# Application of Energy Efficient Technologies in Wastewater Treatment Facilities

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## Outline

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- Energy Efficiency, Demand Response and Other Energy System Opportunities in Wastewater Treatment Plants (WWTPs)
  - Retrofit Projects
  - New Construction and Expansion Projects
- Case Study – Retrofit Project
- Case Study – Expansion Project
- Benchmarking
- Concluding Remarks

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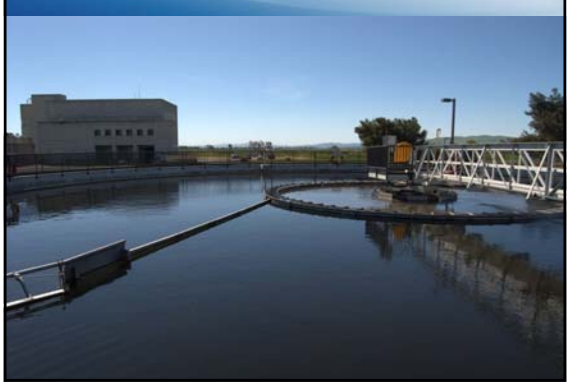
## Introduction



## Wastewater Treatment Plant Energy Consumption

- Wastewater treatment plants (WWTP) are one of the most energy intensive facilities managed by the public sector.
- Over 16,000 WWTP exist in the United States
  - Consumes ~3% of the nations' electrical power
- According to a 1993 study by Burton Environmental Engineering, wastewater treatment plants consume close to 1% of the electrical power in Northern and Central California

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## Common Wastewater Treatment Methods

- Activated Sludge
  - Most common
  - Most energy intensive
- Oxidation Ditch, Extended Aeration
- Fixed Film Reactors (Trickling Filters, Rotating Biological Contactors)
- Evaporation Ponds

Least energy intensive

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## Common Levels of Treatment

- Preliminary
  - Screening and grit removal
- Primary
  - Removal of a portion of the suspended solids and organic matter from wastewater
- Secondary
  - Removal of biodegradable organic matter and suspended solids
  - Also a part of this treatment is disinfection – destroys remaining microorganisms remaining in the wastewater
  - Secondary treatment usually is the most energy intensive and accounts for 30% to 60% of the total plant energy consumption
- Tertiary
  - Removal of residual suspended solids and nutrient removal
- Sludge Treatment and Disposal
  - Thickening, conditioning, stabilizing, dewatering and drying sludge prior to disposal

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## Integrated Energy Audits of Wastewater Treatment Plants

| Plant | Type of Treatment | Treatment Level | Average Flow |
|---|---|---|---|
| Municipal WWTP A | Aerobic Activated Sludge | Secondary | 3.87 MGD |
| Municipal WWTP B | Aerobic Activated Sludge | Partial Secondary; Partial Tertiary | 7.5 MGD average; 12.6 MGD max. |
| Municipal WWTP C | Aerobic Activated Sludge | Secondary | 3.14 MGD |
| Municipal WWTP D | Oxidation Pond | Tertiary | 1.1 MGD |
| Municipal WWTP E | Oxidation Pond | Tertiary | 2.4 MGD |
| Municipal WWTP F | Oxidation Pond | Secondary | Not Available |
| Municipal WWTP G | Trickling Filter | Secondary | 7.0 MGD average; 30 MGD max |
| Municipal WWTP H | Oxidation Pond | Not Available | Not Available |
| Municipal WWTP I | Activated Sludge (Domestic WW); Trickling Filter (Industrial WW) | Secondary | 1.96 MGD |

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## New Construction/Expansion Design Review of Wastewater Treatment Plants

| Plant | Type of Treatment | Treatment Level | Average Flow |
|---|---|---|---|
| Winery A WWTP | Aerobic Activated Sludge | Aeration Only | 46,000 GPD |
| Winery B WWTP | Oxidation Pond | Secondary | 34,318 GPD |
| Municipal WWTP 1 | Aerobic Activated Sludge | Tertiary | 32 MGD |
| Municipal WWTP 2 | Aerobic Activated Sludge | Tertiary | 1.4 MGD |
| Municipal WWTP 3 | Aerobic Activated Sludge | Secondary | 4.4 MGD |
| Municipal WWTP 4 | Aerobic Activated Sludge | Tertiary | 5.5 MGD |
| Municipal WWTP 5 | Aerobic Activated Sludge | Tertiary | 3.6 MGD |
| Municipal WWTP 6 | Aerobic Activated Sludge | Tertiary | 6 MGD |

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## How to Improve Energy Efficiency in WWTP?

