WWTP Energy Management Solutions and Case Studies

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2016 Vail Operator Training Seminar
October 13, 2016
Residuals Resource Recovery

“N.E.W.” PARADIGM - The Future!

Wastewater Treatment Plants

Nutrients

Carbon/Energy

Water

Water and Resource Recovery Facilities
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Energy optimization: essential for sustainable resource recovery

• Energy is 2nd to labor in cost of “used” water management
• Energy consumption has significant environmental & social impacts
• Energy requirements limit recovery of some resources
• Energy optimization = (reducing consumption; increasing recovery)
Energy Management Drivers

- Increase in energy costs
  - Water and wastewater treatment typically accounts for 30 to 60 percent of municipal government energy usage
- Increase in resource demand and prices fueled by growth in emerging markets
- Geopolitical pressure on resources worldwide and impacts locally
- Pressure to reduce O&M costs and financial burden on end users
- Stringent discharge standards
  - Nutrient removal
  - Complex and energy intensive treatment processes
- Need for reclaimed water in certain US geographies
- Growing concern of human activity impact on the environment – climate change!
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A “Holistic” Approach to Energy Management

- Purchased Energy
  - Electricity
  - Fuel Oil
  - Natural Gas
  - Energy embedded in chemicals

- Other Energy Sources
  - High Strength Waste such as FOG
  - Food waste

- Raw Wastewater
  - Chemical energy as COD
  - Sensible heat

- Treated Effluent
  - Chemical energy as COD
  - Sensible heat

- Biosolids
  - Chemical energy in solids

- Other Energy Losses
  - Biogas Flaring
  - Lost energy through biological processes

Wastewater Treatment Plant
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Typical Energy Use Profile of WWTP

- Aeration
- Sludge Stabilization
- Dewatering
- Gravity Thickening
- Disinfection
- Lighting And Building
- Headworks
- Clarification
- Pumping/Hydraulics
- And
- Building
- Disinfection
- Lighting
- Gravity Thickening
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Energy Management

- A multi-pronged approach to energy management
  - Energy Use Optimization
  - Energy Recovery
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Silver Bullets for Energy Efficiency

• Treat pollutant load by the lowest energy metabolic pathway possible
• Operate existing pumps/equipment at its optimum (best efficiency) point
• Select equipment for new plants or replacement of existing equipment with energy efficiency in mind
• Treat side stream recycles for nutrient removal instead of recycling to the mainstream liquid treatment process
• Supplement anaerobic digestion with other high strength wastes, e.g. FOG, when practical and available
• Consider low energy natural treatment systems when feasible
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Impact of Process Sophistication on Energy Demand

No activated Sludge, Trickling Filter Based Systems
~ 1,000 kWh/MG

Activated Sludge Based Systems with nutrient removal
~ 1,400 to 1,600 kWh/MG

Activated Sludge Based System with nutrient removal and advanced treatment
~ 1,700 to 1,900 kWh/MG
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Balancing Carbon in the Wastewater Holds the Key to Energy Optimization

• Effective primary treatment reduces carbon load to subsequent processes reducing energy consumption
• Redirected carbon offers potential of significant energy recovery
• Conventional BNR relies on carbon for nitrogen and phosphorus removal.
• Mainstream deammonification and anaerobic processes are alternatives to current energy intensive carbon driven processes
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Effective primary treatment: reduces carbon load to subsequent processes and facilitates energy recovery from sludge

- Chemically Enhanced Primary Treatment
- Microscreens
- Dissolved air flotation
- “A” stage of A/B Process
- Anaerobic treatment (UASBs, AnMBR)
What is Carbon Redirection?

- The diversion of biodegradable material away from the influent to a secondary treatment system

Conventional

Carbon Redirection

Raw Sewage $\rightarrow$ BOD$_5$ $\rightarrow$ Oxygen/Air $\rightarrow$ Primary Treatment

Raw Sewage $\rightarrow$ BOD$_5$ $\rightarrow$ BOD$_5$ $\rightarrow$ Oxygen/Air $\rightarrow$ Secondary Treatment
What is Carbon Redirection?

- Realizing energy savings requires anaerobic digestion, or no digestion
  - Aerobic digestion would just move power from the liquids to the solids train
Why Would a Utility be Interested in Carbon Redirection?

• The Good:
  – Lower Energy Usage
  – More biogas for beneficial use
  – Lower Biosolids Production
  – Smaller Bioreactors/More Bioreactor capacity
  – Sets plant up for future technologies like Mainstream Anammox

• The Bad:
  – Makes conventional nitrogen removal in secondary treatment more difficult. Less carbon is available for denitrification
How do I do Carbon Redirection?

