWATER COLLECTION AND TREATMENT FACILITIES

1997 EDITION

A REPORT OF THE WASTEWATER COMMITTEE

OF THE

GREAT LAKES -- UPPER MISSISSIPPI RIVER

BOARD OF STATE AND PROVINCIAL PUBLIC HEALTH AND
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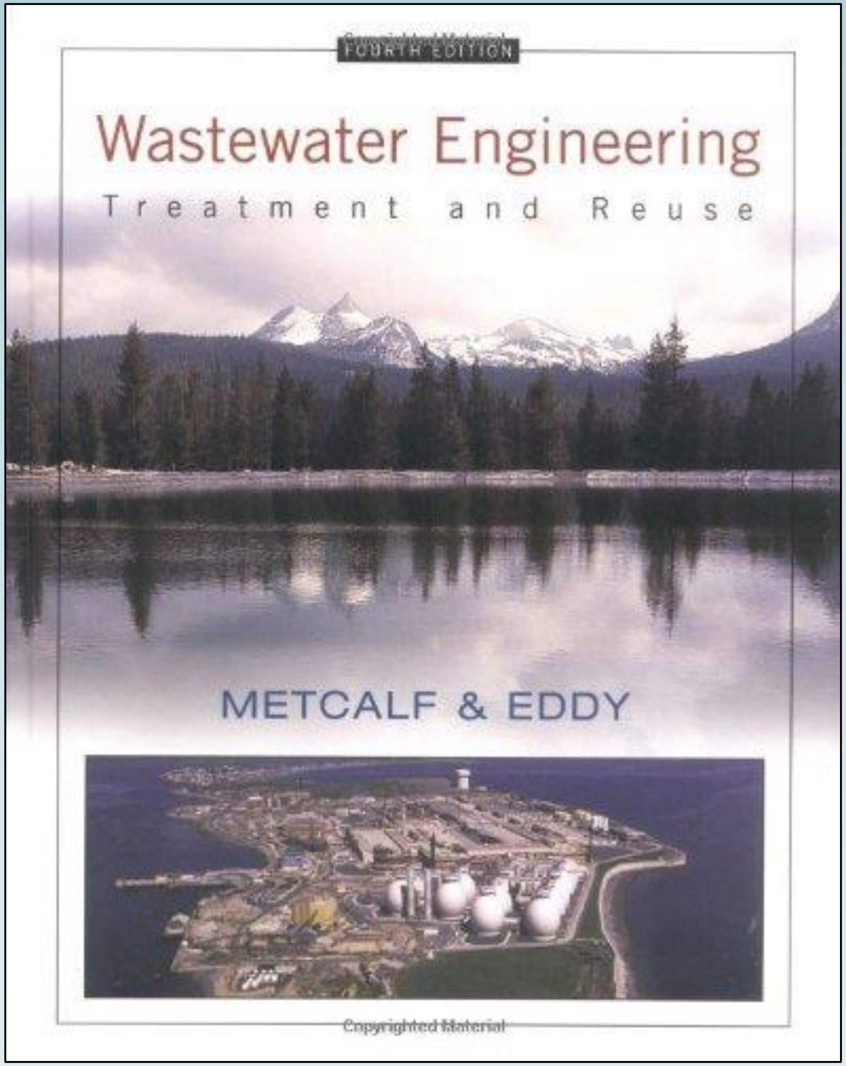

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Questions?

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Biosolids and Residuals Processing & Energy Management Workshop

December 12, 2013

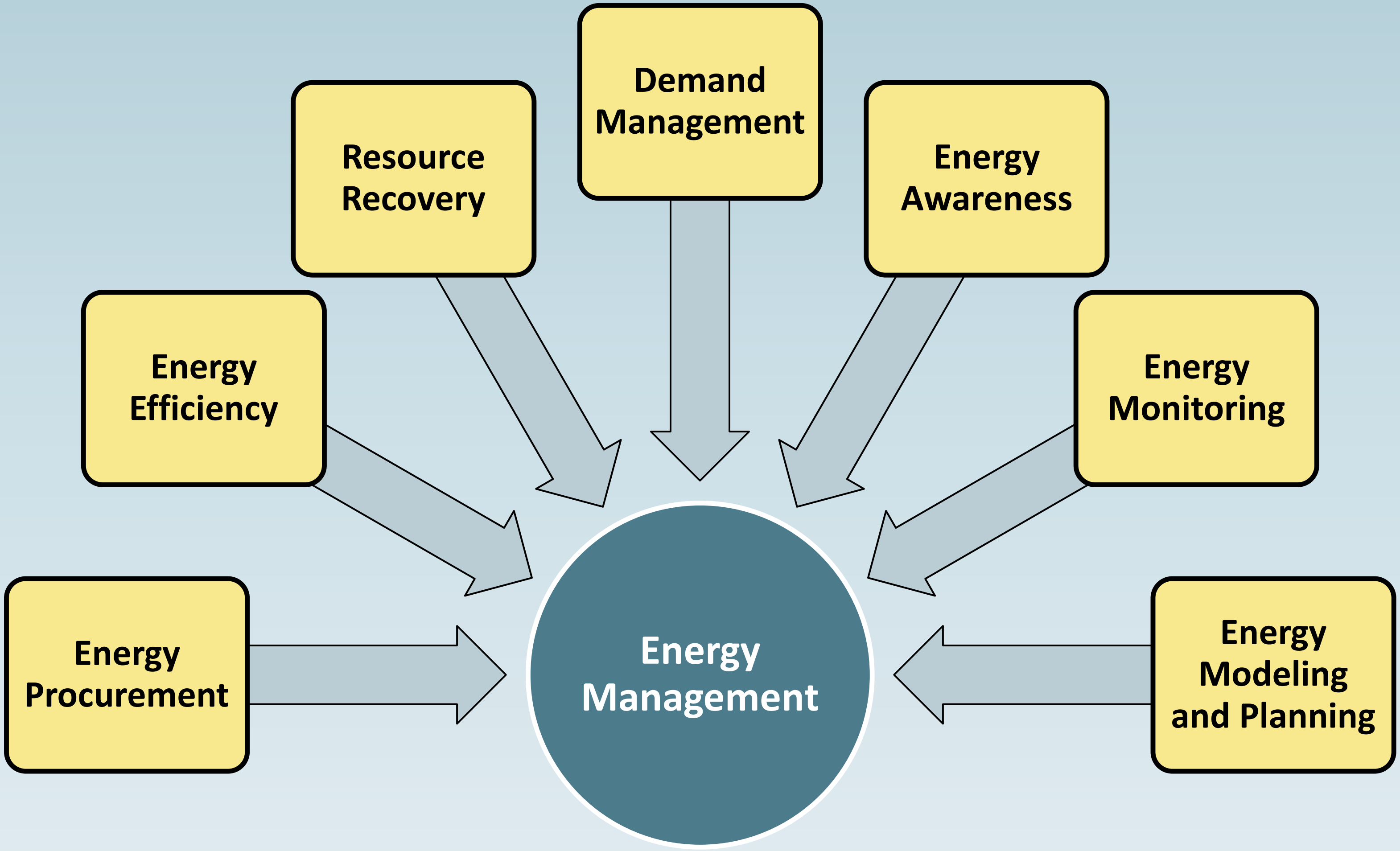
HAZEN AND SAWYER
Environmental Engineers & Scientists

Energy Management

Agenda

- Electric Utilities Overview
- Electric Billing
- Demand Management
- Resource Recovery
- Power Monitoring
- Typical Energy Efficiency Opportunities

Energy management is more than energy efficiency



Demand Management

Resource Recovery

Energy Awareness

Energy Efficiency

Energy Monitoring

Energy Procurement

Energy Management

Energy Modeling and Planning

Energy Management has potential savings of 10-40%

Biogas

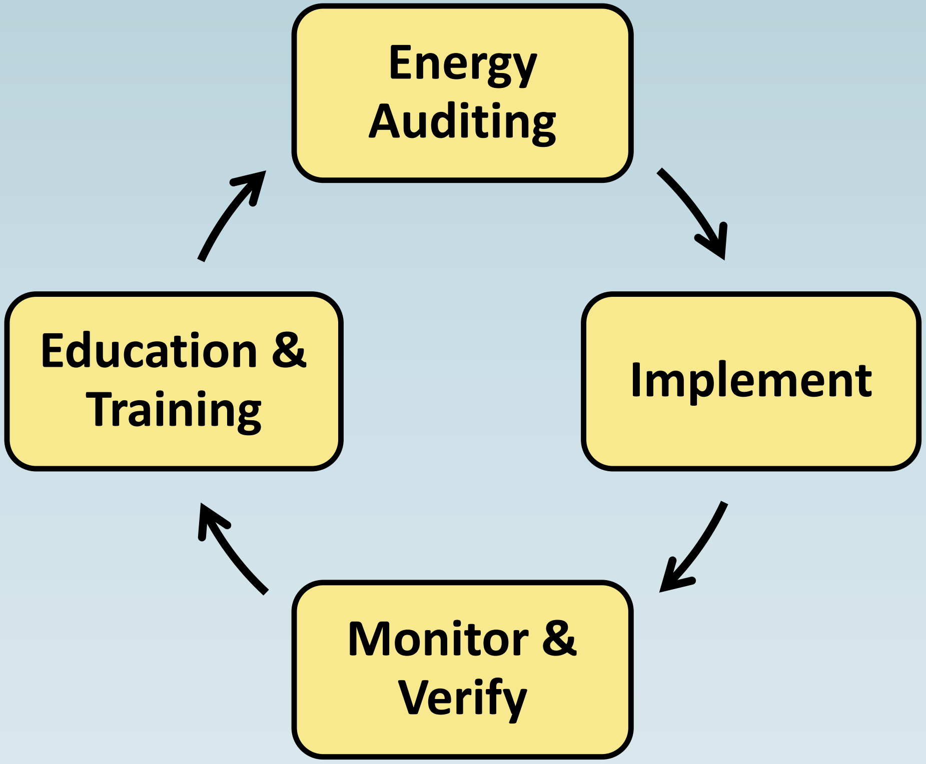
Energy Procurement

Renewables

Process Optimization

DAMAGED DIFFUSER

Energy Management is a Continuous Process



Energy Auditing

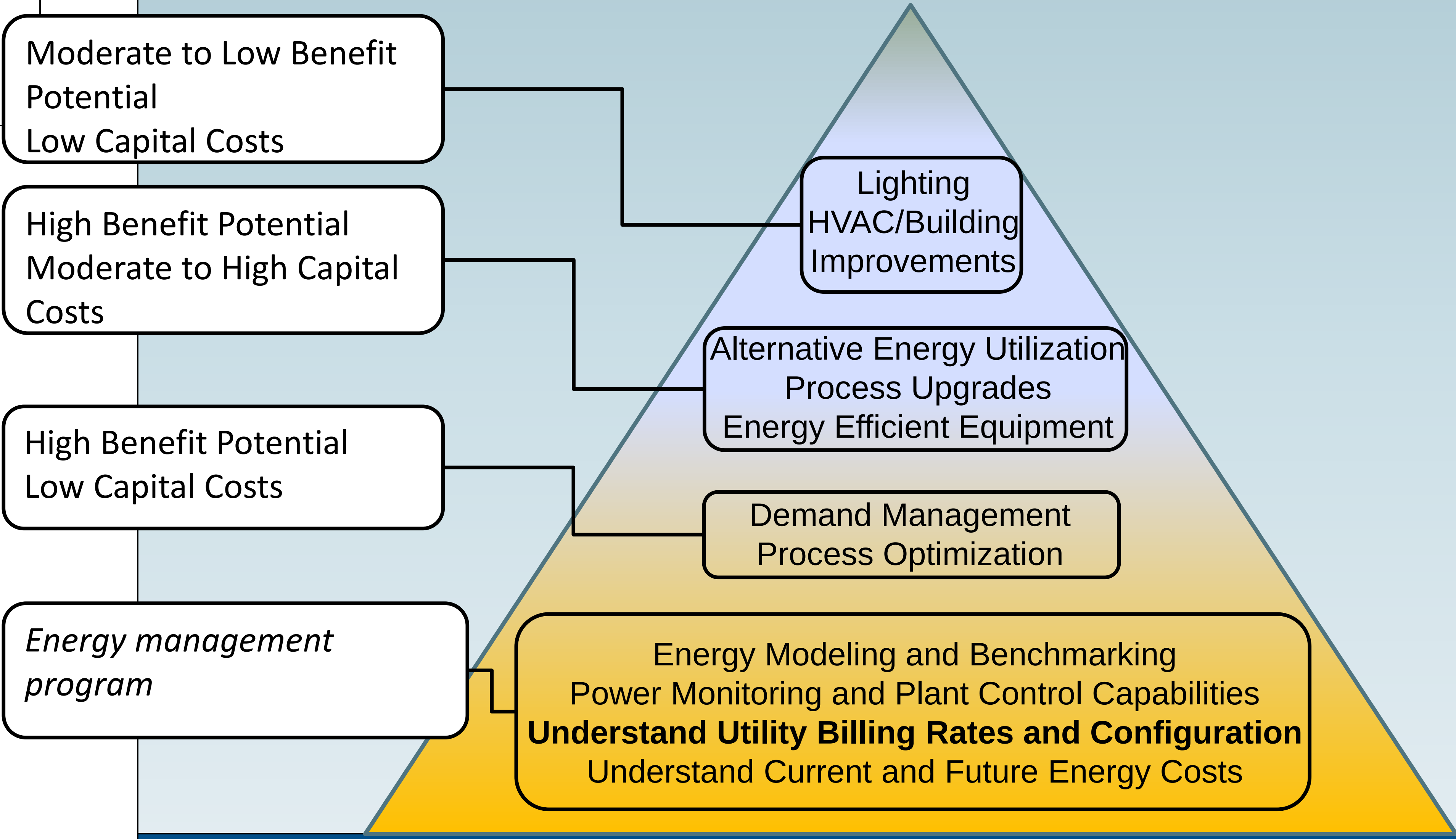
Implement

Monitor & Verify

Education & Training

Energy Management Program

Managing energy begins with an energy management program



Moderate to Low Benefit Potential
Low Capital Costs

High Benefit Potential
Moderate to High Capital Costs

High Benefit Potential
Low Capital Costs

Energy management program

Lighting
HVAC/Building Improvements

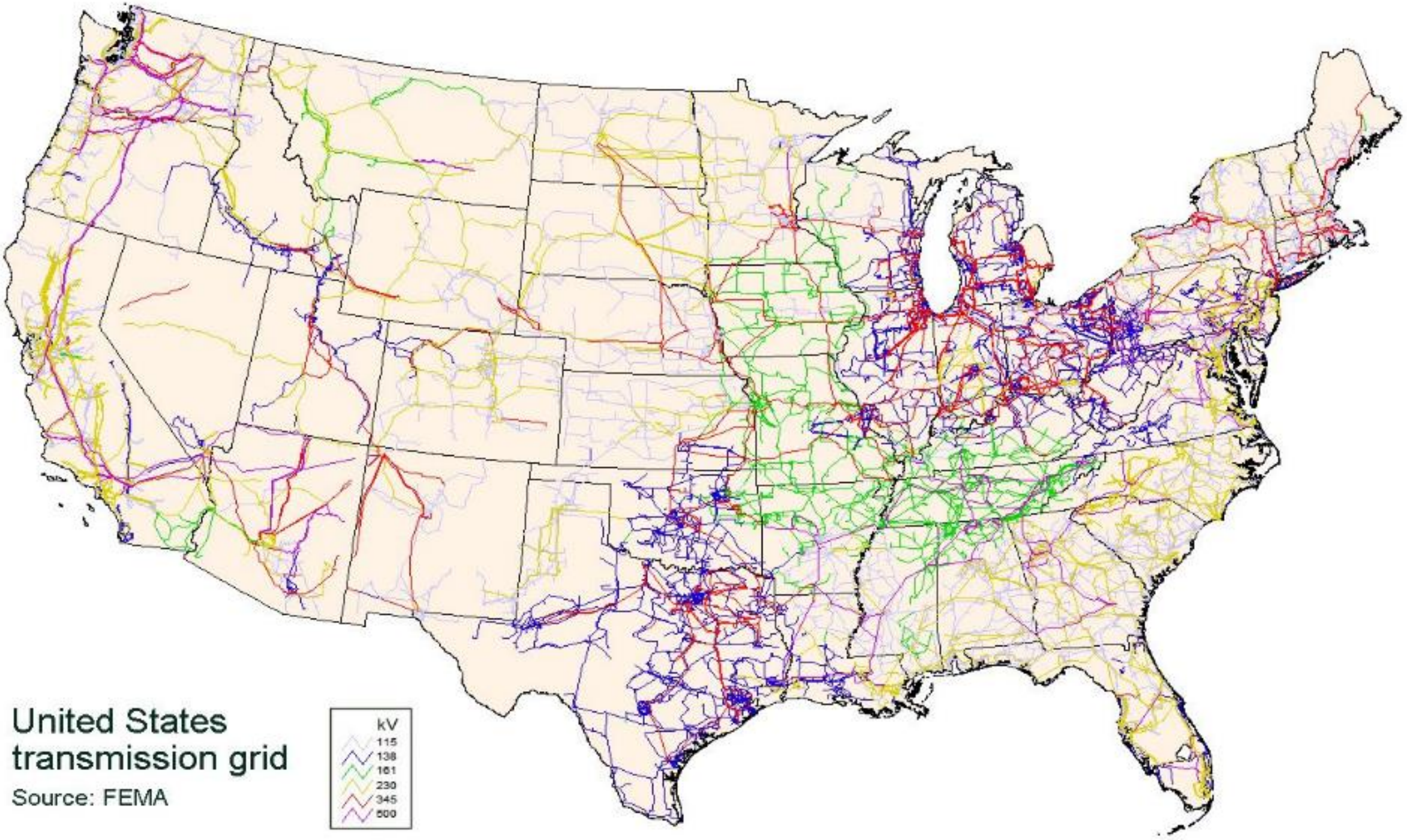
Alternative Energy Utilization
Process Upgrades
Energy Efficient Equipment

