U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Demonstration of Advanced Technologies for Multi-Load Washers in Hospitality and Healthcare – Ozone Based Laundry Systems

August 2014


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The Department of Energy coordinates technology demonstrations with the General Service Administration's Green Proving Ground program: **GSA website**. The Green Proving Ground leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies and practices, while the Department of Energy-funded technology demonstrations are conducted in both federal and non-federal buildings. Findings are used to support the development of technology performance specifications and inform decision-making within federal agencies and the real estate industry. The programs aim to drive innovation in energy and environmental performance in buildings and help lead market transformation through deployment of new technologies. Learn more at: http://energy.gov/eere/buildings/technology-demonstrations#propose

## Disclaimer



The work described in this report was funded by the U.S. Department of Energy under Contract No. DE-AC05-76RL01830.

## Acknowledgements

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## I. Executive Summary

The U.S. Department of Energy (DOE) Building Technologies Office seeks to develop and accelerate the integration of energy efficient technologies and solutions into new and existing buildings. An area of interest is multi-load washers used in the healthcare and hospitality industry because they are among the most energy intensive pieces of equipment used in these facilities. Multiple technologies are available on the market for significantly reducing energy and water consumption of multi-load washers. However, adoption of these advanced technologies has thus far been limited because of uncertainty about return on investment and concerns about reliability, performance, and user satisfaction, including hotel guest/healthcare patient satisfaction. Quantifying the energy and water savings potential of current market-ready systems will help promote the adoption of these technologies in the commercial sector.

The objective of this demonstration project was to evaluate market-ready retrofit technologies for reducing the energy and water use of multi-load washers in healthcare and hospitality facilities. Specifically, this project evaluated laundry wastewater recycling technology in the hospitality sector and ozone laundry technology in both the healthcare and hospitality sectors. This report documents the demonstration of two ozone laundry system installations. The demonstration of a wastewater recycling system is documented in a separate report.[1]

The ozone laundry systems were installed in two facilities. These are:

- Charleston Place Hotel in Charleston, SC
- Rogerson House assisted living facility in Boston, MA

Both facilities have laundry system hot water heated by natural gas fired boilers and are served by the city water/sewer utility.

In addition to quantifying the savings offered by this technology, the project also endeavored to characterize the relative satisfaction of the performance of the ozone technology. Overall satisfaction was gauged based on discussions with laundry staff and engineering, including ease of integration, and operation and maintenance requirements, as well as, consistency of the condition of the laundry and whether there was any change in customer complaints.

Ozone laundry technology is an add-on retrofit for improving the energy and water efficiency of multi-load washers in commercial laundries. An ozone system consists of an ozone generator that creates the ozone gas (90% oxygen) from ambient air and injects it into the wash water where it dissolves, opens up the fibers and releases stains. Opening up the fibers makes the linens easier to dry and can result in a decrease in drying time. After the wash cycle is completed, the ozone is then vented through a carbon tower and absorbed. Adding ozone equipment to existing washing machines can completely eliminate a laundry's need for hot water because ozone works best in cold water. It also can reduce the wash cycle and dryer times thus allowing for more

[1] BK Boyd, GB Parker, GP Sullivan, JM Petersen, WJ Goetzler, KJ Foley, TA Sutherland, 2014. "Demonstration of Advanced Technologies for Multi-Load Washers in Hospitality and Healthcare – Wastewater Recycling." Prepared by Pacific Northwest National Laboratory and Navigant Consulting, Inc. for the U.S. Department of Energy, Washington, DC.

laundry productivity. In addition, the rinse cycle can be reduced from two cycles to one allowing for a water/sewer savings. Because ozone leaves only oxygen behind, it is also environmentally friendly.

Table 1 shows the laundry throughput (per thousand pounds)-normalized results of the Charleston Place Hotel demonstration. The approximate installed cost of the ozone system is $42,200. The utility costs are $0.80/therm natural gas (blended), 9.4 cents/kWh, and $10.38/thousand gallons of water/sewer.

**Table 1. Charleston Place Hotel Laundry Throughput-Normalized Results‡**

| Utility Component | Pre-Ozone Cost ($/klb) | Post-Ozone Cost ($/klb) | Cost Savings ($/klb) |
|---|---|---|---|
| **Natural Gas** | $8.64 | $3.03 | $5.61 |
| **Water/Sewer** | $20.42 | $17.36 | $3.06 |
| **Electricity for Ozone system** | $0.00 | $0.30 | ($0.30) |
| **Total** | **$29.06** | **$20.69** | **$8.37** |
| **Simple Payback Period** | | | **2.8 years** |

‡ Based on 150,000 pounds of laundry/month, $15,072/year utility cost savings and ozone system cost of $42,200.

The results show that the ozone system slightly increases electricity consumption due to the operation of the ozone generation equipment, while providing significant natural gas savings, resulting in net natural gas energy and cost savings. The system also shows significant water/sewer savings resulting in significant net total utility cost savings. In addition to the savings, laundry staff and facility engineering noted the technology integration went smoothly and overall guest satisfaction of the linens remains high.

Table 2 shows the laundry throughput (per thousand pounds)-normalized results of the Rogerson House demonstration. The approximate installed cost of the ozone system is $12,000. The utility costs are $0.90/therm natural gas, 13.8 cents/kWh (blended) and $16.12/thousand gallons of water/sewer.

**Table 2. Rogerson House Laundry Throughput-Normalized Results‡**

| Utility Component | Pre-Ozone Cost ($/klb) | Post-Ozone Cost ($/klb) | Cost Savings ($/klb) |
|---|---|---|---|
| **Natural gas** | $8.44 | $3.11 | $5.33 |
| **Water/sewer** | $25.99 | $30.87 | ($4.88) |
| **Electricity for Ozone system** | $0.00 | $0.35 | ($0.35) |
| **Total** | **$34.43** | **$34.33** | **$0.10** |
| **Simple Payback Period** | | | **671 years** |

‡ Based on 15,000 pounds of laundry/month, $18/year utility cost savings and ozone system cost of $12,000.

The results show that the ozone system modestly increases facility electricity consumption and provides significant natural gas energy savings, but shows additional water/sewer costs as a result of an increase in cold water usage. The increase in water/sewer costs essentially cancels out the natural gas savings, resulting in no financial payback. The unexpected increase in cold water use that resulted in a net increase in water/sewer costs was the result of a greater quantity of cold water used during the rinse cycles in order to maintain satisfactory cleaning performance after installation of the ozone system[2]. The decrease in natural gas use and cost due to the use of less hot water was therefore offset by the increase in water/sewer use and costs and the net increase in electricity cost for the ozone generator, resulting in negligible overall cost savings for this laundry operation. In addition to the utility impact, overall resident satisfaction was determined to be satisfactory as the technology integration went smoothly and linen cleanliness quality remained consistent.

**Conclusions**

The major conclusions from the demonstration results are as follows.

**Charleston Place Hotel**

The Charleston Place Hotel is characterized as having relatively moderate natural gas and water/sewer rates and laundry throughput averaging about 5,000 pounds per day. The ozone system installed at Charleston Place Hotel delivers significant water heater energy savings and modest water savings. The simple payback period for this ozone system installation is 2.8 years, which is within the range of a 2-3 year payback period that most businesses find acceptable. It also shows the system can be integrated at a high-end hospitality facility without negatively impacting the quality of the linens.

**Rogerson House Assisted Living Facility**

The Rogerson House assisted living facility is characterized as having relatively moderate natural gas prices and high water and sewer rates (and an average laundry throughput of approximately 500 pounds per day. Despite the energy (natural gas) savings provided by the ozone system, the additional water usage resulted in negligible monthly cost savings and thus essentially no financial payback. These results indicate that unlike energy savings, water savings is not assured by the installation of an ozone system. Careful attention is required during the reprogramming of the wash cycles to ensure that total water usage is not increased arbitrarily as a result of any equipment modifications that require washer program changes. Assuming the system could be re-adjusted to achieve net neutral water consumption, the results of this study indicate that for a location with similar laundry and utility costs, a minimum laundry throughput of around 1,500 pounds per day would be required for ozone laundry technology to be financially attractive. The demonstration also shows that the ozone system can be integrated at a healthcare facility without negatively impacting the quality of the linens processed in the central laundry.

[2] The laundry operations staff and ozone system vendor provided this information in discussion with the demonstration team at the conclusion of the demonstration. As discussed in the body of the report, further adjustments to the wash programs could likely be made to the Rogerson House equipment to reduce the cold water usage during the rinse cycles, while maintaining satisfactory cleaning and rinsing performance.

## II. Introduction

Most institutional laundry systems found in on-premises hospitality and healthcare facilities are batch systems, using multi-load washers (MLWs) and washer extractors with thousands of pounds of throughput daily. MLWs and washer extractors are among the most energy intensive equipment in these facilities.

Improvements in efficiency in batch laundry MLWs are available from system improvements or retrofits. These retrofits are commonly either 1) a low-temperature ozonation system supplementing traditional hot water-based detergents; or 2) a wastewater recycling system that reduces total water consumption.

For example, a field demonstration project in a commercial hotel laundry was undertaken by Pacific Northwest National Laboratory (PNNL) in a Red Lion Hotel in Portland, Oregon in 1995. The laundry serves a large hotel/motel chain and processes an average of 25,000 pounds of laundry per day. A wastewater recovery system was installed in the laundry in September 1995. After approximately 5 months, the retrofit system achieved final results of 52% savings in water consumption and 44% savings in energy to heat water. In this case study, performance measurements show monthly savings of approximately $3,400 on water, sewage, and natural gas resulting in a simple payback of 4.1 years (Garlick et al, 1996).

