

# **Addendum:**

## **Emerging Technologies**

*For Wastewater Treatment &  
In-Plant Wet Weather Management*

**EPA 832-R-11-002  
September 2011**

**Office of Wastewater Management  
U.S. Environmental Protection Agency  
Washington, D.C.**

# Preface

The U.S. Environmental Protection Agency (U.S. EPA) is charged by Congress with protecting the nation's land, air, and water resources. Under a mandate of environmental laws, the Agency strives to formulate and implement actions leading to a balance between human activities and the ability of natural systems to support and sustain life. To meet this mandate, the Office of Wastewater Management (OWM) provides information and technical support to solve environmental problems today and to build a knowledge base necessary to protect public health and the environment well into the future.

This publication has been updated to provide current state of development as of the publication date. It is expected that this document will be revised periodically to reflect other advances in this rapidly evolving area. Except as noted, information, interviews, and data development for the Addendum was collected by the EPA. Some of the information, especially related to embryonic technologies, was provided by the manufacturer or vendor of the equipment or technology, and could not be verified or supported by full-scale case study. In some cases, cost data were based on estimated savings without actual field data. When evaluating technologies, estimated costs, and stated performance, efforts should be made to collect current and more up-to-date information.

The mention of trade names, specific vendors, or products does not represent an actual or presumed endorsement, preference, or acceptance by the U.S. EPA or Federal Government. Stated results, conclusions, usage, or practices do not necessarily represent the views or policies of the U.S. EPA.

*Electronic copies of this addendum and the original emerging technologies document can be downloaded from the U.S. EPA Office of Wastewater Management web site at: <http://water.epa.gov/scitech/wastetech/publications.cfm>*

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## Chapter 6

### Energy Conservation Measures

#### 6.1 - Introduction

Energy consumption for municipal wastewater treatment accounts for 15% to 30% of the operating cost at large treatment facilities and 30% to 40% at small facilities (WEF, 2009). Energy is required throughout the wastewater treatment process and facilities, with aeration, pumping and solids management operations typically accounting for the greatest share of a utility's energy use. The demand and cost of this energy to a wastewater utility continues to rise due to a number of factors including:

- Implementation of increasingly stringent discharge requirements.
- Enhanced treatment of biosolids, including drying and pelletizing.
- Higher pumping and treatment requirements and costs associated with infiltration and inflow from aging wastewater collection systems.
- Increasing electricity rates associated with the cost of fossil fuels used for energy production and with construction of new electric power generating and distribution infrastructure to meet increasing demand.

As a consequence of rising energy demand and costs, many wastewater facilities have developed energy management strategies and implemented energy conservation measures (ECMs) to reduce their energy consumption and costs as well as reduce their carbon footprint and associated greenhouse gas emissions. ECMs are herein defined as energy efficient equipment retrofits, operational modifications and process control enhancements whose implementation leads to reduced energy consumption and costs and often, improved treatment efficiency. This chapter focuses on the advances in ECMs used at wastewater facilities, particularly those that have been developed and implemented over the past 5 years.

#### 6.2 - Technology Assessment

A summary of table of several innovative, emerging and established ECMs is provided in Table 6.1. Individual technology summary sheets with performance and cost/savings\* information are included for several innovative and emerging ECMs documented in the literature. Many energy conservation measures are established and essential measures relating to efficient pumping systems including pumps, drives and motors. In addition established ECMs include fine bubble diffuser systems that increase the oxygen transfer efficiency thereby decreasing energy demand. Other recently established processes includes the Vertical Linear Action Mixer which has been shown to effectively mix digester contents and significantly reduce energy consumption compared to other standard mixing methods (Massart, 2008).

Innovative development in energy conservation measures mainly focus on aeration system control or efficient equipment. Aeration ECMs control includes the Integrated Air Flow Control system which eliminates the pressure control loop common in many automatic DO control systems

leading to more efficient blower operation and reduced energy consumption. Also included is the Automated SRT/DO Control ECM which uses algorithms to optimize DO and SRT set points and reduce energy consumption while maintaining process performance. Innovative aeration equipment include highly efficient turbo blowers which use friction-free bearing designs coupled with the use of high efficiency motors and integral speed control to achieve high energy efficiency. Reactor mixing systems are also described including hyperbolic mixers which use a stirrer located close to the bottom of a tank to promote complete mixing. A pulsed large bubble mixing is included which achieves mixing requirements and reduced energy consumption by using short bursts of compressed air instead of mechanical mixers.

**Table 6.1 –Energy Conservation Measures – State of Development**

<b>Established Technologies</b>
Pumping
○ NEMA Premium® efficiency motors
○ Variable Frequency Drives (VFDs)
Aeration
○ Fine-Pore Aeration Diffusers
○ Adjustment of Submergence of Mechanical Mixers
○ Cycling Mechanical Aerators On and Off
○ Bioprocess Intelligent Optimization System (BIOS)
○ Incineration Heat Recovery
<b>Innovative Technologies</b>
Aeration Systems
○ Integrated Air Flow Control
○ Automated SRT/DO Control
○ Intermittent Mixing
○ Pump Station Optimization
○ High Speed (Gearless) Turbo Blowers
○ Dual Impeller Aerator (mechanical mixing)
○ Single-stage Centrifugal Blowers with Inlet Guide Vanes and Variable Diffuser Vanes
○ Hyperbolic Mixers
○ Pulsed Large Bubble Mixing
○ Bioprocess Intelligent Optimization System (BIOS)
○ New Diffuser Cleaning Technology
<b>Emerging Technologies</b>
Aeration Systems
○ Critical Oxygen Point Control
○ Ultra-fine Bubble Diffusers
Other Processes
○ Low Pressure Low Output Lamps for UV Disinfection
○ Automated Channel Routing for UV Disinfection
Membrane Air Scour Alternatives
○ Solar Drying

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## Technology Summary

### Integrated Air Flow Control

#### Objective:

Integrated Air Flow Control is a proprietary aeration control system which can result in better stability and simplified tuning of the aeration system process leading to more efficient blower operation and reduced energy consumption.

#### State of Development:

Innovative. This technology is being used in the US and is approaching an established process.

#### Description:

This technology eliminates the pressure control loop common in many automatic DO control systems. The pressure control loop can cause instability in the operation of the blowers and control valves (cyclic oscillation, or hunting) as the control system attempts to adjust air flow and pressure in response to changes in the process and ambient air conditions.