Demand Management
Process Optimization

Energy Modeling and Benchmarking
Power Monitoring and Plant Control Capabilities
Understand Utility Billing Rates and Configuration
Understand Current and Future Energy Costs

Electrical Utilities

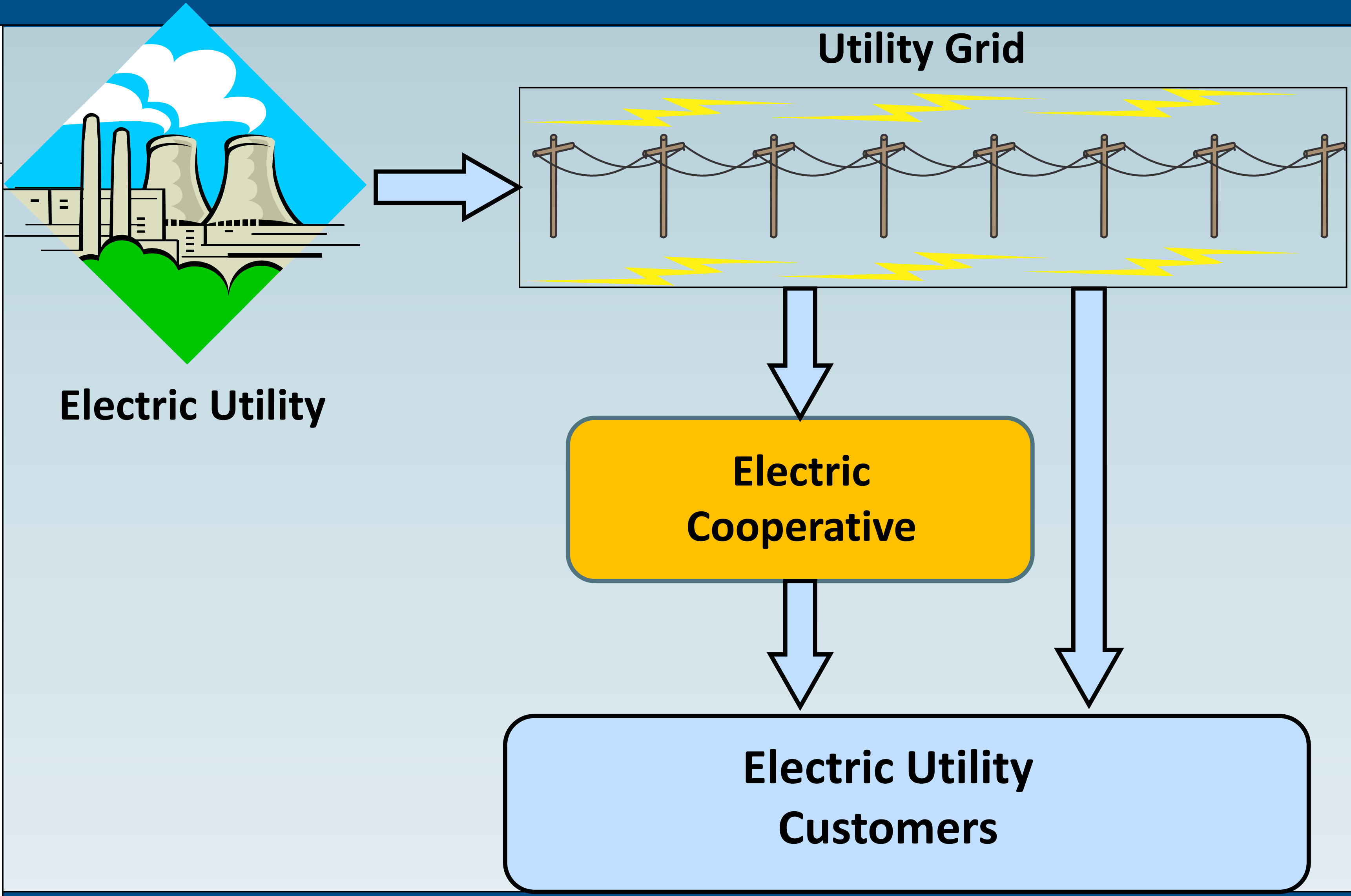
United States Electric Grid



United States transmission grid

Source: FEMA

Utility Distribution Systems



Utility Grid

Electric Utility

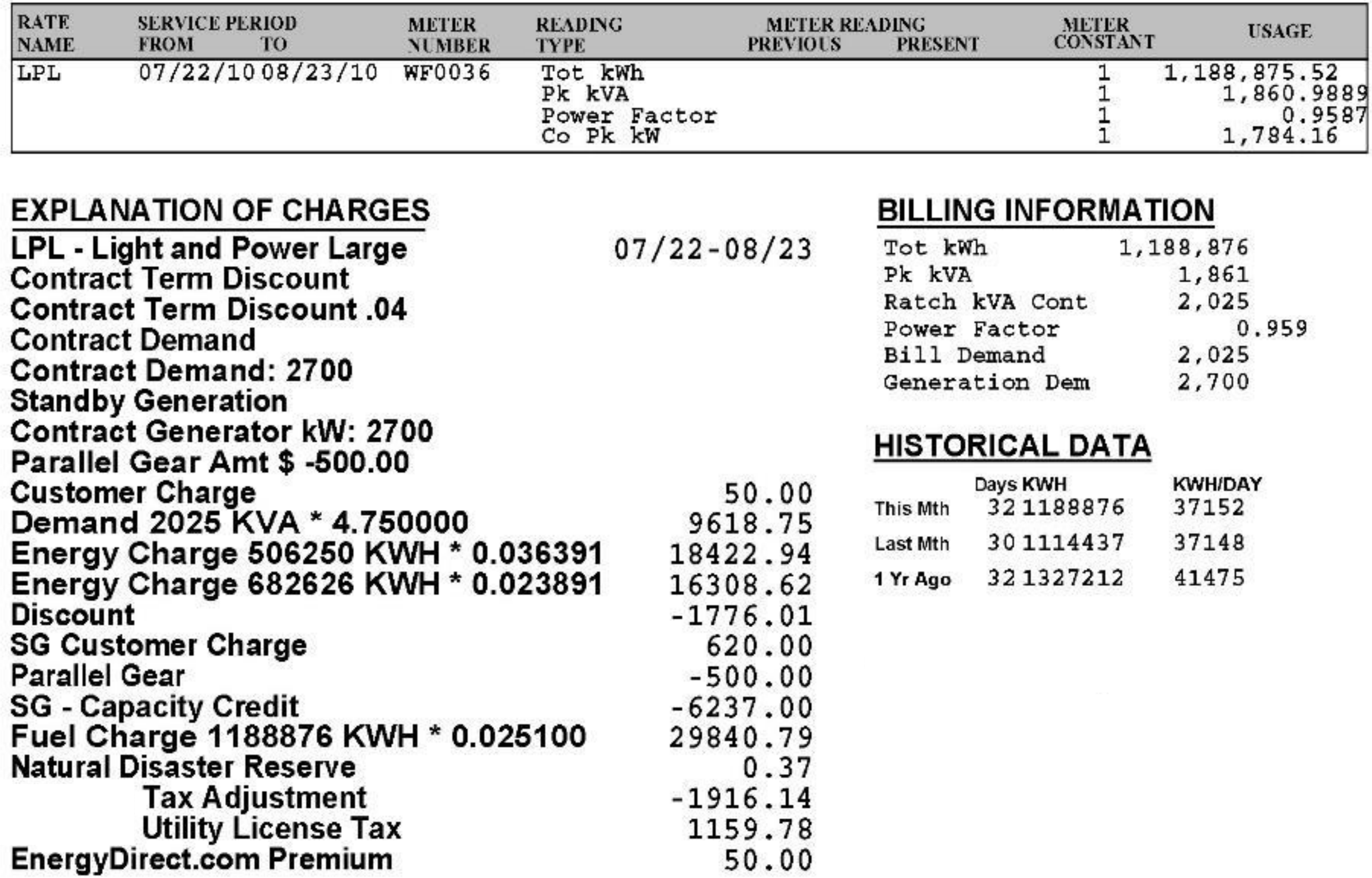
Electric Cooperative

Electric Utility Customers

Electrical Utility Billing

“How” you are charged for energy is just as important as “how much” energy you use.

Utility Bill Example



RATE NAME	SERVICE PERIOD FROM	TO	METER NUMBER	READING TYPE	METER READING PREVIOUS	PRESENT	METER CONSTANT	USAGE
LPL	07/22/10	08/23/10	WF0036	Tot kWh			1	1,188,875.52
				Pk kVA			1	1,860.9889
				Power Factor			1	0.9587
				Co Pk kW			1	1,784.16

EXPLANATION OF CHARGES

LPL - Light and Power Large	07/22-08/23
Contract Term Discount	
Contract Term Discount .04	
Contract Demand	
Contract Demand: 2700	
Standby Generation	
Contract Generator kW: 2700	
Parallel Gear Amt $ -500.00	
Customer Charge	50.00
Demand 2025 KVA * 4.750000	9618.75
Energy Charge 506250 KWH * 0.036391	18422.94
Energy Charge 682626 KWH * 0.023891	16308.62
Discount	-1776.01
SG Customer Charge	620.00
Parallel Gear	-500.00
SG - Capacity Credit	-6237.00
Fuel Charge 1188876 KWH * 0.025100	29840.79
Natural Disaster Reserve	0.37
Tax Adjustment	-1916.14
Utility License Tax	1159.78
EnergyDirect.com Premium	50.00

BILLING INFORMATION

Tot kWh	1,188,876
Pk kVA	1,861
Ratch kVA Cont	2,025
Power Factor	0.959
Bill Demand	2,025
Generation Dem	2,700

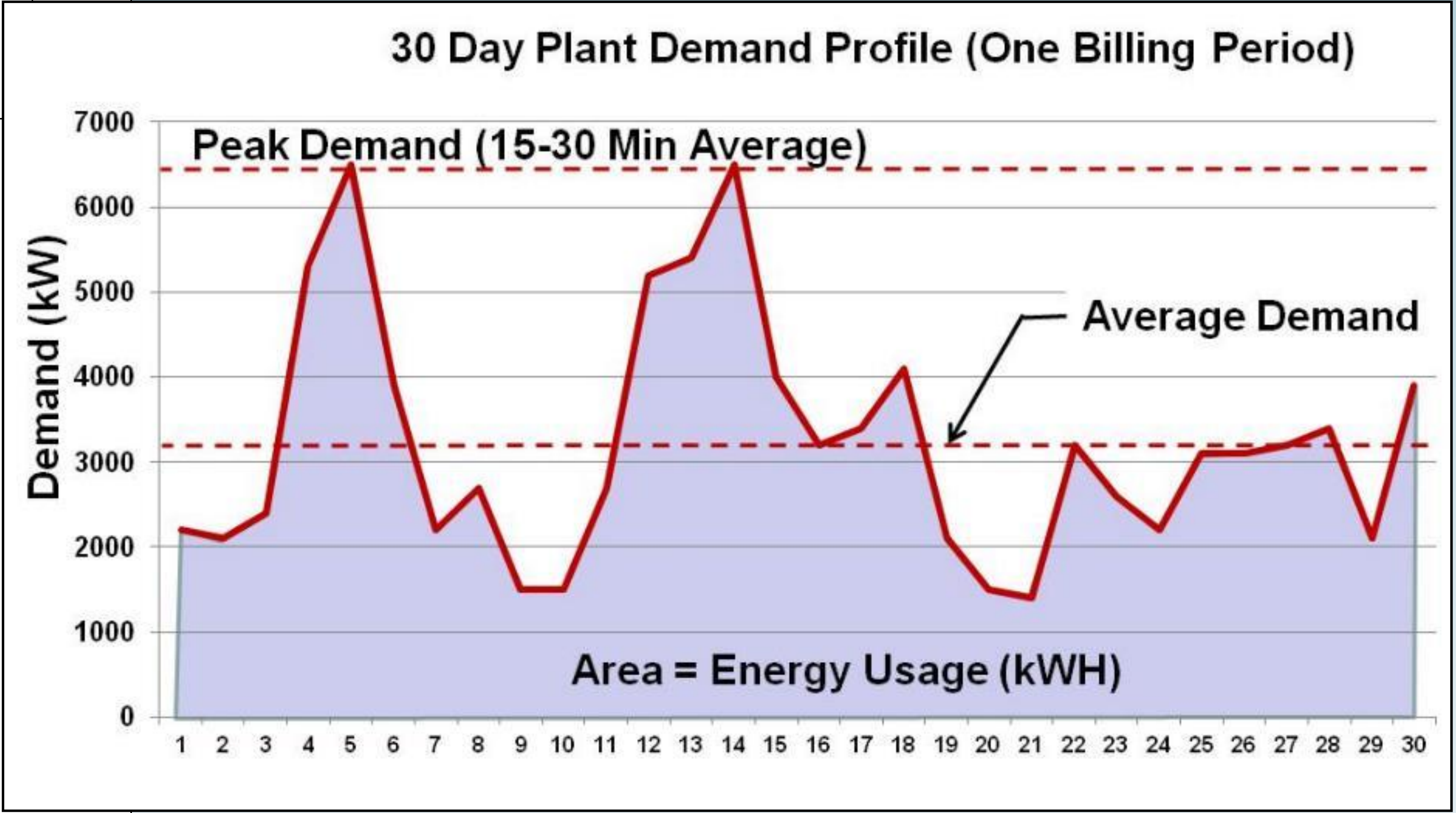
HISTORICAL DATA

	Days	KWH	KWH/DAY
This Mth	32	1188876	37152
Last Mth	30	1114437	37148
1 Yr Ago	32	1327212	41475