• There are currently three primary ways to redirecting carbon away from secondary treatment
  – Conventional Primary Treatment
  – Chemically Enhanced Primary Treatment
  – High Rate Biological Contact or A-Stage Treatment
Conventional Primary Treatment

• Normally provides between 25% and 45% BOD₅ removal
• This is accomplished through the removal of settleable solids across the primary clarifier

55% to 75% of Influent BOD₅ to Secondary Treatment

25% to 45% of Influent BOD₅ to Anaerobic Digestion
Chemically Enhanced Primary Treatment

- Normally provides between 40% and 80% BOD$_5$ removal
- This is accomplished through the removal of settleable solids and colloidal material across the primary clarifier
  - Ferric or Alum addition coagulates colloids for
  - Polymer
  - Polymer improves settling and therefore particulate BOD$_5$ removal

20% to 60% of Influent BOD$_5$ to Secondary Treatment

40% to 80% of Influent BOD$_5$ to Anaerobic Digestion
Impact of Primary Clarification (1 MGD Facility)
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High Rate Biological Contact or A-Stage Treatment

- Very low SRT system (0.25 days to 0.5 days sludge retention time)
- This is accomplished through the removal of settleable, colloidal, and soluble BOD$_5$ across the primary clarifier
  - No chemical usage!

Low Dissolved Oxygen Bioreactor

BOD$_5$ to Secondary Treatment

30% to 60% of Influent BOD$_5$ to Anaerobic Digestion

40% to 70% of Influent BOD$_5$ to Secondary Treatment
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Biological Contact Mechanisms of COD (or BOD) Removal

**Conventional (SRT > 1 day)**
- Truly Soluble COD
- Colloidal COD
- Particulate COD

**Uptake**
- Oxygen ($$) (or nitrate)
- Hydrolysis & Coagulation (solubilization)

**Growth**
- Waste Sludge

**High Rate (SRT < 0.5 day)**
- Truly Soluble COD
- Colloidal COD
- Particulate COD

**Storage**
- Oxygen ($$

**Enmeshment**
- Some Coagulation

**Growth**

**Waste Sludge**
Typical Carbon Diversion System Performance

-40%

-30%

Primary Effluent Biodegradable COD Load (lb/day)

Conventional Primary Treatment

Low Load CEPT

Conventional CEPT

A Stage

Particulate

Colloidal

Soluble (Non-VFA)

VFA
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The Realm of Energy Recovery Opportunities

Energy Consumed On-Site to Reduce Dependence on Fossil Fuels

- Wastewater Solids (6,000 – 9,000 BTU/lb)
- Fats, Oils & Grease (~16,700 BTU/lb)
- Food Wastes (1,500 – 3,000 BTU/lb)

WWTP ENERGY RECOVERY PROCESSES FOR SOLIDS
- Biochemical
- Anaerobic Digestion
- Thermochemical
  - Incineration with Energy Recovery
  - Gasification
  - Pyrolysis
  - Drying

Electricity
Steam
Fuel (Gaseous or Solid)

“Green” Renewable Energy Provided for Off-Site Beneficial Use
Utilization of redirected carbon as a renewable energy source: Residuals to energy

- Direct conversion to energy (incineration)
- Preparation and utilization as a fuel
  - Sludge to biogas (cogeneration)
  - Sludge to syngas (gasification)
  - Sludge to oil
  - Sludge to solid fuel (carbonization)

- Status
  - Direct conversion proven but not widely used
  - Some technologies proven, lack of markets
  - Biogas cogeneration most widely used
Carbon redirection and biogas cogeneration in combined heat & power schemes

• Proven energy recovery scheme
• Qualifies as a renewable fuel for green power programs
• Reduces greenhouse gas and other air emissions
• Enhances facility power reliability
• Further gains from sludge pre-conditioning and co-digestion
• Next generation: higher conversion efficiencies (fuel cells?)
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Elements of an Energy Management Plan

**Energy Use Baseline**
- Energy benchmarking e.g. kWh/MG, kWh/lb BOD treated, kWh/lb N treated.
- Electrical sub-metering
- Utility billing rate structure
- Current and future energy costs

**Non-Process Energy Use Optimization and Generation**
- Lighting, building and HVAC Improvements
- Renewable energy such as solar, wind and/or hydroelectric

**Energy Management Plan**

**Process Optimization**
- Process control optimization and improvements
- Process modifications or upgrades (low metabolic pathway)
- Energy efficient equipment

**Process (Calorific) Energy Recovery**
- Biochemical processes
- Thermochemical processes
- Treatment of other high energy dense waste materials e.g. FOG
Energy Management – A Continuous Process!

