Pump Station Efficiency Reduces Greenhouse Gas Emissions

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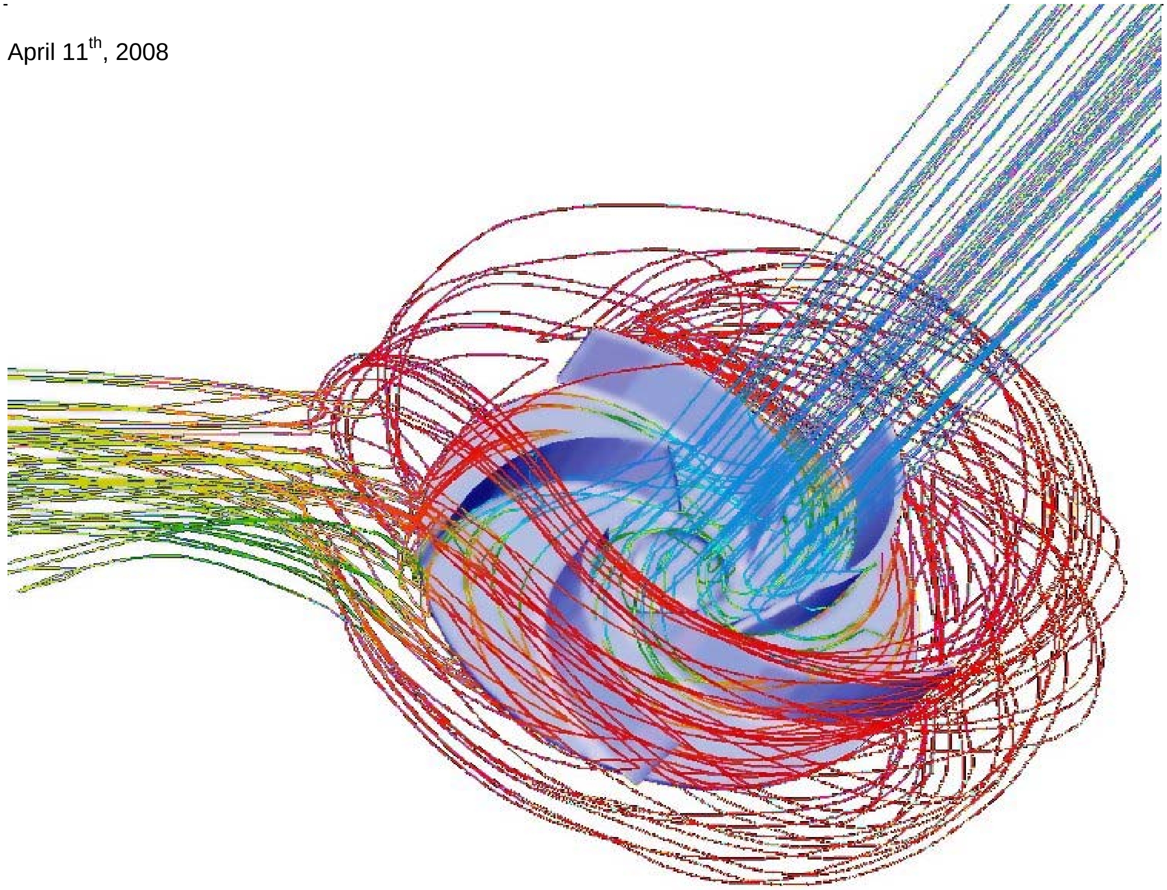

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Global warming and greenhouse gas emissions

Scientists recently published strong evidence that climate warming trends observed around the world are a result of human activity (IPCC, 2007a). Their studies indicate that temperature increases observed since the mid-20th century have resulted from concurrent increases in greenhouse gas (GHG) emissions, which include carbon dioxide (CO_2), methane (CH_4), and other gases emitted as a result of human activities (IPCC 2007b).

Anthropogenic greenhouse gas emissions result primarily from burning of fossil fuels for electricity, heat, or transportation. For instance, US industrial activities, including wastewater treatment handling and processing, generate approximately 1.75 billion tons of CO_2 equivalent GHG emissions per year, or approximately 25 percent of net US annual GHG emissions (DOS, 2007). Of that amount, it is estimated that approximately 17 million tons of CO_2 equivalent GHG emissions per year[1] are released during wastewater treatment. These emissions result primarily from wastewater pumping, but also other treatment operations (CSS, 2007).