#### Comparison to Established Technologies:

This technology represents an improvement to previous automated control systems that use cascaded control strategy that includes a pressure control loop's output as a setpoint for blower air control. Energy savings on the order of 10% have been reported from implementing this technology.

#### Available Cost Information\*:

Project Cost of \$200,000 (2007 Dollars) for a 23.7 MGD plant (average daily flow) with average energy savings of \$135,786/yr and a simple payback period of 1.5 years.

#### Vendor Name:

Dresser Roots (see web for various regional offices)

#### Installations:

Bucklin Point WWTF/United Water  
102 Campbell Avenue  
East Providence, RI 02916

Brent Herring, Superintendent  
401-434-6350 X-182

#### Key Words for Internet Search:

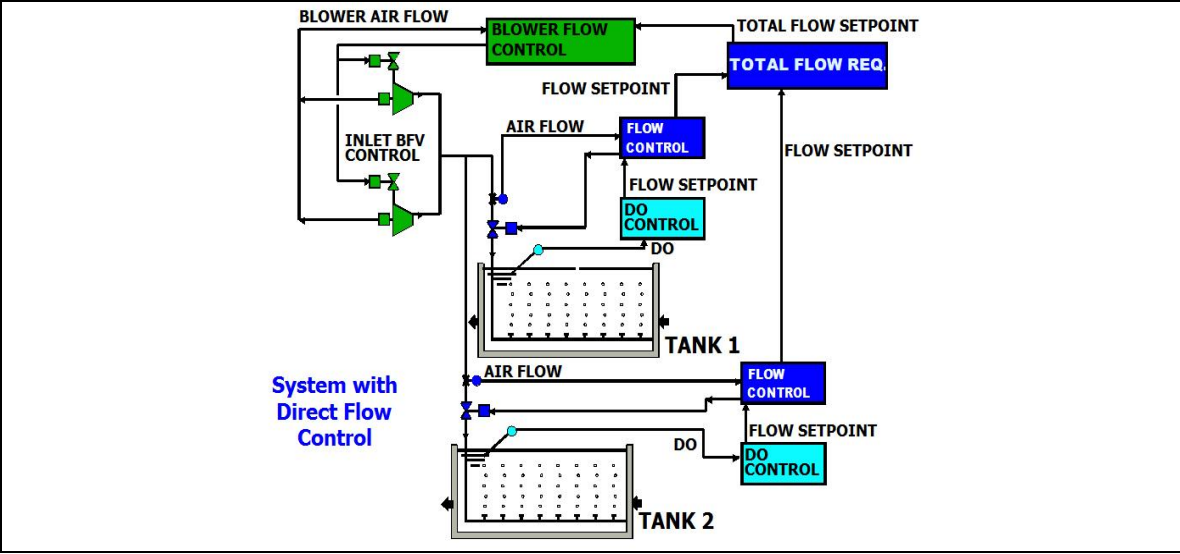
Do control, blower control, wastewater treatment

#### Data Sources:

Bucklin Point WWTF/United Water

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10-005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>



Integrated Air Flow Control Diagram



**Automated SRT/DO Control**

**Objective:**

Optimization and automatic control of dissolved oxygen (DO) and sludge age (SRT) in aeration systems to optimize DO and SRT set points and reduce energy consumption while maintaining process performance.

**State of Development:**

Innovative. The OPTIMaster™ algorithm is approaching an established process while SRTMaster™ has been implemented for over 12 years and DOMaster™ was implemented over 8 years.

**Description:**

Proprietary algorithms (OPTIMaster™), (DOMaster™) and (SRTMaster™) which provide set point optimization based on actual data and process variables: sludge modeling, plant historical data, and statistical process control. The software utilizes a biological process model based control algorithms for sludge age and DO and automates control of these parameters (through automatic sludge wasting and blower output adjustment) to optimize aeration. OPTIMaster™, DOMaster™ and SRTMaster™ could be used separately or together.

**Comparison to Established Technologies:**

This technology represents an improvement to conventional technology as follows:

SRTMaster™ allows the automatic control of SRT and equalization of mass solids loading on thickening facility, improving activated sludge process stability and reducing energy usage and chemicals use for sludge thickening. DOMaster™ is an improvement over traditional DO control because it provides more robust control by using activated sludge modeling and data mining instead of traditional proportional–integral–derivative (PID) control. OPTIMaster™ allows automatic selection of DO and SRT set points. The criteria for selection are reduction of energy usage while maintaining low effluent suspended solids concentration and absence of foam.

All software modules have artificial intelligence features used for alerting operators about meter problems (TSS, DO, Flow) as well as changes in process BOD loadings or migration of solids to the clarifiers.

**Available Cost Information:**

Project Cost of \$135,000 for a 22.4 MGD plant (average daily flow) with average energy savings of \$26,980/yr and a simple payback period of 5 years.

**Vendor Name:**

Ekster and Associates Inc.  
 1904 Lockwood Ave.  
 Fremont, CA 94539  
 tel: (510) 657-7066  
 E-mail: [info@srtcontrol.com](mailto:info@srtcontrol.com)

**Installations:**

Oxnard Wastewater Treatment Plant  
6001 Perkins Road  
Oxnard, CA 93033-9047

Mark Moise, Operations Manager  
(805) 488-3517

Email: Mark.Moise@ci.oxnard.ca.us

**Key Words for Internet Search:**

DO control algorithm, SRT control algorithm, OPTIMaster™, SRTMaster™, DMaster™, wastewater treatment, Ekster

**Data Sources:**

Oxnard Wastewater Treatment Plant

Mark Moise, Alex Ekster , *Operation of a Solids Contact Tank at Low Dissolved Oxygen and Low Total Suspended Solids Concentrations*, Proceedings of WEFTEC, Conference and Exposition, San Diego, 2007.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

## Technology Summary

### Intermittent Mixing

#### Objective:

Reduce energy usage for maintaining solids in suspension in biological nutrient removal reactors and mixed liquor channels.

#### State of Development:

Innovative. This technology is being used in the US and has been implemented at a US plant in 2008.

