Energy Conservation Measures for Municipal Wastewater Treatment Plants

Case Studies of Innovative Technologies and Practices

Presented at the Ground Water Protection Council Conference: Water and Energy in Changing Climates

Laura Dufresne, P.E.

The Cadmus Group, Inc.

September 29, 2010

Acknowledgements

- USEPA funded project
  - Jim Wheeler, EPA Office of Wastewater Management
  - Phil Zahreddine, EPA Office of Wastewater Management
- Technical experts
  - Steve Couture, Cadmus
  - Dave Reardon, HDR
  - Ken Henderson, HDR

Presentation Overview

- Importance of Energy Management
- Study Background and Methodology
- Summary of Innovative and Emerging ECMs
- Examples and Case Studies
- Wrap up and Questions

Importance of Energy Management

- Treating municipal wastewater takes a lot of energy
  - 15 – 30 % of operating costs for large facilities
  - 30 – 40% of operating costs for small facilities
  - Total energy use in U.S.:
    - 100 billion kWh per year
    - At $0.075/kWh, total estimated cost of $7.5 billion
- Areas for improvement
  - Energy savings from more efficient operation
  - New technologies with short payback periods

Source: WEF MOP 32, 2009; Carns 2005

Importance of Energy Management (continued)

- Opportunities for waste capture and reuse
  - Biogas from sludge treatment can be captured onsite and used to generate electricity
  - Recovered heat from equipment can also be used at the plant

A CHP system fueled by biogas saved the Back River WWTP in Baltimore more than ***$1.8 million dollars*** *annually in electricity costs. Installation was ~$14 million, resulting in a simple payback of < 8 years*

Importance of Energy Management (continued)

- Nutrient recovery
  - Example: Ostara process
    - Recovers phosphorus and other nutrients from sludge, converts them to fertilizers
    - As of September, 3 Ostara facilities in the U.S.
    - For more information, see http://www.ostara.com/
- Wastewater recovery and reuse

Comprehensive Energy Management

- EPA Energy Management Guidebook for Water and Wastewater
  - Plan-do-check-act management approach to improving energy efficiency
  - Available online at http://www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf
- ENERGY STAR Portfolio Manager
  - Benchmark energy use and track improvements over time
  - Performance rating system
  - Logon at http://www.energystar.gov/index.cfm?c=water.wastewater_drinking_water

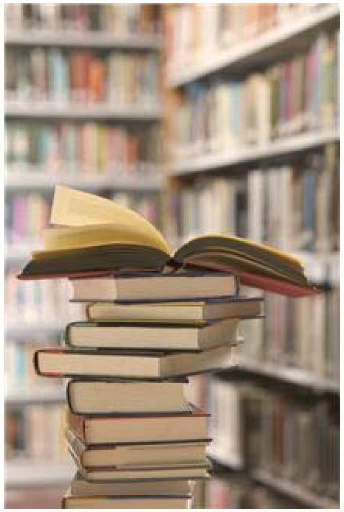
Web Resources and Tools (Examples)

- Pump System Assessment Tool (PSAT)
  - http://www1.eere.energy.gov/industry/bestpractices/software_psat.html
- Motors
  - MotorMaster+ http://www.motorsmatter.org/
  - 1*2*3 Approach to Motor Management http://www.motorsmatter.org/tools/123approach.html
- Technical Resources
  - CEE, extensive reference list http://www.cee1.org/ind/mot-sys/ww/resources.php3
  - EPA sustainable water infrastructure home page http://water.epa.gov/infrastructure/sustain/index.cfm
- Financing Resources
  - CWSRF http://www.epa.gov/owm/cwfinance/cwsrf/contacts.htm
  - CEC How to finance energy efficiency projects http://www.energy.ca.gov/reports/efficiency_handbooks/400-00-001A.PDF

Study Background and Methodology

Began in Spring of 2009

- Literature review, selection of case study candidates (30+)
- Findings reviewed by diverse panel of experts
- Collected case study data, drafted report
- Peer review by different set of experts



