Energy Awareness in Water and Wastewater System Design

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ABSTRACT

Water/wastewater systems were and are planned, designed, constructed and placed into operation based on 20-year projections as required by state and federal regulatory requirements. Life-cycle costs for these facilities generally show that energy costs overshadow initial capital costs, yet code requirements rarely include energy efficiency considerations. As a consequence, existing water/wastewater systems are not energy-efficient. Designers rarely include flexibility in their designs to provide system owners/operators the option to control their systems in an energy-efficient manner. While standards of practice present approaches and codes to meet public health and welfare requirements, no guidelines are available to ensure systems are energy-efficient despite the fact energy use and costs are becoming a focus of concern.

An approach to addressing this dichotomy is to develop energy consumption guidelines. Such guidelines would provide guidance for design, control, and equipment selection options that reduce a system's energy consumption without impacting the health, welfare and level of service to their customers. The guidelines will present approaches to assure that energy consumption is a priority in the design of proposed improvements or a new system.

The State of Wisconsin Focus on Energy program is developing water/wastewater energy consumption guidelines based on field assessment information reflecting conditions and operational experiences that yield practical approaches to energy-saving opportunities. This paper will discuss the challenges facing the engineering profession and community in changing established water/wastewater system practice, program experiences, and how this approach can be applied to the planning of efficient communities.

Introduction

The water/wastewater industry has always concentrated on achieving its issued quality standards. The industry has been extremely cautious in accepting new, innovative or alternative technologies. The industry has been focused on earning and maintaining public trust and in doing everything to protect the public's health and welfare. With these noble focuses it is not surprising that energy awareness and management have not been a prioritized effort. In fact, it is rare to locate a water/wastewater utility that has personnel that even see their monthly energy bill let alone know the valuable information that it contains.

When an improvement or expansion of a water or wastewater system is planned, designed, constructed and placed into operation they are based on 20-year need projections and code requirements (State of Wisconsin et al. 2006) with little or no energy efficiency considerations. As a consequence, existing water/wastewater (W/WW) systems meet quality regulatory requirements but are generally not energy-efficient providing major opportunities for an energy efficiency program.

Non-Energy Factors Affect Energy

The water/wastewater industry has many attributes that make it a prime candidate for an energy efficiency program. The service which the water/wastewater industry provides to communities is required to be available all the time (24 hrs/day, 365 days/year). Regulatory codes require system improvements to be sized to meet projected 20-year peak conditions without the requirement to address present operating conditions when a system is upgraded and/or modified. Most design codes present the requirements for designs to meet 20-year growth projections and particularly meet peak conditions such as aeration requirements, flow velocities in channels (wastewater systems), water pressures and necessary fire flow conditions (water systems). All of the design requirements relate to projected future flow conditions that may or may not occur.

Design codes also require that a present worth analysis be developed to identify the most cost-effective alternative for implementation. To provide this analysis, it is conventional practice to develop a construction cost estimate for capital cost and then estimate a yearly operations cost which includes an estimate for energy costs but does not include energy efficiency.

Energy consumption related to facility planning efforts is an estimate of the cost of energy to make the system function and meet regulatory quality standards. The development of a present worth analysis is to identify the cost-effective alternative to implement. What the codes promote is a cost-effective alternative, not the development of an energy-efficient alternative.

Therefore an energy efficiency analysis is not a component of design codes but a requirement an owner needs to proactively request and require from their designer when a design is being developed for them. This requirement should be accepted in the water/wastewater industry because the participants in the industry, as stewards of the environment, should be concerned with energy consumption in meeting water quality standards. Energy efficiency for existing flows and projected design flows must be integrated into any design.

Opportunity to Integrate Energy into Design

Design standards or codes generally focus on peak flows and constructing facilities able to convey and transport them. This is usually accomplished by having the equipment convey, transport and treat 20-year peak flows. To achieve the redundancy clause in the codes, two of the same size units are usually provided. This approach needs to be altered so the proposed improvements are analyzed and assessed to identify the equipment sizing to efficiently convey, transport and treat the existing flow in an energy-efficient manner while also having capacity to process peak flow and achieve quality permit requirements. Too many systems exist today that do not have the capability of energy efficiently meeting present treatment or process requirements. In fact, many will never be energy-efficient because their main focus or design criteria was to meet loading conditions 20 years in the future. By that time, the equipment will be beyond its life expectancy or technology could be available to more efficiently do the necessary task.