The US federal government has yet to take a substantial action directed explicitly towards reducing GHG emissions. In its place, many state and regional efforts have taken steps towards reducing and regulating GHG emissions. For instance, regional entities including the Western Governors' Association[2], the Eastern Climate Registry[3], Powering the Plains[4], the U.S. Mayors Climate Protection Agreement[5], and several other groups have implemented GHG reduction targets, cap-and-trade programs, increase energy efficiency, and provide clean and diversified energy. Additionally, state initiatives including climate action plans (29 states), renewable energy portfolio standards (23 states), climate advisory boards (12 states), GHG emissions targets (12 states), energy efficiency portfolio standards (10 states), mandatory CO_2 reporting for stationary sources (5 states), and GHG emission caps or registries (3 states), specifically target reduction of GHG emissions.

The currently US political climate, outside of the Bush Administration, appears to be favorable to GHG regulation. All three frontrunners for the White House support adoption of a cap-and-trade[6] system, and the current legislature has also shown substantial

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[1] This figure does not include GHG emissions resulting from sludge degradation and methane outgassing, which accounted for an additional 37 million tons of CO_2 equivalent GHG emissions in 2006 (US EPA, 2008).

[2] http://www.westgov.org/wga/initiatives/cdeac/index.htm

[3] http://www.easternclimateregistry.org/

[4] http://www.gpisd.net/resource.html?Id=61

[5] http://www.ci.seattle.wa.us/mayor/climate/default.htm#what

[6] A cap-and-trade system is set in place when regulators (typically government) set a maximum emissions 'cap,' then issue emission permits to GHG emitting companies or entities. The companies/entities may not exceed the cap without purchasing additional 'credits' from a company or entity that is not using its full share of permitted emissions.

support for a cap-and-trade system, for increases in energy efficiency standards, and for additional goals or standards for use of renewable energy in place of fossil fuel. Generally speaking, US states, counties, cities, and other local governments are also increasingly initiating GHG emissions analyses, and passing measures that support or require reductions in GHG emissions and increases in energy efficiency.

What does this mean for the wastewater industry?

Since wastewater industry GHG emissions represent less than 1 percent of the US total, do wastewater treatment managers and administrators really need to be concerned about GHG emissions? For the time being and under the current federal administration, the answer is, for most parts of the country, yes. Wastewater treatment operations in Nebraska, North Dakota, and South Carolina probably have little to worry about, since at the time of this publication, their states had yet to conduct GHG inventories or set relevant state standards for GHG emissions. But all other states are taking substantial initiative, with California and many northeastern states leading the way towards stringent GHG regulations. Many cities and local jurisdictions, such as Portland, Oregon and Sonoma County, California, are implementing regulations above and beyond those at their respective state level. Over the last year and a half, even federal lawmakers' opinions about climate change and GHG emissions are more in alignment with the stringent regulatory environments of Europe, Japan, or Australia. So in five to ten years, it is very reasonable to predict that the US wastewater industry as a whole will be subject to substantial GHG regulations.

Where do wastewater GHG emissions come from? What can we do?

Wastewater industry GHG emissions come from two primary sources: digestion or decomposition of sewage and the decomposable fraction of sludge, which releases CO_2 and methane (CH_4); and consumption of energy used to power lift station and other pumps used for wastewater conveyance. Some GHG emissions result from wastewater treatment processes such as dewatering of biosolids, or from maintenance and operation of office buildings and other support facilities. But these sources are generally minor in comparison to digestion/decomposition and pump power usage.

Reduction of GHG emissions associated with digestion and decomposition of sewage and sludge may be accomplished through collection and disposal (generally via burning) of emitted methane. Additionally, sewage and sludge can be treated to induce release of methane gas for collection, using a methane digester. The methane digester creates an anaerobic environment where microbial decay is promoted, resulting in generation of methane. The methane is then collected and flared, or more typically, purified and used as fuel to generate heat or electricity. This process has been well-researched and documented[7], and methane digesters and other facilities are available from various companies throughout the US to reduce GHG emissions and provide low-cost heat and electricity.

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[7] See the following resources: http://epa.gov/chp/markets/wastewater.html; http://epa.gov/chp/documents/wwtf_opportunities.pdf; http://www.epa.gov/CHP/markets/wastewater_fs.html; A list of potential state grants and tax breaks for adding a methane digester to a wastewater treatment plant may be found here http://www.epa.gov/CHP/funding/bio.html.

