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Wastewater treatment is an energy intensive process which, together with water treatment, comprises about three percent of U.S. annual energy use.[1] Yet, since wastewater treatment facilities are often peripheral to major electricity-using industries, they are frequently an overlooked area for automated demand response opportunities.

Demand response is a set of actions taken to reduce electric loads when contingencies, such as emergencies or congestion, occur that threaten supply-demand balance, and/or market conditions occur that raise electric supply costs. Demand response programs are designed to improve the reliability of the electric grid and to lower the use of electricity during peak times to reduce the total system costs. Open automated demand response is a set of continuous, open communication signals and systems provided over the Internet to allow facilities to automate their demand response activities without the need for manual actions. Automated demand response strategies can be implemented as an enhanced use of upgraded equipment and facility control strategies installed as energy efficiency measures. Conversely, installation of controls to support automated demand response may result in improved energy efficiency through real-time access to operational data.[2,3]

This paper argues that the implementation of energy efficiency opportunities in wastewater treatment facilities creates a base for achieving successful demand reductions. This paper characterizes energy use and the state of demand response readiness in wastewater treatment facilities and outlines automated demand response opportunities.

Energy Use in the Wastewater Treatment Process

In order to assess the potential for demand response in wastewater treatment facilities, it is important to understand the magnitude of energy use and demand in these facilities, the daily and seasonal load patterns, and the role of energy-intensive equipment in the wastewater treatment process.

Load variation in wastewater treatment facilities depends on many factors including seasonal and daily load patterns, the type of industry, location, and population size.[4] For example, many manufacturing facilities have fairly constant wastewater flow rates during daily production, but these can change dramatically during cleanup and shutdown.[4] Industrial wastewater flow rates vary in this manner depending on the time of day, day of the week, season of the year, or sometimes the nature of the discharge.[4] Particularly for municipal treatment facilities, wastewater flows often follow a diurnal pattern where the peak flows generally occur twice a day: once in the late morning when wastewater from the peak morning water use reaches the treatment facility and a second peak flow during the early evening between 7 and 9 p.m.[4] Figure 1 shows a sample summer load pattern for a municipal wastewater treatment facility.

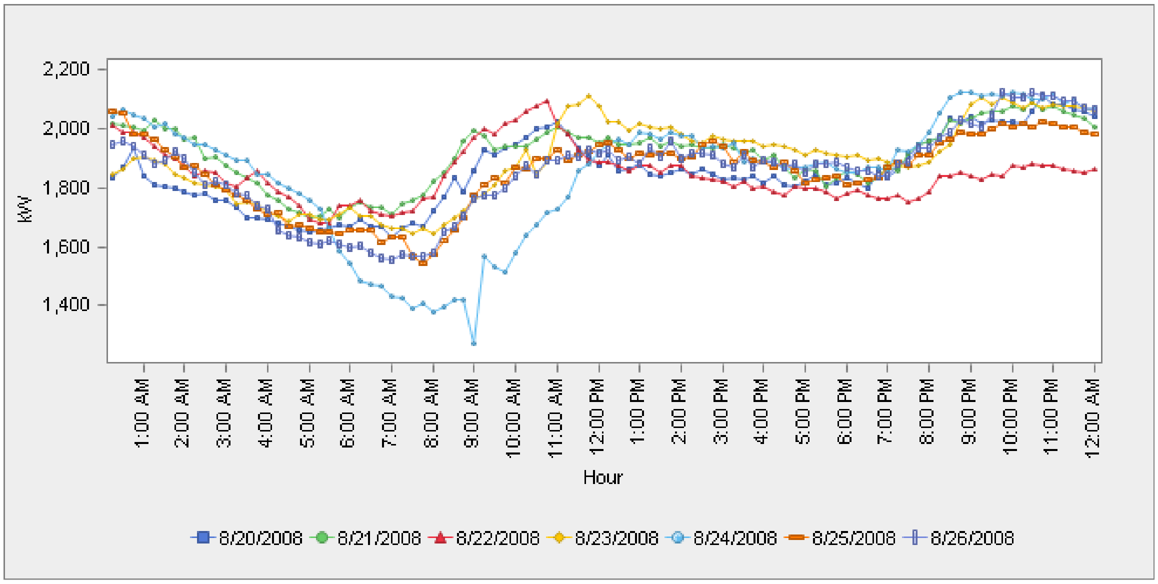

Figure 1: Municipal Wastewater Treatment Facility Load Pattern

Wastewater treatment facility electricity demand is high during the summer months, particularly in areas with hot summers like Southern California.[5] The facility demand required to treat and transport wastewater is significant during the peak electricity demand periods experienced by the electrical utilities.[5] This, combined with the characteristic energy-intensity of the wastewater treatment process, makes wastewater treatment facilities prime candidates for automated demand response.