Wisconsin Approach

To address this opportunity the State of Wisconsin chose to initiate a water/wastewater program through their Industrial Sector component of their Focus on Energy initiative. This program is designed to identify, assess and implement resource acquisition and market transformation in the water/wastewater industry for both public and private facilities.

- Public-private partnership
- Encourage energy efficiency
- Promote use of renewable energy
- Ensure the future supply of energy for Wisconsin
- Reduce peak loads
- Obtain resource acquisition
- Promote market transformation
- Promote implementation of energy efficiency
- Encourage adoption of energy efficiency practices
- Involve both end-users and key service/equipment providers
- Increase end-user demand for energy efficiency
- Provide education and training

Science Applications International Corporation (SAIC) was chosen to implement this program. The initial effort associated with the program was to develop a program theory that would address the characteristics of the water/wastewater industry (SAIC 2001). The overall program target/focus was to address the market barriers to be removed or reduced by providing support and intervening actions to promote, educate, train and assist in the adoption of energy-efficient practices and energy management in the water/wastewater treatment sectors.

Targeted Marketing Design

Water/wastewater communities are a relatively close-knit and concise market with many installations under government operation. Therefore, support to this market and the programs was directly marketed and delivered. The program also built-in coordination and expansion of the activities that existing organizations were offering to water/wastewater operations. Collaboration with key equipment and service providers was also pursued and implemented through the program. The program design strategy was built upon existing organizations.

Table 1 summarizes the barriers encountered in water/wastewater markets (SAIC 2001).

Table 1. Barriers Encountered in Water/Wastewater Markets

Barriers	Responses
Barriers	▪ Unfamiliarity with new requirements and new technologies available to meet those requirements ▪ Lack of adequate demonstrations to show facility managers and decision-makers the feasibility and benefits of new energy efficiency strategies ▪ Minimization of risk-traditional focus on safety considerations and regulatory requirements in the exclusion of secondary concerns such as energy and operating costs ▪ Constraints of limited staff resources, limited training, and education ▪ Public decision-making and budgeting process
Program Result Indicators for Overcoming Barriers	▪ Industry plan (roadmap) to address upcoming needs with respect to operations, compliance, and energy efficiency ▪ Increased awareness and use of information resources ▪ Demonstrations of promising energy-efficiency technologies ▪ Attendance at training events ▪ Development of energy management plans from training ▪ Installations at water utilities and wastewater facilities ▪ Use of incentives to reduce risk in new technologies ▪ Cooperative efforts with other organizations and companies

Barriers varied in each segment of the market. For example, small- and medium-sized utilities typically have unique challenges requiring more technical assistance. Often, the same person is responsible for operating both the water/wastewater treatment facilities. They generally do not have the in-house staff or resources to devote to pursuing significant and advanced energy or environmental improvement projects. Typically geographically isolated, water/wastewater systems did not have access to energy efficiency services because they had been supply-constrained on the products, services, and skills needed to advance energy efficiency.

Small or large, decision-makers were driven by operational costs and environmental compliance. Therefore, the water/wastewater program was designed to provide: 1) demonstrations of best practices, and 2) new cost-effective, energy-efficient and environmentally compliant strategies customized to the specific needs of the market with a focus on each individual facility.

Targeted Marketing Trends

Specific program components that supported this overall theory and approach to the Water/Wastewater program are detailed in Table 2 (SAIC 2001).