Several studies of ozone laundry retrofit systems have been undertaken by utilities offering incentives for ozone system retrofits and by the ozone equipment manufacturers and installers. A large chain hotel achieved more than a 90% reduction of hot water use in their laundry facility after an ozone system was installed, resulting in more than 9,000 therm/yr of natural gas savings with an additional savings of 2,000 therm/yr in dryer energy use for the facility. The data were provided by the manufacturer/installer of the ozone system (Wyndham 2010).

A 2009 DOE study performed by Navigant Consulting, Inc. (Navigant) estimated industry-wide potential savings of 124 trillion British thermal units per year (Btu/yr) as a result of efficiency retrofits in institutional laundry systems (Zogg et al. 2009). This estimate was based on nationwide utility consumption estimates rather than throughput or turns per day. This technical potential is based on an estimated primary annual energy consumption of 248 trillion Btu/yr and roughly 50% savings per unit with wastewater recycling systems or low-temperature detergents, which is consistent with the Red Lion field demonstration.

Recognizing that both ozonation and wastewater recycling retrofits in MLWs can deliver significant energy and water savings, DOE funded a demonstration of these energy-efficiency measures through the Better Buildings Alliance (BBA) to further examine the potential savings. DOE demonstrations were considered important and necessary to provide rigorous and independent measurements of the energy and water savings of retrofitted systems.

Despite marketing efforts and financial incentives by some energy and water utilities, the hospitality and healthcare industries are not widely adopting and embracing these technologies because of uncertainty about payback period and concerns about reliability, performance, and guest satisfaction. Therefore, these DOE-led demonstrations will quantify the water-heating energy savings as well as water savings, ascertain the user and customer satisfaction, and allow the industry to estimate its return on investment (ROI) and/or life-cycle cost savings of installing these measures.

## III. Project Scope

The scope of this demonstration project is to quantify the energy and water savings potential of ozone laundry systems and wastewater recycling systems to help accelerate the adoption of these technologies in the commercial sector, across not only the hospitality and healthcare industry, but all sectors that employ MLWs. In addition to quantifying the savings offered by this technology, the project also endeavored to characterize the relative satisfaction of the performance of the ozone technology. Overall satisfaction was gauged based on discussions with laundry and hotel management staff and included gaining a sense of ease of integration, and operation and maintenance requirements of the equipment, as well as, consistency of the condition of the laundry and whether there was any change in resident/guest complaints.

The overall objective of this project is to enable widespread technology transfer in the industry and specifically among the Commercial Buildings Integration program's BBA members. Possible follow-on activities include the development of general technical specifications of efficient multi-load laundry equipment that are tailored for specific applications and/or sectors (hospitality, healthcare, etc.), vetted with the hospitality and healthcare partners and other BBA partners, finalized, published, and disseminated.

Three sites were selected to undertake field demonstrations of the energy and water savings of retrofit technologies: a hotel in Seattle WA, a hotel in Charleston SC, and an assisted living facility in Boston, MA. This report documents the demonstration of two of the sites, each retrofitted equipped with an ozone injection system at the central laundry. These two sites are:

- Charleston Place Hotel in Charleston, SC
- Rogerson House assisted living facility in Boston, MA

The Seattle, WA site is a demonstration of a wastewater recycling system retrofitted to the central laundry at the Grand Hyatt Hotel. The results of that demonstration are documented in a separate report.[3]

At each demonstration site, a plan was developed to meter and monitor all relevant system inputs and to collect non-metered/monitored data.[4]

Utility rates for each demonstration site were determined to aid in the economic analysis. These included electricity rates from the rate schedule(s), natural gas rate from the rate schedule(s), and water supply and wastewater treatment rates from the rate schedule(s).

Across the three demonstration sites, the laundry systems data collection included:

- Equipment energy use including
  - Electrical energy of ozone generator
  - Natural gas (or electric) for water heating

[3] BK Boyd, GB Parker, GP Sullivan, JM Petersen, WJ Goetzler, KJ Foley, TA Sutherland, 2014. "Demonstration of Advanced Technologies for Multi-Load Washers in Hospitality and Healthcare – Wastewater Recycling." Prepared by Pacific Northwest National Laboratory and Navigant Consulting, Inc. for the U.S. Department of Energy, Washington, DC.

[4] The methodology and results of the technology analysis are described in the scoping report, found here: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22310.pdf. Note that the metering approach and test plan described in the scoping report were subject to change due to individual site-specific circumstances.

    - Electrical energy use of washer, where possible
    - Steam for heating water, where applicable
- Equipment water use including
    - Cold water volume and temperature
    - Hot water volume and temperature
- Equipment total usage including
    - Washer cycles per period (tracked daily, weekly or monthly)
    - Washer cycle selection – to track type of cycles to match pre and post periods for consistency
    - Other use (non-metered) data collected including
        - Chemicals (detergent, fabric softener, etc.) use
        - Throughput (e.g., pounds of laundry processed per month)

In addition, data were collected on user (facility laundry staff) and customer satisfaction, including but not limited to overall user satisfaction of the retrofit system, observations of operations of the retrofit system (e.g., did the operations of the laundry system change with the retrofit), maintenance of the laundry system before and after retrofit, condition of the laundry before and after retrofit (changes in color, fabric wear, etc.), and customer (hotel guests, residents) feedback, if any.

The results of the demonstrations widely distributed throughout the BBA and industry in general. Case studies will be developed and disseminated to highlight the technologies, technology applicability/acceptance, energy (and water) savings potential, and cost savings.

Technical specifications may be developed for potential use by the BBA stakeholders to consider procuring new/retrofit applications. The specifications can also be used to promote water/energy utility incentives in markets where there are currently no incentives for these technologies. These materials will be vetted and distributed through DOE to the BBA stakeholders and members and others in multiple venues, as one element to help transform the industry to adopt efficient technologies.

## IV. Project Approach

This project was jointly undertaken by PNNL and Navigant, with PNNL responsible for the overall management and coordination of the project and conducting the wastewater recycle demonstration in Seattle, WA and Navigant responsible for conducting the ozone laundry technology demonstrations described in this report.

The project followed a three-phase approach:

- Phase I: Select the technology platforms and the demonstration sites.
- Phase II: Determine the demonstration protocols and conduct the demonstration at the selected sites.
- Phase III: Prepare a final report that presents the results, recommendations, and conclusions.

The following sections describe the specific approach used for each phase of the project.

### A. Systems Selected for the Demonstration

The project team initially considered four multi-load washer technologies for this demonstration project:

1. Laundry wastewater recycling
2. Low-temperature detergents
3. Ozone technology
4. Polymer bead technology

For each technology, the team investigated reported energy and water savings, technology development status, market availability, and number of providers of the technology. The team also considered other notable aspects of each technology such as installation requirements, operational requirements, and suitability for use in healthcare or hospitality facilities. The results of this analysis indicated that laundry wastewater recycling and ozone technology would be the most suitable technologies for this demonstration project.[5]

Specifically, ozone laundry technology emerged as an appropriate technology choice due the following characteristics:

- High potential energy savings
- Mature but underused technology
- Readily available on the market from multiple vendors
- Relatively low market penetration
- Retrofit technology compatible with almost any multi-load washer
- Minimal space requirements
- Little or no additional training required for operation
- Oxidizing/sanitizing properties of ozone ideal for healthcare and hospitality laundry needs

An ozone system consists of an ozone generator that creates the ozone from ambient air and injects it into the wash water. Once dissolved in the water, the ozone reacts with insoluble soils, making them soluble, after which the mechanical action of the washing separates the soils from the fabric. Ozone also acts as a natural disinfectant, providing sanitization capabilities.

The installation of the ozone system itself does not inherently reduce energy consumption; rather, the addition of ozone in the wash water enables the laundry facility to significantly reduce the wash water temperatures, which results in hot water energy savings. Ozone stays dissolved more effectively in cold water, so the wash temperatures can be reduced from the 140°F level typically used in commercial laundries. In many cases, equivalent cleaning performance can be achieved using no hot water at all. Some wash cycles, particularly those that use chlorine bleach, may require warmer water temperatures around 90°F to maintain the bleaching effect for adequate stain removal. Since hot water heating energy is the largest component of energy usage during the wash process, reducing or eliminating the need for hot water during the wash cycle can achieve significant energy savings. Ozone can also enable water savings, as it allows the washer to perform a lighter rinse using less water for some cycles, resulting in overall water savings after installing the ozone system.

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[5] Ibid.

Immediately after installation of an ozone system, the ozone vendor, often in consultation with the detergent chemical supplier, will adjust the pre-programmed wash cycles as described above. The cleaning performance is then monitored for several days to assess whether any further modifications to the wash programs are required. If the cleaning performance is not acceptable, additional adjustments are made to the wash temperatures and detergent chemistry until satisfactory cleaning results are achieved using the new ozone system.

After the initial installation and startup period, ozone systems typically require little maintenance apart from filter or cartridge replacements within the ozone generator. Ozone systems can be used in all commercial facility types, regardless of the degree of laundry soiling.

