Collection of Energy Consumption Data from the Operation of Decentralized Wastewater Systems

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ABSTRACT

Energy monitoring technologies were researched and tested by a project team Stone Environmental, Inc. for use in a Decentralized Wastewater Management Demonstration Project near Greenwood Lake, New York. The team found that energy consumption monitoring technologies for onsite wastewater systems could be described in four categories: pump timer calculations, consumer monitoring devices, professional-grade data loggers, and customized control panel or sub-meters. Of the technologies researched for this study, a consumer or "in-home" monitoring device was selected for its cost, open platform data collection, and the effectiveness with which it could encourage positive changes in energy consumption habits.

KEYWORDS

Electricity monitoring, energy usage, energy data collection, onsite wastewater systems, decentralized wastewater treatment

INTRODUCTION

The significant consumption of energy by municipal water and wastewater treatment facilities is rapidly gaining attention as society moves into a new era of energy awareness. The well-established linkages between water and energy represent major opportunities for energy conservation and generation. While larger-scale treatment facilities have begun to study and implement energy conservation measures, lack of process-specific energy consumption data remains a challenge. Sub-metering, or collecting energy consumption data separately, for each process has proven invaluable in understanding the details of large facility energy usage.

Decentralized wastewater treatment and dispersal systems encompass a broad spectrum of technologies. While some of these technologies are completely gravity-controlled and passive, others utilize pumps, rotating contactors, blowers, and other electrical components—a range of technologies representing an equally broad but essentially undocumented range of energy requirements at the individual onsite system scale. Stone Environmental, Inc. (Stone) is leading a Decentralized Wastewater Management Demonstration Project near Greenwood Lake in New York, for the Orange County Water Authority. Funded by the US Environmental Protection Agency and the New York State Energy Research and Development Authority, the project focuses on demonstrating decentralized wastewater treatment technologies as viable, energy-efficient solutions for areas with limiting site conditions and serious community-scale challenges to surface water quality, groundwater quality, and public health.

A goal of the demonstration project is to expand the available literature regarding detailed electricity consumption for decentralized wastewater treatment technologies. Thus, monitoring of the demonstration systems will include a comprehensive assessment of the energy required to operate and maintain the decentralized treatment and dispersal system components.

The energy data collection methods and technologies examined for this project cover a broad spectrum from basic calculations and assumptions using a pump runtime meter as a surrogate for energy monitoring, to high-end sub-metering devices. This manuscript describes the comparison of energy monitoring technologies including sensors, data loggers, displays, and software. Proprietary systems are compared with new open platform options, such as Google PowerMeter ® for usability in the decentralized wastewater industry. Comparative data and display formats are researched with respect to their applicability to engineers, designers, operators, and decentralized wastewater system users.

Electrical energy data that are accessible and well-presented to the system operator and user can be a welcome tool for wastewater system O&M and troubleshooting. Ultimately, the best technologies for collecting information about energy consumption are those that affect user behavior, encouraging water and energy conservation. Some technologies appear to be capable of bridging that gap, integrating the conservation of water and energy in decentralized wastewater treatment and dispersal systems by making easily accessed and well-presented energy consumption data available to the system users. Such useful presentations of energy consumption create vehicles for forming tangible conceptual links between water use and energy consumption.

METHODOLOGY

From previous project experience, the staff at Stone was well acquainted with professional-grade data loggers and sensors distributed by companies like Onset Computer Corp. and Campbell Scientific, Inc. Data loggers that were traditionally used to monitor weather and other environmental parameters have found a rapidly expanding market in energy consumption monitoring. Data loggers provided a reasonable solution to energy monitoring, but were more expensive than what the team had envisioned as reasonable for implementation at the scale of individual onsite wastewater systems. Thus, data collection began on alternatives to the professional-grade data loggers that were familiar. The following primary factors were identified as important for the applications considered for the Greenwood Lake, New York demonstration sites:

- Cost
- Ease of use for operators and homeowners
- Ease and frequency of data retrieval
- Data of a sufficiently fine resolution to record individual pump events
- Reliability
- Accuracy

During the course of researching and identifying energy monitoring solutions, it became clear that an additional factor should be a primary concern:

- Effective as a positive influence on water and energy usage behavior

Using these factors, our research began to coalesce around four main categories of energy monitoring solutions, discussed in the following section. Estimates and quotes were gathered for any solutions that satisfied the primary criteria, even at the most basic level. With customizable solutions, like data loggers and custom-built panels, options were specified that were perceived to be the most useful in individual or small shared-wastewater system applications. The usefulness and format of sample software output was considered, when applicable, as well as operator costs and requirements for more frequent site visits and specialized training.

After Stone staff collected and organized information about the range of potentially applicable energy monitoring technologies, the Greenwood Lake demonstration project team met to discuss the alternatives. While no technology appeared to provide an ideal solution across all of the primary criteria, one solution seemed to provide a reasonable and acceptable outcome. It was then purchased and tested in a residential setting, as discussed in the following sections.