Study Focus

- Report includes conventional technologies with proven track record
  - Pumping and Aeration
- Focus is on innovative and emerging technologies
  - Aeration control and new equipment
  - Advanced treatment processes such as UV disinfection, Anoxic Zone Mixing
  - Solids processing

Findings will be posted on the web this Fall:
http://water.epa.gov/scitech/wastetech/publications.cfm

Summary of Findings

ECM Category	ECM Description
Design and Control of Aeration Systems	Intermittent aeration
	Dual impeller mechanical aerator
	Integrated air flow aeration control
	Automated SRT/DO Control
	Advanced control using parameters other than DO (off-gas monitoring, Symbio®, BIOS)
Blower and Diffuser Technology for Aeration Systems	High speed turbo blowers
	Single-stage centrifugal blowers with inlet guide vanes and variable diffuser vanes
	Ultra-fine bubble diffusers
	New diffuser cleaning technology

Summary of Findings (continued)

ECM Category	ECM Description
Advanced and Other Treatment Processes	Low-pressure, high-output lamps for UV disinfection
	Automated channel routing for UV disinfection
	Membrane air scour for MBRs
	Hyperbolic mixers
	Pulsed air mixing of anoxic and anaerobic zones
Solids Processing	Vertical linear motion mixer
	Upgrading multiple hearth furnaces to incorporate waste heat recovery/combustion air preheating
	Solar drying

Summary of Findings – Case Studies

Case Study No.	Facility	Avg Daily Flow (MGD)	ECM(s)	Project Cost	Energy Savings	Payback Period (Yrs)[1]
1	Green Bay Metropolitan Sewerage District De Pere, WI	8.0	Aeration system upgrade: • Replaced 5 positive displacement blowers with 6 HST® ABS magnetic bearing turbo blowers	$850,000 ($2004)	$63,758/yr 2,143,975 kWh/yr (50% reduction)	13.3
2	Sheboygan Regional WWTP Sheboygan, MI	11.8	Aeration system upgrade: • Replaced 4 positive displacement blowers with 2 Turblex ® blowers with upgraded DO control and SCADA • Installed air control valves on headers, upgraded PCL	$790,000 ($2005) ($773,000 with $17,000 utility incentive) for blowers, $128,000 ($2009) for air control valves	$25,6440/yr associated with blower replacement (358,000 kWh/yr – 13% reduction) $38,245/yr associated with air control valves (459,000 kWh/yr – 17% reduction)	14
3	Big Gulch Wastewater Treatment Plant, Mukilteo, WA	1.5	• Replaced mechanical aeration with Sanitare fine bubble diffusers and air bearing KTurbo blowers. • Upgraded to automated DO control • Installed automated ORP-based control for nitrification (dNOx Anoxic Control System)	For Oxidation Ditch A: $487,066 ($2007) - ($447,875 with $39,191 incentive), For Oxidation Ditch B: $1,045,023 ($2007) - ($998,429 with $46,594 incentive),	$10,649 per year (based on Y2010 savings following Ditch A and Ditch B commissioning)	> 20 years (see Note 1)

Summary of Findings – Case Studies (cont.)

Case Study No.	Facility	Avg Daily Flow (MGD)	ECM(s)	Project Cost	Energy Savings	Payback Period (Yrs)[1]
4	City of Bartlett, TN Wastewater Treatment Facility	1.0	Added VFD Control of oxidation ditch rotors using 4-20mA signal from optical DO probes	$13,500 total ($2007)	$9,176/yr 71,905 kWh/yr (13% reduction)	1.5
5	Oxnard, CA Plant #32	22.4	Optimization and control of SRT and DO using proprietary process modeling based control algorithms	$135,000	$26,980/yr 306,600 kWh/yr (20% reduction)	5
6	Bucklin Point – Narragansett Bay Commission (RI)	23.7	DO Optimization Using Floating Pressure Blower Control and a Most Open Valve Strategy	$200,000 ($2007)	Average of approx $135,786/yr for first 3 years 1,247,033 kWh/yr (11.6% reduction) for first 3 years	1.5

Summary of Findings – Case Studies (cont.)