**B. Vendor and Site Selection**

After selecting the technologies, the team followed parallel tracks to identify and select candidate sites and individual vendors of each technology. These parallel tracks included:

- Contacting the lead at DOE for the BBA Commercial Real Estate & Hospitality and Healthcare peer groups to make them aware of the search for a demonstration site and seek support for assisting in the identification of candidate sites. The team developed a flier to hand out to the peer groups at appropriate venues and for posting on the BBA web site. A copy of the flier is included in Appendix E.
- Identifying and contacting vendors of each technology to ascertain their interest in participating in a demonstration. This approach would allow the team to monitor an already-planned installation, thus saving the expense of purchasing and installing the technology. Initial contact was by phone with a follow-up of information on the project, including the flier developed for the DOE BBA members. The team developed a set of vendor engagement talking points to be used during the initial phone contact to provide the information about the demonstration. Twelve vendors (9 ozone technology, 3 wastewater recycle technology) were initially contacted and screened for their interest. The full list of vendors is included in Appendix F. Those indicating interest in collaborating in a demonstration were pursued.

Selection of the vendor and host sites required the consideration of the following key criteria:

1. Interested vendors with current or planned retrofit projects (including willingness of the vendor to allow metered data to be published)
2. Type of technology (ozone or wastewater recycle)
3. Location of those projects
4. Timing of those projects
5. Whether or not the planned projects are in a hospitality or healthcare facility

Of these considerations, the timing of the project was most important given the limited window for monitoring/metering and the desire to measure baseline data on the existing laundry system prior to installation of the efficient technology.

This approach resulted in several vendors interested in cooperating in a demonstration with candidate sites identified that met the monitoring window, as well as being located in convenient geographic areas for PNNL (West coast) and Navigant (East coast) to cost-effectively undertake a demonstration. Multiple candidate sites met the key criteria for demonstrating the ozone technology, but only one site met the criteria for demonstrating the wastewater recycle technology.  No additional host sites came forward as a result of the flier.

For the ozone technology demonstration, the candidate sites selected were located in Navigant's geographical region.  Given the ozone retrofit sites were already proposed to be retrofitted by the vendor at the sites' expense, the team agreed to undertake two demonstrations of the ozone technology: one in a hospitality facility and one in a healthcare facility.

For the ozone demonstrations described in this report, the team partnered with ClearWater Tech, LLC of San Luis Obispo, CA[6] and Ozone Water Technologies, Inc. of Tryon, NC.[7] The technology vendor's participation was critical to the success of each respective demonstration.  Vendor responsibilities included the following:

- Identifying potential host sites
- Providing the equipment
- Providing guidance and oversight of the equipment installation
- Equipment startup and commissioning
- Ongoing troubleshooting support throughout the duration of the demonstration
- Validation and verification of equipment performance
- Removal of the vendor's equipment at the end of the demonstration if requested.

After reviewing several sales leads identified by ClearWater Tech, the team selected the Charleston Place Hotel in Charleston, SC as the target host site.  The team also worked with Texchine Incorporated,[8] an ozone consulting and system installation company, which had worked with ClearWater Tech in the past and is located nearby the Charleston Place Hotel.  This allowed for frequent visits by Texchine and close interaction with the host site staff during all aspects of the demonstration program.

After reviewing several sales leads identified by Ozone Water Technologies, the team selected the Rogerson House in Boston, MA as the target host site.

### C. Execution of Agreements

Site agreements were signed by the Director of Engineering at the Charleston Place Hotel and by the Vice President of Operations at the Rogerson House.  The site agreement described the terms and conditions of the demonstration, including liability and host site commitments.  No work could take place until an agreement was signed by all parties.  This process took approximately 1 month to complete.  Copies of the site agreements are included in Appendix C.

[6] ClearWater Tech, LLC. 850 Capitolio Way Unit E, San Luis Obispo, CA 93401, www.cwtozone.com/
[7] Ozone Water Technologies, Inc. Jim Gross, President & CEO. 26 Oak St. P.O. Box 1437, Tryon, NC 28782, www.ozonewatertech.com/
[8] Texchine, Incorporated. Jay Dixon, President. 207 Beaufort Street, Chapin, SC 29036, www.texchine.com/

## V. Demonstration Description

### A. Charleston Place Hotel

**Site Description**

Charleston Place Hotel, pictured in Figure 1, is a luxury hotel in Charleston, SC offering dining, a business center, swimming pool, spa, and health club. The hotel has 320 deluxe rooms, 80 club-level rooms, and 40 suites.

**Figure 1. Charleston Place Hotel in Charleston, SC (Photo: Charleston Place)**

**Existing Laundry System Description**

The Charleston Place Hotel laundry facility consists of three Braun 250-pound multi-load washers and one Washex 90-pound multi-load washer. One of the 250-pound Braun washers is pictured in Figure 2.


**Figure 2. 250-pound Braun washer at the Charleston Place Hotel (Photo: Texchine, Inc.)**

Peristaltic pumps are used to pump the laundry chemicals through tubes to the individual washers.

Based on discussions with the Rogerson House staff, the washers are used every day of the week, with around seven wash cycles per day typically run on the Braun washers and between two and three wash cycles per day typically on the Washex washer. The most frequently laundered items include linens and towels. Based on the equipment capacities and number of loads per day, the team estimates that the hotel processes around 5,000 pounds of laundry per day.

The hot water for the clothes washers is heated by a natural gas boiler with a nominal thermal efficiency of 75%.

**Ozone Laundry System Description**

The ozone system used at the Charleston Place Hotel was the Eco$_3$Tex™ system from ClearWater Tech, LLC. The system at the Charleston Place Hotel consisted of three ECO2 ozone generators and one ECO1 ozone generator. These were paired with two AEROUS-8 oxygen concentrators. The three ECO2 ozone generators serviced the three Braun washers and the ECO1 ozone generator serviced the Washex washer. The ozone was pumped through tubes leading to the back side of the washers. The system is in continuous operation during each wash and rinse cycle. A controlled connection to each washer instructs the ozone generator when to feed ozone into the washer.

Figure 3 shows the ozone system components as installed.


**Figure 3. Ozone System Components[9] (Photo: Texchine, Inc.)**

[9] Left: Front Panel of ECO2, Right: ECO2 ozone generator with partial view of AEROUS-8 underneath (black box)

Immediately after installation of the ozone system, the ozone installer adjusted the pre-programmed wash cycles to be compatible with the new ozone system.  The wash cycles were reprogrammed to use all or mostly cold water, and the detergent quantities were reduced to prevent over-sudsing under the new wash conditions.

During the next few weeks, the on-site laundry staff provided feedback regarding the observed performance (cleanliness/operation) under the new system.  The staff mentioned that ozone was neutralizing the characteristic scent from the hotel's fabric softener.  Based on this feedback, the washers were further adjusted so that an ozone injection was eliminated from the cycle that uses the fabric softener.

After these final adjustments, the laundry staff was satisfied that all the various types of laundry loads were being washed as effectively as they were before the ozone system was installed.  The post-ozone monitoring period began after the final wash program adjustments were made.

**B. Rogerson House**

**Site Description**

Rogerson House, pictured in Figure 4, is an assisted living facility in Boston, MA offering full-time residence, a day program, and respite care for people with memory loss and Alzheimer's disease.  The assisted living facility accommodates up to 66 overnight residents.


**Figure 4.  Rogerson House Assisted Living Facility in Boston, MA (Photo: Rogerson House)**

**Existing Laundry System Description**

The Rogerson House laundry facility consists of two UniMac multi-load washers, each with a clothing capacity of 60 pounds, as pictured in Figure 5.  Figure 5 shows the nameplate model information, which is the same for both washers.

**Figure 5. Rogerson House Laundry Equipment (Photo: Navigant)**

The laundry chemicals are located in a separate room adjacent to the laundry room. Peristaltic pumps are used to pump the chemicals through tubes leading up into the ceiling and over into the adjacent laundry room.

The washers are used every day of the week, with five to six wash cycles per day typically run on each washer. Based on observations while visiting the Rogerson House site, each washer load fills roughly half to three-quarters of the maximum load volume of the machine. This equates to a maximum of approximately 500 pounds of laundry throughput per day. The most frequently laundered items include bed sheets and towels, personal laundry items, and bed pads. Table 3 shows the different wash programs used on these machines.

**Table 3. Rogerson House Wash Programs**

| Program Number | Program Name | Program Description |
|---|---|---|
| 01* | Sheets | Uses soap & bleach. No pre-rinse cycle. |
| 02* | Towels | Uses soap & bleach. Includes pre-rinse cycle. |
| 03* | Personal Laundry (A) | No bleach |
| 04* | Bed Pads | Extra bleach |
| 05 | Rags & Mops | Bleach & rinse |
| 06 | Personal Laundry (B) | Same as #3 with slight amount of bleach |
| 07 | Delicates | Same as #3 with cool water |
| 08 | Bulky Items | Quilts, sleeping bags (same as #3 with more water) |
| 09 | Rinse Only | For items that have wrinkled or have too much soap |

*Most frequently used cycles

The hot water for the clothes washers is heated by a natural gas boiler with a nominal thermal efficiency of 80%, as shown in Figure 6.