Table 2. Water/Wastewater Program Theory for Partners

Program Theory Topic	General Components	Specific Components– Partners	Expected Near-Term Results for Partners	Expected Longer-Term Results for Partners
Marketing	Direct Marketing Activities	Direct marketing will be used as the primary recruitment and contact to all industries. This will include: letters and calls; visits to potential partners; regional and local meetings; trade shows; newsletters; case studies; program fact sheets; coordination with other organizations and program allies.	• Raise awareness of energy efficiency and of Focus on Energy • Move non-participants forward to program	• Increased sense that "energy efficiency might have value for my operation" • Increased awareness that "there might be companies or programs out there to help me
Opportunity Identification and Development	Improve technical knowledge of energy efficiency actions that could be taken	Energy opportunity screening audits; technical training courses; blast faxes and mailings to announce events and offer events and training; et signed participation agreement; tool lending library; New construction assistance; monthly fax information sheet; GBRT	• Raise level of knowledge among participants. • Facilitate energy-efficient project decision-making	• Change energy-related decision-making methods or approach so efficiency is carefully considered in the future • Improve knowledge of resources (from other programs and from program allies) to reduce information barriers for future projects • Improve the knowledge of the impacts and benefits of specific energy improvement projects
	Promote energy efficiency decision-making	Develop energy management practice guides; provide assistance to validate cost and savings estimates; assist partners complete action plans; provide energy management training and for other related areas to promote energy efficiency as part of regular operations.		
	Assist in finding supporting resources	Develop and offer various financial mechanisms, e.g., technical feasibility grants, low-interest loans, financial technical assistance. Connect participants with lenders; provide financing advisory information or tool; TA web database; RFP development and bid review assistance; links to allied programs such as through Making Sense conferences; partner project listings to program allies; annual reviews		
Project Implementation	Technical assistance	Technical assistance; technical training courses; on-call technical advisory services.	• Assist participants in moving projects forward • Increase awareness of employees to energy-efficient practices • Increase interaction between participants and this program, allied programs and program allies	• Implement energy efficiency projects • Build sustainable expectation that energy efficiency projects are doable and worthwhile • Embed energy efficiency into the regular business and operations practices
	Assist in finding supporting resources	Provide assistance for: connections to Trade Allies; connections to other Wisconsin or Federal programs; connect participants with lenders.		
	On-going education and training support	In-plant training for employees, management and technical staff; annual progress reviews		
Non-Energy Program Benefits	Ads, articles, and awards	Recognition in Focus on Energy ads; recognition at events; recognition in fliers, press releases; case studies; integrate to environmental aspects in industry	• Provide participants with public recognition • Improve interaction of energy with environmental aspects	• Improved system reliability

The table displays the program theory that was developed to address this market to identify energy saving opportunities, assess them, describe the elements of the opportunity, calculate the payback (based on energy savings only), provide the partner with a report to provide facilitation assistance to move the opportunity to implementation.

Moving to Energy Efficiency

The primary method used to drive the overall program was to perform for each a site survey and provide a review and assessment of individual facilities to identify, prioritize and define the energy reduction opportunities of each site had.

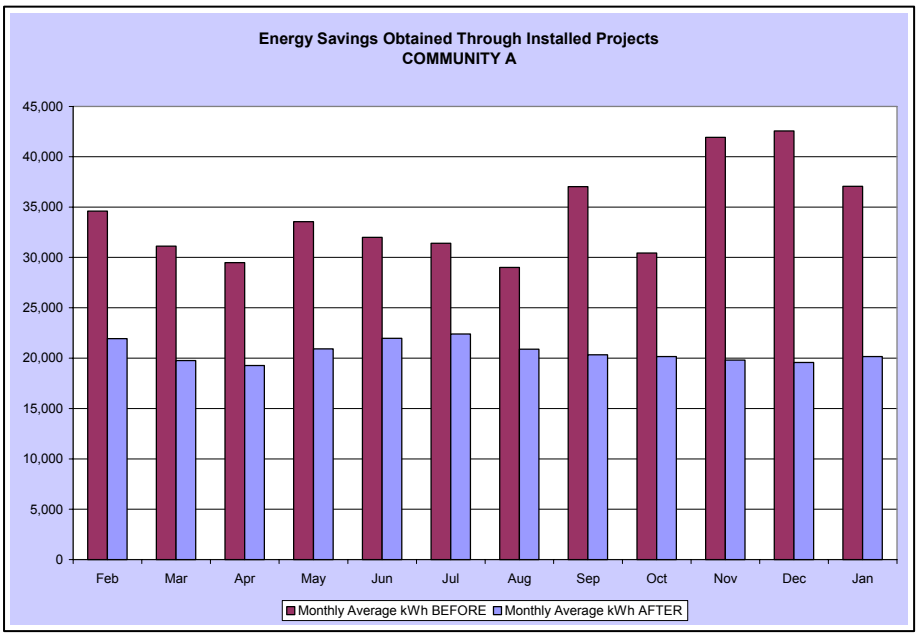
- Community did not grow as forecasted
- Operating same way since start-up
- Loading conditions changed dramatically
- Unnecessary equipment running
- Mayor says, "Run everything."
- Operating pressure is too high
- Excess air is being exhausted
- Dissolved oxygen is too high
- Well pumps are throttled