RESULTS

The energy monitoring solutions organized neatly into four main categories, listed below in order of increasing complexity:

1. Energy calculations using a pump run timer
2. Consumer or “in-home” energy monitors
3. Professional-grade data loggers and sensors
4. Custom panel-installed meters / Sub-metering

In general, both cost and level of accuracy increase from category 1 to category 4. However, other key factors, including data accessibility, retrieval, resolution, and ease of use did not trend accordingly. Data collection became a particularly important factor in the technology ultimately chosen by the project team.

Category 1: Energy calculations using a pump run timer

Many pump run timers are basic, inexpensive counters that can easily be installed in most pump service panels. These counters generally measure the number of hours of work that a single pump has performed. Multiple pump systems use multiple timers, which can be compared by the operator to diagnose pump maintenance issues.

To derive energy consumption from the amount of time a pump has run one of the following methods is commonly used. Field measurement of the pump’s electrical usage can be measured and recorded during a pump cycle using a voltmeter or multimeter. Alternatively, the energy consumption of a particular pump can be obtained from the pump specifications. The typical energy consumption amount, however it is obtained, is then multiplied by the most recent timer results to calculate total energy used since the previous timer reading.

This method had the advantage of being extremely inexpensive, with little or no up-front costs depending on the type of pump control panel used. However, data resolution is measured in blocks of multiple months, and depends entirely on the frequency of operator visits to the system. Accuracy was estimated to be low, as the variable energy demands of a pump cycle would be distilled to a single consumption parameter for ease of calculation. Ultimately, this option was considered inadequate for the demonstration project because it did not satisfy the goal of providing feedback to the users based on actual, daily energy and water use.

Category 2: Consumer or “in-home” energy monitors

Consumer energy monitors, or “in-home” monitors, are relatively new technology. All of the options considered by the project team shared the following characteristics:

- Display units were designed to show energy consumption data in a way that was accessible to the average user

- Sensors used Current Transformer (CT) technology to measure amperage
- Results were displayed in both kilowatt-hours (kWh) and money consumed
- Monitors integrated with free data collection and display websites (e.g. Google PowerMeter)
- Multiple sensors could interface with a single unit

Costs for these units ranged from $150 to $300 for a complete kit, making them affordable for most onsite wastewater treatment system applications. Since most units work on a non-proprietary platform, the range of software that could be used to display and analyze results was broad (Figure 1).

Figure 1. Real-time web-based display of energy consumption.

Consumer or in-home energy monitors can often sync with Google PowerMeter, a free application hosted on the web by Google, which allows users to display current and historic data from multiple sensor sources (Figure 2). Data can be downloaded at a resolution as fine as 10-minute increments. Field trials conducted by energy utilities using these units have been shown to reduce electricity consumption by an average of 15% (Eiden, 2009). The easily displayed connection between real-time energy usage and cost allows users to understand the value of energy conservation measures. It will also allow onsite wastewater system users to see the relationship between the amount of water consumed and the energy cost of treatment.

Consumer energy monitors satisfied the requirements for key criteria, and excelled with regard to cost and the effectiveness of changing energy consumption behavior. Therefore, the team chose solutions from this category for the demonstration project.

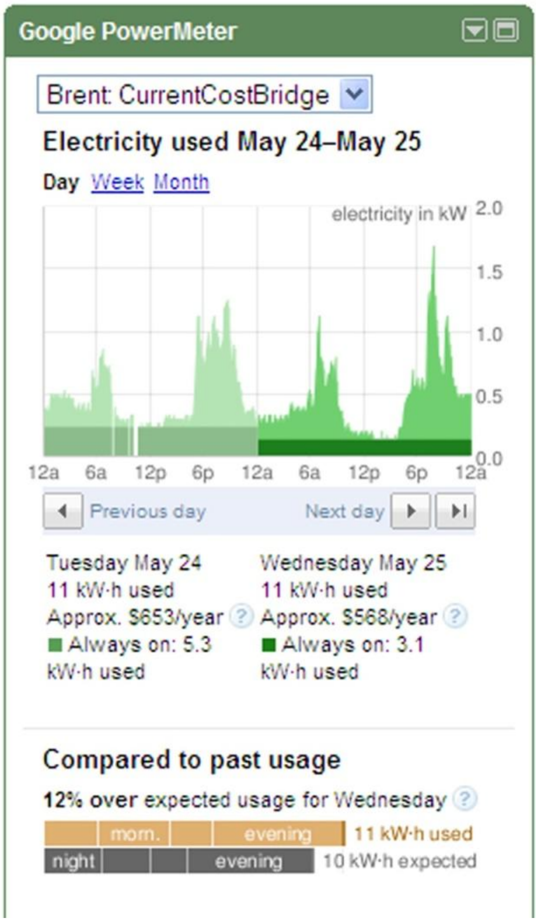

Figure 2. A Google® PowerMeter Gadget is available to display and access stored energy usage data. Energy consumption in 10-minute increments or larger can be downloaded in text or spreadsheet formats.