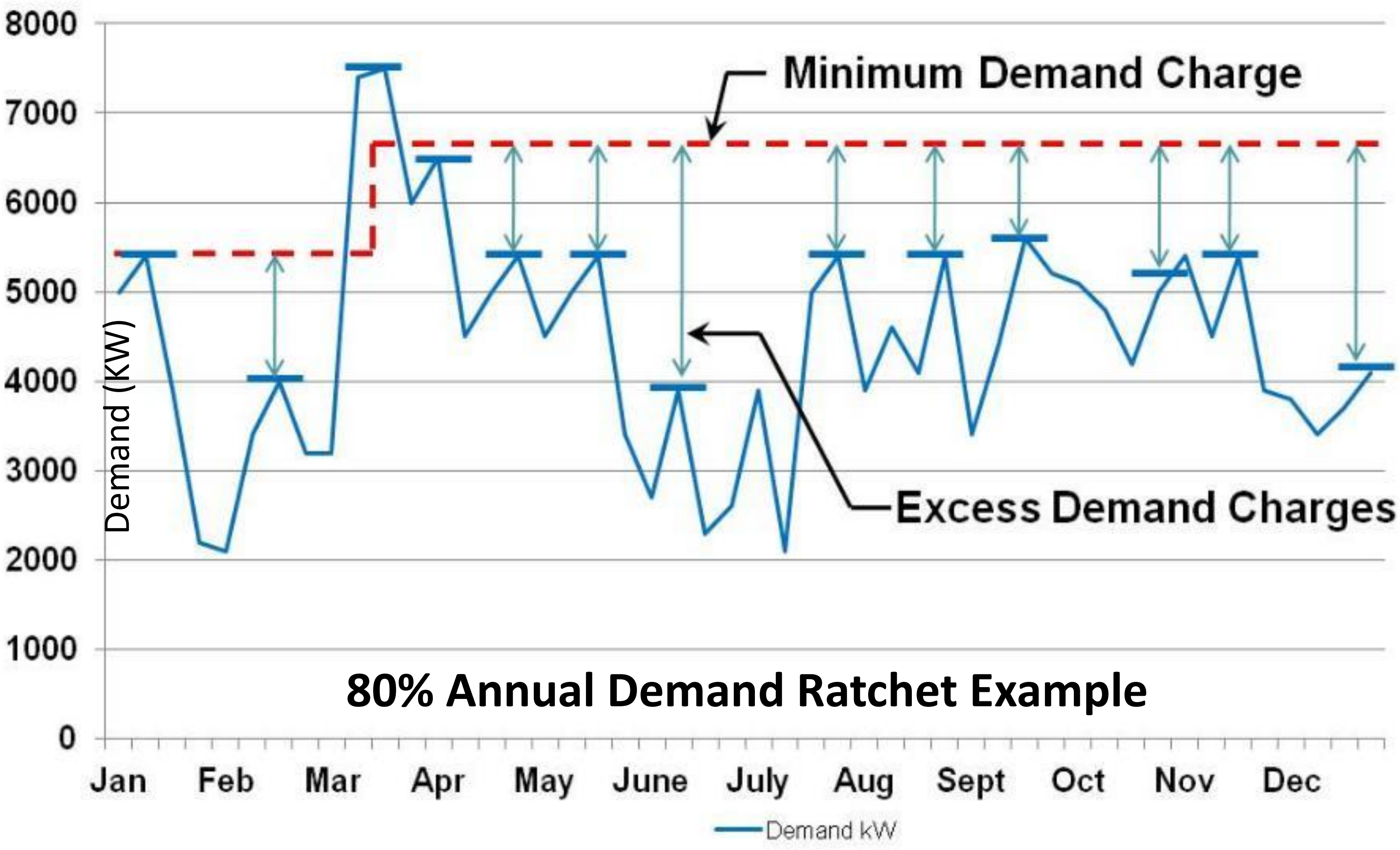
Electrical utility bills are typically comprised of several “charges”.

- **Energy Usage Charge (kWh)**
  - Energy consumed during the billing period.
  - Typically “Flat Rate” or “Time of Use”.
- **Demand Charge (kW)**
  - Typically 15-30 minute peak power demand during a billing period
- **Fixed Charges**
  - Independent of demand or usage.
  - Facility charges
  - Minimum demand/energy charges

The demand profile establishes both “demand” and “energy usage”.

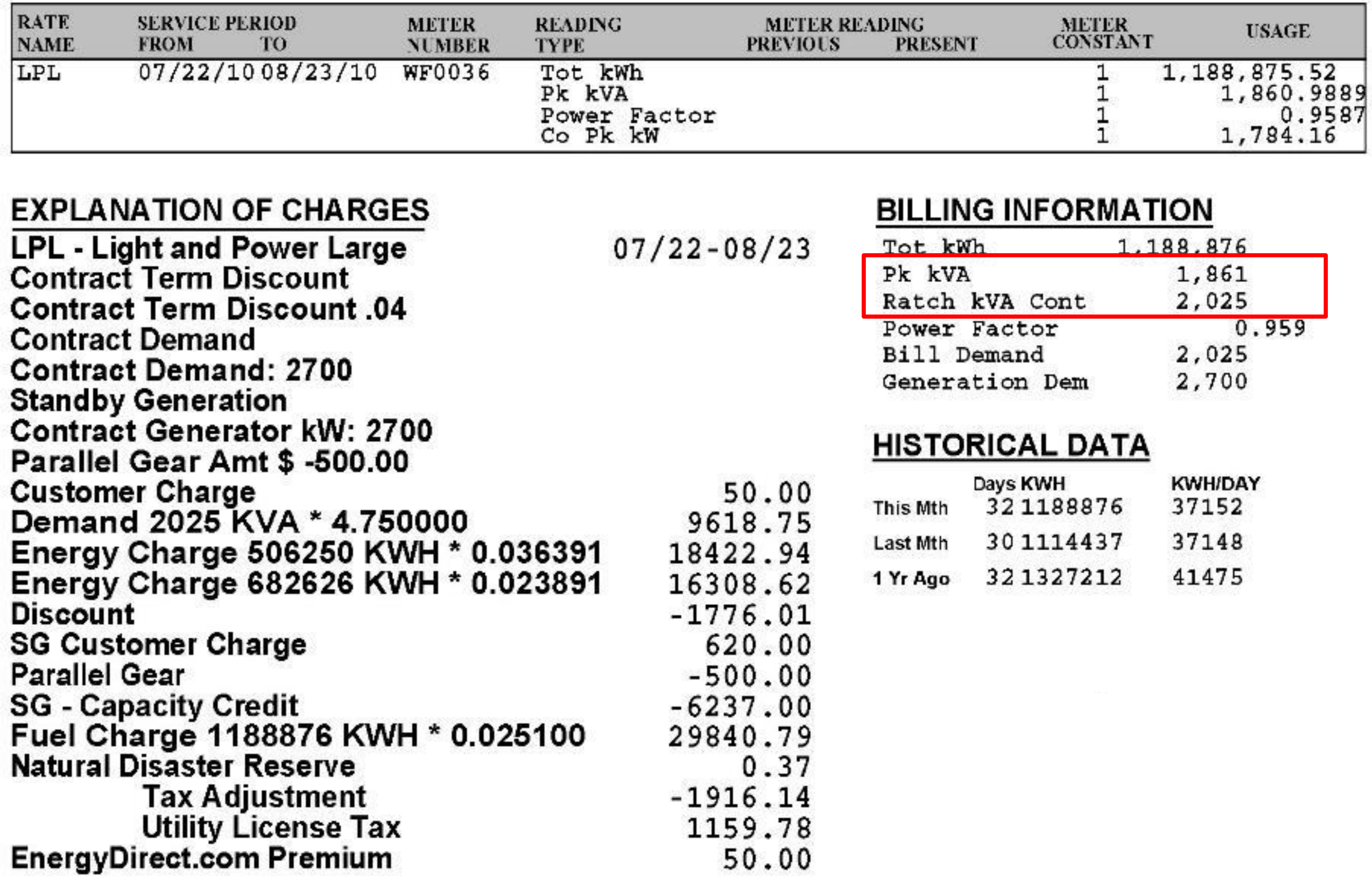


Demand ratchets can significantly impact electrical utility cost.



80% Annual Demand Ratchet Example

Demand ratchets can significantly impact electrical utility cost.



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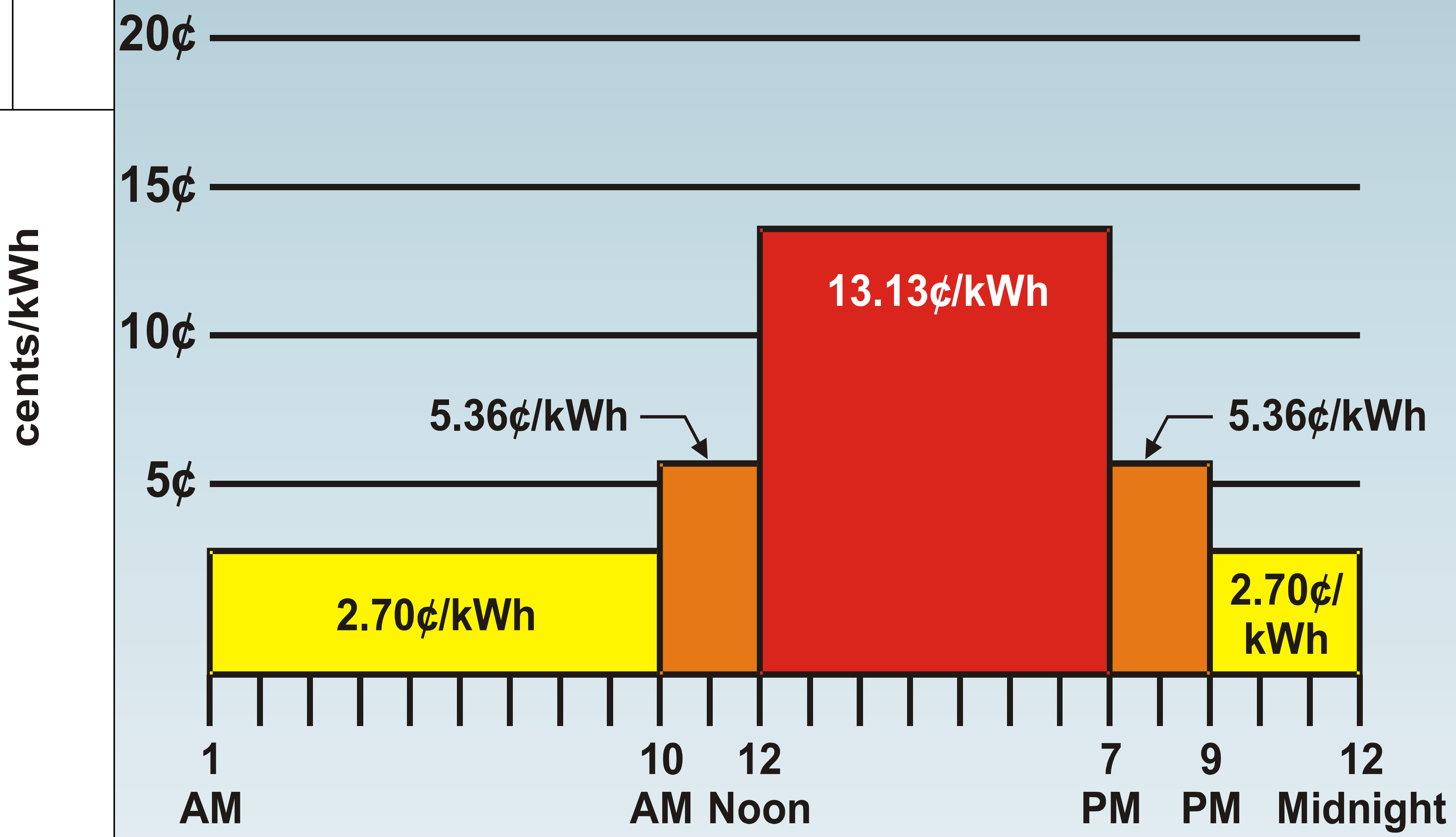
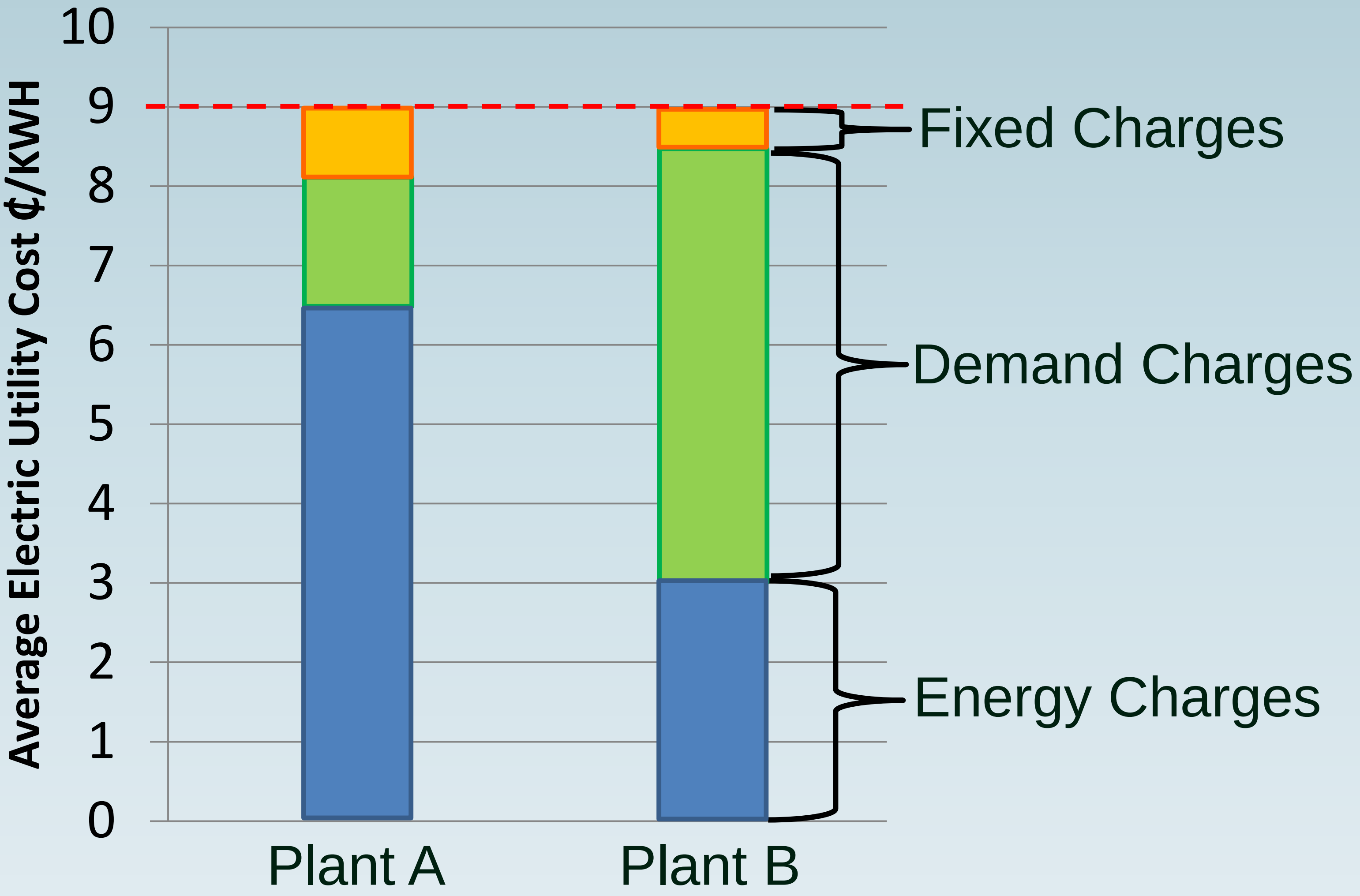
"Time of Use" energy and demand billing is very common



Utility billing structures will vary significantly



Energy efficiency benefit example: LED Lighting

- LED outdoor lighting reduces plant's outdoor lighting demand by 50kW
- Annual Energy Savings - 175,000 kWh per year.