#### Description:

An optimization algorithm is used to convert mixing in the anoxic/anaerobic zones of BNR reactors and mixed liquor channels from continuous to intermittent (On/Off). This patent pending method of maintaining solids in suspension allows reduced energy usage without compromising effluent quality and process reliability. A special programming routine is used to avoid aeration control system oscillation. The routine sequences the tanks rather than simultaneously providing air to all the tanks to re-suspend solids.

Aeration system modifications are often required including installation of new valves, actuators, pneumatic lines, and electrical systems, in addition to control system programming.

#### Comparison to Established Technologies:

As shown below, the intermittent mixing provides significant energy savings compared to the continuous mixing method.

#### Available Cost Information:

Project Cost of \$ 181,592 for a 167MGD plant (average daily flow) at the San Jose/Santa Clara Water Pollution Control Plant, with average energy savings of \$ 757,614 and a simple payback period of 3 months. This corresponds to reduction in associated aeration energy in the range of 23% and 38%. Another study showed pulse aeration of anaerobic and anoxic zones resulted in 13% less aeration demand with an annual energy saving potential close to \$430,000.

#### Vendor Name:

Ekster and Associates Inc.  
1904 Lockwood Ave.  
Fremont, CA 94539  
tel: (510) 657-7066  
E-mail: [info@srtcontrol.com](mailto:info@srtcontrol.com)

#### Installations:

San Jose/ Santa Clara Water Pollution Control Plant (SJ/SC WPCP)  
700 Los Esters Rd.,  
San Jose, CA 95134  
Bhavani.Yerrapotu, Division Manager  
Telephone: (408) 945-5300  
Bhavani.Yerrapotu @sanjoseca.gov

**Key Words for Internet Search:**

Pump stations, Pumping, Pumps Scheduling, Ekster

**Data Sources:**

San Jose/ Santa Clara Water Pollution Control Plant

Issayas T. Lemma, Steve Colby, Tom Herrington *Pulse Aeration of Secondary Aeration Tanks Holds Energy Saving Potential without Compromising Effluent Quality*  
Proceedings of 82nd WEFTEC, Conference and Exposition, Orlando, 2009.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

## Technology Summary

Pump Station Optimization
<p><b>Objective:</b> Optimization of pump station operation by selecting the optimum combination of pumps in operation for each flow to maintain peak efficiency for each pump and, as a result, reduce energy use and pump maintenance. This selection is automated using proprietary software.</p> <p><b>State of Development:</b> Innovative. This technology is being used in the US and has been implemented at a US plant in 2008.</p>
<p><b>Description:</b> The optimization program utilizes field data such as pump station flows, pump discharge pressures, wet well levels, and pump power usage to select the combination of pumps and pump speed at each flow rate. The software program utilizes two optimization algorithms in tandem (genetic and gradient reduction algorithms) rather than a single algorithm. The vendor reports that this methodology guarantees that the selected pumps and speed combination for each flow regime results in the consumption of less energy compared to any other possible combination. Pump station energy reduction in the range of 17% and 23.5% has been reported at the San Jose/Santa Clara Water Pollution Control Plant.</p>
<p><b>Comparison to Established Technologies:</b> This software program allows optimization of combinations of pumps equipped with constant speed and variable speed motors.</p>
<p><b>Available Cost Information:</b> Project Cost of \$43,768 for a 167 MGD plant (average daily flow) with average annual energy savings of \$ 244,858 and a simple payback period of 2.1 month.</p>
<p><b>Vendor Name:</b> Ekster and Associates Inc. 1904 Lockwood Ave. Fremont, CA 94539 tel: (510) 657-7066 E-mail: <a href="mailto:info@srtcontrol.com">info@srtcontrol.com</a></p> <p><b>Installations:</b> San Jose/ Santa Clara Water Pollution Control Plant (SJ/SC WPCP) 700 Los Esteros Rd., San Jose, CA 95134 Bhavani.Yerrapotu, Deputy Director Telephone: (408) 945-5300 Bhavani.Yerrapotu @sanjoseca.gov</p>
<p><b>Key Words for Internet Search:</b> Pump stations, Pumping, Pumps Scheduling, Ekster</p>

**Data Sources:**

San Jose/ Santa Clara Water Pollution Control Plant

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

**High Speed (Gearless) Turbo Blowers**

**Objective:**

Improved blower and aeration efficiency by using advanced bearing designs to operate at higher speeds with less energy input compared to multi-stage centrifugal and positive displacement blowers.

**State of Development:**

Innovative. Introduced in the U.S. market around 2007 and have been and are being tested and installed in a number of plants.

**Description:**

The technology employs advanced bearing designs resulting in near friction-free operation at higher speeds (upwards of 40,000 rpm) with less energy input compared to multi-stage centrifugal and positive displacement blowers. Turbo blowers typically are configured as package systems with integrated VFDs and automated control systems that improve the technology's energy efficiency. They are currently available in two primary configurations: (1) air bearing and (2) magnetic bearing. In an air bearing blower, an air film is formed between the impeller shaft and its bearings as the shaft rotates at high speeds, resulting in floating of the shaft and integral impeller. In a magnetic bearing design, the impeller shaft is magnetically levitated to provide floating of the shaft. This friction-free bearing design coupled with the use of high efficiency motors and integral speed control contributes to the comparative high energy efficiency of the turbo blower technology.

**Comparison to Established Technologies:**

Turbo blowers have many practical advantages (Gass, 2009 and Jones, 2009) including 10% to 20% more energy efficiency compared to multi-stage centrifugal and positive displacement blowers. They also exhibit good turndown capacity (up to 50%) with little efficiency drop off, small footprint and light weight. They are generally quiet, with low vibration and few moving parts, and have relatively low maintenance requirements.

**Available Cost Information:**

The De Pere Plant in Green Bay, WI, magnetic bearing design:

Project Cost of \$850,000 (2005 Dollars) for an 8.0 MGD plant (average daily flow) with average energy savings of \$63,758 /yr and a simple payback period of 13.3 years.

The Big Gultch Plant in Mukilteo, WA, air bearing design:

Project Cost of \$1,446,304 for a 1.45 MGD plant (average daily flow) with average energy savings of \$43,756/yr (estimated in 2010) and a simple payback period of 33 years (based on adjusted loading basis).