Category 3: Professional-grade data loggers and sensors

Professional-grade data loggers provided the best mix of accuracy, data resolution, reliability and customization. The team's comfort-level was high with the installation and performance of these devices, after years of success in past projects logging environmental parameters with similar technology. Sensors could be attached to multiple pumps with extremely fine data resolution, providing a robust dataset describing the function and energy usage of the wastewater system's components. Sensors are available using CT technology (similar to the consumer energy monitors) as well as alternate sensor technologies. Data collection and retrieval have been proven to be reliable, although a trained operator with a proprietary data download device or software is typically required to interact with the stand-alone devices. Cellular, Wi-Fi, and Ethernet connections are available as data logger options, but for our project these options were cost prohibitive. Data uploaded remotely also typically requires access to a proprietary web-hosting solution, with additional annual costs depending on the frequency of data upload.

Cost became a major concern for the team when it was realized that two data logger installations would most likely total between $1,000 and $3,000, depending on the options that were selected.

Most importantly, data from this category of solutions would be viewed and used by the project team, and possibly by the onsite wastewater system operators, but not by the users themselves. Any data used to reinforce positive energy consumption behavior changes would be filtered through the project team or a wastewater operator at intervals of several months, greatly reducing the likelihood that positive energy consumption behavior changes would become habitual.

Category 4: Custom panel-installed meters/Sub-metering

The team contacted distributors of pump control panels, seeking options for the addition of energy monitoring components. Another reasonable option would be a separate utility meter for the onsite wastewater system, something that is often a feature of larger cluster systems with treatment or dispersal components on a separate parcel of land from the buildings serviced by the system.

Energy monitoring components were available in many configurations, but each required customized design and panel construction, making even basic monitoring functionality cost prohibitive for our project.

The major benefit of custom panels and sub-metering is the inherent accuracy of a direct-measurement of energy consumption. Operators can record this data quickly during regular inspections.

Unfortunately, this solution shares the data collection problem of Category 1 data are only collected when the operator reads the meter, and fine resolution data that might lead to positive changes in energy consumption by the homeowners are generally not recorded.

Product testing

In December 2010, our team purchased 2 Current Cost ENVI® units (Figure 3), sold in the United States by PowerSave, Inc. Since then, they have been connected in various configurations for testing, prior to permanent installations for the Greenwood Lake demonstration project (scheduled for summer 2011). They performed best with the addition of an Ethernet bridge, allowing data to be automatically uploaded to Google PowerMeter every 10 minutes. Real-time usage data are available on the LCD display of the monitor, while historical usage is available for any monitored devices via a pull-down menu on the PowerMeter gadget. The sensors have remained synced with the unit, and no interruptions between the sensor and base unit have occurred.

Figure 3. A consumer-grade electricity monitoring device that can track and store data from up to ten different energy using devices. Photo courtesy Current Cost Ltd.

The Ethernet bridge was interrupted twice in 3 months of testing this configuration: once after a power outage, and once with no apparent explanation. Both instances of disconnection were easily fixed by unplugging the device and then reconnecting it.

Uploading energy usage data directly from the device to a computer (using a USB cable) using the Current Cost software was extremely problematic. However, the same dataset is easily downloadable from PowerMeter in a variety of file formats.

DISCUSSION AND CONCLUSIONS

Consumer monitors

The team decided to use a consumer-grade electricity meter for ease of use and practicality of placement in a residential setting. It was envisioned that the homeowner would be an active participant in the monitoring and conservation of water and energy by having a simple way to access energy monitoring data at will. Product testing bolstered this idea, as both children and adults became more engaged in understanding the value of energy. Energy conserving measures were visible and quantifiable in real-time, leading to tangible improvement in energy conservation habits during the test.

The ease with which energy consumption data is accessible through in-home monitors, and their affordable price points, make them ideal for monitoring energy usage by residential onsite wastewater systems and components. New products, software, and applications are constantly appearing on the market. Utility companies have begun widespread trials of programs that give free monitors to homeowners, counting on energy conservation behavior changes to provide a return on the investment. New versions of consumer-grade energy monitoring hardware in the United Kingdom are compatible with electronic water meters as well.

As of May 2011, Google has decided to discontinue development of its PowerMeter software. The service is still available, and there are no current plans to make PowerMeter unavailable, but new features will no longer be created. However, many proprietary and freeware applications are available with similar functionality (including new apps for mobile devices) and the trend appears to be that more will be developed.

Data loggers

It came as a surprise to the team that dedicated data logger companies (especially Onset Computer Corporation) are now marketing energy monitoring applications more aggressively than their traditional environmental data collection applications. New products are rapidly entering the marketplace, with cost and ease-of-use as major drivers in product development. It is entirely possible that professional-grade data loggers are on the cusp of entering the consumer in-home market.

Next Steps for the Greenwood Lake, New York, demonstration project

When the construction of the demonstration project onsite wastewater systems are completed, the consumer energy monitors will be installed and tracked by the project team, the operators, and the homeowners. Energy usage data from these installations is vital to the team's complete understanding of the demonstration project technologies and their applicability in future onsite wastewater installations.

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