- Review historical energy consumption and influent flow
- Integrated energy audits
- Design review for energy efficiency when expanding a plant's operation or building a new plant
- Benchmarking plant

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## Energy Efficiency, Demand Response and Other Energy System Opportunities

## Energy Efficiency Measures from Integrated Energy Audits

| Energy Efficiency Measure | Municipal WWTP A | Municipal WWTP B | Municipal WWTP C | Municipal WWTP D | Municipal WWTP E | Municipal WWTP F | Municipal WWTP G | Municipal WWTP H | Municipal WWTP I |
|---|---|---|---|---|---|---|---|---|---|
| Premium Efficiency Motors | | x | x | x | x | x | | x | x |
| Automated Dissolved Oxygen Control | x | | x | | x | x | x | x | x |
| Fine Bubble Diffusers | x | | | | | | | | |
| High Efficiency Air Compressor | | x | | | | | | | |
| Lighting Control | x | x | x | | | | x | | |
| High Efficiency Lighting | | | x | x | | | x | | |
| Variable Frequency Drives on Blowers | x | | | | | | x | | x |
| Variable Frequency Drives on Pumps | | x | x | x | x | x | x | x | |
| Variable Frequency Drives on Mechanical Aerators | | | x | | x | x | | x | x |

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## Demand Response Measures from Integrated Energy Audits

| Demand Response Measure | Municipal WWTP A | Municipal WWTP B | Municipal WWTP C | Municipal WWTP D | Municipal WWTP E | Municipal WWTP F | Municipal WWTP G | Municipal WWTP H | Municipal WWTP I |
|---|---|---|---|---|---|---|---|---|---|
| Install Variable Frequency Drives on Pumps and Reduce Speed During Demand Response (DR) Event | | | | | x | | x | | |
| Install Variable Frequency Drives on Aerators and Reduce Speed During DR Event | | | x | | x | | | | |
| Turn Off Pumps for Duration of DR Event | | x | | | | x | | x | |
| Turn Off Aerators for Duration of DR Event | | | | x | | | | x | x |
| Utilize Equalization Tank and Shift Pump Operation During DR Event | | x | | | | | | | |
| Over-Aerate Basins/Digesters and Reduce Flow of Blowers During DR Event | x | | | | | | x | | |
| Delay Operation of Sludge Dewatering / Thickening Equipment During DR Event | x | | | | | | x | | x |
| Turn Off Blowers for Odor Removal for Duration of DR Event | | x | | | | | | | |

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## Other Energy System Opportunities from Integrated Energy Audits

| Energy System Opportunity | Municipal WWTP A | Municipal WWTP B | Municipal WWTP C | Municipal WWTP D | Municipal WWTP E | Municipal WWTP F | Municipal WWTP G | Municipal WWTP H | Municipal WWTP I |
|---|---|---|---|---|---|---|---|---|---|
| Install an Anaerobic Digester and Combined Heat and Power System | x | | | | | | | | |
| Install a Combined Heat and Power System | | x | | | x | | | | x |
| Install a Photovoltaic System | | | | | x | | | | |
| Shift Aeration to Off-Peak Periods | | | | | | | | x | |
| Shift Irrigation Pumping to Off-Peak Periods | | | | | | | | x | |

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## Total Energy Savings from Integrated Energy Audits

| Plant | Average Flow | % Energy Savings Identified |
|---|---|---|
| Municipal WWTP A | 3.87 MGD | 33% |
| Municipal WWTP B | 7.5 MGD average; 12.6 MGD max. | 8% |
| Municipal WWTP C | 3.14 MGD | 5% |
| Municipal WWTP D | 1.1 MGD | 5% |
| Municipal WWTP E | 2.4 MGD | 18% |
| Municipal WWTP F | Not Available | 8% |
| Municipal WWTP G | 7.0 MGD average; 30 MGD max | 19% |
| Municipal WWTP H | Not Available | 16% |
| Municipal WWTP I | 1.96 MGD | 21% |

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## Energy Efficiency Measures for New Construction/Expansion Projects

| Energy Efficiency Measure | Winery A WWTP | Winery B WWTP | Municipal WWTP 1 | Municipal WWTP 2 | Municipal WWTP 3 | Municipal WWTP 4 | Municipal WWTP 5 | Municipal WWTP 6 |
|---|---|---|---|---|---|---|---|---|
| Premium Efficiency Motors | x | x | x | x | x | x | x | x |
| Automated Dissolved Oxygen Control | x | x | x | x | x | x | | x |
| High Efficiency Blowers | | | x | x | | x | | |
| High Efficiency Aerators | | | | | | | | x |
| Fine Bubble Diffusers | | x | x | x | | x | | |
| High Efficiency Dewatering System | | | x | | x | x | | x |
| Low Pressure Ultraviolet Disinfection | | | | x | | x | x | x |
| High Efficiency Pumps | x | | | x | x | x | x | x |
| Variable Frequency Drive Applications (Pumps, Aerators, Blowers, etc.) | x | | x | x | x | x | x | x |
| High Efficiency Lighting | | | x | | x | | | |
| High Efficiency HVAC | | | x | x | x | x | | x |

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## Case Study of an Integrated Energy Audit

## Case Study: Retrofit Project

**Background**

BASE performed an integrated energy audit for a wastewater treatment plant in Central California. The facility used an aerobic activated sludge system which included primary and secondary treatment.