**Vendor Name:**

ABS USA  
140 Pondview Drive  
Meriden, CT 06450

Tel: 203-238-2700  
Fax: 203-514-4364  
E-mail: [info.abs.usa@cardo.com](mailto:info.abs.usa@cardo.com)

**Installations:**

Green Bay metropolitan Sewerage District - DePere Wastewater Treatment Plant  
315 Leonard Street  
De Pere, WI 54115

Michael Kersten  
Operations Manager  
Telephone: (920) 339-4094  
email: [mkersten@gbmsd.org](mailto:mkersten@gbmsd.org)

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**Vendor Name:**

KTurbo USA Inc.  
118 Pierson Drive, Unit 118  
Batavia, IL 6-510  
Tel: 630-406-1473  
Email: [trinity@kturbo.co](mailto:trinity@kturbo.co)

**Installations:**

Big Gulch Wastewater Treatment Facility  
Mukilteo Water & Wastewater District  
PO BOX 260  
Mukilteo, WA 98275

Thomas G. Bridges  
Wastewater Treatment Plant Manager  
Telephone: 425-355-6637  
email: [gilb@mukilteowwd.org](mailto:gilb@mukilteowwd.org)

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**Key Words for Internet Search:**

Turbo, high speed, frictionless, high efficiency blower

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**Data Sources:**

Gray & Osborne, Inc. 2008. *Wastewater Treatment Plant Capacity Study and Engineering Report*. March, 2008.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>





High-Speed Turbo Blower with Air Bearings  
Reproduced courtesy of HSI, Inc.

High-Speed Turbo Blower with Magnetic Bearings  
Reproduced courtesy of Atlas Copco

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## Technology Summary

Dual Impeller Aerator (mechanical mixing)
<p><b>Objective:</b> Provide additional mixing energy near the floor of an aeration basin, permitting greater power turndown when a VFD is used and an associated energy savings.</p> <p><b>State of Development:</b> Innovative.</p>
<p><b>Description:</b> A dual impeller aerator by Eimco Water Technologies includes a lower impeller near the bottom of the basin floor to augment the surface impeller. This provides additional mixing energy near the floor of the basin, permitting greater power turndown when a VFD is used and an associated energy savings.</p>
<p><b>Comparison to Established Technologies:</b> Improved energy efficiency compared to single impeller mechanical aerators which are limited in their turn down due to the need to keep the contents of the basin from settling.</p>
<p><b>Available Cost Information:</b> Not available.</p>
<p><b>Vendor Name:</b> Ovivo USA (Formerly Eimco Water Technologies LLC) 2404 Rutland Drive Austin, TX 78758</p> <p>Tel: 512-834-6000 Fax: 512-834-6039 Email : <a href="mailto:info.US@ovivowater.com">info.US@ovivowater.com</a></p>
<p><b>Installations:</b> Information not available.</p>
<p><b>Key Words for Internet Search:</b> Dual impeller, turn down, basin floor mixing. Energy efficient mixing</p>
<p><b>Data Sources:</b> USEPA (2010) <i>Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities</i>. Office of Water. EPA 832-R-10- 005 September 2010. <a href="http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf">http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf</a></p>

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## Technology Summary

### Single-stage Centrifugal Blowers with Inlet Guide Vanes and Variable Diffuser Vanes

#### Objective:

Utilizing inlet guide vanes and variable outlet vane diffusers on a single stage centrifugal blower makes it possible to operate the blower at its highest efficiency point.

#### State of Development:

Innovative (some, but not all turbocompressors, are innovative).

#### Description:

Single-stage centrifugal blowers equipped with inlet guide vanes pre-rotate the intake air before it enters the high speed blower impellers. This reduces flow more efficiently than throttling. Blowers that are also equipped with variable outlet vane diffusers have improved control of the output air volume. Utilizing inlet guide vane and discharge diffusers on a single-stage centrifugal blower makes it possible to operate the blower at its highest efficiency point, not only at the design condition but also within a greater range outside of the design condition. PLC control can be used to optimize inlet guide vane operation (i.e., positioning) based on ambient temperature, differential pressure, and machine capacity. Automated DO and variable header pressure control can increase efficiency.

#### Comparison to Established Technologies:

Increased energy efficiency compared to positive displacement blowers. Can be less maintenance intensive, and can result in lower monitoring/operational costs if properly automated.

#### Available Cost Information:

Project Cost of \$901,000 for an 11.8 MGD plant (average daily flow) with average energy savings of \$63,889/yr and a simple payback period of 14 years.

#### Vendor Name:

Siemens Energy – Turbo machinery Solutions  
4654 W. Farm Road 130  
Springfield, MO 65802  
Tel: 800-299-1035 or 417-864-5599  
Fax: 417-866-0235

#### Installations:

Sheboygan Regional Wastewater Treatment Plant  
3333 Lakeshore Drive  
Sheboygan, WI 53081

Dale Doer

Wastewater Superintendent

Tel: 920-459-3464

Single Stage, mail: [Dale.doerr@sheboyganwwtp.com](mailto:Dale.doerr@sheboyganwwtp.com)

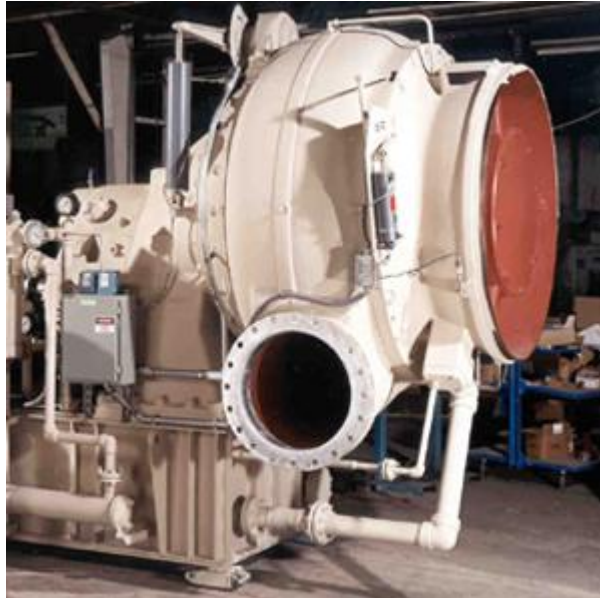
#### Key Words for Internet Search:

Single Stage Blower, Inlet Guide Vanes, Variable diffuser Vane

**Data Sources:**

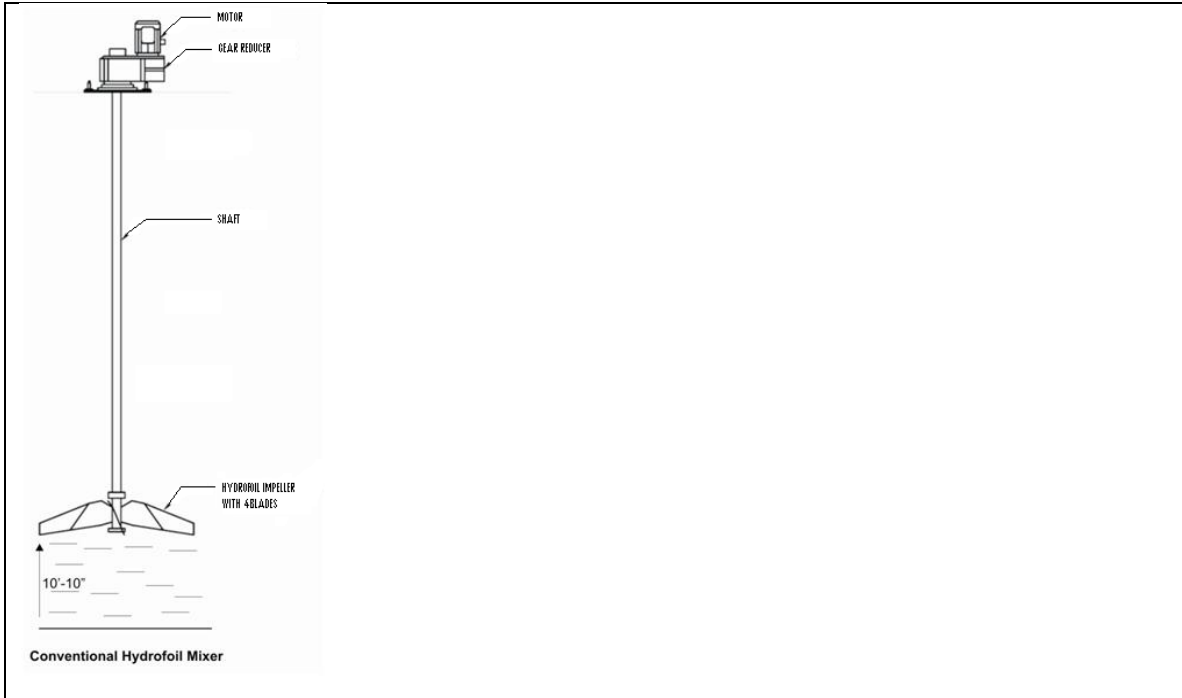
USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>



Single-Stage Centrifugal Blower with Inlet Guide Vanes and Variable Diffuser Vanes by Turblex® (now part of Siemens Energy). Used with permission.

Hyperbolic Mixers
<p><b>Objective:</b> Hyperboloid mixer results in increased efficiency by promoting complete mixing, and has shown significant energy savings compared to traditional submersible mixers.</p> <p><b>State of Development:</b> The hyperboloid mixer has undergone full-scale testing at two large wastewater treatment plants in the U.S. It has been used in Europe for more than ten years with installations in Germany, Holland, and Belgium (Gidugu et al. 2010).</p>
<p><b>Description:</b> The mixer is a vertical shaft-type mixer with a hyperboloid-shaped stirrer located close to the bottom of a tank. The stirrer is equipped with transport ribs that cause acceleration of the wastewater in a radial direction to promote complete mixing (see schematic below).</p>
<p><b>Comparison to Established Technologies:</b></p>
<p><b>Available Cost Information:</b></p>
<p><b>Vendor Name:</b></p> <p><b>Installations:</b></p>
<p><b>Key Words for Internet Search:</b></p>
<p><b>Data Sources:</b> Gidugu, S., S. Oton, and K. Ramalingam. 2010. Thorough Mixing Versus Energy Consumption. New England Water Environment Association Journal, Spring 2010.</p>



Conventional Hydrofoil Mixer  
Source: Gidugu et al. Used with permission.



Pulsed Large Bubble Mixing	
<p><b>Objective:</b> An innovative mixing technology by Enviromix called BioMx® reduces energy required for anoxic or anaerobic zone mixing by firing short bursts of compressed air into the zone instead of mechanically mixing it.</p> <p><b>State of Development:</b> Innovative.</p>	
<p><b>Description:</b> Uniquely designed nozzles produce a mass of large air bubbles, ranging from marble to softball size, which mix the water as they rise to the surface. The large air bubbles, much larger than those made by coarse bubble diffusers, are designed to minimize oxygen transfer and maintain anoxic or anaerobic conditions. The system includes a PLC to manage the timing of the air control valve firing, which gives the operator flexibility to respond to different conditions within the tank.</p>	
<p><b>Comparison to Established Technologies:</b> Testing at the F. Wayne Hill Water Resources Center in Gwinnett County, Georgia showed that energy (in kW) required to mix one anaerobic cell using the BioMx® system was 45 percent less than the energy required by a submersible mixer. Also, when operated in three cells using the same compressor, 60 percent less energy was required. The manufacturer reports that the system has non-clogging, self cleaning in-tank components that require no maintenance.</p>	
<p><b>Available Cost Information:</b> Not Available</p>	
<p><b>Vendor Name:</b> EnviroMix 180 East Bay Suite 200 Charleston, SC 29401 Tel: 843-573-7510 Fax: 843-573-7531 Email: <a href="mailto:sales@enviro-mix.com">sales@enviro-mix.com</a></p>	
<p><b>Installations:</b> Testing done at the F. Wayne Hill Water Resources Center in Gwinnett County, Georgia in 2009-2010.</p>	
<p><b>Key Words for Internet Search:</b> Coarse bubble, Pulse mixing,</p>	
<p><b>Data Sources:</b> Randall, C.W. and W. O. Randall. 2010. <i>Comparative Analysis of a Biomix System and a Submersible Propeller Mixer: Mixing in Anaerobic Zones at the F. Wayne Hill Water Resources Center, Buford, Georgia.</i> (Report provided in an e-mail from Clifford W. Randall on May 4, 2010).</p>	

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.  
<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

**Critical Oxygen Point Control**

**Objective:**

Improve aeration efficiency by controlling the optimum delivery of oxygen in the aeration basins. This is done by determining the critical oxygen point of the wastewater under aeration and utilizing this data to change the DO setpoint.