Less widely discussed are contributions of GHG emissions associated with the energy use of pumps. Wastewater pumps housed in lift stations and elsewhere in water treatment facilities require substantial amounts of energy to operate. Since water is intrinsically heavy, pumping it uphill or against a pressure gradient consumes energy and results in GHG emissions. For instance, the Inland Empire Utilities Agency operates a moderate sized, 8.5 mgd wastewater treatment plant in Ontario, CA. The facility's total combined 1195 horsepower for all pumps as of 2001 consumed approximately 4,750,000 kWh of electricity annually. Assuming 1.345 lbs of CO2 emitted per kWh of electricity during electricity generation (US DOE, 2000), operation of the pumps in this single facility for one year emitted approximately 3,200 tons of CO2, which is equivalent to traveling about 7 million miles in a passenger vehicle at 20 miles per gallon.

Pumps obviously use energy to lift or move water. But a pump also uses considerable amounts of energy to overcome frictional and vibrational forces within the motor and pump mechanism, as well as the turbulence and friction associated with the water as it passes through the pump and pipelines. The wire-to-water efficiency of a pump describes the amount of energy that a pump uses specifically for moving water, versus energy used to overcome friction, vibration, and turbulence. As efficiency increases, more of the energy applied to a pump is transferred into moving water. Therefore, by increasing pump efficiency, less energy can be used to perform the same amount of work, thereby reducing GHG emissions and energy costs.

As an example, the wastewater treatment plant in Ontario, CA mentioned above was part of a joint study with the California Energy Commission and the US Department of Energy. By conducting an energy efficiency study of the plant's 19 water pumps, the plant's operators found that only three of the most frequently maintained pumps had good wire-to-water efficiencies (near 70 percent). All others operated between 47 and 60 percent efficiency. After replacing worn parts, including eddy current clutches, and old motors, the plant reduced its energy consumption by about 475,000 kWh per year, saving enough money on electricity to repay the repair cost in two years and reduce annual GHG emissions by about 320 tons (700,000 miles driving at 20 mpg; CEC & US DOE, 2002).

This example is not unique. Department of Energy studies indicate that by increasing pump efficiency, wastewater treatment facilities can realistically save up to 20 percent of the total energy consumed during wastewater pumping (DEP, 2002). Several case studies also support this claim for water pump stations in general, including an efficiency study and retrofit at Austin Energy in Austin, Texas, where strategic upgrades annually saved 43,000 tons of CO_2 emissions and $1.2 million in energy consumption costs for pumping of cooling water (US DOE, 2006a); or a pumping system for Boise Paper in Wallula, Washington, where a study and upgrades saved an estimated 330 tons of CO2 emissions and $17,500 in energy costs annually (US DOE, 2006b).

Why do pumps lose efficiency?

Losses in pump efficiency occur over time as parts wear, degrade, or are damaged during pump operations. **Table 1** lists several potential causes of pump efficiency losses.

Table 1:
Some Causes of Centrifugal Pump Efficiency Losses

- cavitation
- water hammer
- pressure surges
- foreign objects
- impeller imbalance or wear
- bent shaft
- harmonic vibration
- clogged pipelines or pumps
- loose hardware
- use of vortex pumps
- shape of the impeller
- degradation of wear rings
- operating at critical speed
- increased internal recirculation
- loss of proper impeller clearance
- eroded or corroded internal pump passages
- over-lubricated or over-loaded bearings
- buildups that may rub along mechanical seals
- impeller and casing wear causing increased clearances
- overtightening packing or improper seal installation
- solids rubbing against components, especially the seal
- operating too far from the best efficiency point of the pump
- improperly managed hourly, daily, or monthly increases/reductions in flow/pressure

Source: McNally Institute, 2008.

The above list can be organized into two general categories: mechanical degradation and ineffective operation. Mechanical degradation, such as degradation of wear rings, loss of impeller clearance, or enhanced wear from buildups, requires ongoing pump and facility maintenance to correct and ensure maximum efficiency. Perhaps most critical to reducing the effects of wear is maintaining the internal wearing ring clearance and the smoothness of impeller and casing waterways; also, maintaining pumps and all system components in virtually new condition will avoid losses in efficiency resulting from worn parts and equipment (Hydraulic Institute, 2008).