Annual Electrical Energy Consumption = 9,912,000 kWh/yr
Average Maximum Electrical Demand= 1,520 kW

Average Plant Flow = 4 MGD

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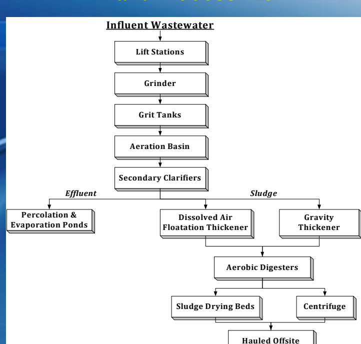
## Case Study: Retrofit Project (cont'd)

### Plant Process Flow

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## Case Study: Retrofit Project (cont'd)
### Energy Efficiency Recommendations

| Energy Efficiency Measure | Electrical Energy Savings (kWh/yr) | Demand Savings (kW) | Potential Savings ($/yr) | Implem. Cost ($) | Simple Payback (years) |
|---|---|---|---|---|---|
| 1. Install Lighting Controllers throughout the Facility | 8,113 | 3.0 | 1,100 | 1,948 | 1.8 |
| 2. Install Automated Dissolved Oxygen Control System and Variable Frequency Drives on Aeration Basin Blowers | 604,176 | 69.0 | 57,767 | 150,250 | 2.7 |
| 3. Install Variable Frequency Drives on Aerobic Digester Blowers | 1,788,771 | 204.2 | 170,169 | 174,750 | 1.0 |
| 4. Install Higher Efficiency Fine Bubble Diffusers | 862,506 | 98.5 | 82,051 | 400,000 | 4.9 |
| **Total Energy Savings** | **3,263,566 kWh/yr** | | | | |
| **Total Demand Savings** | | **374.7 kW** | | | |
| **Total Cost Savings** | | | **$308,087/yr** | | |
| **Total Implementation Cost** | | | | **$726,948** | |
| **Simple Payback Period** | | | | | **2.4 years** |

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## Case Study: Retrofit Project (cont'd)
### Demand Response Recommendations

| Demand Response Measure | Demand Reduction (kW) | Potential Energy Credit ($/yr) | Implem. Cost ($) | Simple Payback (years) |
|---|---|---|---|---|
| 1. Over-Aerate Aeration Digesters and Reduce Flow of Aeration Blowers During Demand Response Events | 130.3 | 1,625 | 0 | Immediate |
| 2. Delay Operation of Centrifuge Systems During Demand Response Events | 160.7 | 2,006 | 0 | Immediate |
| 3. Over-Aerate Aeration Basin No. 3 and Reduce Flow of Blowers During Demand Response Events | 187.7 | 2,342 | 0 | Immediate |
| **Totals** | **478.7** | **5,973** | **0** | **0** |

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## Case Study: Retrofit Project (cont'd)
### Other Energy System Recommendation

| Other Energy System Opportunity | Potential Energy Conserved | Demand Savings | Potential Cost Savings | Potential Incentive | Implem. Cost | Simple Payback |
|---|---|---|---|---|---|---|
| 1 Install Anaerobic Digesters and a Combined Heat and Power System | 5,665,175 kWh/yr | 646.7 kW | $498,260/yr | $144,000 | $8,956,000 | 18 years |

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## Case Study: Retrofit Project (cont'd)

**Additional Energy Efficiency Recommendations**

- Install Higher Efficiency Lighting
- Repair Compressed Air Leaks
- Install a Diffused Air Aeration System in Older Aeration Basin
- Install a Supervisory Control and Data Acquisition (SCADA) System
- Install Variable Frequency Drives on Effluent Pumps
- Install Higher Efficiency Aeration Blowers
- Install a Photovoltaic System

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## Case Study: Retrofit Project (cont'd) Summary of Energy Savings

- Total Electrical Energy Savings: 3,263,566 kWh/yr *(~33% energy savings!!)*
- Demand Reduction: 375 kW
- Energy Cost Savings: $308,087/yr
- Without Incentives
- Total Incremental Costs: $726,948
- Payback Period: 2.4 years
- With Incentives
- Potential Incentives: $205,115
- Total Incremental Costs: $521,833
- Payback Period: 1.7 years

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## Case Study: Retrofit Project (cont'd) Implementation Results

- Energy Efficiency Measures *(4 recommendations)*
  - Facility plans on implementing all of the recommended measures and are in the process of trying to acquire funding for the projects
- Demand Response Measures *(3 recommendations)*
  - Facility does not plan on pursuing any demand response measures at this point
- Other Energy System Opportunity *(1 recommendation)*
  - Facility is investigating further into implementation of this measure

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## Case Study of a Design Review for a WWTP Expansion Project

## Case Study: Design Review of Expansion Project

**Background**

Expansion and upgrade of a conventional activated sludge WWT plant in California from 16 MGD to 32 MGD.

