Energy Use Optimization and Recovery Strategies to Strive for Energy Neutrality

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AAEES Workshop
The “N.E.W.” Paradigm

Nutrients
Water
Carbon/Energy

Wastewater Treatment Plants → Water and Resource Recovery Facilities
Energy Management Drivers

• Increase in energy costs
  • Water and wastewater treatment typically accounts for 30 to 60 percent of municipal government energy usage

• Reduce O&M costs and financial burden on end users

• Stricter regulations
  • Nutrient removal
  • Complex and energy intensive treatment processes
  • Biosolids land application challenges

• Climate change adaptation

• Resiliency
Energy Management Focus Areas

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

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
Can WRRF’s be Net Zero Energy?

- Research by David Bagley at U of Toronto (North Toronto TP) in 2001:
  - Electricity consumed: 0.2 kWh/m³
  - Potential Energy of Raw Wastewater: 1.8 kWh/m³
  - WW contains ~10 times the energy needed for conventional treatment
  - In theory we only need to be 10% efficient at converting BOD to electricity
Carbon – A Limited Resource with Competing Demands

- Tradeoffs between achieving low energy and low nutrients
  - Carbon demand to drive biological nutrient removal vs. methane production to generate electricity
- Need for balancing competing aspects of nutrient removal, net energy usage, and high quality effluent water goals
Knowing the Carbon and Energy Flow
CS 1 – Greater New Haven WPCF

• 60 mgd facility
  • Nutrient Removal: 5 mg/L
    TN annual average

Energy audit led to optimization and process control enhancements!
## CS 1 - Power Mapping and Energy Model

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

### OMI Electricity Baseline End Use Budget

#### East Shore Facility

**Month:** December

<table>
<thead>
<tr>
<th>Large Motors:</th>
<th>No. of Motors</th>
<th>Operating Motors</th>
<th>Power Factor</th>
<th>HP per Motor</th>
<th>KW per Motor</th>
<th>Run Hours per Day</th>
<th>Billed KW</th>
<th>Monthly KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent Pumps</td>
<td>3</td>
<td>3</td>
<td>0.90</td>
<td>250.0</td>
<td>166.6</td>
<td>24.0</td>
<td>0.00</td>
<td>0</td>
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<tr>
<td>Influent Pumps</td>
<td>2</td>
<td>1.8</td>
<td>0.90</td>
<td>125.0</td>
<td>93.3</td>
<td>24.0</td>
<td>151.07</td>
<td>112,392</td>
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<tr>
<td>Centrifugal Blowers</td>
<td>5</td>
<td>4.8</td>
<td>0.90</td>
<td>700.0</td>
<td>522.2</td>
<td>24.0</td>
<td>704.57</td>
<td>524,496</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>830,950</td>
<td></td>
</tr>
</tbody>
</table>

#### Small Motors:

| Bar Screens | 2 | 4 | 0.90 | 2.0 | 1.5 | 24.0 | 1.61 | 1,199 |
| Primary Clarifiers | 3 | 3 | 0.90 | 1.0 | 0.7 | 24.0 | 2.01 | 1,496 |
| Secondary Clarifiers | 8 | 8 | 0.90 | 1.0 | 0.7 | 24.0 | 5.37 | 3,996 |
| RAS (WRFY) Pumps | 8 | 8 | 0.90 | 25.0 | 18.7 | 24.0 | 134.28 | 99,904 |
| Secondary Scum pumps | 4 | 4 | 0.90 | 5.0 | 3.7 | 12.0 | 13.43 | 4,956 |
| Primary sludge pumps | 6 | 6 | 0.90 | 30.0 | 22.4 | 12.0 | 60.43 | 22,476 |
| Thresl Primary sludge pumps | 2 | 1 | 0.90 | 5.0 | 3.7 | 12.0 | 3.36 | 1,249 |
| Primary sludge thickeners | 2 | 2 | 0.90 | 1.0 | 0.7 | 24.0 | 1.34 | 999   |
| WAS Pumps | 10 | 5 | 0.90 | 15.0 | 11.2 | 24.0 | 50.36 | 37,495 |
| **Total** | | | | | | | | 744,071 |

| RAS Tank | 4 | 4 | 0.90 | 7.5 | 5.6 | 24.0 | 20.14 | 14,388 |
| **Total Motor Loads** | | | | | | | | 1,380,961 |

<table>
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<tr>
<th>Other Loads:</th>
<th>KW Load</th>
<th>Run Hours per Day</th>
</tr>
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<tbody>
<tr>
<td>Lighting</td>
<td>207.2</td>
<td>20.0</td>
</tr>
<tr>
<td>Lighting Upgrade</td>
<td>(75.0)</td>
<td>20.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>282.2</td>
<td>20.0</td>
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<thead>
<tr>
<th>Air Conditioning</th>
<th># of Units</th>
<th>KW Load</th>
<th>Run Hours per Day</th>
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<tbody>
<tr>
<td>65</td>
<td>78.0</td>
<td></td>
<td>78.00</td>
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<tr>
<td><strong>Total</strong></td>
<td>32.6</td>
<td></td>
<td>32.60</td>
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<table>
<thead>
<tr>
<th>Heating</th>
<th>KW Load</th>
<th>Run Hours per Day</th>
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<tbody>
<tr>
<td>32.6</td>
<td></td>
<td>32.60</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td>14,148</td>
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<table>
<thead>
<tr>
<th>Computer Loads</th>
<th># of Work Stations</th>
<th>KW per Work Station</th>
<th>Run Hours per Day</th>
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<tbody>
<tr>
<td>30</td>
<td>0.5</td>
<td>18.0</td>
<td>14.25</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>7,952</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Miscellaneous Receptacles</th>
<th>KW per Sq. Ft</th>
<th>Run Hours per Day</th>
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<tr>
<td>1.5</td>
<td>320,000</td>
<td>46.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>188,276</td>
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</tbody>
</table>