The assessment was provided to the site management and operations personnel in a concise report that presented a description of each opportunity on site, description of the modification that was necessary, and an order of magnitude for payback period. We then provided technical and financial assistance as needed to move the identified modification to implementation. During the site visits we interfaced with system operations and management personnel. The surveys were valuable because they allowed program personnel to become familiar with the site's treatment processes and operational flexibility. The interface time also provided an opportunity to learn the practical barriers that were presenting themselves.

- Not mandated; why do it?
- It works, why fix it?
- I don't get a benefit.
- Why should it be my job to save energy?
- I don't see my utility bills.
- I see my bills, but don't understand them.
- I want to maintain a DO of 5-7 in case my loading suddenly increases.
- Competition with other investments.
- EE viewed as a one-time action.

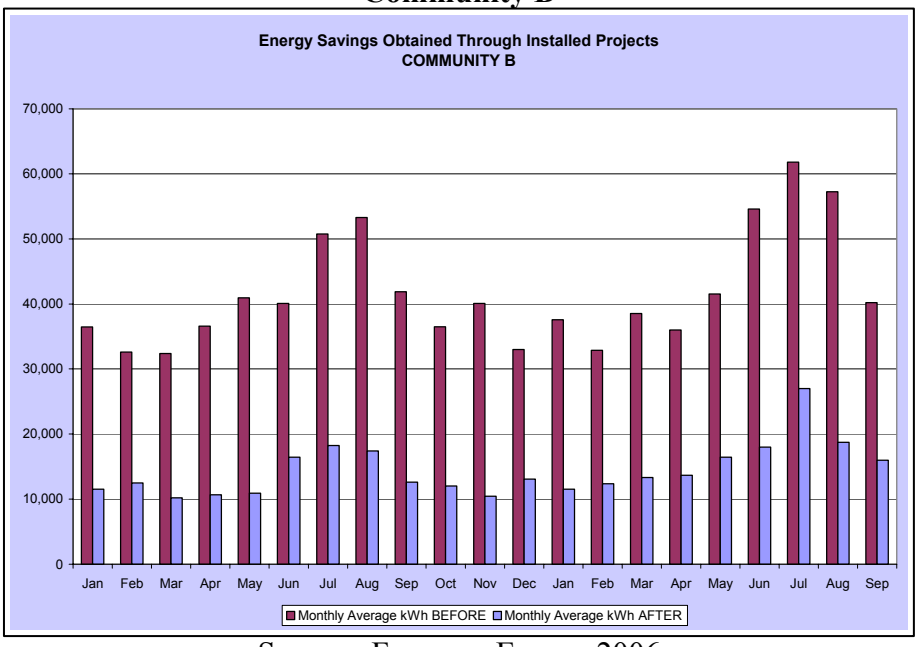
During the site surveys we identified a variety of energy-saving opportunities. These were generally the result of the surveyed systems receiving a loading much lower (usually approximately 35 percent) than their forecasted design flows. Recognizing this trend, it was determined that design approaches and regulatory codes might benefit from revisions to also require an assessment to energy efficiently meet today's loadings. Figures 1 and 2 are examples of typical savings obtained at facilities that were surveyed and then they implemented energy-efficient recommendations from the reports provided by Focus on Energy.