**Major Energy Consuming Equipment**

- Various Wastewater Pumps (*Influent, Sludge, Return Activated Sludge, Waste Activated Sludge, Effluent, etc.*)
- Centrifuge for Sludge Dewatering
- Aeration Blowers

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## Case Study: Design Review (cont'd)

### Energy Efficiency Measures

| Energy Efficiency Measure | Baseline | Energy Savings (kWh/yr) | Demand Reduction (kW) | Energy Cost Savings ($/yr) | Increm. Cost ($) | Potential Incentive ($) | Payback Period (yr) |
|---|---|---|---|---|---|---|---|
| 1. High Efficiency HVAC Units | CA Title 24 (Appliance Efficiency Regulations) | 20,939 | 9.6 | 2,513 | 17,500 | 2,931 | 5.8 |
| 2. High Efficiency Lighting | CA Title 24 (Area Category Method) | 104,588 | 12.8 | 12,551 | 0 | 5,229 | 0 |
| 3. Premium Efficiency Motors | 2005 CA Title 20 Standard Motors | 123,869 | 16.5 | 14,864 | 100,087 | 9,909 | 6.1 |
| 4. Variable Frequency Drives (VFDs) on Centrifuges | Constant Speed Centrifuge | 159,323 | 72.8 | 19,119 | 96,313 | 12,746 | 4.4 |
| 5. Automatic DO System & VFDs on Aeration Blowers | Manual Control DO System w/ Blowers Controlled On/Off | 945,157 | 108 | 113,539 | 159,750 | 75,693 | 0.7 |
| 6. Control Pumping Flow with VFDs | Pumps Operate On/Off at Rated Speed | 844,007 | 264.3 | 101,281 | 353,750 | 67,521 | 2.8 |
| 7. Fine Bubble Diffusers | Coarse Bubble Diffusers | 2,437,104 | 278.2 | 292,452 | 650,000 | 194,968 | 1.6 |

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## Case Study: Design Review (cont'd)
### Summary of Energy Savings

- Total Electrical Energy Savings: 4,635,987 kWh/yr
- Demand Reduction: 762 kW
- Energy Cost Savings: $556,319/yr
  *(assumed $0.12/kWh)*

- Without Incentives
- Total Incremental Costs: $1,377,400
- Payback Period: 2.5 years

- With Incentives
- Potential Incentives: $368,997
- Total Incremental Costs: $521,833
- Payback Period: 1.8 years

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## Benchmarking

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## Benchmarking WWTPs

- U.S Environmental Protection Agency has designed an internet-based benchmarking tool called ENERGY STAR Portfolio Manager for benchmarking municipal wastewater treatment facilities.
- Calculates weather normalized energy intensity (kBtu/MGD) for WWTPs based on user-specified data, which includes:
  - Location of plant
  - 12 months of energy data
  - Plant design flow rate (million gallons per day)
  - Average influent flow (million gallons per day)
  - Average influent and effluent biological oxygen demand (mg/l)
  - Whether trickle filtration is present
  - Whether nutrient removal is a part of process
- Scores plants on a scale of 1 to 100 – the higher the score the more efficient the plant is compared to other similar size plants in nation

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## Benchmarking WWTPs (cont'd)

- Benchmark best applied to WWTPs 150 MGD or smaller.
- Tool is based on survey of 257 plants by the American Waterworks Association Research Foundation
- Limitations of benchmark include:
  - Does not ask if plant is aerobic or anaerobic
  - Level of wastewater treatment
  - Major type of influent that is processed (industrial, residential, food processing, etc.)
  - Whether any on-site electricity generation is present

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## Implementation Barriers

## Barriers to Implementing Energy Efficiency Measures

- Meeting regulatory requirements is priority
- Capital investment to implement energy efficient projects
- Funding for projects must be approved by governing board
- Unaware of newer energy efficient technologies available
- Newer energy efficient technologies must be proven to operate effectively
- If process is working, hesitant to change process

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## Some Concluding Remarks

- Significant opportunities exist in wastewater treatment plants – retrofits, expansion or new construction
- According to the 2000 EPRI market assessment study, it is estimated that energy savings ranging from 20% to 40% are possible for the WWT industry
- Many programs are available to assist WWTP in implementing energy efficiency projects

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## Contact Information

*For more information please contact:*

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# Thank You!

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