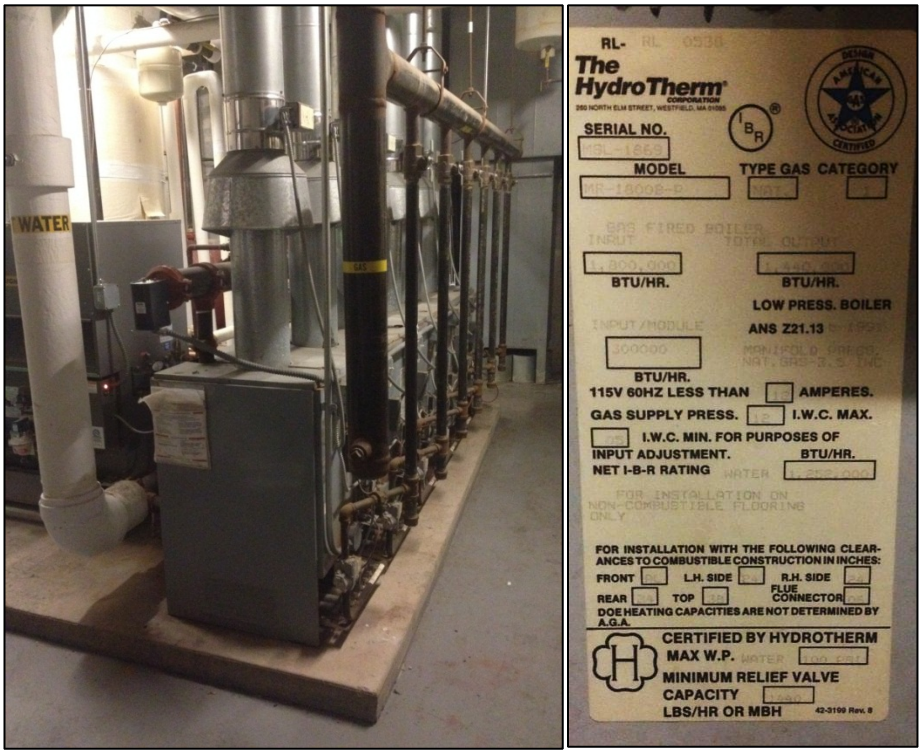


**Figure 6. Hot Water Boiler for Rogerson House Laundry Equipment (Photo: Navigant)**

**Ozone Laundry System Description**

The ozone system used at the Rogerson House was the LaundrOzone™ system from Ozone Water Technologies, Inc. The system consisted of two wall-mounted boxes: one containing the ozone generation equipment and the other containing a single compressor. The ozone generation box uses a modular design, which can accommodate up to four sets of ozone equipment (one for each washer connected to the system). Due to space constraints in the laundry room itself, the ozone system was installed in the adjacent room with the laundry chemicals. The ozone was pumped through a tube leading up into the ceiling and over into the adjacent laundry room. With the LaundrOzone™ system, the ozone is injected directly into the sump part of the clothes washer. The system is in continuous operation during each wash and rinse cycle. A controlled connection to each washer instructs the ozone generator when to feed ozone into the washer. Figure 7 shows the ozone system components as installed.


**Figure 7. Ozone System Components (Photo: Navigant)**

**(Left: Front Panel, Center: Ozone Generator, Right: Compressor)**

Immediately after installation of the ozone system, the ozone vendor worked with the detergent chemical supplier to modify the pre-programmed wash cycles to be compatible with the new ozone system. The wash cycles were switched to cold water only, and the detergent quantities were reduced to prevent over-sudsing under the new wash conditions.

During the next few weeks, the on-site laundry staff provided feedback regarding the observed performance results under the new system. The staff mentioned that a few of the wash programs—specifically, those involving bleach—were not removing stains as well as they had been before the installation of the ozone system. Based on this feedback, the heavy wash programs that use bleach were further adjusted until satisfactory cleaning performance was achieved.

After these final adjustments, the laundry staff was satisfied that all the various types of laundry loads were being washed as effectively as they were before the ozone system was installed. The post-ozone monitoring period began after the final wash program adjustments were made.

## VI. Demonstration Approach

### A. Charleston Place Hotel

#### Metered Data

The team collected baseline data on the existing laundry equipment at the Charleston Place Hotel for a period of 48 days. The team then collected data for a period of 35 days following the installation of the ozone laundry system. The length of the data collection period before and after the ozone system installation provided a robust data set from which credible conclusions could be derived. It also helped reduce the effects of holidays or other anomalies that may have occurred on any given day during the data collection periods.

The team collected the following metered data from the meters that were in place when the ozone equipment was installed during the baseline and post-retrofit periods:

- Hot and cold water flow consumption, displayed as cumulative totals on the meters
- Hot and cold water line temperatures, recorded at one-minute intervals

Natural gas for heating the washer water was not metered due to the difficulty and disruption to the site operations in the installation of insertion natural gas meters. Therefore, the natural gas savings was calculated from the Btu savings from the metered hot water and temperatures. Hot water heating energy was calculated using the following equation:

$$\text{Hot Water Heating Energy (Btu)} = \Delta\text{T} \times \textit{Hot water gallons} \times \rho_{water} \times C_p \times \frac{1}{\eta_{boiler}}$$

Where:

$\Delta$T = the temperature rise between incoming water temperature and target hot water temperature

$\rho_{water}$ = 8.34 lb/gallon

$\eta_{boiler}$ = nominal boiler efficiency

$C_p$ = 1 Btu/lb °F, specific heat of water

Detailed information regarding the metering equipment used for this project can be found in Appendix A.

Figure 8 graphically depicts the metering approach for this system.

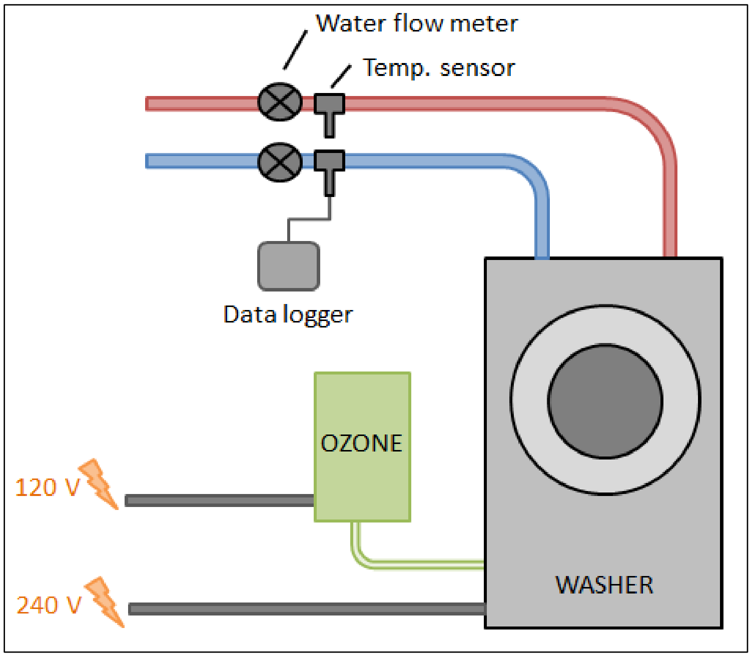


**Figure 8. Washer and Ozone Generator Metering Concept**

Figure 9 shows the installed metering equipment.

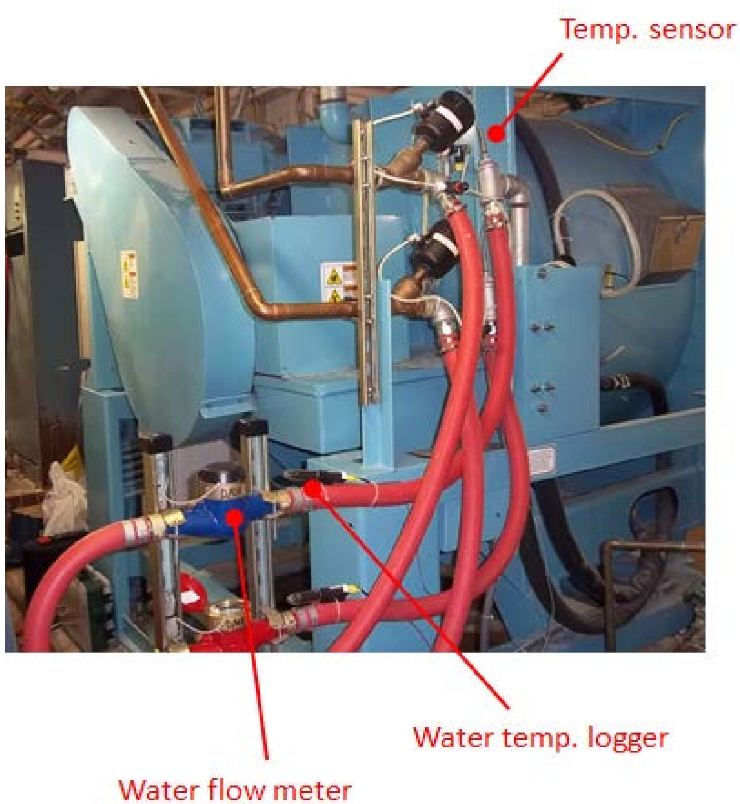


**Figure 9. Clothes Washer Metering Equipment (Photo: Texchine, Inc.)**

In addition to the metered data described above, the washers logged the number of daily laundry cycles during both the pre-ozone and post-ozone periods.  Based on observations from the ozone installer who visited the site, the same types of linens were run pre-ozone and post-ozone.  This allowed for the data from both periods to be normalized on a per-cycle basis, so that more meaningful comparisons could be made between the two periods.