Figure 1. Energy Savings Obtained through Installed Projects: Community A



Source: Focus on Energy 2006

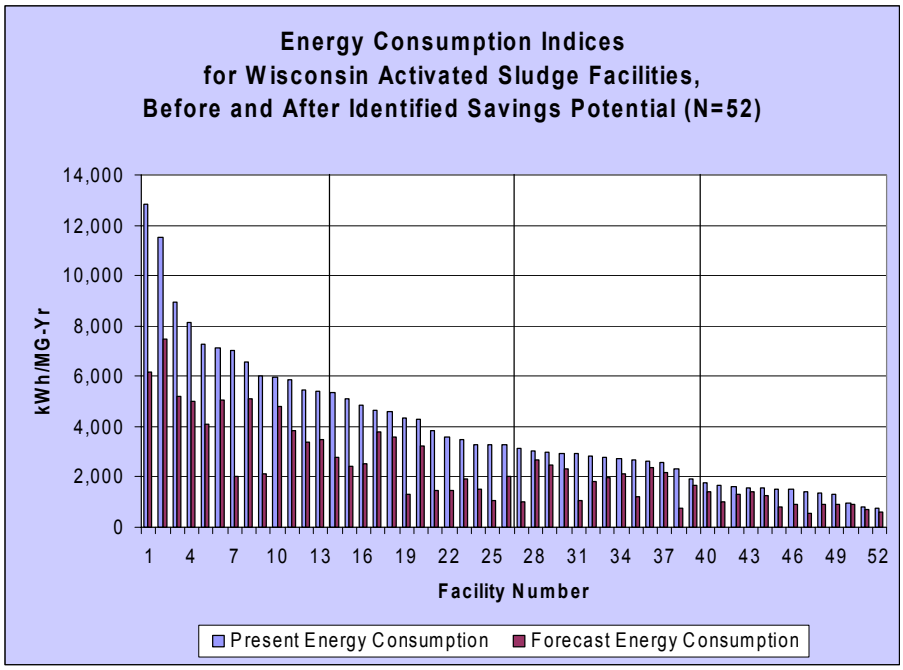
Figure 2. Energy Savings Obtained through Installed Projects: Community B



Source: Focus on Energy 2006

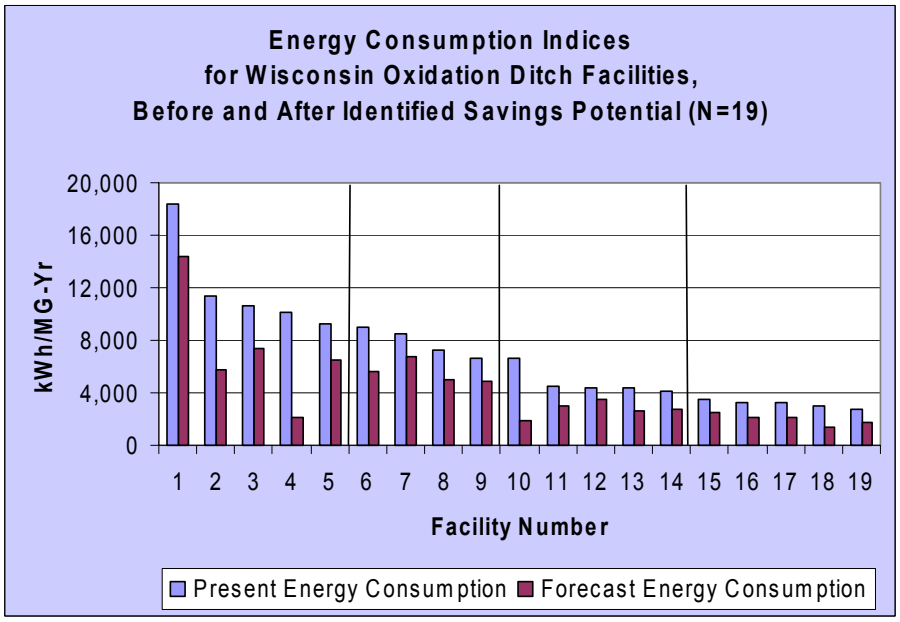
Figures 3, 4 and 5 are graphs presenting the summarized results from the reports presenting the savings available at existing facilities.