| Total Baseline Electricity Loads | 1,957,237 |

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- Detailed mapping of power systems and MCCs
- Static energy model to account for unit process energy consumption
- Model calibration through online power monitoring of key load centers
CS 1 – Energy Monitoring Dashboard
CS 1 – The Energy Management Improvements

• Mapping, Modeling & Monitoring Outcomes
  • Found 0.6 million kWh/year of power used by 3rd party contractor
  • Identified weaknesses in emergency power supply
  • Found discrepancies between utility bills and on-line metering

• Energy management improvements
  • Aeration: 1 million kWh/yr
  • Lighting: 0.66 million kWh/yr
  • Instituted ISO NE demand response program to generate revenue and reduce power load by 1.7 MW
CS 2 - Green Bay Metropolitan Sewerage District (GBMSD)

• Formed in 1931 owns and operates:
  • GBF, designed to treat 49.2 mgd through secondary treatment
  • DPF, designed to treat 14.2 mgd through secondary treatment

• NEW Water – Water Conservation & Stewardship

*Gain flexibility by tapping energy in wastewater solids!
Energy Summary for 2035 - Annual Average Flows (Revised: October 09 2015)

5.2 Mbtu/hr
3
3.5 Mbtu/hr
3
( 5.0 Mbtu/hr )
4
2.7 MW
3
( 3.9 MW )
4
9.3 Mbtu/hr
3
( 13.3 Mbtu/hr )
4
2.7 Mbtu/hr
3
6.6 Mbtu/hr
3
10.6 Mbtu/hr
3
11.5 Mbtu/hr
3
12 Mbtu/hr
3
15.2 Mbtu/hr
3
2.25 Mbtu/hr
3
494,834 ft³/day
3
873,958 ft³/day
3
113,760 gal/day
3
24/7 Operation
3
24/5 Operation
3
LHV basis
3
Million British Thermal Units per Hour
3
Notes:
1 247 Operation
2 245 Operation
3 LHV basis
4 Full Load Output with 2 Engine Generator units operating

Legend:
APC Air Pollution Control Equipment
LHV Lower Heating Value
Mbtu Million British Thermal Units per Hour
MW Megawatts

Digester Performance with thickened sludge only
Biogas Production 494,834 ft³/day
Biogas Energy 12.4 Mbtu/hr
CS 3 – Douglas L. Smith Middle Basin WWTP

• 14.5 mgd
• Project Components:
  • Anaerobic digestion facilities expansion
  • FOG and HSW receiving facility
  • Two 1060 kW co-generation units
• Results
  • Tipping fee: $300,000/yr
  • Electricity savings :$400,000/year

*Increased solids handling capacity while decreasing carbon footprint!*
CS 3 - Digester Gas Production Increased with Addition of FOG Waste
CS 4 - VandCenter Syd (VCS)

- 3rd largest water and wastewater company in Denmark. Headquartered in Odense.
- 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!*
CS 4 – Ejby Mølle WWTP Process Flow Diagram

- Headworks
- Primary Clarifiers
- WAS Thickening
- Anaerobic Digestion
- Secondary Treatment
- Trickling Filters
- Filtration
- Dewatering
- Energy Generation
- Sludge to Compost

Legend:
- Wastewater
- Sludge
- Gas, heat and electricity
- Fe: Iron precipitant dosed
- Poly: Polyelectrolyte dosed
Availability of detailed historic energy consumption and generation data was key in the evaluation of optimization opportunities.
• Adopted screening criteria
  • Readily implementable; primarily process modifications
  • Significant impact on energy profile
  • Proven process

• Short Listed EOOs
  • Implement chemical enhanced primary treatment (CEPT)
  • Nitrify centrate in trickling filters (TFs)
  • Decommission TFs and convert TF clarifiers to CEPT for wet weather treatment
  • Shorter BNR system solids retention time (SRT)
  • Reduce effluent filtration operation to 12 hours per day

• Long Term EOOs
  – Implement deammonification for nitrogen removal in recycle returns (sidestreams)
  – Replace oxidation ditch mechanical aerators with fine bubble diffused aeration
CS 4 – Path to Energy Self Sufficiency

Energy Produced 2011
Additional Energy Produced
Additional Energy Saved

- 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
Conclusions

• Typical municipal wastewater theoretically has more energy in wastewater solids compared to energy required for its treatment
• Energy benchmarking and monitoring is essential to evaluate potential improvement scenarios
• Two pronged holistic approach to energy management and self sufficiency
  • Energy use optimization
  • Energy recovery
• Net energy-positive condition achievable with external carbon (codigestion)
• Balancing nutrient removal, carbon management and water reclamation requirements are key to striving for energy neutrality