Energy efficiency benefit example: LED Lighting

So…..

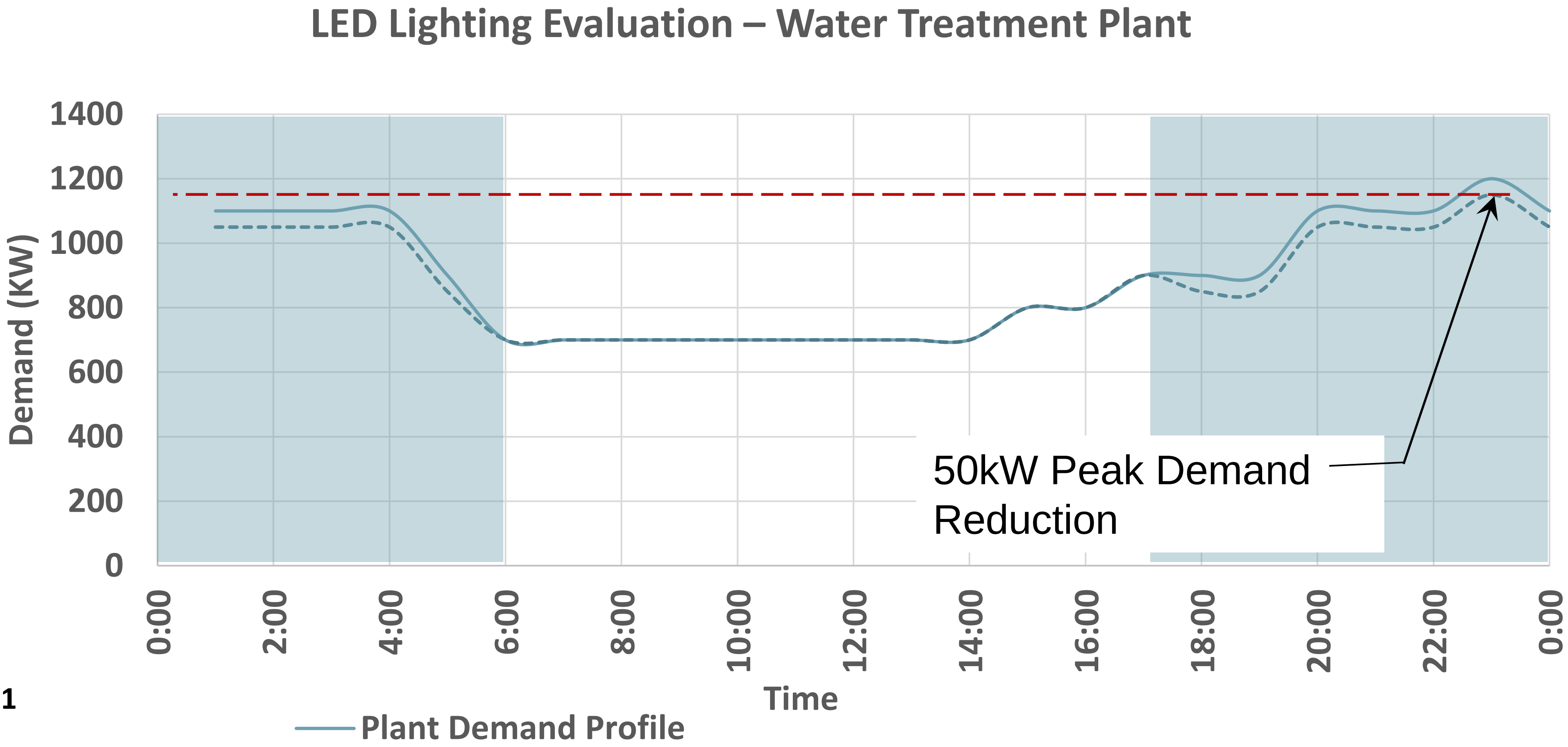
175,000KWH X 8.5₵/KWH = **~$15,000/yr.** of savings right?

Maybe not!…….

Energy efficiency benefit example: LED Lighting

SVEC Rate LP-10 - $17/kW any time, $0.041/KWH any time

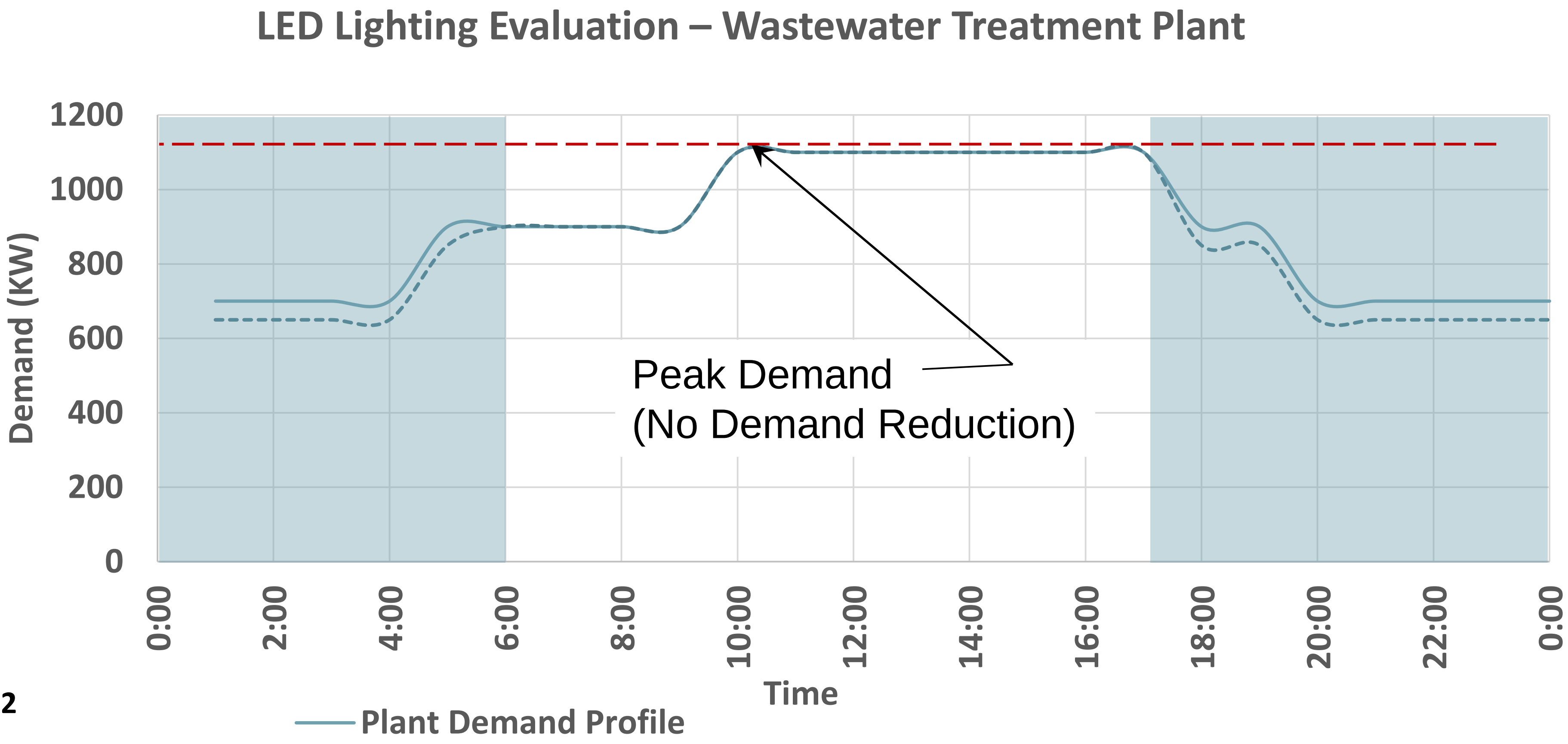
- LED light demand offset - $10,400/yr,
- LED light energy usage offset - $7,100/year



Energy efficiency benefit example: LED Lighting

SVEC Rate LP-10 - $17/kW any time, $0.041/KWH any time

- ➢ LED light demand offset - **$0**
- ➢ LED light energy usage offset - $7,100/year



Key Point.

<u>"When"</u> energy is used and <u>"how much"</u> energy is used determines the overall cost.

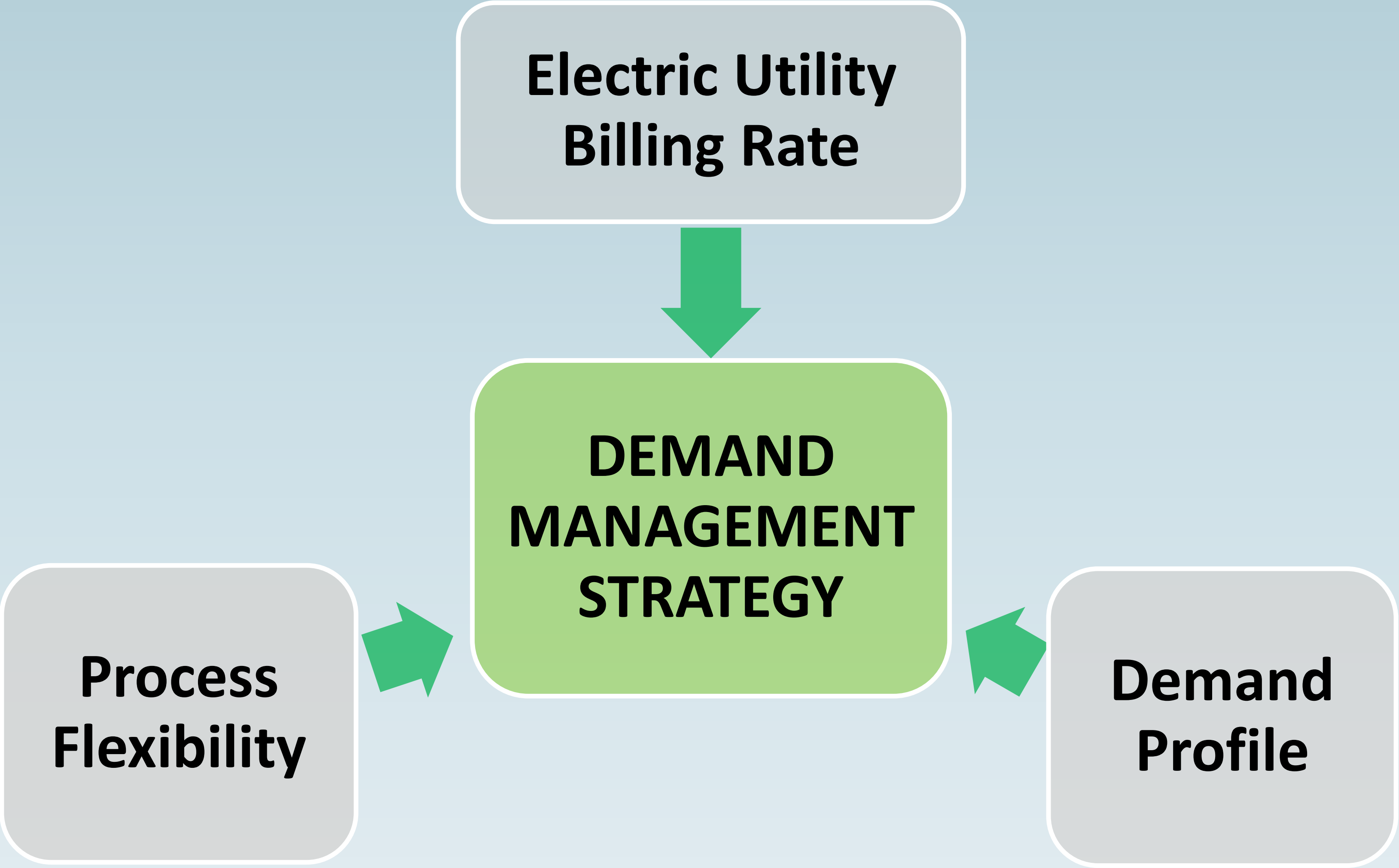
Demand Management

“Using Energy More Efficiently”

Common Demand Management Strategies

- ➢Manage plant operations to reduce demand during on-peak hours
- ➢Defer non-critical operations to off-peak hours
- ➢Interlock intermittent loads
- ➢Utilize on-site power generation capacity to manage plant demand
- ➢Electric utility load response programs

Demand Management Strategies Will Depend on Multiple Elements



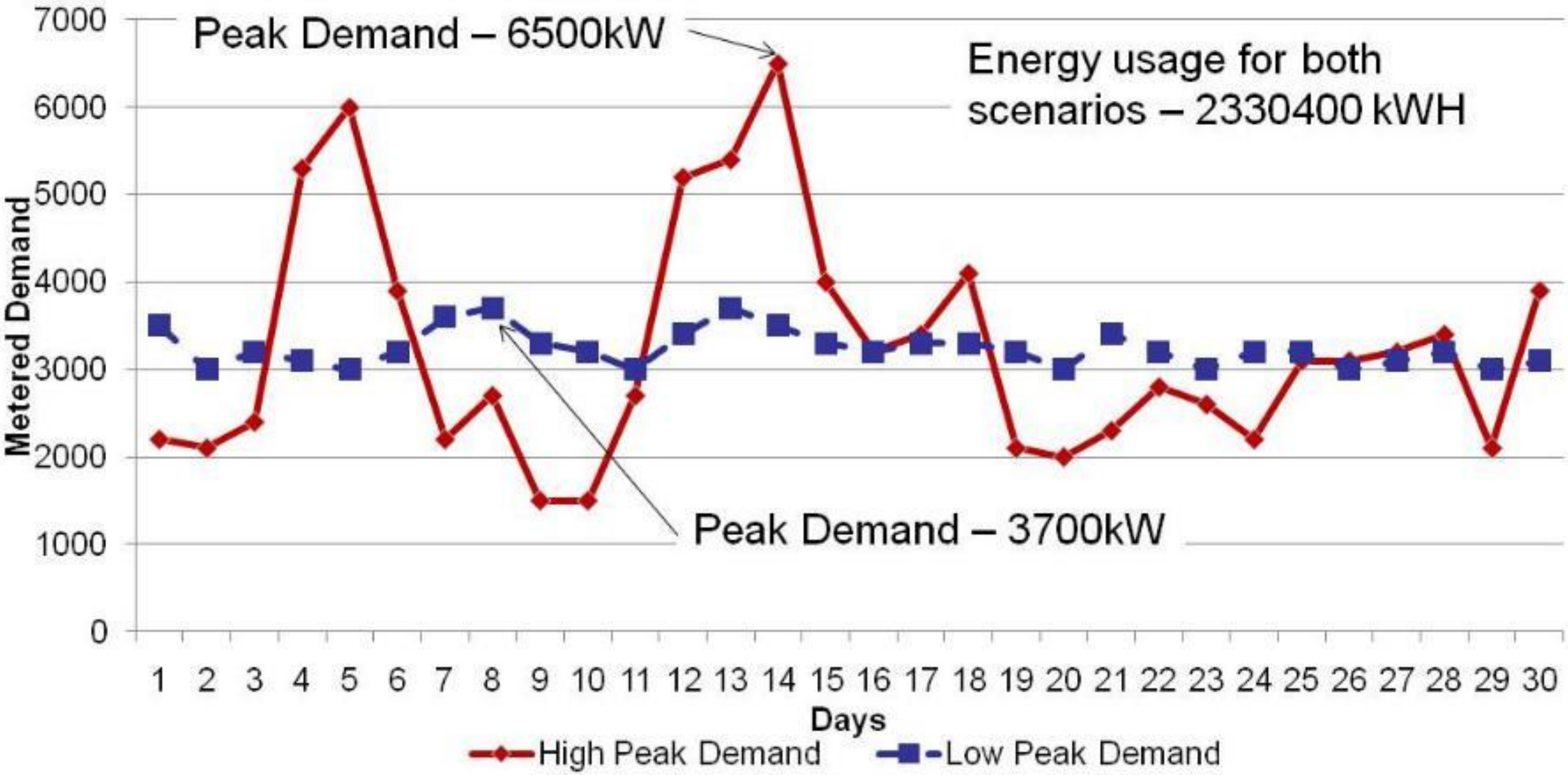
Electric Utility Billing Rate

DEMAND MANAGEMENT STRATEGY

Process Flexibility

Demand Profile

Plant demand profile impacts energy costs



Plant demand profile impacts energy costs

- Evaluate the energy costs for two demand profiles

  Energy Charge – 3.0¢/KWH

  Monthly Demand Charge - $10.00/kW

	Energy Usage	**Energy Charge @ 3.0¢/KWH**	**Metered Demand**	**Demand Charge @ $10.00/KW**	**Total Charges**	**Average Cost per/KWH**
High Peaking Scenario	2330400 KWH	$69,912	6500kW	$65,000	$134,912	5.8¢/KWH
Low Peaking Scenario	2330400 KWH	$69,912	3700kW	$37,000	$106,912	4.6¢/KWH