Due to the difficulty in isolating the ozone system electricity usage at the electrical panel, the team was unable to collect real-time metered electrical data for the ozone system during its operation at the hotel. However, in order to provide a reasonable proxy for the electrical usage of the ozone system, the team worked directly with the ozone vendor to meter an equivalent washer/ozone system. The team conducted and independent review of these results and confirmed that the electrical usage of the equivalent ozone system is a valid proxy for the electrical energy usage of the ozone system installed at the Charleston Place hotel.  And, as shown in Section VII, the per-cycle estimated electricity consumption is similar in magnitude to the Rogerson site where the ozone electricity usage was metered. Also, the energy usage of the ozone system is a small fraction of the total laundry energy consumption. Details on the calculations and methodology can be found in Appendix B.

The team also did not collect metered electrical data from the clothes washers because the washers were hard-wired into the electrical supply and would have required custom metering equipment due to their 200/240 voltage levels, as well as unacceptable interruptions in laundry operations to perform the equipment installation. The team concluded that because the internal mechanics of the clothes washers are unaffected by the installation of the ozone system, and the cycles/day of the washers did not change from per to post installation of the ozone system, the difference in per-cycle energy consumption before and after ozone installation would be negligible (if any), and thus would not impact the conclusions of this report.

**Non-Metered Data**

In addition to technical data, the team held informal discussions with the laundry operations staff to determine overall satisfaction with the ozone technology.  The team was also able to assess the following through the ozone installer's frequent visits to the host site and discussions with the on-site laundry staff:

- Ease of operation – Have the operating characteristics of the laundry system changed pre- and post-system installation and if so, what are those changes?
- Human resources – Has there been a change in labor or maintenance requirements and staffing pre- and post-system installation and if so, what are those changes?
- Overall cleaning performance – Has the cleanliness of the laundry changed as a result of the ozone laundry installation?

**Calculated Performance Metrics**

Based on the metered and non-metered data, the team calculated three key performance metrics for the ozone system:

- Energy savings (including cost savings)
- Water savings (including cost savings)
- Payback period for the installed system

The details regarding these calculations are provided in the Results section of this report.

### B. Rogerson House

#### Metered Data

The team collected baseline data on the existing laundry equipment at Rogerson House for a period of 5 weeks. The team then collected data for a period of 7 weeks following the installation of the ozone laundry system. The length of the data collection period before and after the ozone system installation provided a robust data set from which credible conclusions could be derived. It also helped reduce the effects of holidays or other anomalies that may have occurred on any given day during the data collection periods.

The team collected the following metered data during the baseline and post-retrofit periods:

- Hot and cold water flow consumption, recorded a 10-second intervals
- Hot and cold water line temperatures, recorded at 30-second intervals
- Electrical energy use for the ozone generator, recorded at 2-minute intervals

Natural gas for heating the washer water was not metered due to the difficulty and disruption to the site operations in the installation of insertion natural gas meters. Therefore, the natural gas savings was calculated from the Btu savings from the metered hot water and temperatures. Hot water heating energy was calculated using the following equation:

$$\text{Hot Water Heating Energy (Btu)} = \Delta\text{T} \times Hot\ water\ gallons\ \times \rho_{water}\ \times C_p\ \times \frac{1}{\eta_{boiler}}$$

Where:
$\Delta$T = the temperature rise between incoming water temperature and target hot water temperature
$\rho_{\text{water}}$ = 8.34 lb/gallon
$\eta_{\text{boiler}}$ = nominal boiler efficiency
$C_p$ = 1 Btu/lb °F, specific heat of water

For each piece of metering equipment, the recording interval represents the finest interval that could be used while providing approximately 2 weeks of data storage capacity.

Figure 10 depicts the metering approach for this system. The metering equipment was installed in the same manner as for the Charleston Hotel location.

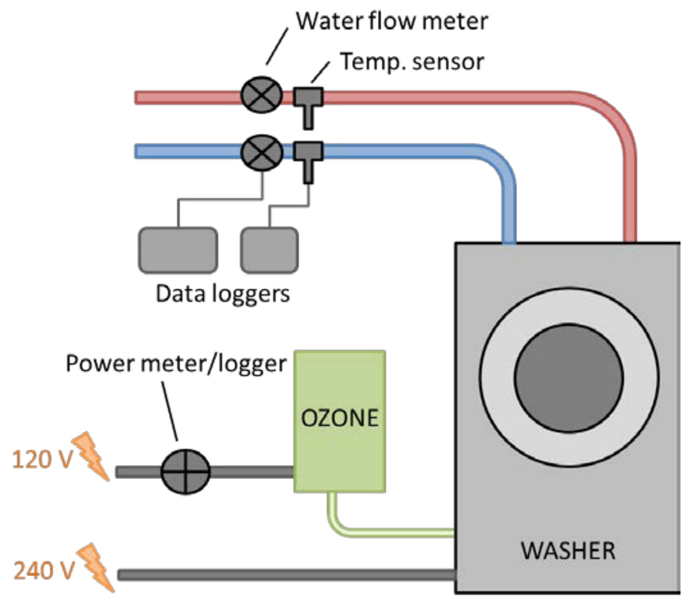


**Figure 10. Washer and Ozone Generator Metering Concept**

In addition to the metered data described above, the team also determined the number of daily laundry cycles before and after the installation of the ozone system. This allowed for the data from both periods to be normalized on a per-cycle basis, so that more meaningful comparisons could be made between the two periods.

Unlike the washers at the Charleston Place Hotel, the washers at Rogerson House do not have the capability to log the number of daily laundry cycles. Thus, the team had to determine the number of daily laundry cycles using the hot water temperature data and the water consumption data. Figure 11 shows an example of how the number of wash cycles could be determined using both the hot water temperature data and the water consumption data. For the post-ozone period, shown in Figure 12, only the water consumption data could be used to determine the number of wash cycles because several of the programmed ozone wash cycles did not use any hot water; thus, the hot water temperature data was not useful.

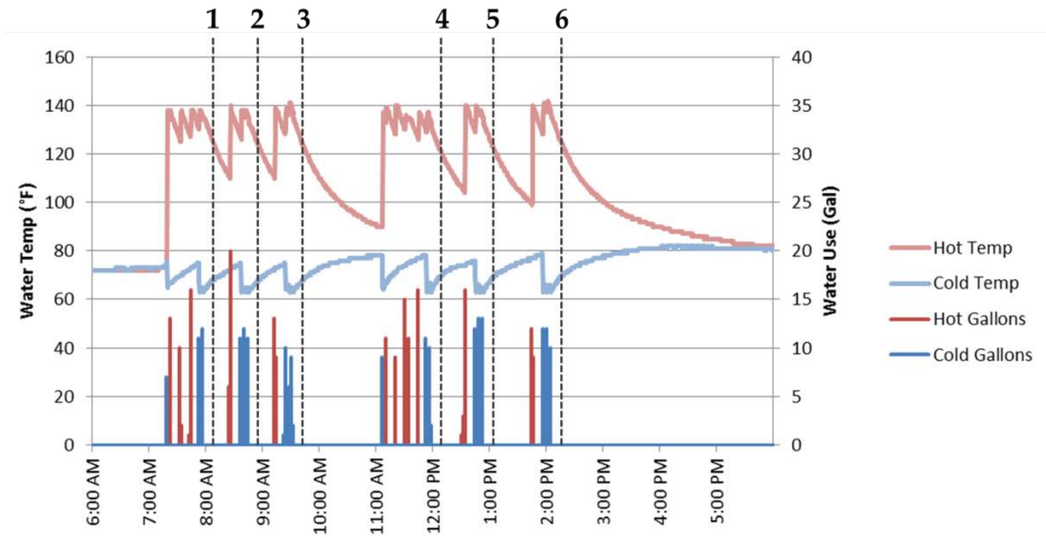


**Figure 11. Counting Wash Cycles during the Baseline Period**

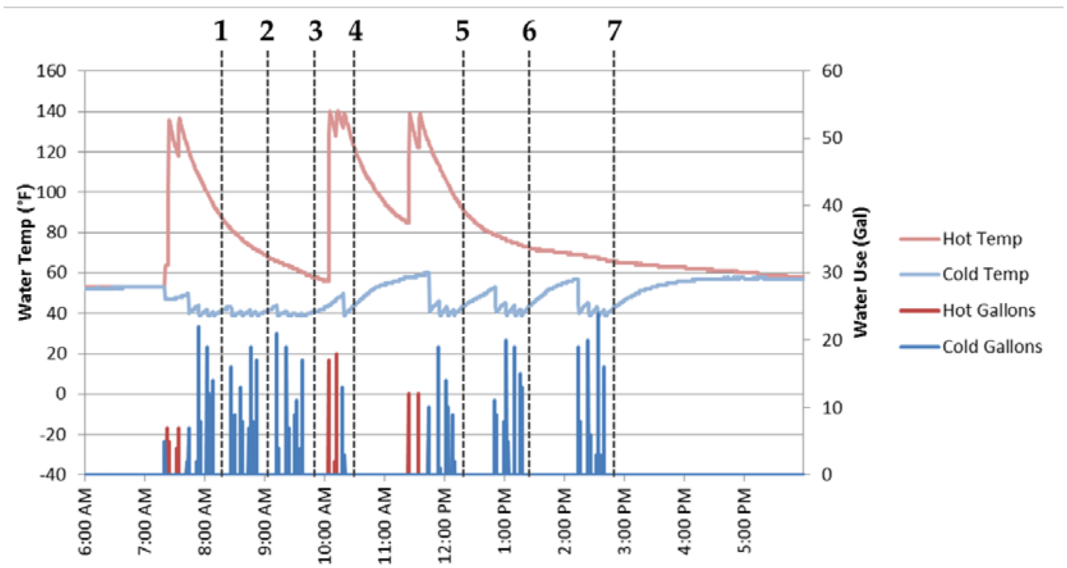


**Figure 12. Counting Wash Cycles during the Post-Retrofit Period**

The team did not collect metered electrical data from the clothes washers because the washers were hard-wired into the electrical supply and would have required custom metering equipment due to their 200/240 voltage levels. However, based on general knowledge of washer energy usage and review of utility data the team confirmed there was no difference in the washers' electrical consumption before and after installation of the ozone system.