In 2001, wastewater treatment facilities in California consumed 2,012 GWh of electricity.[6] Within these facilities, the energy intensity for water collection and treatment ranged from 1,100 kWh/million gallons to 4,600 kWh/million gallons.[6] One of the reasons for this wide range is the variability in transporting and pumping wastewater. The average amount of electricity used for transporting and pumping wastewater from a residential or commercial area to a municipal wastewater treatment facility is 150 kWh/million gallons, but this value can vary greatly depending on wastewater treatment facility topography, as well as system size and age.[6] Some wastewater collection systems rely on gravity to transport wastewater to a treatment facility, while others use energy intensive pumps to lift or transfer the wastewater.[6] Another reason for the variability in wastewater treatment energy intensity is the dependence of energy use on the quality of the waste stream, the level of treatment required to meet regulations, and the treatment technologies used.[6]

A New York State Energy Research and Development Authority (NYSERDA) study found that the national average energy intensity for wastewater treatment was 1,200 kWh/million gallons.[7] New York State's average energy use for treating wastewater was

1,067 kWh/million gallons for large facilities (> 75 million gallons per day) and 3,749 kWh/million gallons for small facilities (< one million gallons per day), with a statewide average of 1,353 kWh/million gallons. This shows that the energy use in large facilities is much lower than in small facilities, and that large facilities process a significantly higher portion of wastewater, bringing the average to the lower end of the range.

The potential for implementation of automated demand response and energy saving measures depends on the technologies involved in the wastewater treatment process. Wastewater is generally treated by removing coarse and suspended solids and organic matter from the waste stream through screens and sedimentation in the primary treatment process. It is then aerated in secondary treatment, which raises the dissolved oxygen levels, helping promote the growth of microorganisms which remove the remaining soluble and organic material. Finally, nutrients and toxic compounds are removed and the water is chemically disinfected. Figure 2 shows the average distribution of energy end-uses in the municipal wastewater treatment process based on eight municipalities in New York State.

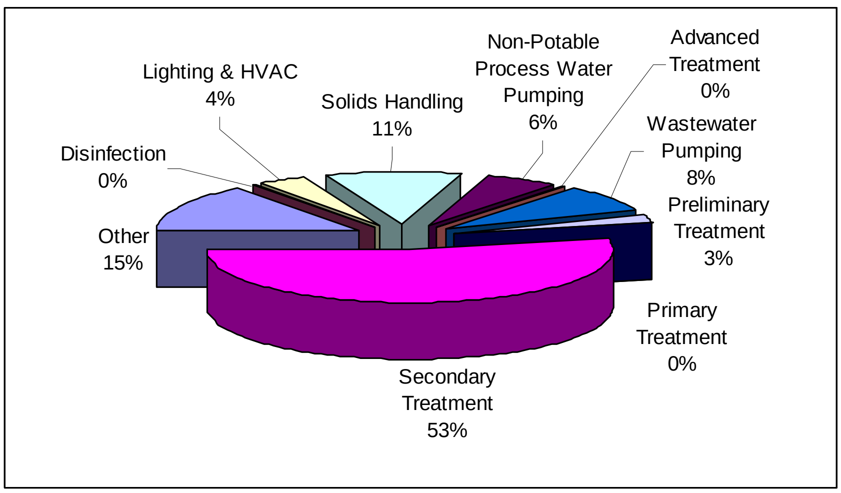

Figure 2. Wastewater Treatment Equipment Energy Use[8]

The energy use by individual equipment in the wastewater treatment process plays an important role in formulating automated demand response strategies since energy-intensive equipment should be the primary target for demand response. The most energy-intensive equipment in a wastewater treatment facility are pumps and aerators fans. The energy required for influent wastewater pumping can range from 15 to 70 percent of the total electrical energy depending on the wastewater treatment facility site elevation and influent sewer elevation.[9] In many cases, wastewater treatment facilities with diffused aeration systems can use 50 to 90 percent of electric power demand to run aerator blower motors.[10] Developing demand response strategies focusing on this key equipment may result in the most significant load reductions.