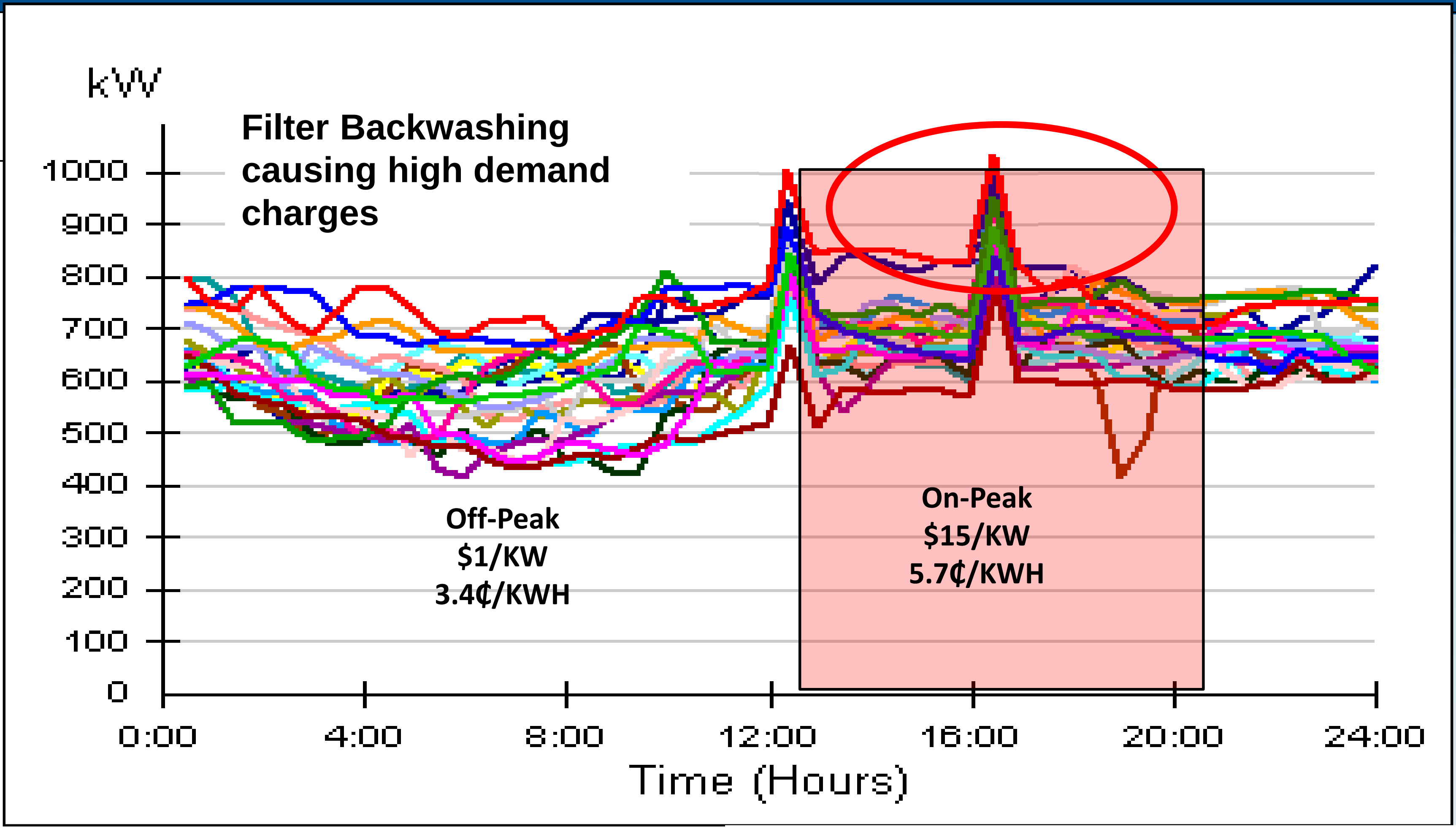
Case Study – Managing plant loads to reduce demand charges – HRRSA

- **Electric Utility Rate**
  - ➢Demand charges - $17.33/KW (any 15 min period)
  - ➢Energy Charges $0.041/KWH

- **Opportunity** – Stop non-critical mixing loads during each 20 min filter backwash cycle.
  - ➢Filter backwash loads (~100hp)
  - ➢Digester mixing loads (~85hp).

- **Annual benefit** - ~$10,000/year (@ 80% load factor) in demand savings

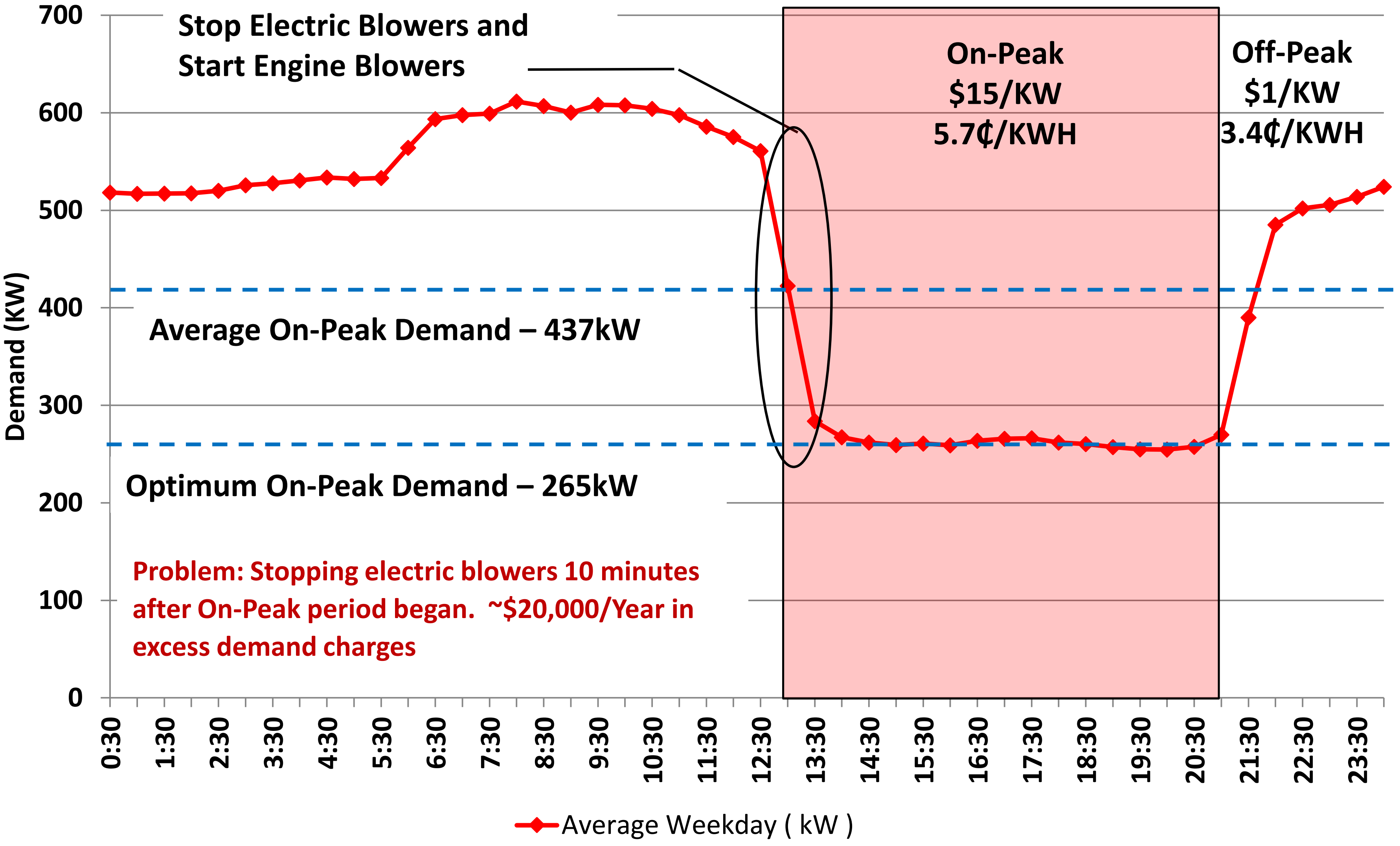
Case Study – Reduced demand charges through filter backwash timing



The Cause: Automatic Deep-bed filter backwash process during on-peak periods - ~150kW

The Response: Move timing to lower demand periods. Potential to save ~$1500 per month

Case Study – Managing demand during on-peak periods



Stop Electric Blowers and Start Engine Blowers

On-Peak
$15/KW
5.7¢/KWH

Off-Peak
$1/KW
3.4¢/KWH

Average On-Peak Demand – 437kW

Optimum On-Peak Demand – 265kW

Problem: Stopping electric blowers 10 minutes after On-Peak period began. ~$20,000/Year in excess demand charges

Demand Management Key Points

- ***Demand Management primary objective is to lower <u>energy costs</u>.***

- ***Demand Management strategies can be implement at a <u>low or zero cost</u>.***

- ***Power monitoring and an understanding of the utility billing structure are key components to developing demand management strategies***

Onsite power generation systems can be used to manage demand

Standby Power Generator Systems

Biogas Fueled CHP Systems

Average Fuel and Energy Costs

Fuel Source	Average Fuel Cost ($/MMBTU)	Electric Energy Conversion Efficiency (%)	Cost of Electric Energy Generated ($/KWH)
No.2 Non-Road Diesel @ $3/Gal	$21.43	37.5%	$0.23*
Natural Gas	$7.70	37.5%	$0.088*
Electric Utility	$17.88	100%	$0.071**