Detailed information regarding the metering equipment used for this project can be found in Appendix A.

**Non-Metered Data**

In addition to technical data, the team held informal discussions with the laundry operations staff to determine overall satisfaction with the ozone technology. End-user and customer satisfaction is important to successfully transforming the industry to adopt and retrofit multi-load laundry systems with higher-efficiency technologies. The team was also able to assess the following through its frequent visits to the host site and discussions with the on-site laundry staff:

- Ease of operation – Have the operating characteristics of the laundry system changed pre- and post-system installation and if so, what are those changes?
- Interface with existing equipment – Has the complexity/ease of operation of the equipment (including any added equipment) changed pre- and post-system installation and if so, what are those changes and how have they impacted the overall laundry operations?
- Human resources – Has there been a change in labor or maintenance requirements and staffing pre- and post-system installation and if so, what are those changes?

**Calculated Performance Metrics**

Based on the metered and non-metered data, the team calculated three key performance metrics for the ozone system:

- Energy savings (including cost savings)
- Water savings (including cost savings)
- Payback period for the installed system

The details regarding these calculations are provided in the Results section of this report.

## VII. Results

### A. Charleston Place Hotel

**Metered Water and Temperature Data**

This section provides the results of the metered water consumption and temperature data. The next section translates these data to energy performance metrics and cost savings. Table 4 shows the summarized results of the raw metered data before and after installation of the ozone system at the Charleston Place Hotel. Each data point represents the total from all washers at the site.

**Table 4. Metered Water and Temperature Data for Charleston Place Hotel**

| Period | Avg. No. Cycles per day | Water Consumption[1] (gallons) | | | Average Temperature (°F) | | No. Cycles in Period |
|---|---|---|---|---|---|---|---|
| | | **Cold** | **Hot** | **Total** | **Cold** | **Hot** | |
| **Pre-Ozone** | 23.7 | 113,642 | 358,688 | 472,330 | 78 | 143 | 1,138 |
| **Post-Ozone** | 29.5 | 250,539 | 114,227 | 364,766 | 73 | 145 | 1,034 |

1. Total for all washers at the site.

The data summary indicates several significant differences between the two data periods that must be addressed before drawing any conclusions from the data:

- The average number of cycles per day during the post-ozone period (29.5) was higher than the pre-ozone period (23.7). The team attributes this difference to seasonal fluctuations in guest occupancy at the host site.
- The average incoming cold water temperature during the post-ozone period was slightly lower than the pre-ozone period.

To provide a more equal basis for comparing the data between the two periods, the team first normalized each dataset by the number of wash cycles during the measurement period, so that the water consumption, ozone energy, and number of cycles are represented on a per-cycle basis. This is shown in Table 5.

**Table 5. Normalized Water Use per Cycle Metered Data for Charleston Place Hotel**

| Period | No. Days in Period | Water Consumption[1,2] (gallons/cycle) | | | Average Temperature (°F) | |
|---|---|---|---|---|---|---|
| | | **Cold** | **Hot** | **Total** | **Cold** | **Hot** |
| **Pre-Ozone** | 48 | 100 | 315 | 415 | 78 | 143 |
| **Post-Ozone** | 35 | 242 | 110 | 353 | 73 | 145 |

1. Total form all washers at the site.
2. Pre-ozone and post-ozone data sets normalized by the total number of cycles in each measurement period.

The data show differences in incoming groundwater temperatures during the course of the demonstration, which is likely a result of the season as the demonstration was initiated in August 2013 (78° F) and ended in November 2013 (73° F).

Both data sets were normalized to represent the data on a consistent 30-day basis, or 711 total wash cycles. This corresponds to the average number of monthly cycles during the pre-ozone period. The results are shown in Table 6.

**Table 6. Normalized Monthly Results for Charleston Place Hotel**

| Period | Water Consumption[1,2] (gallons/month) | | | Average Temperature (°F) | | Ozone System Energy (kWh/month) | Cycles/Month) |
|---|---|---|---|---|---|---|---|
| | **Cold** | **Hot** | **Total** | **Cold** | **Hot** | | |
| **Pre-Ozone** | 71,001 | 224,101 | 295,102 | 78 | 143 | -- | 711 |
| **Post-Ozone** | 172,276 | 78,545 | 250,821 | 73 | 145 | 483 | 711 |
| **% Savings** | -- | **65%** | **15%** | -- | -- | -- | -- |

1. Total for all washers at the site.
2. Pre-ozone and post-ozone data normalized to represent 711 cycles over a 30-day period.

Table 6 shows a 65% decrease in hot water consumption and a 15% decrease in total water consumption and an increase in electricity consumption of 0.68 kWh/cycles (normalized on a 711 cycles/month basis). The decrease in total water consumption on a monthly basis directly translates to water and sewer cost savings, and the increase in electricity use by the ozone system translates in a net increase in electricity cost as shown in the Calculated Performance Metrics section below.

Figure 13 shows the normalized monthly water consumption during the pre-ozone and post-ozone periods.

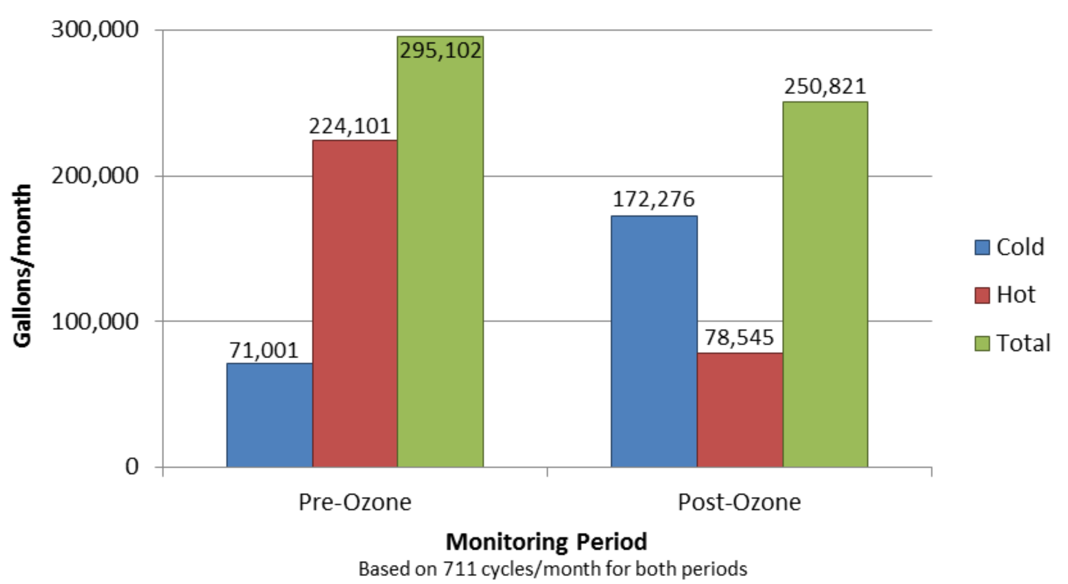


**Figure 13. Monthly Water Consumption During Pre-ozone and Post-ozone Periods for Charleston Place Hotel**

Figure 14 shows how the relative breakdown of cold water and hot water changed from the pre-ozone period to the post-ozone period. Hot water usage represented 76% of total water usage during the pre-ozone period and decreased to 31% of total water usage during the post-ozone period.

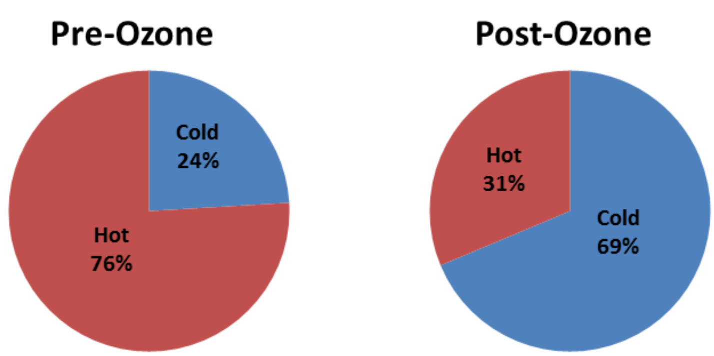


**Figure 14. Breakdown of Hot and Cold Water Usage Pre- and Post-Ozone System for Charleston Place Hotel**

Table 7 illustrates the weigh-normalized results at the Charleston Place Hotel on a per thousand pounds (klb) of laundry processed basis to provide a basis for comparison with other laundries.

**Table 7. Charleston Place Hotel Weight-Normalized Results**

| Utility Component | Pre-Ozone Cost ($/klb) | Post-Ozone Cost ($/klb) | Cost Savings ($/klb) |
|---|---|---|---|
| **Natural Gas** | $8.64 | $3.03 | $5.61 |
| **Water/Sewer** | $20.42 | $17.36 | $3.06 |
| **Electricity** | $0.00 | $0.30 | ($0.30) |
| **Total** | **$29.06** | **$20.69** | **$8.37** |

The decrease in hot water usage on a monthly basis directly translates to energy savings, which is described in detail in the Calculated Performance Metrics section below.