**State of Development:**

Emerging.

**Description:**

Critical oxygen point control is a control method based on respirometric measurements. Bacteria respire by diffusion of oxygen across their cell wall. Oxygen diffuses from a high concentration external to the bacterial cell wall to the low concentration internal to the bacterial cell. Diffusion will only take place once the oxygen concentration differential across the cell wall is sufficient to drive the oxygen through it. The minimum concentration at which this occurs is called the critical oxygen point. Below the critical oxygen point, the biodegradation rate will rapidly decrease. At the critical oxygen point, the biodegradation rate will be at a maximum for the available food source (i.e., organic compounds and ammonia in the wastewater being treated). Accurately knowing the critical oxygen point for the active biomass allows the optimal DO setpoint to be determined.

Strathkelvin Instruments (Scotland, UK) has developed a proprietary software upgrade to their Strathtox line of respirometers that, in real time, determines the critical oxygen point of the wastewater under aeration and utilizes this data to change the DO setpoint to control the optimum delivery of oxygen in the aeration basins.

**Comparison to Established Technologies:**

The vendor claims substantial savings in reducing aeration cycles while increasing utilization of available capacity and reducing energy costs.

**Available Cost Information:**

Not available

**Vendor Name:**

Strathkelvin Instruments Limited,  
Rowantree Avenue,  
North Lanarkshire,  
ML1 5RX,  
Scotland, UK

**Tel:** 01698 730400

**Fax:** 01698 730401

**Email:** [info@strathkelvin.com](mailto:info@strathkelvin.com)

**Installations:**

See website which reports on a plant in the UK that reduced plant capacity by 25% resulting in CO<sub>2</sub> and energy reduction while maintaining compliance.

<http://pdfs.findtheneedle.co.uk/107710-1483.pdf>

**Key Words for Internet Search:**

Aeration efficiency, Critical Oxygen Point, respirometric measurements, optimal DO setpoint

**Data Sources:**

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

[http://www.strathkelvin.com/waste\\_water/applications.asp](http://www.strathkelvin.com/waste_water/applications.asp)

**Ultra-fine Bubble Diffusers**

**Objective:**

Use of advanced diffuser technology in aerobic biological treatment processes to achieve enhanced energy reduction over fine bubble diffusers.

**State of Development:**

Emerging.

**Description:**

Recent advances in membrane materials have led to ultra-fine bubble diffusers, which generate bubbles with an average diameter between 0.2 and 1.0 mm. The primary appeal of ultra-fine bubble diffusion is improved oxygen transfer efficiency (OTE). Additionally, some composite materials used in the manufacture of ultra-fine bubble diffusers are claimed to be more resistant to fouling, which serves to maintain the OTE and reduce the frequency of cleaning. Concerns about ultra-fine bubble diffusion include slow rise rates and the potential for inadequate mixing. Two proprietary ultra-fine bubble diffuser designs, panel diffusers by Parkson and AeroStrip® diffusers by the AeroStrip Corporation, are discussed below.

**Comparison to Established Technologies:**

Ultra-fine Bubble Diffusers are reported to achieve enhanced energy reduction over fine bubble diffusers. The advantages of panel diffusers include the increased OTE and the even distribution of aeration. Disadvantages can include a higher capital cost, a higher head loss across the diffuser, increased air filtration requirements, and a tendency to tear when over-pressurized.

Panel diffusers by Parkson are membrane type diffusers built onto a rectangular panel. They are designed to cover large areas of the basin floor and lay close to the floor. Panel diffusers are constructed of polyurethane and generate a bubble with a diameter of about one mm.

AeroStrip® is a proprietary diffuser design manufactured in Austria by Aquaconsult. The device is a long strip diffuser with a large aspect ratio. According to the manufacturer, it is a homogenous thermoplastic membrane held in place by a stainless steel plate. The AeroStrip® diffuser provides many of the same advantages and disadvantages as panel diffusers; however, it appears to be less prone to tearing. Also, the smaller strips allow tapering of the diffuser placement to match oxygen demand across the basin. AeroStrips may be mounted at floor level or on supports above the floor.

Manufacturer’s claims regarding the strip membrane diffuser include:

- Energy efficiencies between 10 percent and 20 percent greater than the traditional ceramic and elastomeric membrane diffuser configurations.
- Uniform bubble release across the membrane surface.
- Bubbles resist coalescing.
- Membrane not prone to clogging.

<ul style="list-style-type: none"> <li>○ Diffusers are self cleaning, although AeroStrip panels have been reported to be susceptible to frequent fouling requiring bumping and flexing of the membrane to dislodge.</li> </ul>
<p><b>Available Cost Information:</b> Not available.</p>
<p><b>Vendor Name:</b> Parkson Corporation telephone 1.888.PARKSON fax 954.974.6182 <a href="mailto:technology@parkson.com">technology@parkson.com</a></p> <p>AQUACONSULT Anlagenbau Ges.m.b.H.Wassergasse 22-26/9 A- 2500 Baden Austria</p> <p>Tel.: +43-2252 41 481 Fax: +43-2252 41 480 e-mail: <a href="mailto:office@aquiconsult.at">office@aquiconsult.at</a></p> <p><b>Installations:</b> Information not available.</p>
<p><b>Key Words for Internet Search:</b> Fine bubble diffuser, panel diffuser, strip diffuser, thermoplastic membrane</p>
<p><b>Data Sources:</b> <a href="http://www.parkson.com/files/Brochures/HiOx_UltraFlex_Aeration_System.pdf">http://www.parkson.com/files/Brochures/HiOx_UltraFlex_Aeration_System.pdf</a> <a href="http://www.aquiconsult.at/indexe.php">http://www.aquiconsult.at/indexe.php</a></p> <p>USEPA (2010) <i>Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities</i>. Office of Water. EPA 832-R-10- 005 September 2010. <a href="http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf">http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf</a></p>

Low Pressure High Output Lamps for UV Disinfection

Objective:

Reduce energy consumption for UV disinfection by replacing medium pressure lamps with low pressure low output lamps.

State of Development:

Emerging.