Figure 3. Energy Consumption Indices for Wisconsin Activated Sludge Facilities Before and After Identified Savings Potential (N=52)



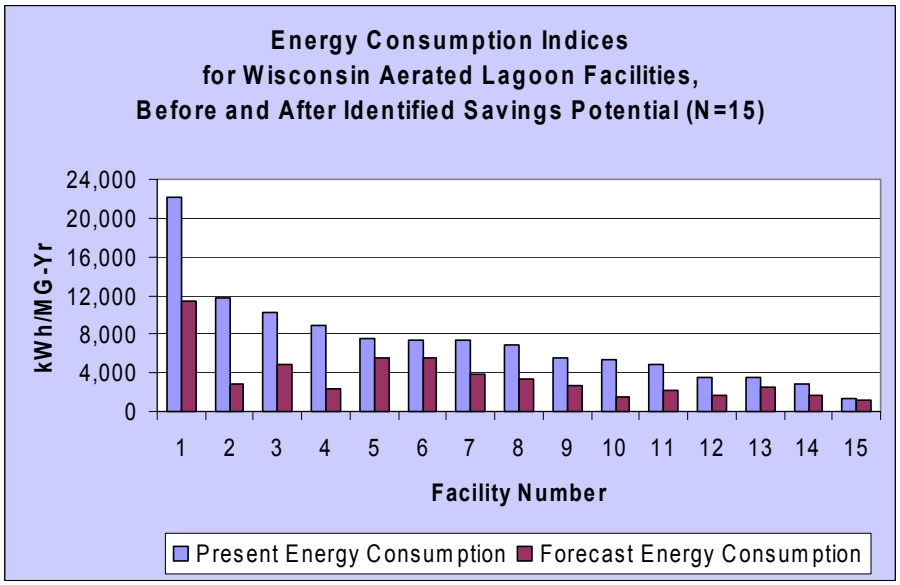
Source: Focus on Energy 2006

Figure 4. Energy Consumption Indices for Wisconsin Oxidation Ditch Facilities Before and After Identified Savings Potential (N=19)



Source: Focus on Energy 2006

Figure 5. Energy Consumption Indices for Wisconsin Aerated Lagoon Facilities Before and After Identified Savings Potential (N=15)



Source: Focus on Energy 2006

The summarized data presents the available savings at facilities that have followed the design approach to forecast 20-year flow conditions and organic loadings that must be met and the requirement to provide redundant equipment for key processes. This approach resulted in many systems being provided with equipment that can not be reduced in capacity to efficiently meet the requirements of their current loadings.

Developing Best Practices/Showing the Way

To address these issues of inefficiencies and develop facility improvements that are energy-efficient and meet quality discharge or supply requirements, a guidance document (Focus on Energy 2006) is being developed to assist designers in addressing present needs effectively and efficiently and meet 20-year forecasts, while not hindering accepted regulatory code requirements. We have developed a document that addresses the considerations or best practices that designers need to assess while developing a systems improvement project. The guidance document will also provide facility management and decision makers with information so they will also learn about energy saving and management. The considerations are presented as best practices in the water/wastewater industry. The focus of the energy guidance manual is to have energy-efficient designs and improvements installed so all public health and welfare requirements are met, however at the same time, the system(s) are energy-efficient.

Figure 6 lists the water/wastewater best practices that were developed in different categories because they interface with all facets of a water/wastewater system. Energy awareness is required in all of these categories to assure systems are developed that are energy-efficient.

- *Demand Reduction*. Provides insight on how to reduce demand requirements during peak times.