**Non-metered Data**

In addition to technical data, the team gathered the following non-technical information to determine overall satisfaction with the ozone technology:

- Ease of operation – No major changes were required to the standard operating procedures as a result of the ozone installation. The ozone system functions in the background from the perspective of the on-site laundry staff.
- Human resources – No changes were reported in labor or overall system maintenance requirements as a result of the ozone laundry installation.
- Overall cleaning performance – No complaints were reported regarding the cleanliness of the laundry as a result of the ozone laundry installation. However, the staff noticed the ozone was neutralizing the characteristic scent from the hotel's fabric softener. The washers were adjusted to maintain the fabric softener's scent.

**Calculated Performance Metrics**

As mentioned above, the team further normalized the post-ozone data to adjust for the differences in incoming groundwater temperatures during the demonstration. This affects the energy consumed by the hot water boiler to heat the water from its incoming temperature to the target temperature of approximately 140°F. The average temperature rise was 65°F for the pre-ozone period and 72°F for the post-ozone period. Normalizing the results of the post-ozone data using a temperature rise of 65°F rather than 72°F provides a more valid and useful basis from which to compare the pre-ozone and post-ozone results. By normalizing in this way, the post-ozone results represent what the pre-ozone energy consumption would have been during the same time period (i.e., with the same incoming ground water temperatures).

Table 8 shows the calculated hot water heating energy and costs during the pre-ozone and post-ozone periods. The table indicates that the ozone system provided hot water energy savings of $842 on a monthly basis, corresponding to a savings of 65%.

**Table 8. Water Heating Energy and Cost Calculations for Charleston Place Hotel**

| Period | Energy (therms/month) | Normalized Energy (therms/month) | Energy Cost ($/month) |
|---|---|---|---|
| **Pre-Ozone** | 1,620 | 1,620 | $1,296 |
| **Post-Ozone** | 629 | 568 | $454 |
| **Energy Savings** | -- | **1,052** | **$842** |
| **Savings (%)** | -- | **65%** | |

Calculation assumptions:

1. Each period represents 711 wash cycles over 30 days.
1. Conversion factor of 100,000 Btu per therm.
2. Nominal thermal efficiency of 75% for hot water boiler.
3. Energy values based on temperature rise of 65°F for pre-ozone period and 72°F for post-ozone period.
4. Normalized energy values based on 65°F temperature rise for both periods.
5. Energy cost based on $0.80/therm average gas rate for the Charleston Place Hotel.

Table 9 shows the total water consumption and costs during the pre-ozone and post-ozone periods. The table indicates that the ozone system provides water and sewer cost savings of 15% or $460/month.

**Table 9. Total Water Consumption and Costs for Charleston Place Hotel**

| Period | Total Water (gallons/month) | Water & Sewer Costs ($/month) |
|---|---|---|
| **Pre-Ozone** | 295,102 | $3,063 |
| **Post-Ozone** | 250,821 | $2,604 |
| **Water Consumption Savings** | 44,281 | **$460** |
| **Savings (%)** | 15% | **15%** |

Calculation assumptions:

1. Each period represents 711 wash cycles over 30 days.
2. Water and sewer cost based on $10.3811 per 1,000 gallons.

Table 10 shows the additional electrical energy consumption and costs to operate the ozone system. The table indicates that the ozone system uses approximately 483 kWh per month, at a cost of $45.

**Table 10. Ozone System Electrical Consumption and Cost for Charleston Place Hotel**

| Period | Energy Use (kWh/month) | Electricity Cost ($/month) |
|---|---|---|
| **Pre-Ozone** | 0 | -- |
| **Post-Ozone** | 483 | **$45** |

Calculation assumptions:

1. Each period represents 326 wash cycles over 30 days.
2. Based on the Charleston Place electricity billed rate of $0.094/kWh.

Simple payback period was calculated using the following equation:

$$\text{PBP} = \frac{Ozone\ system\ cost\ (\$)}{\Delta(gas + water + sewer + electricity)\ costs}$$

Table 11 shows the calculated payback period for the ozone system based on the retail price of the system and the monthly energy and water cost savings calculated above. Combining the net monthly costs of each utility component, the total net monthly savings is $1,256 after installation of the ozone system. Based on a retail cost of approximately $42,200 and an estimated annual cost savings of $15,072, a simple payback period would be 2.8 years.

**Table 11. Simple Payback Calculation for Charleston Place Hotel**

| Utility Component | Pre-Ozone Monthly Cost ($/month) | Post-Ozone Monthly Cost ($/month) | Cost Savings ($/month) |
|---|---|---|---|
| **Natural gas** | $1,296 | $454 | $842 |
| **Water/Sewer** | $3,063 | $2,603 | $460 |
| **Electricity** | $0 | $45 | ($45) |
| **Total Monthly Cost** | $4,359 | $3,102 | $1,256 |
| **Annual Cost Savings** | | | $15,072 |
| **Ozone System Cost** | | | $42,200 |
| **Simple Payback Period (years)** | | | **2.8** |

Calculation assumptions:

1. Each period represents 711 wash cycles over 30 days.

### B. Rogerson House

#### Metered Water and Temperature Data

This section provides the results of the metered water consumption and temperature data. The next section translates these data to energy performance metrics and cost savings. Table 12 shows the summarized results of the raw metered data before and after installation of the ozone system at Rogerson House. Each data point represents the total from both washers at the site.

**Table 12. Metered Water and Temperature Data Summary for Rogerson House**

| Period | Avg. No. Cycles per day | Water Consumption[1] (gallons) | | | Average Temperature (°F) | | No. Cycles in Period |
|---|---|---|---|---|---|---|---|
| | | **Cold** | **Hot** | **Total** | **Cold** | **Hot** | |
| **Pre-Ozone** | 10.9 | 9,695 | 18,499 | 28,194 | 56 | 141 | 380 |
| **Post-Ozone** | 10.2 | 34,947 | 8,937 | 43,884 | 39 | 141 | 498 |

Note:

1. Each data point represents the total from both washers at the site.

The data summary indicates several significant differences between the two data periods that must be addressed before drawing any conclusions from the data:

- The average number of cycles per day during the post-ozone period (10.2) was slightly less than the pre-ozone period (10.9). The team attributes this minor difference to normal fluctuations in laundry volume at the host site.
- The average incoming cold water temperature during the post-ozone period was significantly lower than the pre-ozone period. (Note that normalization of the data for changes in cold water temperature is presented in the Calculated Performance Metrics section below.)

To provide a more equal basis for comparing the data between the two periods, the team first normalized each dataset by the number of wash cycles during the measurement period, so that the water consumption, ozone energy, and number of cycles are represented on a per-cycle basis. This is shown in Table 13.

**Table 13. Metered Water and Temperature Data Results Presented as Per-Cycle Values for Rogerson House**

| Period | No. Days in Period | Water Consumption[1,2] (gallons/cycle) | | | Average Temperature (°F) | |
|---|---|---|---|---|---|---|
| | | **Cold** | **Hot** | **Total** | **Cold** | **Hot** |
| **Pre-Ozone** | 35 | 26 | 49 | 74 | 56 | 141 |
| **Post-Ozone** | 49 | 70 | 18 | 88 | 39 | 141 |

1. Each data point represents the total from both washers at the site.
2. Pre-ozone and post-ozone data sets normalized by the total number of cycles in each measurement period.

Next, the team further normalized both data sets to represent the data on a consistent 30-day basis, or 326 total wash cycles. This corresponds to the average number of monthly cycles during the pre-ozone period. The results are shown in Table 14.

**Table 14. Metered Data Results Presented as Normalized Monthly Values for Rogerson House**

| Period | Water Consumption[1,2] (gallons/month) | | | Average Temperature (°F) | | Ozone Energy (kWh/month) | No. Monthly Cycles (cycles/month) |
|---|---|---|---|---|---|---|---|
| | **Cold** | **Hot** | **Total** | **Cold** | **Hot** | | |
| **Pre-Ozone** | 8,317 | 15,870 | 24,187 | 56 | 141 | -- | 326 |
| **Post-Ozone** | 22,877 | 5,850 | 28,727 | 39 | 141 | 38 | 326 |
| **% Pre to Post Change** | -- | **-63%** | **+19%** | -- | -- | -- | -- |

1. Total data for all washers.
2. Pre-ozone and post-ozone data normalized to represent 326 cycles over a 30-day period.

Table 14 highlights a 63% decrease in hot water consumption normalized on a monthly basis. The decrease in hot water usage basis directly translates to energy savings, as shown in the Calculated Performance Metrics section below. Table 14 also highlights a 19% increase in the total water consumption normalized on a monthly basis. The increase in water consumption was a result of the changes that were made to the wash cycle programs during the initial setup period in order to maintain satisfactory cleaning results after installation of the ozone system. The increase in total water consumption directly translates to an increase in water and sewer costs, as shown in the Calculated Performance Metrics section below.

Figure 15 shows the normalized monthly water consumption during the pre-ozone and post-ozone periods.