Ineffective pump operation may be a result of pumps that are oversized for the job that they are meant to do, misapplied pumps, operation of pumps in a throttled condition to compensate for use of oversized pumps, careless management of system flows and pressure, pumping systems with bypass flow, use of multiple pumps systems where excess pressure is generated, using high system pressure instead of a booster pump, or changes from initial design conditions, such as cross connections, parallel main lines, or changes in pipe diameter or material (DOE, 2005).

Efficiency and GHG Reduction Solutions

To most effectively increase pump efficiency, reduce electricity use, and reduce GHG emissions, it is useful to view the efficiency problem as twofold: what physical changes need to be made – maintenance, replacement of worn or inappropriately sized pumps, removal of internal buildups on pipes and pumps, impeller replacement – and what ongoing monitoring is needed to identify problems and substandard conditions that cause or could cause reduced efficiency. Unfortunately, the complex network of pumps and lift stations, pipelines, and other collection and treatment facilities associated with wastewater treatment begs the question: where to start?

It is common in wastewater facilities for several individual pumps or pump stations to operate with high or relatively high efficiency, while the remainder – sometimes only a handful – operate at low or extremely low efficiency. This type of scenario results in excess power consumption and excess GHG emissions for the facility as a whole, and raises the problem of how to identify the problematic components. Without efficiency data for each pump station or pump in your facility, it is nearly impossible to make a cost-effective or time-effective decision regarding maintenance or replacement.

A second, longer term challenge is identifying the most appropriate pumps for each pump station or pump application, to ensure that ongoing electricity use reduction, GHG emission reduction, and efficiency are optimized. Selecting the most appropriate pumps for ongoing and future uses requires a significant amount of data on historic flow rates, water volumes, and efficiency problem-areas. Without such information, selecting the most efficient pumps and pump configurations in the future is not possible.

Perhaps the easiest and most cost effective way to fill in these data gaps is to monitor the system on an ongoing basis. For example, parameters such as flow rate, energy consumption, and pump efficiency, if monitored consistently, would provide the data needed to identify inefficient or problem equipment. Over time, data collected by ongoing pump and pump station monitoring could be used select and configure replacement hardware.

Fortunately, advances in flow and efficiency monitoring technology can significantly streamline the monitoring process. For instance, pump station managers such as the MultiSmart by MultiTrode[8] include many built-in features that datalog level, pressure, pump energy usage, flow rates, and system efficiency. Algorithms include running the most efficient pump. Some pump station managers, such as the MultiSmart, also include complete integration with any SCADA system to facilitate easy data acquisition and real-time supervisory control. This capability allows comprehensive reporting as well as real time data, empowering operations staff to optimize the network on a short-term and long-term basis.

While pump station managers require some up-front investment, life-cycle studies have shown that for wastewater pumps and lift stations, equipment capital cost for efficiency improvements are quickly offset by energy savings (Asdal, 2007; DOE, 2005). As shown in Table 2, at only 8 cents per kWh, increasing the efficiency of a single, 100-hp pump by 20 percent results in an annual savings of 145,000 kWh of electricity, $11,600

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[8] See Also http://www.multitrode.com/products/MultiSmart/overview.cfm.

in electricity cost, and 98 tons of CO_2 equivalent GHG emissions, or the emissions equivalent of driving 215,600 miles at 20 mpg. These numbers speak for themselves: investing in pump efficiency reduces GHG emissions *and* saves money.

Table 2:
Annual Energy, Cost, and GHG Emissions Savings of Increasing Efficiency of a 100-HP Pump by 20 Percent

Annual Energy, Cost, Emissions	**Energy Cost**			
	6 cents per kWh	**8 cents per kWh**	**10 cents per kWh**	**12 cents per kWh**
		100 HP Pump		
kWh required	726,000	726,000	726,000	726,000
Electricity Cost	$43,600	$58,000	$72,600	$87,120
Tons GHG emissions	488	488	488	488
		100 HP Pump with 20 Percent Increase in Efficiency		
kWh	580,800	580,800	580,800	580,800
Electricity Cost	$34,880	$46,400	$58,080	$69,696
Tons GHG emissions	391	391	391	391
		Savings with 20 Percent Efficiency Increase		
kWh	***145,200***	***145,200***	***145,200***	***145,200***
Electricity Cost	***$8,720***	***$11,600***	***$14,520***	***$17,424***
Tons GHG emissions	***98***	***98***	***98***	***98***

Source: DOE, 2005; RSE Consulting, 2008.

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