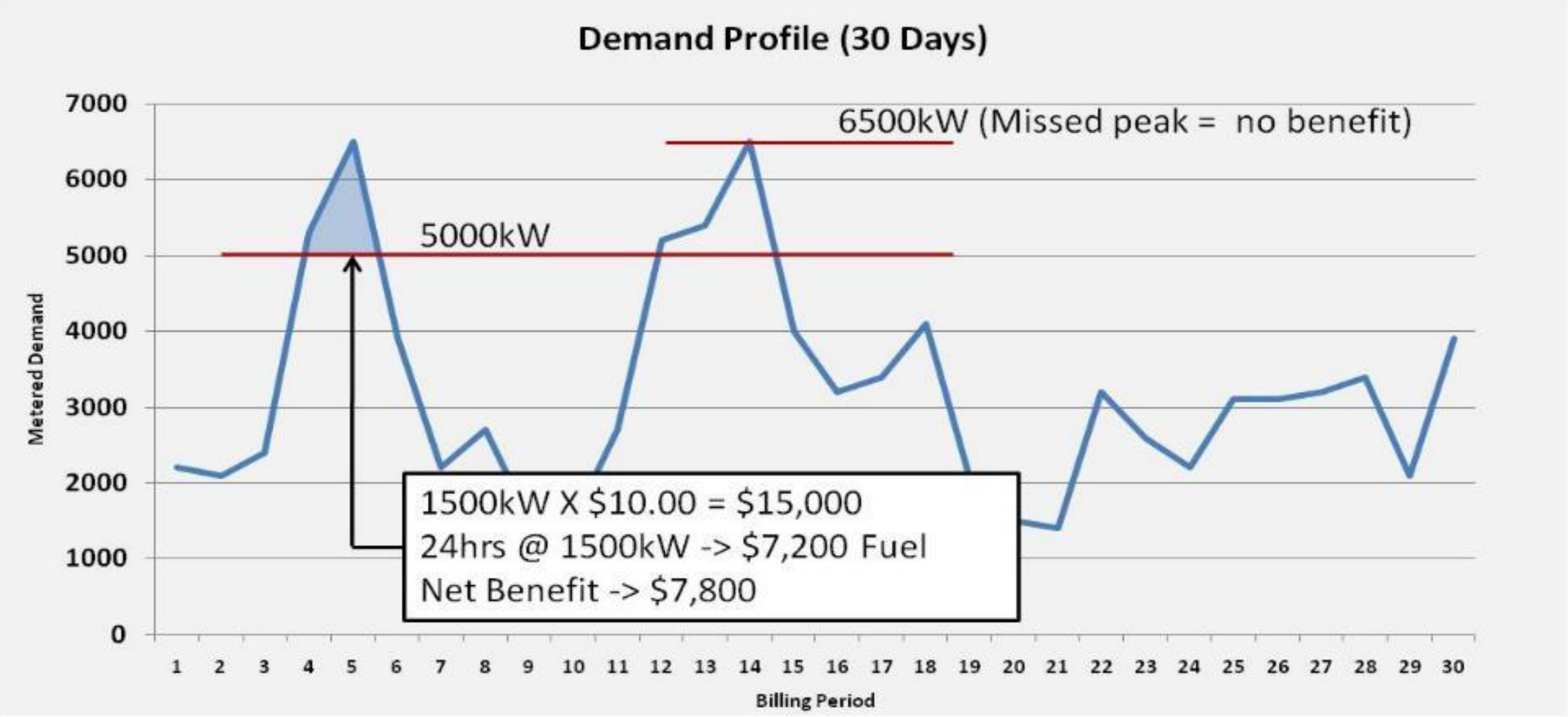
* 2.0₵/KWH O&M costs included

** Does not include fixed charges

On average, generating electric energy costs more than purchased electric energy

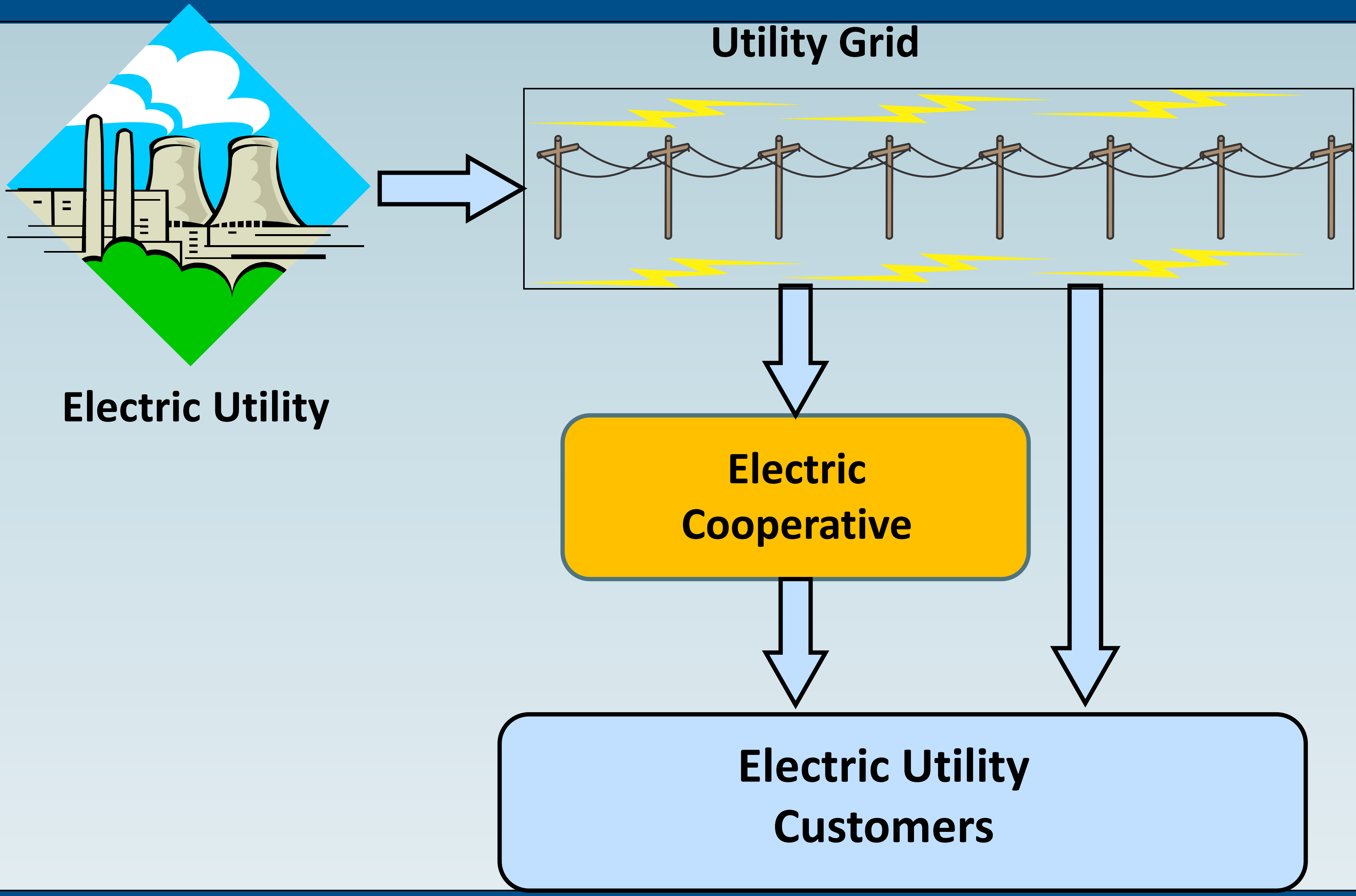
Onsite Power Generation Systems – Peak Shaving

- Operate generators to reduce demand charges
- **This strategy can be risky!**
- EPA emission restrictions
- Better to defer load



1500kW X $10.00 = $15,000
24hrs @ 1500kW -> $7,200 Fuel
Net Benefit -> $7,800

Load management is valuable to electric utilities



Utility Grid

Electric Utility

Electric Cooperative

Electric Utility Customers

Demand Response Programs

- End user’s ability to shed load is valuable to electric utilities
- Many electric utilities will pay end users for “capacity”.
- Plant owner is compensated by the utility to have the standby power generators available in the event of an utility emergency
- Generally less than 100 hours/year of operation

EPA Emission Requirements

- EPA National Emission Standards for Hazardous Air Pollutants (NESHAP)
  - ➢ Regulates the Carbon Monoxide emissions for existing non-emergency engines
  - ➢ Regulations not applicable to emergency use application and biogas fueled CHP systems.
- EPA New Source Performance Standards (NSPS)
  - ➢ New non-emergency generators must meet stringent emission limits. Most applications require emissions after treatment for non-emergency applications
- Air Permitting

Resource Recovery

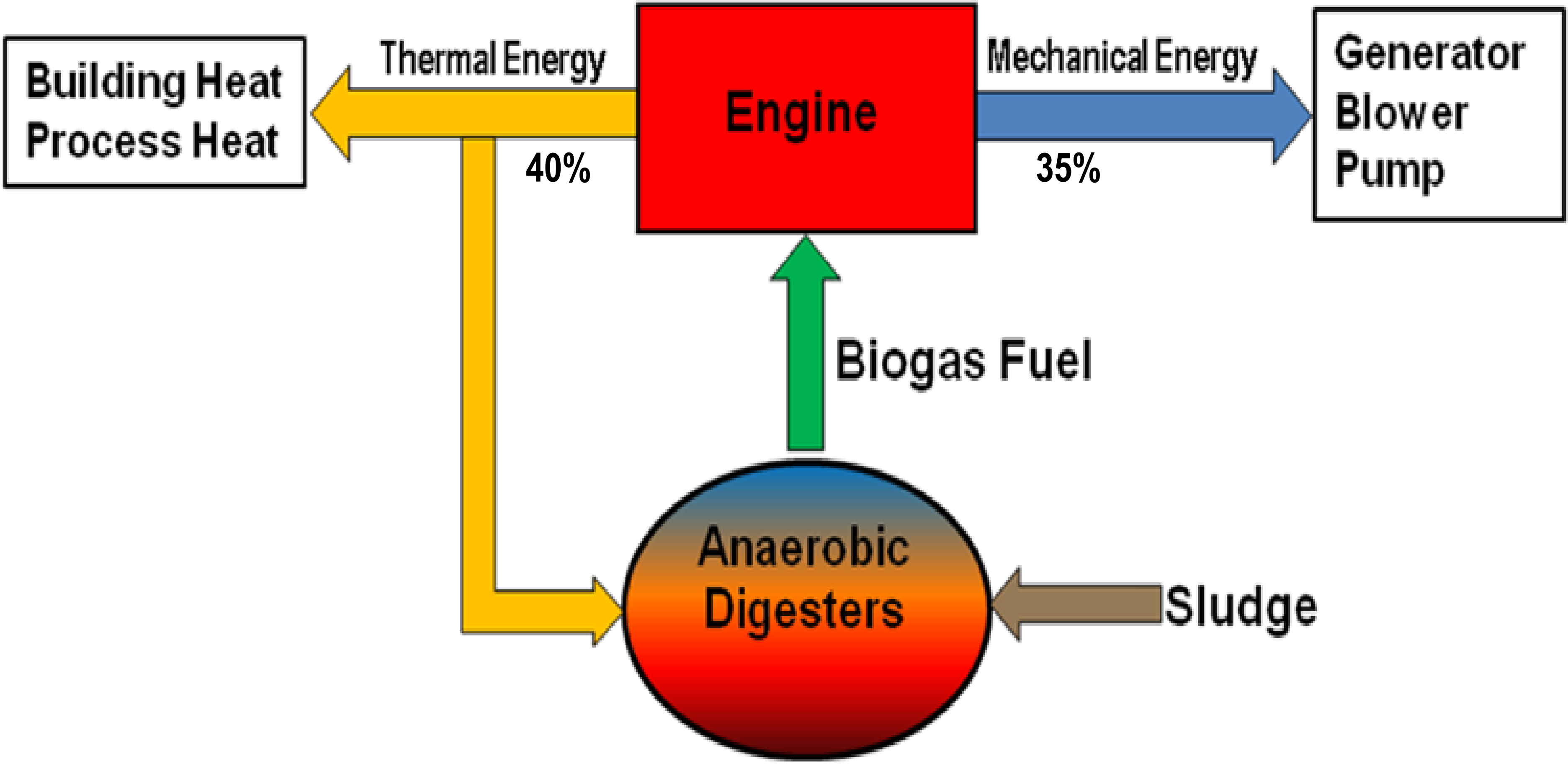
Energy Sources Available

- Biogas
- Thermal Energy
- Chemical Energy
- Hydraulic Energy
- Renewable Energy

Combined Heat and Power Generation Systems - CHP

Typical WW plant will support 15-30kW of generation capacity per MGD

Combined Heat and Power Generation Systems - CHP



Biogas to energy systems have been around a while!

Gas from Sewage Waste Runs City Power Plant

How the sewage disposal plant at Birmingham, England, supplies its own power is described in the illustration. Gas from the sewage drives an engine of 20 brake horsepower, which operates a centrifugal sludge pump

SEWAGE that costs large cities tremendous sums each year can be turned into a source of power equivalent to thousands of tons of coal! The waste now dumped into rivers or shipped to sea may be used to run factories or to light buildings!

That conversion of sewage into power is possible has been proved conclusively by the city of Birmingham, England. There a suction gas engine of 20 brake horsepower has been successfully driven by the gases given off by sewage sludge.

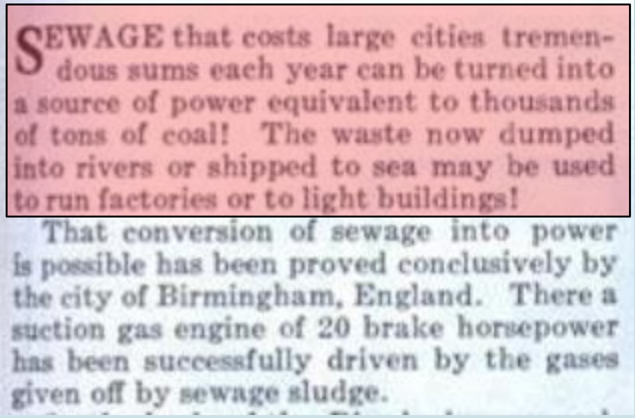
On the basis of the Birmingham experiments, an American city that must now pay for the disposal of 400,000 tons of sewage sludge a year might produce 320,000,000 cubic feet of gas suitable for heat and power, or, in terms of energy, 16,000,000 horsepower hours at 20 cubic feet per brake horsepower.

The apparatus for producing gas from sewage consists of two sludge digestion tanks in which the sewage is allowed to ferment. The gases given off are composed of from 25 to 75 per cent of methane, or marsh gas.

A gas engine of the usual type will run on sewage gas without adjustment of the valves. Sewage gas has a higher calorific value than some illuminating gas, averaging about 650 thermal units to the cubic foot, as against 550.

The Birmingham engine runs about six hours a day and is used to operate a centrifugal sludge pump that moves the wet sludge from the gas-generating tank to the drying grounds. In this process a small proportion of the waste material produces enough power to run the pumps of the sewage disposal plant. If all the material were used, there would probably be enough gas available to light the city.

Popular Science
1922



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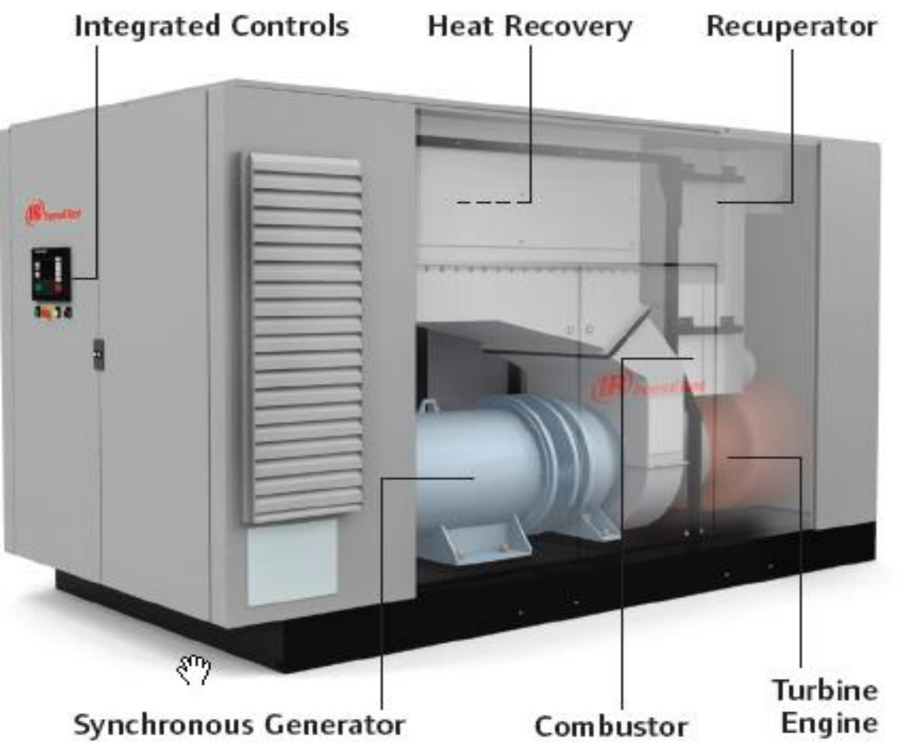
Boy haven't we come a long way in the last 90 years….

Combined Heat and Power Generation Systems - CHP

- “Free” fuel source
- Generate an average of 20% to 40% of the electric energy usage.
- Considered renewable energy source.
- Generally feasible where energy costs are above 7.5₵/KWH

Combined Heat and Power Generation Systems - CHP

Microturbine



Reciprocating Internal Combustion Engine

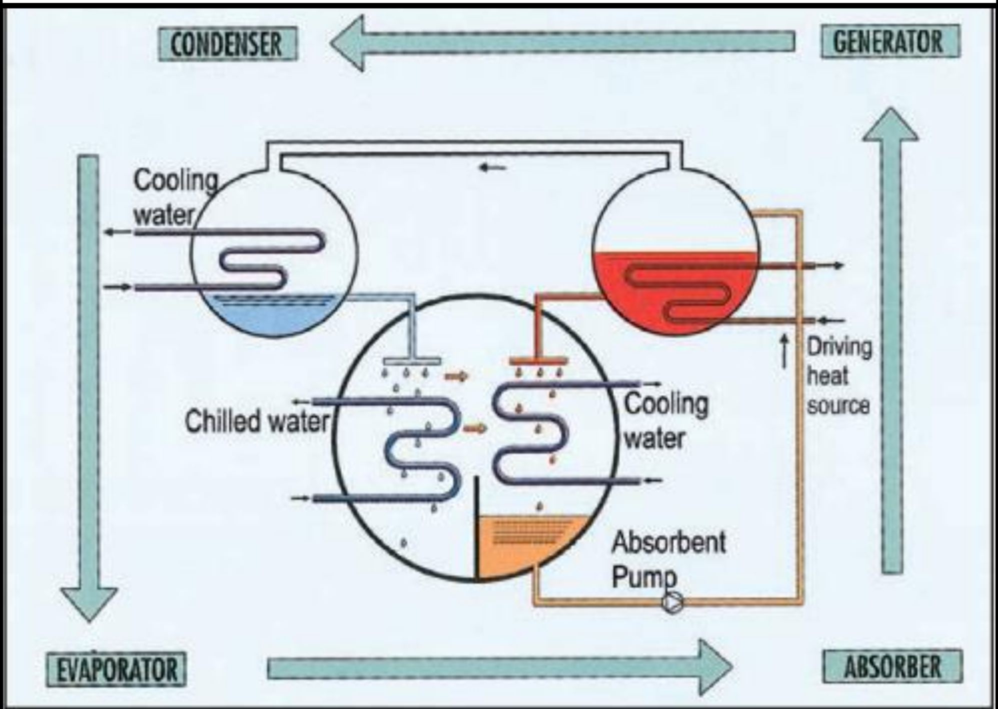
Image Courtesy GE/Jenbacher Engines

Combined Heat and Power Generation Systems - CHP

Prime Mover Technology	Common Size Range (kW)	Typical Electrical Efficiency (%)	Typical Thermal Efficiency (%)	Installed Cost ($/kW)	Gas Conditioning Requirements
Spark Ignited Reciprocating Engines	150-5000kW	35%-40%	25% 45% with exhaust heat recovery	1500 - 2000 $/kW with Heat Recovery	Moderate
Microturbines	30 – 250kW	30%	45%	2000-2500 $/kW with Heat Recovery	High
Fuel Cells	100 – 250kW	50%		$5000+	Very High
Stirling Engines (New Technology)	~50kW	25%	45%	$2500+	Low

Waste Heat Recovery Systems

- Beneficial Uses of Thermal Energy
  - Digester Heating (Most Common)
  - Building Heat and Cooling (Absorption Chillers)
  - Sludge Drying



Absorption Chiller Process Diagram

Combined Heat and Power Generation Systems - CHP

CHP systems can be used to drive process equipment

- Offset plants purchased power with mechanical energy
- Common applications are process pumping and aeration
- Benefit is dependent on the process demand.