- Leadership/Executive Endorsement and Support
- Energy benchmarking

Lessons learns and best management practices

Incorporate technology breakthroughs

Monitor and measure results vs. goals

Develop an Energy Management Plan

Implement the Plan
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Case Studies

• Greater New Haven Water Pollution Abatement Facility – New Haven, Connecticut
• VandCenter Syd’s Ejby Mølle Wastewater Treatment Plant - Odense, Denmark
• Crooked Creek Water Reclamation Facility – Gwinnett County, Georgia
Case Study 1 – Greater New Haven WPCF

- 60 mgd facility
  - Nutrient Removal: 5 mg/LTN annual average

Energy audit and monitoring lead to energy optimization opportunities and process control enhancements!
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Case Study 1 - Power Mapping and Energy Model

- Detailed mapping of power systems, MCCs, etc.
- Static energy model to account for unit process energy consumption
- Model calibration through online power monitoring of key load centers

<table>
<thead>
<tr>
<th>OMI Electricity Baseline End Use Budget</th>
<th>East Shore Facility</th>
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<tbody>
<tr>
<td>Month</td>
<td>December</td>
</tr>
<tr>
<td>No. of Motors</td>
<td>Operating Motors</td>
</tr>
<tr>
<td>Large Motors:</td>
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</tr>
<tr>
<td>Influent Pumps</td>
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<tr>
<td>Influent Pumps</td>
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<tr>
<td>Centrifugal Blowers</td>
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<td>Totals</td>
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<td>Small Motors:</td>
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<td>Bar Screens</td>
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<td>Secondary Clarifiers</td>
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<tr>
<td>Primary sludge pumps</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>WAS Pumps</td>
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<tr>
<td>BLENDE TANK</td>
<td>4</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
</tr>
<tr>
<td><strong>Total Motor Loads</strong></td>
<td></td>
</tr>
</tbody>
</table>

| Other Loads:                              |                     |               |           |              |                  |          |
| Lighting                                  | 207.2               | 20.0          | 207.20     | 128,464      |
| Lighting Upgrade                          | (75.0)              |                |            |              |
| Air Conditioning                          | 78.0                | 6.0           | 78.00      | 0            |
| Heating                                   | 32.6                | 2.4           | 32.60      | 14,148       |
| Computer Loads                            |                      |               |           |              |                  |          |
| # of Work Stations                        | 30                  | 0.5           | 96%       |              |                  |          |
| KW per Work Station                       |                     |               |           |              |                  |          |
| Power Factor                              | 14.15               |                | 7.952     |
| Miscellaneous Receptacles                 | 48.0                | 3.1           | 48.00      | 35,712       |
| Totals                                   |                     |               |           |              |                  |          | 186,276    |
| **Total Baseline Electricity Loads**      |                     |               |           |              |                  |          | 1,967,237  |
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Case Study 1 – Energy Monitoring Dashboard

Real Time Energy Statistics

**ENERGYtick Dashboard**

- Date: Saturday, 04/02/2005 at 10:15
- Power: 1001 kW

Real Time Energy Information from NXEGEN RTIS

LMP Data from ISO-NE

**Today Vs Yesterday**

**Today Vs Last Monday**

**Today Vs Peak Day (04/02/2005)**

**Today Vs Avg. WeekDay**

**CONSUMPTION - Last 30 days**

Last refresh: 4/18/2005 7:07:52 AM

**OMI NH Admin Bldg-Main**

- Hours: Undefined
- Utility: UI
- Rate: UI R311 Large ToU

**Radio: B001**

- Meter#: 12345
- Energy: Electrical
- Channels: 1, 2

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Case Study 1 – The Energy Management Plan

- Power mapping and energy model served as cornerstones for development of the Energy Management Plan
- Mapping, Modeling & Monitoring Outcomes
  - Found 600,000 kWh/year of power used by 3rd party contractor
  - Identified weaknesses in emergency power supply setup
  - Found discrepancies between utility bills and on-line metering
- Energy Management Plan focused on projects with high return on investment
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Case Study 1 – Greater New Haven WPCF

- Energy Management Plan Implementation:
  - Instituted light improvements resulting in 658,000 kWh/yr electrical savings and a 2.7 year payback on investment
  - Instituted ISO NE demand response program to generate revenue and reduce power load by 1.7 MW
  - Modified SCADA system, new DO control, installed new instruments to optimize aeration basin blowers
    - Retrofitted blowers helped save 1 million kWh/yr

- Reduced overall power use by 3 million kWh/yr
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Case Study 2 – VandCenter Syd (VCS)

• 3rd largest water and wastewater company in Denmark. Headquartered in Odense.