Description:

Low-pressure high-output lamps are similar to low-pressure low-intensity lamps except that a mercury amalgam is used instead of mercury gas.

Comparison to Established Technologies:

In some cases, WWTPs can save on energy costs by specifying low-pressure low intensity lamps. The power draw can be significantly lower than medium-pressure lamps. Tradeoffs are (1) a larger footprint for the same disinfection level, which can be significant because as many as 20 low-pressure low-intensity lamps are needed to produce the same disinfecting power as one medium-pressure lamp, and (2) higher operating costs for maintenance and change out of additional lamps.

Leong et al. (2008) reported that the energy demand for low-pressure high-output systems is similar to that of low-pressure low-intensity systems. Thus, low-pressure high-output lamps may be a good option for reducing the number of lamps and footprint while keeping the energy requirements low. Salveson et al. (2009) presented results of a pilot test at the Stockton, CA WWTP comparing design conditions and operation of medium pressure and low-pressure high-output lamps. The power draw for the low-pressure high-output lamps was between 20 and 30 percent of the power draw for the medium pressure lamps, reducing annual O&M costs significantly. These results are similar to information reported from one manufacturer for a 30 mgd plant treating secondary effluent.

Available Cost Information:

Information not available.

Vendor Name:

Calgon Carbon Corporation  
 P.O. Box 717  
 Pittsburgh, PA 15230  
 Tel: 800-4CARBON  
 Phone: 412 787-6700  
 Fax: 412 787-6676  
[info@calgoncarbon-us.com](mailto:info@calgoncarbon-us.com)

Installations:

Results of a pilot test at the Stockton, CA WWTP were reported in the report referenced below by Salveson et al. (2009).

**Key Words for Internet Search:**

UV disinfection, low-pressure low intensity lamps, low-pressure high-output lamps.

**Data Sources:**

Salveson, A., T. Wade, K. Bircher, and B. Sotirakos. 2009. *High Energy Efficiency and Small Footprint with High-Wattage Low Pressure UV Disinfection for Water Reuse*. Presented at the International Ultraviolet Association (IUVA)/ International Ozone Association (IOA) North American Conference. May 5, 2009. Boston, MA.

Leong, L.Y.C., J. Kuo, and C Tang. 2008. *Disinfection of Wastewater Effluent—Comparison of Alternative Technologies*. Water Environment Research Foundation (WERF), Alexandria, VA.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>



Automated Channel Routing for UV Disinfection
<p><b>Objective:</b> Reduce energy use and extend UV lamp life for UV disinfection systems.</p> <p><b>State of Development:</b> Emerging.</p>
<p><b>Description:</b> Automation can reduce the number of lamps and/or channels operating based on real-time flow and wastewater characteristic data. Controls can be designed to turn off lamps or divert flow to a few operating channels depending on the UV system design. Control is most commonly flow-paced control or dose-paced control. Flow-paced is the simplest with number of lamps/channels in service based strictly on influent flow rate. Dose-paced control is based on the calculated dose, which is derived from flow rate, UV transmittance (UVT) and lamp power (including lamp age and on-line intensity output) data (Leong et al. 2008). During periods of high solids removal, UVT will increase and UV output can be decreased to achieve the same dose. During wet weather events or other periods of low effluent quality, lamp output can be increased in response to reduced UVT.</p>
<p><b>Comparison to Established Technologies:</b> At the University of California, Davis Wastewater Treatment Plant, process controls were implemented to divert flow automatically to one of two channels during low flow conditions (Phillips and Fan 2005). This change provided the flexibility to operate at 33, 50, 67 and 100 percent of maximum power. The original design limited operation to 67 and 100 percent of maximum power. The annual energy use at the UC Davis WWTP is expected to decrease by 25 percent once the process changes are fully implemented in the fall of 2010.</p>
<p><b>Available Cost Information:</b> Information not available.</p>
<p><b>Vendor Name:</b> Information not available</p> <p><b>Installations:</b> University of California, Davis Wastewater Treatment Plant Mike Fan, Superintendent Waste Water Treatment and Solid Waste Tel: 530- 752-7553 Email: <a href="mailto:mmfan@ucdavis.edu">mmfan@ucdavis.edu</a></p>
<p><b>Key Words for Internet Search:</b> UV disinfection, automated channel routing, energy efficient UV control</p>
<p><b>Data Sources:</b> Leong, L.Y.C., J. Kuo, and C Tang. 2008. <i>Disinfection of Wastewater Effluent—Comparison of Alternative Technologies</i>. Water Environment Research Foundation (WERF), Alexandria, VA.</p>

Phillips, D. L. and M. M. Fan. 2005. *Automated Channel Routing to Reduce Energy Use in Wastewater UV Disinfection Systems*. University of California, Davis. Davis, California.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

Membrane Air Scour Alternatives
<p><b>Objective:</b> Reduce membrane fouling by providing energy efficient air scour fouling control and operational strategies.</p>
<p><b>State of Development:</b> Emerging.</p>
<p><b>Description:</b> Several membrane manufacturers have modified operational strategies to reduce air scour fouling control requirements (Wallis-Lage and Levesque 2009), particularly for MBR systems.</p> <p>For example, Kubota varies the volume of air used for aeration based on the flux (e.g., lower air scour rates are used for lower flux values). The manufacturer of the Huber system claims reduced energy consumption for air scour due to a centrally positioned air intake and low pressure. Siemens uses a combination of air and water to scour the membrane (Wallis-Lage and Levesque 2009). General Electric (GE) implemented “cyclic” air scour whereby aeration would be turned on and off in 10 second intervals. A newer innovation is their 10/30 Eco-aeration where the membrane is scoured for 10 seconds on, 30 seconds off during non-peak flow conditions. GE claims that the 10/30 Eco-aeration can reduce energy consumption by up to 50 percent compared to the standard 10/10 aeration protocol (Ginzburg et al. 2008).</p>
<p><b>Comparison to Established Technologies:</b> The literature includes pilot- and full-scale test data for a membrane fouling controller and algorithm used to clean the GE ZENON ZeeWeed MBR. The system uses real-time analysis of the membrane’s filtration operating conditions to determine the fouling mechanism present in the MBR system. The information obtained from the algorithm dictates the implementation of specific control actions to respond to the particular fouling mechanism (e.g., membrane aeration, backwash, chemical cleaning – the biggest impact on energy consumption being membrane aeration). When aeration is identified as the control action, the fouling controller/algorithm provides the MBR Programmable Logic Controller (PLC) system the information to select between the traditional 10/10 (air scour On/Off) protocol and a 10/30 Eco Aeration energy saving protocol. The algorithm was piloted and later full-scale tested at a 3 million gallon per day (mgd) plant in Pooler, Georgia (Ginsburg et al. 2008). Ginzburg (2008) concluded that additional research is required to further develop the on-line fouling controller to include additional control parameters such as membrane aeration flow rate, backwash flow rate, and backwash duration.</p>
<p><b>Available Cost Information:</b> Information not available.</p>
<p><b>Vendor Name:</b> Enviroquip (a division of Eimco Water Technologies) -partnership with Kubota Corporation, Japan)</p>