Case Study No.	Facility	Avg Daily Flow (MGD)	ECM(s)	Project Cost	Energy Savings	Payback Period (Yrs)[1]
7	Washington Suburban Sanitary Commission (MD) Western Brach WWTP	21.6	Solids processing system upgrade: •Waste Heat Recovery •Flue Gas Recirculation (FGR) •Circle Slot Jets (CSJs) Air injection System	$4,500,000	$400,000 / yr estimated natural gas 320,000 therms/yr (76% reduction)	11.3
8	San Jose/Santa Clara (CA) Water Pollution Control Plant	107	Plant pumping systems optimization, BNR pulsed aeration and DAF Solids Thickening Process optimization using proprietary process control algorithms	$269,569	$1,178,811/yr for electricity and natural gas	3 months
9	Waco Metropolitan Area Regional Sewer System (Waco, TX)	22.8	Aeration system upgrade: •Increased number of diffusers •Installed DO probes and automatic blower and aeration system control	$349,218 ($2002) (Total installed cost = $397,708)	$331,272 total energy savings for first two years after ECM installed 4,643,000 kWh/yr average (33% reduction)	2.4

Examples and Case Studies

- Aeration
  - New DO measurement technology
  - New blower technology (Turbo Blowers and Variable Vane Inlet Guides and Diffusers)
    - Examples: Burlington, VT and Oneida, NY
  - Fine bubble and ultra-fine bubble diffusers
- UV disinfection
  - Low-pressure high-output lamps
- Anoxic zone mixing
- Solar drying

New DO Measurement Technology

- Most common: membrane electrodes
  - Require frequency calibration and maintenance
- New optical DO probes
  - Requires less frequent calibration and less maintenance
  - Good accuracy and reliability
  - Manufacturers include Hach, Orion, YSI, Insite IG, Endress and Hauser, Analytical Technologies, Inc.