Wastewater Treatment Facility Controls

Control systems are essential for automating demand response strategies in wastewater treatment facilities. The use of centralized computer controls, such as Supervisory Control and Data Acquisition (SCADA) systems in wastewater treatment facilities is increasing by about five percent annually.[11] The introduction of centralized controls integrates existing standalone controls or distributed control systems, improving operational efficiency and facilitating the automation of demand response strategies.

Centralized control systems allow for integrated data collection and analysis, and provides opportunities to improve overall facility performance.[12] Within wastewater treatment facilities, SCADA systems direct when to operate remote equipment and make complex decisions based on input from the system.[11] These systems provide continuous and precise control of process variables[11] and can start, slow down, or stop equipment when monitored process information such as flow rates and dissolved oxygen levels deviate from pre-established parameters.[13] SCADA systems can be programmed to monitor and automatically adjust equipment in response to deviations from preset levels for biological oxygen demand, air density, blower efficiency, and facility flow on a real-time basis, and meet discharge regulations with better control at the treatment level.[13,14] Centralized control systems allow for more efficient overall operation of all facility systems, and provide an entry point to the facility to implement automated demand response strategies.

Automated Demand Response Strategies

The technologies that enhance efficiency and control within wastewater treatment facilities could also enable these facilities to become successful demand response participants. Comprehensive and real-time demand control from centralized computer control systems can allow facility managers to coordinate and schedule load shedding and shifting through equipment-level controls to reduce energy demand during utility peak hours. This section outlines several load shedding and load shifting opportunities that could be successful in wastewater treatment facilities.

Opportunities for load shedding during demand response events include turning non-essential equipment off and transitioning essential equipment to onsite power generators. Facilities can turn off aerator blowers, pumps, facility HVAC systems, and other non-essential equipment to shed electrical load during peak hours. Alternatively, facilities can use variable frequency drives to operate this equipment at lower capacity which reduces demand and better matches the requirements for operation within regulatory limits. Centralized control systems can provide wastewater treatment facilities with an automatic transfer switch to running onsite power generators during peak demand periods.[13] Onsite power generators running on anaerobic digester gas, a byproduct of the treatment process, can also provide off-grid power during demand response events. This strategy has been proven successful in municipal wastewater treatment facilities; the East Bay Municipal Utilities District has implemented a load management strategy which includes a digester cover that stores anaerobic digester gas until it can be used during peak-demand periods.[15]

Implementing load shifting strategies in wastewater treatment facilities allows the main energy-intensive treatment processes to be rescheduled to off-peak hours.[16] A major opportunity for shifting wastewater treatment loads from peak demand hours to off-peak hours is over-oxygenating stored wastewater prior to a demand response event. This allows aerators to be turned off during the peak period. However, facilities must be careful to monitor and maintain the correct range of aeration since over-oxygenation due to prolonged detention time can also adversely affect effluent quality. Further, if site conditions allow, wastewater treatment facilities can also utilize excess storage capacity to store untreated wastewater during demand response events and process it during off-peak hours.[15] Additionally, facility processes such as backwash pumps, biosolids thickening, dewatering and anaerobic digestion can be rescheduled for operation during off-peak periods, providing peak demand reductions in wastewater treatment facilities.[13, 17]

Conclusions and Future Directions

Wastewater treatment is an energy intensive process with high electrical load during the utility peak demand periods. Integrated centralized control systems are becoming more commonplace in wastewater treatment facilities. These control systems improve efficiency and allow for greater control of facility process, and can also be used in the integration of automated demand response strategies. These controls can be used to shed or shift loads through lowering the capacity of aerator blowers, pumps and other equipment, temporarily transitioning to onsite power generators, over-oxygenating or storing and processing wastewater during off-peak periods.

While only a few of the demand response opportunities outlined in this paper have been tested and proven as successful load management strategies, similar activities have long been incorporated as energy efficiency measures in wastewater treatment facilities. The success of energy efficiency opportunities in these facilities, combined with the increased use of centralized control systems, demonstrates the potential for automated demand response. Furthermore, the magnitude of the load in these facilities alone suggests the extent of demand response reduction potential, and indicates the need for further study of automated demand response in wastewater treatment facilities. Further research is underway to better understand opportunities for demand response control strategies in wastewater treatment facilities and evaluate how such strategies perform in actual facilities.

Acknowledgements

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