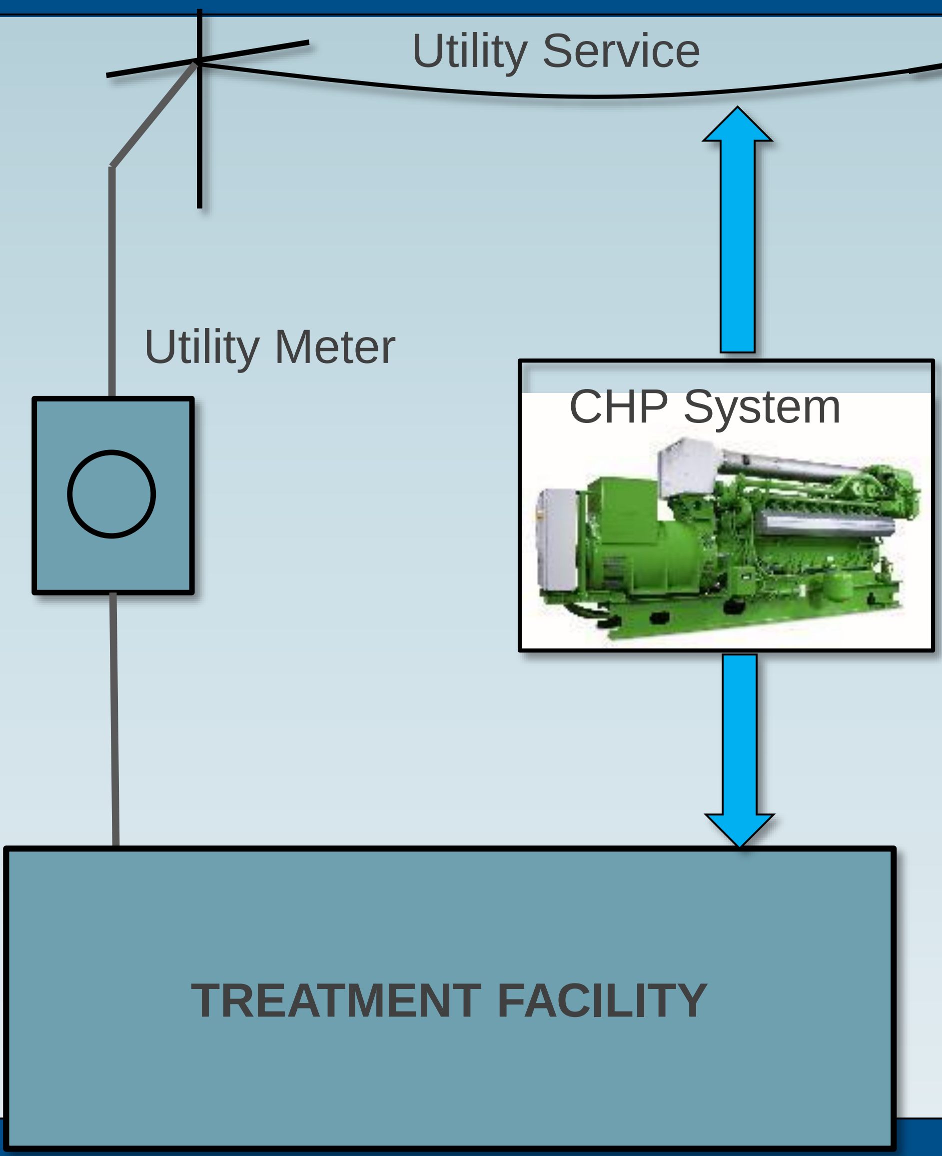
Combined Heat and Power Generation Systems - CHP

CHP systems can be used to generate electricity

- Offset plant's purchased power with electricity
- Benefit is not dependent on process demands.
- Possible to increase benefit by selling energy directly the utility.

Biogas Fueled Engine-Generator

Energy generated from biogas can be sold directly to the utility



Utility Service

Utility Meter

CHP System

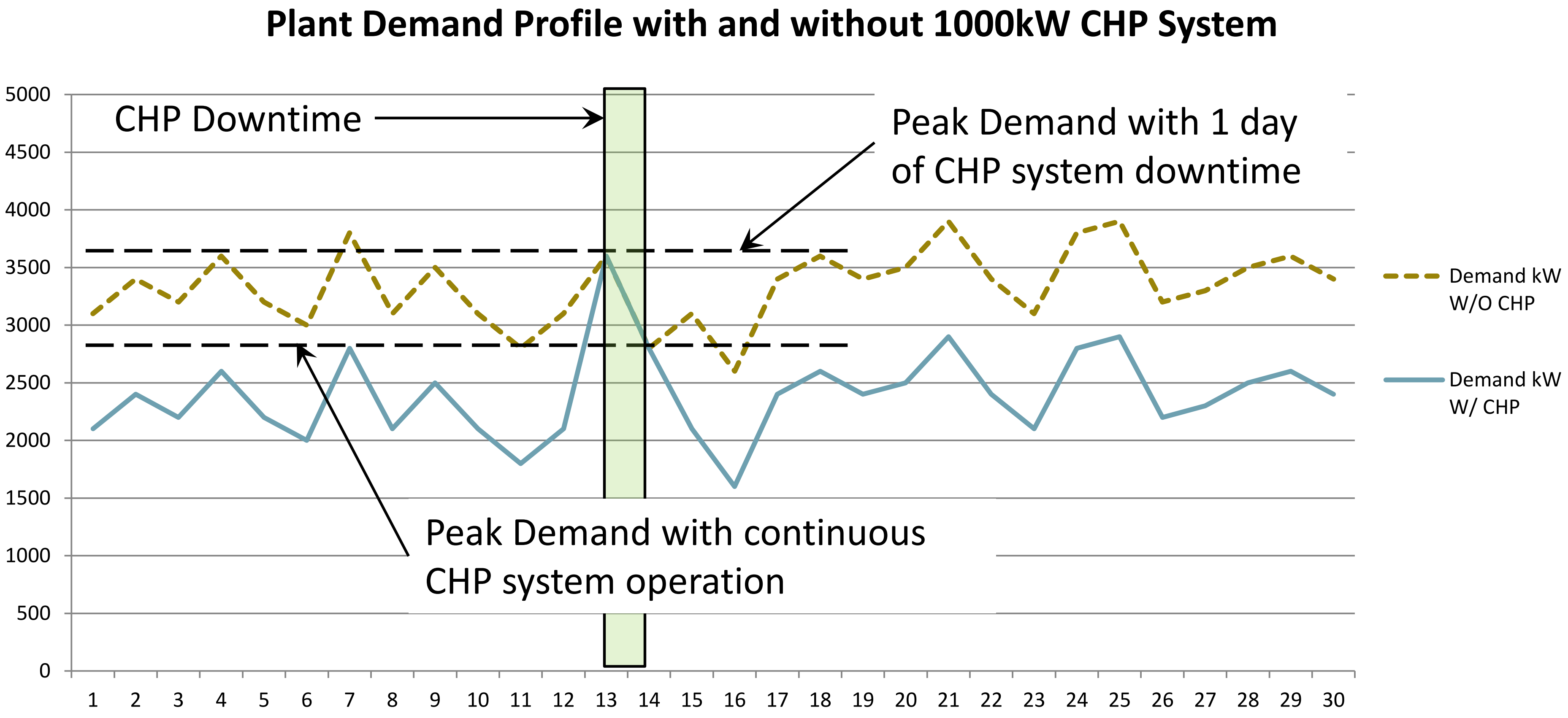
TREATMENT FACILITY

Sell Energy Directly
To Electric Utility

OR

Offset Purchased
Utility Power Source

Utility rates have a significant impact on CHP system benefit



CHP Downtime

Peak Demand with 1 day of CHP system downtime

Peak Demand with continuous CHP system operation

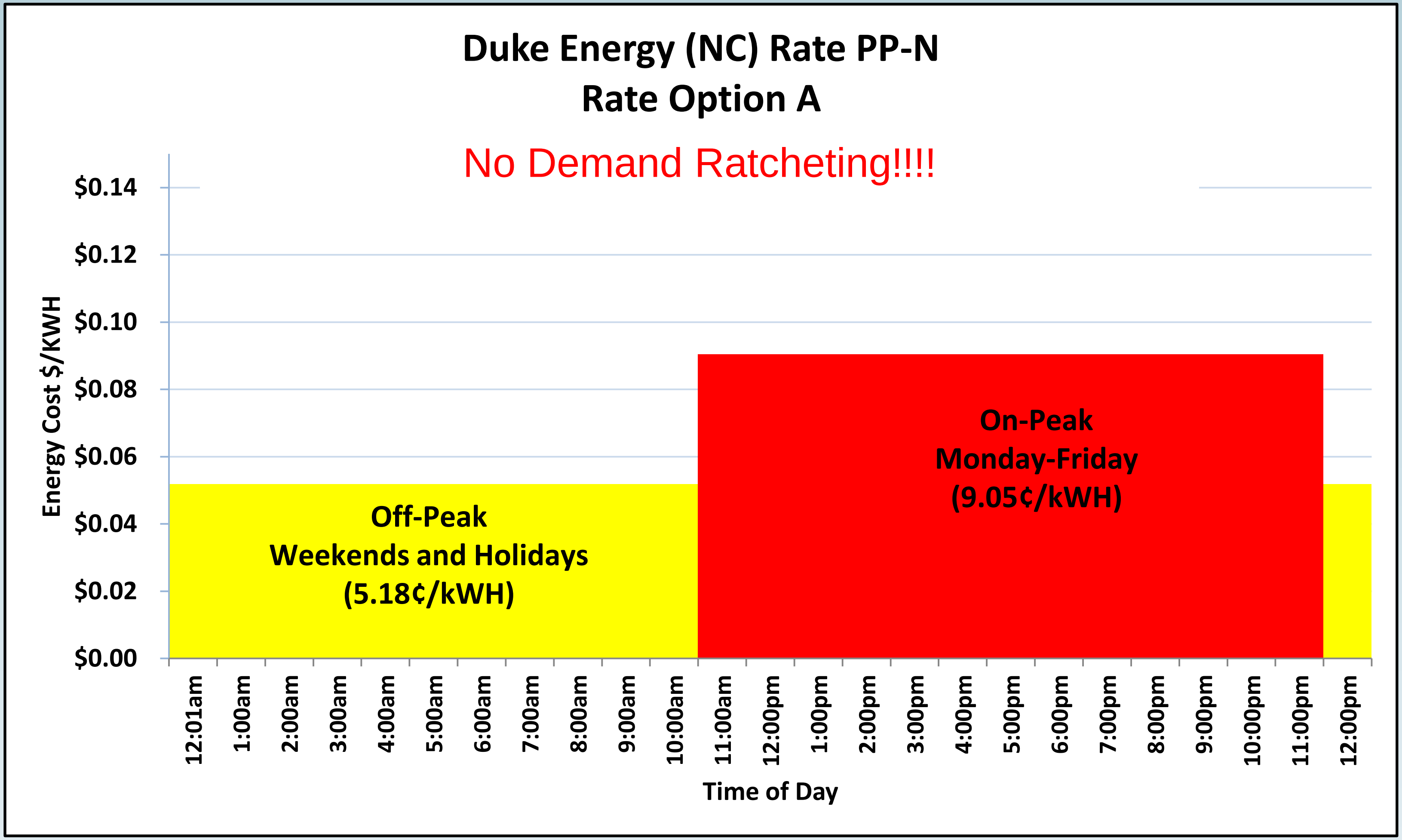
~1000kW demand loss with 1 day of CHP system downtime

CHP System Benefit Analysis SVEC – Rate LP10

	Electric Utility Cost	CHP Demand Offset @17.33/KW	CHP Energy Offset @ $0.041/KWH	CHP System Benefit	CHP System Operation % Savings
No CHP	$164,000	N/A	N/A	N/A	N/A
1000kW Base Load – Continuous Operation	$119,200	$17,300	$27,500	$44,800	27%
1000kW Base Load – 1 day CHP Down Time	$133,000	$0	$26,000	$26,000	**10%**

- 3 day CHP peak period downtime resulted in a 40% loss of the CHP system benefit for the billing period.
- Demand ratchets can extend the loss for up to 12 months! – 80% 12 month ratchet could result in a loss of ~$170,000/year

Some utilities purchase renewable energy on a energy charge only rate.



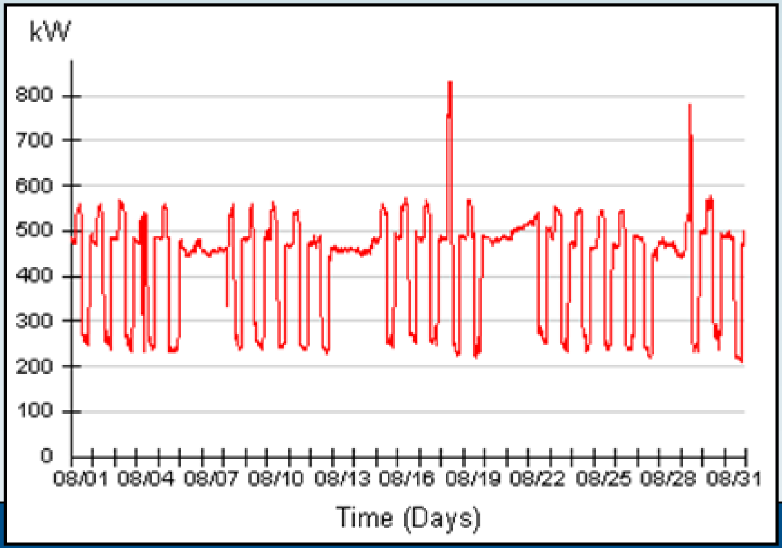
Benefit may depend on renewable energy portfolio standards and goals. ***www.dsireusa.org***

States with Renewable Portfolio Standards (mandatory) or Goals (voluntary), January 2012