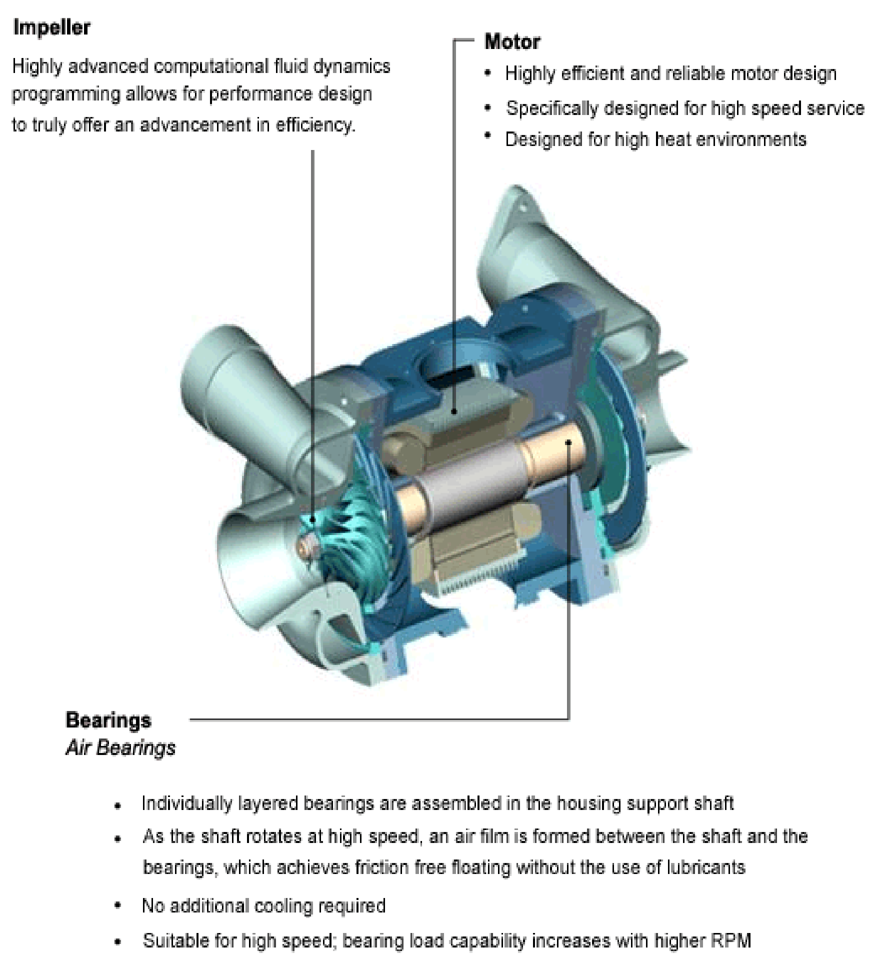
YSI hand-held optical DO probe

Turbo Blowers

- Uses advanced bearing design to operate at high speeds
- 10 – 20 percent more efficient than older models
- Emerged in U.S. in 2007, still need to be tested

Turbo Blowers (cont.)