- *Decrease Waste*. Provides approach to consider heat extraction (not waste it) and recycle where applicable. Turn off unnecessary equipment.
- *Manage Your System*. Provides insight to operators and managers to learn their system from knowing processes to becoming familiar with demands on the system.
- *Process Improvements*. Provides insight to review processes to learn how they work as a system and not as a single process working by themselves.
- *Control Strategies*. Provides information to assist in understanding the value of operating process systems responsive to demand.
- *Education and Awareness*. Presents value in understanding energy consumption.
- *Planning Ahead*. Presents importance in addressing flexibility in design considerations under present as well as future conditions.

Figure 6. Water/Wastewater Best Practices

Water Best Practices	Wastewater Best Practices
Install Premium Efficiency Motors	Install Premium Efficiency Motors
Variable Speed Drives – General Considerations	Variable Frequency Drive Applications
Variable Speed Drives - Use Variable Speed Drives	Demand Reduction – General Considerations
Variable Speed Drive – Pump Discharge Throttling	Demand Reduction – Time of Operation
Demand Reduction – General Considerations	Demand Reduction – Idle or Turn Off Equipment
Demand Reduction – Time of Operation	Decrease Waste – Reduce Fresh Water Consumption
Demand Reduction – Idle or Turn Off Equipment	Decrease Waste – Cover Basins for Heat Retention
Demand Reduction – Filter Backwash	Decrease Waste – Extract Available Heat
Decrease Waste – Leak Detection	Manage Your System – Energy Assessment of Facilities
Decrease Waste – Reduce Sprinkling	Manage Your System – Understanding Energy Management
Decrease Waste – Promote Water Conservation	Manage Your System – Optimize Pump System Efficiency
Manage Your System - Automatic Controls	Manage Your System – Provide Flexible Tank Utilization
Manage Your System – High Volume Users	Manage Your System – Seasonal/Tourist Peaks
Manage Your System –Well Drawdown	Process Improvements – Aeration System Considerations
Manage Your System –Well Production	Process Improvements – Fine Bubble Aeration
Manage Your System – Choice of Well Operation	Process Improvements – Aerobic Digestion Considerations
Manage Your System – System Pressure Considerations	Process Improvements – Biosolids Processing Considerations
Manage Your System – Optimize Pump System Efficiency	Process Improvements – Biosolids Mixing Consideration - Aerobic
Planning Ahead – General Considerations	Process Improvements – Biosolids Mixing Consideration - Anaerobic
Planning Ahead – Review Alternative Water Sources	Process Improvements – UV Disinfection Considerations
Planning Ahead – Computer Modeling	Process Improvements – Final Effluent Recycle Considerations
Planning Ahead – Design Parameters	Control Strategies – Variable Blower Air Flowrate
Planning Ahead – Designs for Today….and Tomorrow	Control Strategies – Dissolved Oxygen Control
Planning Ahead – Operational Flexibility	Control Strategies – Pressure Control
	Control Strategies – Flow Control
	Education and Awareness – Real Time Energy Monitoring
	Education and Awareness – Electric Billing Rate Structure
	Education and Awareness – Energy Knowledge for Personnel
	Planning Ahead – General Considerations
	Planning Ahead – Renewable Energy Resources
	Planning Ahead – Design Parameters
	Planning Ahead – Design for Today and Tomorrow
	Planning Ahead – Staging of Improvements
	Planning Ahead – Staging of Treatment Capacity
	Planning Ahead – Operational Flexibility

Source: Focus on Energy 2006

Best practices do not disagree with the technical requirements of the regulatory design codes, however, they focus on addressing how to more efficiently apply the codes to develop an energy-efficient system to meet all treatment or conveyance requirements.

Conclusion

A successful energy-efficient program must be structured to attract participants through a proactive approach of assisting facility owners and operators in identifying and quantifying energy-saving opportunities. Numerous energy-saving opportunities exist at water/wastewater systems. Many of the opportunities arise in systems where design codes have been applied verbatim without addressing how to apply codes and operate efficiently and effectively at less than 20-year design flows.

To address this situation, water/wastewater best practices have been developed to assist planners, designers, operators and owners in developing systems that meet design codes but are also energy-efficient. The best practices guide is a tool that planners can utilize to identify that their utility systems will meet service requirements but also be energy-efficient.

References

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