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Austin, TX 78758  
Tel: 512-834-6000  
Fax: 512-834-6039  
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HUBER SE  
Industriepark Erasbach A1  
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Germany  
Tel: +49-8462-201-0  
Fax: +49-8462-201-810  
Email: [info@huber.de](mailto:info@huber.de)

ZENON Membrane Solutions (GE)  
Oakville, Ontario, Canada  
Tel: 905-465-3030  
Email: [www.gewater.com](http://www.gewater.com)

Seimens Water Technologies  
Warrendale, PA  
Tel: 866.926.8420  
Email: [information.water@siemens.com](mailto:information.water@siemens.com)

**Installations:**

Pilot and full scale testing was conducted at a wastewater treatment plant in Pooler, Gerogia. See data reference below.

**Key Words for Internet Search:**

Membrane Air Scour, membrane cleaning, membrane fouling, MBR efficiency

**Data Sources:**

Wallis-Lage, C.L. and S. D. Levesque. 2009. *Cost Effective & Energy Efficient MBR Systems*. Presented at the Singapore International Water Week. June 22 – 26, 2009. Suntec Singapore International Convention and Exhibition Center.

Ginzburg, B., J. Peeters, and J. Pawloski. 2008. *On-line Fouling Control for Energy Reduction in Membrane Bioreactors*. Presented at Membrane Technology 2008. Atlanta, GA. WEF.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

**Solar Drying of Sewage Sludge**

**Objective:**

Use of solar heat to evaporate residual water from sludge, reduce thermal energy requirements and sludge utilization/disposal costs.

**State of Development:**

Emerging.

**Description:**

Thermal drying is the use of heat to evaporate residual water from sludge. It typically follows dewatering and can increase the dry solids content from between 18 and 30 percent to more than 90 percent (WEF 2009). The thermal drying process reduces the mass and volume of dewatered solids and results in a product with a high nutrient and organic content that can be used as a low-grade fertilizer. WEF and ASCE (2010) report on growing use in Europe and the United States of an emerging ECM for thermal drying called solar drying. First developed by researchers in Germany, solar drying uses solar energy and convective air drying methods to produce solids containing no more than 10 percent moisture. Solar dryers consist of a wide concrete pad with low walls enclosed in a “greenhouse” type structure. Sludge is pumped onto the pad and arranged in a relatively thin layer or in windrows. A microprocessor monitors temperature and humidity and adjusts fans and louvers to provide sufficient ventilation for drying. Auxiliary heat may be used to enhance drying performance.

**Comparison to Established Technologies:**

The Parkson Corporation reports that approximately 95 percent of energy used for drying is provided by solar panels. They cite 100 installations in a variety of climates and for WWTP sizes ranging from 0.2 to 40 mgd. Solar drying is considered an emerging ECM because of its capacity to significantly reduce fuel requirements compared to conventional dryers. Disadvantages of the technology are its large footprint, the need for sufficient days with adequate solar heating, and potential for odor problems. If odors are present, appropriate control technologies is available and can be provided.

**Available Cost Information:**

Information not available.

**Vendor Name:**

Parkson Corporation  
 telephone 1.888.PARKSON  
 fax 954.974.6182  
[technology@parkson.com](mailto:technology@parkson.com)

**Installations:**

As of 2008, WEF and ASCE (2010) report that 10 solar drying facilities are being built or operated in the U.S., mainly at small plants.

**Key Words for Internet Search:**

Solar drying, sludge drying, thermal drying

**Data Sources:**

WEF. 2009. *MOP No. 32: Energy Conservation in Water and Wastewater Facilities*. Prepared by the Energy Conservation in Water and Wastewater Treatment Facilities Task Force of the Water Environment Federation. McGraw Hill, New York.

WEF and ASCE. 2010. *Design of Municipal Wastewater Treatment Plants – WEF Manual of Practice 8 and ASCE Manuals and Reports on Engineering Practice No. 76, 5th Ed.* Water Environment Federation, Alexandria, VA, and American Society of Civil Engineers Environment & Water Resources Institute, Reston, Va.

USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.  
<http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>

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USEPA (2010) *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*. Office of Water. EPA 832-R-10- 005 September 2010.

Water Environment Federation *Manual of Practice (MOP) No. 32: Energy Conservation in Water and Wastewater Facilities*. Prepared by the Water and Wastewater Treatment facilities Task Force of the Water Environment Federation. McGraw Hill, New York, 2009.

Wallis-Lage, C.L. and S. D. Levesque. 2009. *Cost Effective & Energy Efficient MBR Systems*. Presented at the Singapore International Water Week. June 22 – 26, 2009. Suntec Singapore International Convention and Exhibition Center.

WEF and ASCE. 2010. *Design of Municipal Wastewater Treatment Plants – WEF Manual of Practice 8 and ASCE Manuals and Reports on Engineering Practice No. 76, 5th Ed.* Water Environment Federation, Alexandria, VA, and American Society of Civil Engineers Environment & Water Resources Institute, Reston, Va.

\* Capital costs shown in this chapter may include other needed facilities and/or ancillary equipment needed to implement the ECM and may have been derived from the total cost of a larger project. In some cases, installation costs may not be available and not included. Capital and O&M costs as well as energy savings are site specific and equipment specific and can vary significantly. For details on the basis of some of the reported costs, please consult the EPA document referenced in this chapter which is available at <http://water.epa.gov/scitech/wastetech/upload/Evaluation-of-Energy-Conservation-Measures-for-Wastewater-Treatment-Facilities.pdf>