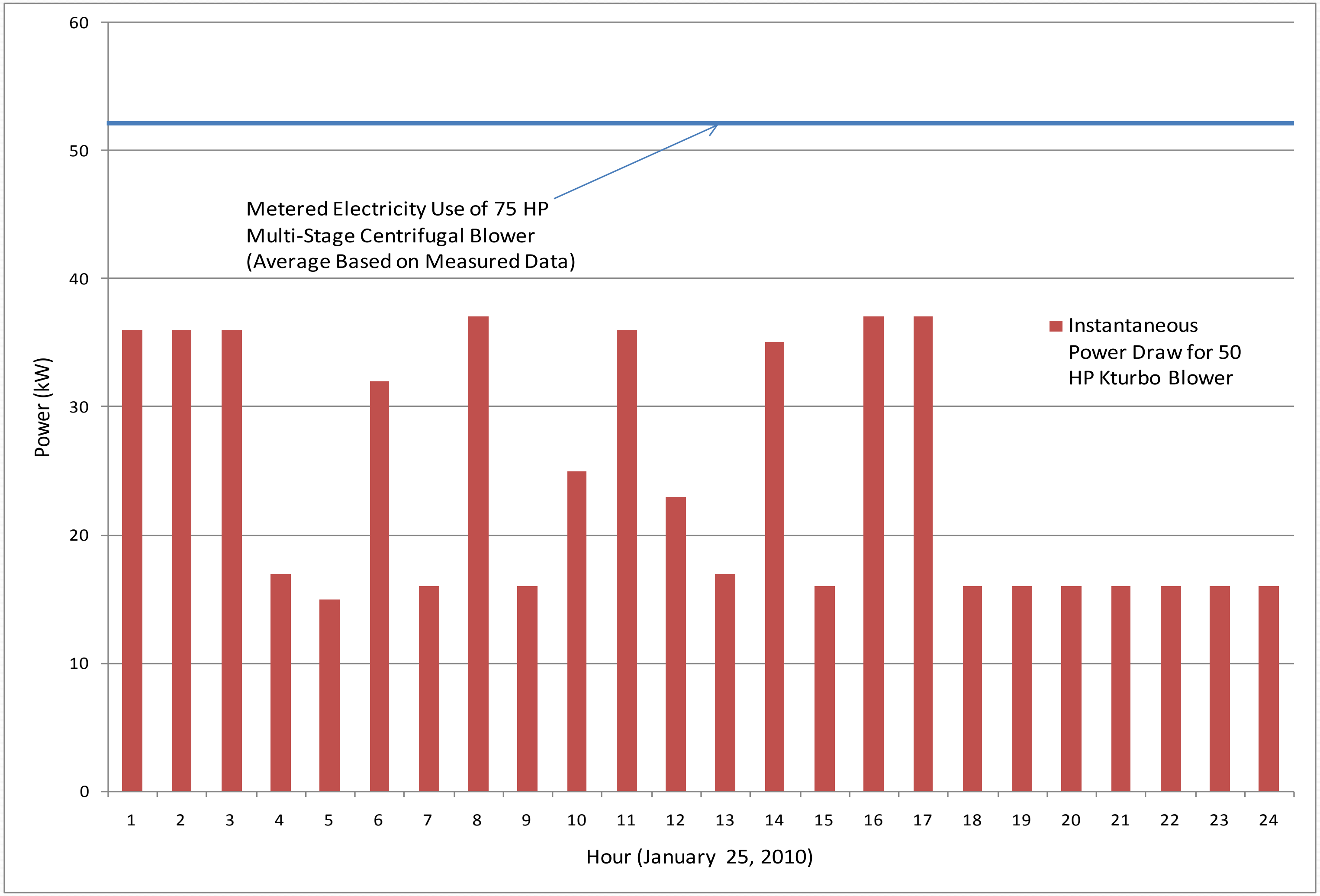
HSI Air Bearing Turbo Blower



Atlas Copco Mechanical Bearing Turbo Blower

Source: manufacturer websites

Example: Burlington, VT



Example: Burlington, VT (Cont.)

- Reduced electricity by 250,000 kWhr and $34,500 per year
- Turbo Blower Cost
  - Installed cost = $56,000
  - Electric utility rebate = $21,000
  - Net cost = $25,000
- Simple Payback < 1 yr

Single Stage Centrifugal with Inlet Guide Vanes and Variable Diffuser Vanes, City of Oneida, NY

Net Present Worth of Blower Selections

Equipment Manufacturer (Type)	Equipment Capital Cost	Annual Energy Costs	Net Present Value
Continental Blower (multistage centrifugal)	$118,000	$93,800	$1.16M
HSI (multistage centrifugal)	$159,600	$98,900	$1.26M
Gardner Denver (multistage centrifugal)	$158,000	$104,000	$1.31M
Turblex (single-stage centrifugal with inlet guide vanes and variable diffuser vanes)	$423,750	$58,000	$1.07M
Roots (positive displacement)	$104,800	$97,200	$1.19M

Notes:
1) Assumed 10-year life span, 4% inflation, $0.12/kWh
Source: Greene and Ramer (2007), used with permission of Mark Greene.

Diffusers

- It's all about bubble size
  - Smaller bubbles have higher oxygen transfer efficiency

- Coarse bubbles (> 5 mm): pre 1970s
- Fine bubble diffuser technology (2 – 5 mm): energy savings of 30 to 40 percent
- Ultra-fine bubbles (0.2 – 1 mm): the next big thing

UV Disinfection: Low-Pressure High Output Lamps

- Low-pressure: least energy but many lamps
- Medium-pressure: fewest no. of lamps but high energy use
- New low-pressure **high output**: low energy AND fewer lamps

Example: Calgon C³500™

EPA ETV program has verified low-pressure high-output UV lamps for wastewater treatment and water reuse. For more information, see http://www.epa.gov/etv/pubs/600s07015.pdf

Evaluation of UV Disinfection Equipment Power and Cost Estimates for Stockton, CA WWTP

Dose (mJ/cm^2)	Lamp Type	Total No. of Lamps	Power (kW)[1]	Annual Energy Costs[2]	Life Cycle Cost[3]
50	Medium Pressure	216	648	$681,000	$20,427,000
	Low Pressure High Output	768	143	$150,000	$14,248,000
70	Medium Pressure	324	1,058	$1,120,000	$31,741,000
	Low Pressure High Output	1,152	219	$231,000	$19,726,000
110	Medium Pressure	540	1,512	$1,589,000	$46,988,000
	Low Pressure High Output	1,792	415	$437,000	$30,615,000

55 mgd Peak Flow, 38 mgd Average Flow, 65% Design UVT
Power draw is based on operational values (kW).
Based on operational values and energy cost of $0.13 per kWh.
Life Cycle Cost = 13.01 (20 years annual cost at 4.5% discount rate) * annual O&M cost + project cost

Source: Salveson et al. 2009; Supplemental information provided in e-mail communication to the author from Nitin Goel, March 24, 2010. Used with permission.