• Operates 7 WTPs and 8 WWTPs with 2,125 miles (3,400 km) of conveyance

• Ejby Mølle WWTP:
  – 385,000 PE BNR facility
  – 76 percent self-sufficient in 2011

Achieving Energy Self-Sufficiency in a Nutrient Removal Facility Through Operational Optimization!
Case Study 2 - Ejby Mølle WWTP Energy Optimization Project Objectives

- Contribute towards achieving VCS’s corporate goal of energy self-sufficiency and carbon neutrality by 2014
- Identify energy optimization opportunities (EOOs):
  - Short-term, readily implementable scenarios to reduce energy consumption and/or increase energy generation, and decrease greenhouse gas emissions
- Identify and document all options, including longer term opportunities for future consideration
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Case Study 2 – Availability of detailed historic energy consumption and generation data was key in the evaluation of optimization opportunities
Case Study 2 - A whole plant mass/energy model and screening criteria lead to an EOO short-list

- **Adopted screening criteria**
  - Readily implementable; Primarily process modifications
  - Significant impact on energy profile; Proven elsewhere

- **Short-listed EOOS**
  - Implement chemical enhanced primary treatment (CEPT)
  - Operate at shorter BNR system solids retention time (SRT)
  - Decommission TFs and convert TF clarifiers to CEPT for wet weather treatment
  - Reduce effluent filtration operation to 12 hours per day

- **Longer term Improvements for positive net energy status**
  - Co-digestion of high strength waste in 2014
  - Implemented deammonification for N removal in sidestreams in 2014; mainstream in 2015
  - Replace oxidation ditch mechanical aerators with fine bubble diffused aeration
Case Study 2 – Path to Energy Self Sufficiency

- Energy Produced 2011
- Additional Energy Produced

- All Operational EOOs + Anammox + Diffusers
- All Operational EOOs
- Chemically Enhanced Primary Treatment
- Partial Effluent Filtration
- Lower Bioreactor Sludge Age
- No Trickling Filters
- Existing Condition (Baseline)

Energy Self-Sufficiency

75% 80% 85% 90% 95% 100% 105% 110% 115% 120%
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Implementation of several EOOs achieved energy self-sufficiency in 2014
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Case Study 3 – Crooked Creek WRF

• 16 mgd design capacity

• Process study of potential future improvements focused on whole plant process modeling to examine relative energy and carbon benefits of different configurations

• Solids stream evaluations focused on anaerobic digestion and biogas production for combined heat and power production

*Process Optimization to Reduce Energy Consumption!*
Case Study 3 – Crooked Creek WRF

- Primary Treatment Approaches Investigated:

**Conventional**
- BOD Removal 20-40%

**A/B Process**
- Aeration Tank
  - HRT = 30 min
  - SRT = 0.5 – 1.0 d
  - DO = 0.5 – 1.0 mg/L
  - MLSS ~ 1,000 – 3,000 mg/L
  - BOD Removal 50-60%

**Chemically Enhanced Primary Treatment**
- CoagPoly
  - BOD Removal 40-70%
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Case Study 3 – Crooked Creek WRF

• A/B Process
  – Currently of interest as a “low energy” process
  – Variation of 2-stage activated sludge
  – Biologically Enhanced Primary Treatment (BEPT)

• Primary Treatment Approach Scenarios

<table>
<thead>
<tr>
<th>Scenario Name</th>
<th>Plant Sizing</th>
<th>Plant Operating Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Conventional</td>
<td>Conventional</td>
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<tr>
<td>Operational CEPT</td>
<td>Conventional</td>
<td>CEPT</td>
</tr>
<tr>
<td>Full CEPT</td>
<td>CEPT</td>
<td>CEPT</td>
</tr>
<tr>
<td>BEPT</td>
<td>BEPT</td>
<td>BEPT</td>
</tr>
</tbody>
</table>
Case Study 3 – Secondary Treatment Energy Use vs. Cogeneration Production

Electricity Produced or Consumed (kWh / year)

- Conventional
- Opn CEPT
- Full CEPT
- BEPT

Closing the Energy Gap

- Secondary Treatment Consumption
- Cogen Production
Conclusions

• Typical municipal wastewater theoretically has more energy in pollutants compared to energy required for its treatment
• Energy benchmarking and monitoring is essential to evaluate potential improvement scenarios
• Energy management is a continuous “cyclical” process
• Two pronged approach to energy management
  – Energy use optimization
  – Energy recovery
• A holistic approach to energy management is critical due to interrelationships between energy use optimization and recovery
• Energy self-sufficiency possible with significant generation as well as reduction measures
• Net energy-positive condition achievable with external carbon (codigestion)
• Balancing nutrient removal, carbon management, energy production, energy conservation and water reclamation requirements are key to striving for energy neutrality
WWTP ENERGY MANAGEMENT SOLUTIONS AND CASE STUDIES

Questions?