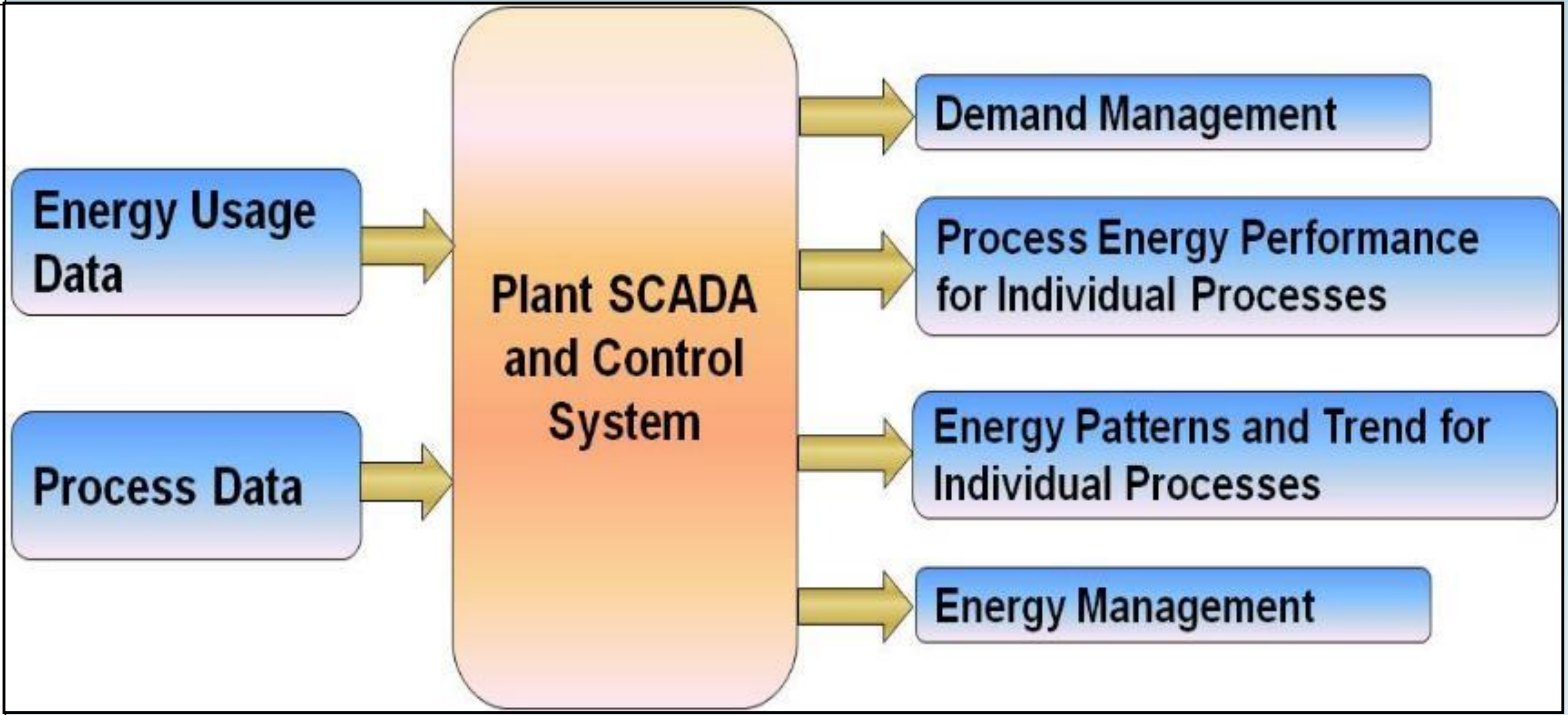
Source:dsireusa.org

Power Monitoring

Power monitoring is key to energy management and optimization



Benefits from incorporating energy usage data into process operations



Energy Usage Data

Process Data

Plant SCADA and Control System

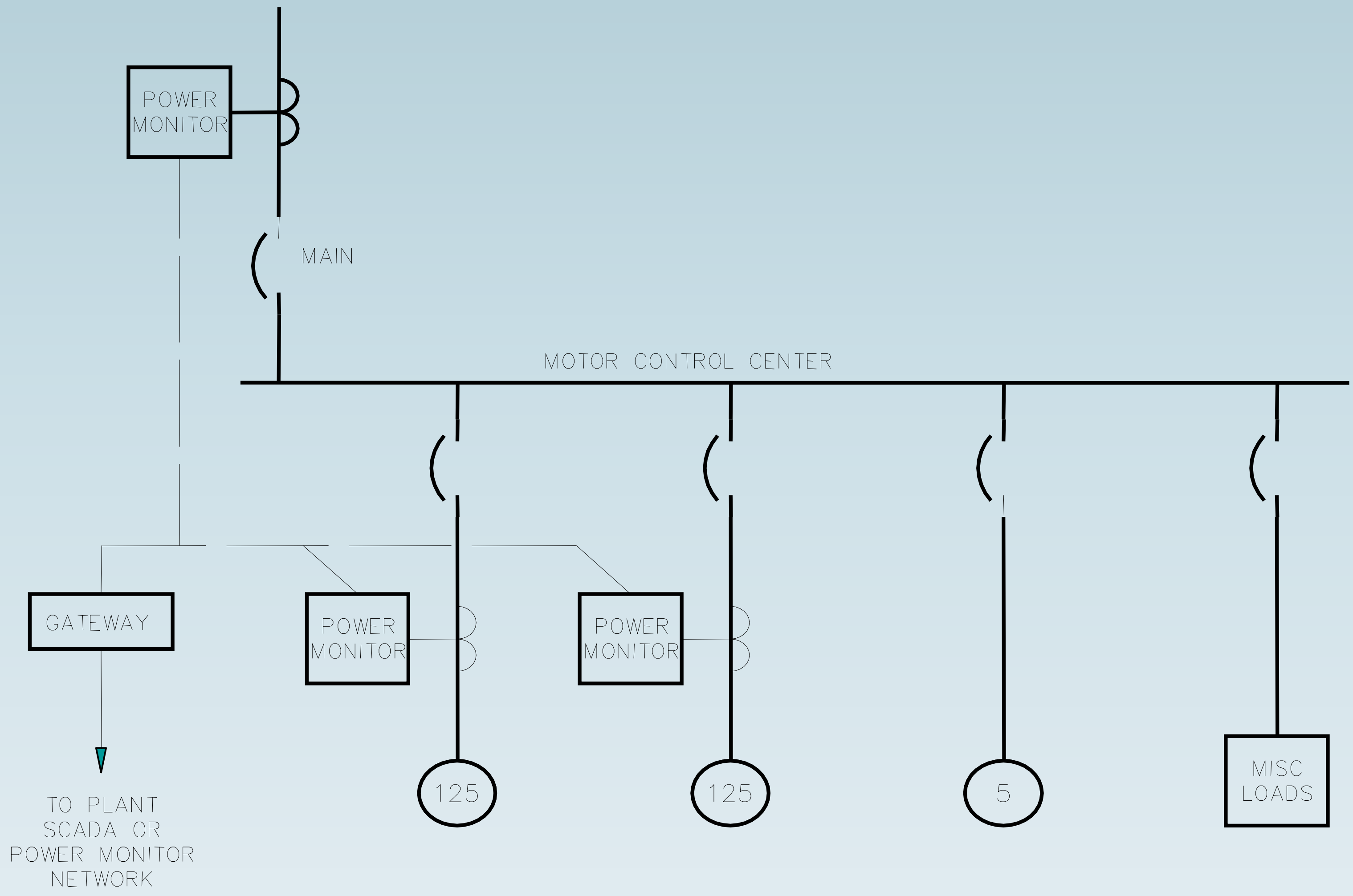
Demand Management

Process Energy Performance for Individual Processes

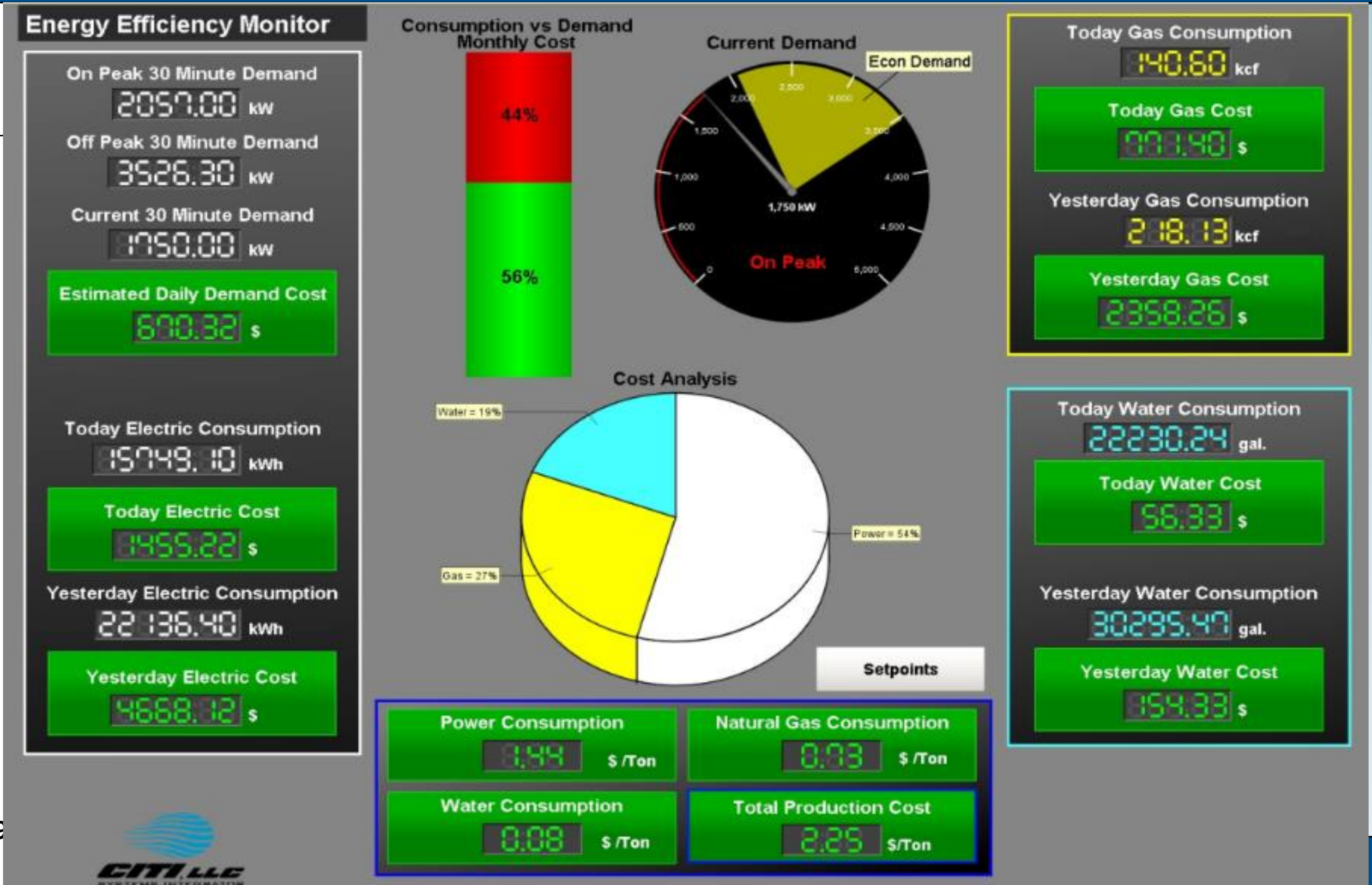
Energy Patterns and Trend for Individual Processes

Energy Management

Monitor individual loads as well as overall distribution equipment loads



Power monitoring dashboard example



Energy Efficiency Monitor

On Peak 30 Minute Demand
2057.00 kW

Off Peak 30 Minute Demand
3526.30 kW

Current 30 Minute Demand
1750.00 kW

Estimated Daily Demand Cost
670.32 $

Today Electric Consumption
15749.10 kWh

Today Electric Cost
1455.22 $

Yesterday Electric Consumption
22136.40 kWh

Yesterday Electric Cost
4668.12 $

Today Gas Consumption
140.60 kcf

Today Gas Cost
771.40 $

Yesterday Gas Consumption
218.13 kcf

Yesterday Gas Cost
2358.26 $

Today Water Consumption
22230.24 gal.

Today Water Cost
56.33 $

Yesterday Water Consumption
30295.47 gal.

Yesterday Water Cost
154.33 $

Power Consumption
1.44 $ /Ton

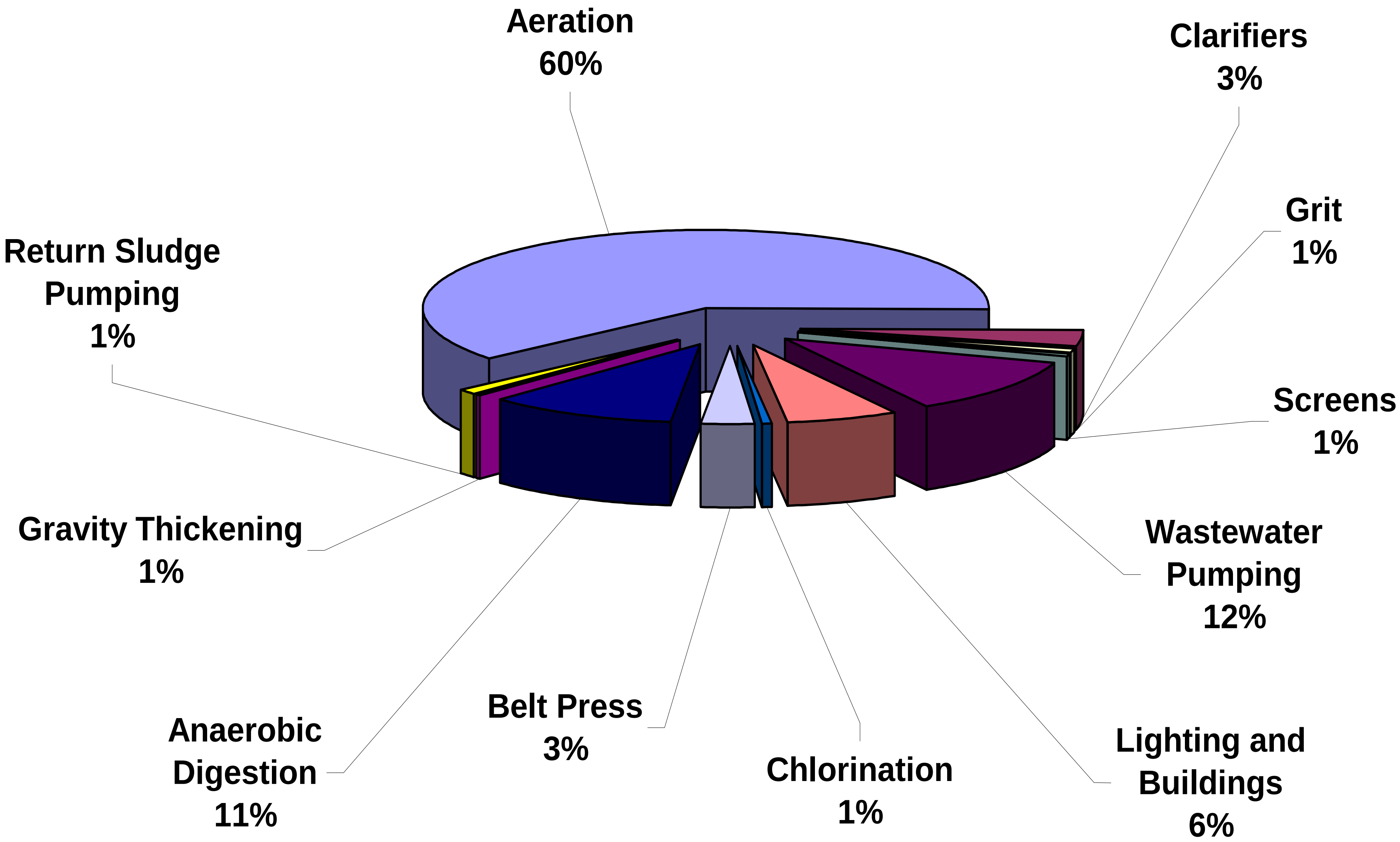
Natural Gas Consumption
0.73 $ /Ton

Water Consumption
0.08 $ /Ton

Total Production Cost
2.25 $/Ton

Typical Energy Management Opportunities

The treatment process typically consumes 90% of the energy usage



National Energy Benchmark Data

Secondary Treatment

Activated Sludge with Advanced Treatment and Nitrification	**1,900**
Activated Sludge with Advanced Treatment, No Nitrification	**1,600**
Activated Sludge with No Advanced Treatment or Nitrification	**1,400**
No Activated Sludge, Trickling Filter	**1,000**

kWh/MG

Source: WEF MOP-32

Energy Optimization – Secondary Treatment Considerations

- Excessive operating units (too many tanks online)
- DO control (excessively high DO)
- Blower turndown limitations
- Over mixing
- Diffuser fouling
- Inefficient aeration equipment
- Primary clarifier efficiency

Damaged equipment

Damaged Diffuser

Aeration equipment can impact energy efficiency

Aerator technologies oxygen transfer efficiencies

Aerator Type	SAE lbO2/hp-hr	AE at 2 mg/L DO lbO2/hp-hr
Surface Aerators	1.5 – 3.2	0.7 – 2.5
Coarse Bubble	1 - 2.5	0.5 – 1.6
Fine Bubble	6 – 8	2.0 - 4.0

- Conversion to fine bubble is not always cost effective.
- Have to make an economic case to change to fine bubble from surface aerators
- Cost of energy impacts economic case

Questions?

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