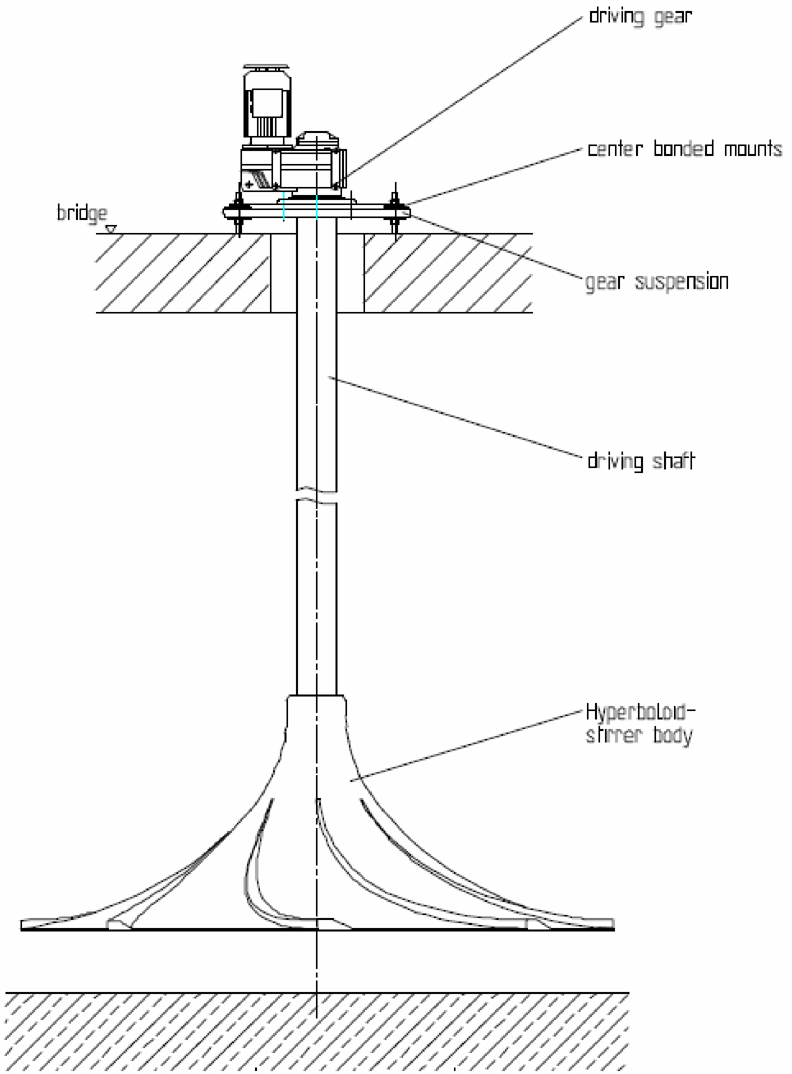
Anoxic Zone Mixing

Hyperbolic Mixer

Tested in

New York
Washington DC

Invent Hyperclassic Mixer



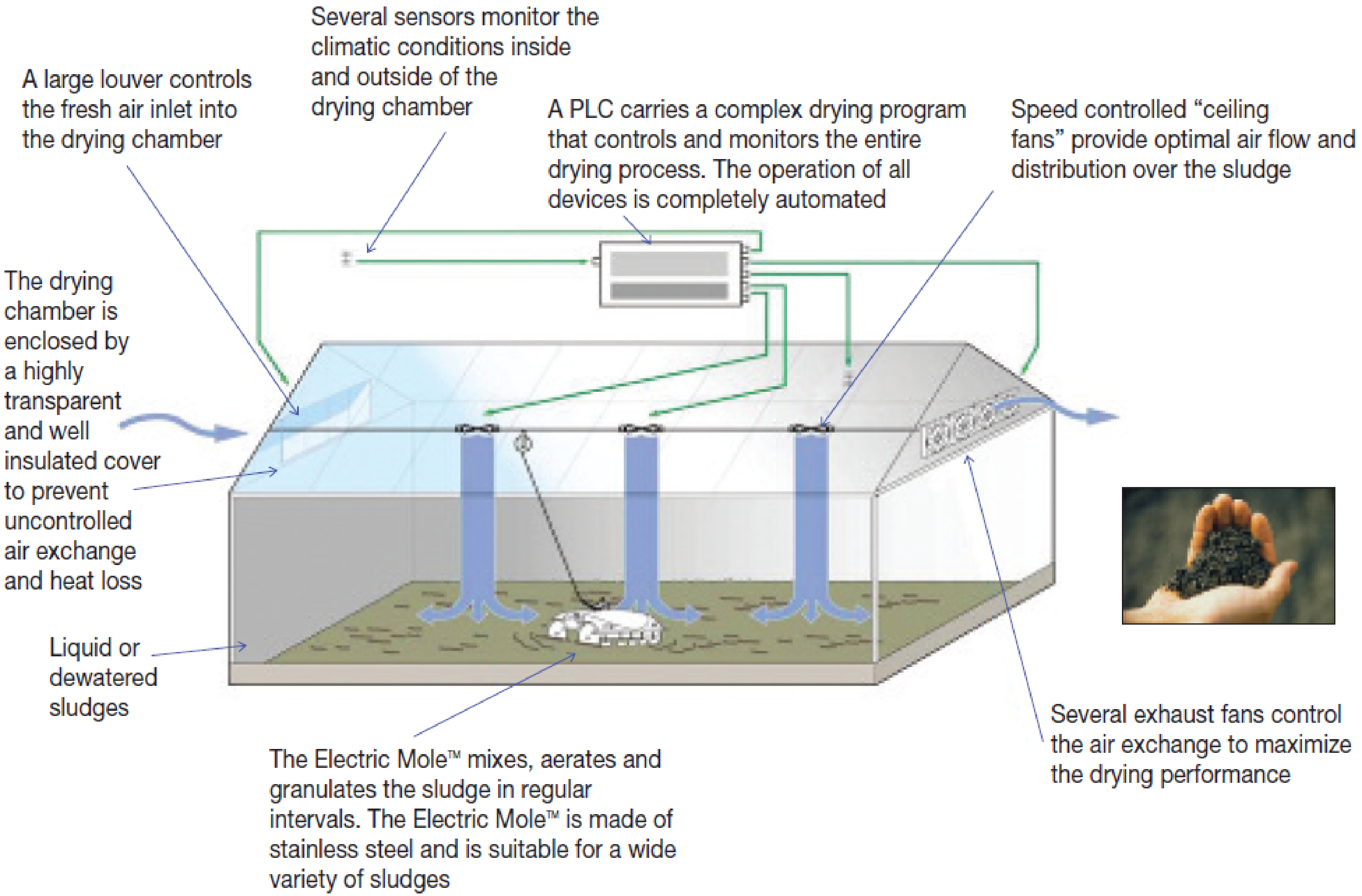
Source: Fillos, J. and K. Ramalingam. 2005

Anoxic Zone Mixing (cont.)

Pulsed large bubble mixing instead of mechanical mixing

Example: Biomix technology

Solids Processing – Solar Drying



Source: http://www.parkson.com/Page.aspx?PageID=289&FileName=Solar%20Drying&CC=true

Conclusions

- Many new technologies available to reduce energy used for wastewater treatment
  - *Cost effective with short payback periods*
- Opportunity for resource recovery and reuse should also be a priority

Questions?

Laura Dufresne, P.E.
The Cadmus Group, Inc.
1555 Wilson Blvd, Suite 710
Arlington, VA 22209
LDufresne@cadmusgroup.com
703-247-6152