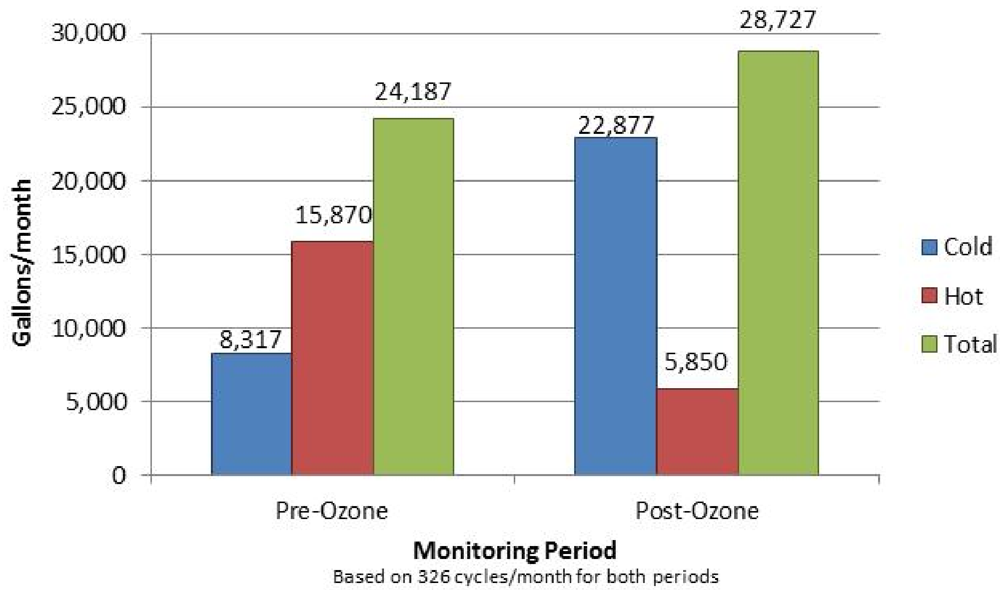


**Figure 15. Monthly Water Consumption During Pre-Ozone and Post-Ozone Periods for Rogerson House**

Figure 16 shows how the relative breakdown of cold water and hot water changed from the pre-ozone period to the post-ozone period. Hot water usage represented 66% of total water usage during the pre-ozone period and decreased to 20% of total water usage during the post-ozone period.

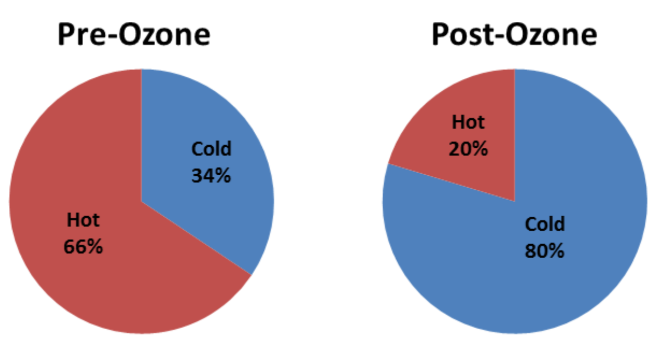


**Figure 16. Breakdown of Hot and Cold Water Usage during Both Periods for Rogerson House**

Table 15 illustrates the weigh-normalized results at the Rogerson House on a per thousand pounds (klb) of laundry processed basis to provide a relative basis for other sites.

**Table 15. Rogerson House Weight-Normalized Results**

| Utility Component | Pre-Ozone Cost ($/klb) | Post-Ozone Cost ($/klb) | Cost Savings ($/klb) |
|---|---|---|---|
| **Natural gas** | $8.44 | $3.11 | $5.33 |
| **Water/Sewer** | $25.99 | $30.87 | ($4.88) |
| **Electricity** | $0.00 | $0.35 | ($0.35) |
| **Total** | **$34.43** | **$34.33** | **$0.10** |

One final normalization of the post-ozone data is described in the Calculated Performance Metrics section below. This final adjustment applies to the energy calculation to account for the significant seasonal differences in incoming groundwater temperatures during the course of the demonstration, which began in October and ended in February.

**Non-metered Data**

In addition to technical data, the team held informal discussions with the laundry operations staff to determine overall satisfaction with the ozone technology:

- Ease of operation – No major changes were required to the standard operating procedures as a result of the ozone installation. The ozone system functions in the background from the perspective of the on-site laundry staff.
- Interface with existing equipment – The interface of the ozone system with the washer equipment is relatively invisible to the end user. The ozone system adds one extra tube along with the several tubes already present for pumping in detergent and bleach chemicals. The ozone generator itself is self-contained and only requires an air filter cartridge to be changed periodically.
- Overall cleaning performance – No complaints were reported regarding the cleanliness of the laundry as a result of the ozone laundry installation.
- Noise – The compressor for the ozone system makes noise, and given that the ozone generator and compressor were installed in the adjacent room (a makeshift office for the maintenance staff); the additional noise is mildly disruptive while the compressor is running. The ideal installation location would be an unoccupied room or within the laundry room itself, where the additional compressor noise would not be as noticeable among the other equipment noises already present in the laundry room.
- Human resources – No changes were reported in labor or overall system maintenance requirements as a result of the ozone laundry installation.
- Health and safety concerns – When the ozone system was first installed a few of the laundry workers expressed concern over the potential negative health effects of ozone. They believed the ozone would leak into the air in the laundry room and negatively impact their health. In response to these concerns, the ozone vendor provided a brochure explaining the overall safety of the ozone system. In addition, an ozone safety monitoring system had been installed in the laundry room that would shut down the ozone generator if it detected a threshold concentration of ozone. (This was included in the total cost of the ozone system). This information eased the concerns expressed by the laundry staff.

### C. Calculated Performance Metrics

The team calculated the key performance metrics based on the 30-day, 326 cycle basis represented in Table 14. This provided an equal basis for comparing the performance before and after installation of the ozone system.

As described above, the team further normalized the post-ozone data to adjust for the differences in incoming groundwater temperatures during the demonstration. This affects the energy consumed by the hot water boiler to heat the water from its incoming temperature to the target temperature of approximately 140°F. The average temperature rise was 85°F for the pre-ozone period and 102°F for the post-ozone period. Normalizing the results of the post-ozone data using a temperature rise of 85° rather than 102° provides a more valid and useful basis from which to compare the pre-ozone and post-ozone results. By normalizing in this way, the post-ozone results represent what the pre-ozone energy consumption would have been during the same time period (i.e., with the same incoming ground water temperatures).

Table 16 shows the calculated hot water heating energy and costs during the pre-ozone and post-ozone periods. The table indicates that the ozone system provided hot water energy savings of $90.32 on a monthly basis, corresponding to a savings of 63%.

**Table 16. Water Heating Energy and Cost Calculations for Rogerson House**

| Period | Energy (therms/month) | Normalized Energy (therms/month) | Normalized Energy Cost ($/month) |
|---|---|---|---|
| **Pre-Ozone** | 140.6 | 140.6 | $126.54 |
| **Post-Ozone** | 62.2 | 51.8 | $46.62 |
| **Energy Savings** | -- | **88.8** | **$79.92** |
| **Savings (%)** | -- | **63%** | |

Calculation assumptions:

1. Each period represents 326 wash cycles over 30 days.
2. Conversion factor of 100,000 Btu per therm.
3. Nominal thermal efficiency of 80% for hot water boiler.
4. Un-normalized energy values based on temperature rise of 85°F for pre-ozone period and 102°F for post-ozone period.
5. Normalized energy values based on 85°F temperature rise for both periods.
6. Energy cost based on $0.90/therm average natural gas rate currently paid by the Rogerson House.

Table 17 shows the total water consumption and costs during the pre-ozone and post-ozone periods. The table indicates that water consumption increased during the post-ozone period, resulting in an additional cost of $70.14 on a monthly basis, corresponding to an increase of 19%.

**Table 17. Total Water Consumption and Costs for Rogerson House**

| Period | Total Water (gallons/month) | Water/Sewer Costs ($/month) |
|---|---|---|
| **Pre-Ozone** | 24,187 | $389.89 |
| **Post-Ozone** | 28,727 | $463.08 |
| **Total Water Consumption & Cost Increase** | 4,540 | **$73.19** |
| **% Increase** | **19%** | **19%** |

Calculation assumptions:

1. Each period represents 326 wash cycles over 30 days.
2. Water and sewer cost based on $16.12 per 1,000 gallons current rate for the Rogerson House.

The Conclusions section of this report further discusses the observed increase in total water usage after installation of the ozone system.

Table 18 shows the additional electrical energy consumption and costs to operate the ozone system. These values were calculated using the formulas described in section VI.A of this report. The table indicates that the ozone system uses approximately 38 kWh per month, at a cost of $5.17. For comparison purposes, this is similar in magnitude to the electrical energy consumption of a residential refrigerator.

**Table 18. Ozone System Electrical Energy Consumption and Cost Calculations for Rogerson House**

| Period | Energy Use (kWh/month) | Electricity Cost ($/month) |
|---|---|---|
| **Pre-Ozone** | 0 | -- |
| **Post-Ozone** | 38 | **$5.24** |

Calculation assumptions:

1. Each period represents 326 wash cycles over 30 days.
2. Based on current billed electricity rate for the Rogerson House of $0.138/kWh.

Simple payback period was calculated using the following equation:

$$\text{PBP} = \frac{Ozone\ system\ cost\ (\$)}{\Delta(gas + water + sewer + electricity)\ costs}$$

Table 19 shows the calculated payback period for the ozone system based on the retail price of the system and the monthly energy and water cost savings calculated above. Combining the net monthly costs of each component, the total net monthly savings is approximately $1.49 after installation of the ozone system. Thus, the ozone system at Rogerson House does not offer a favorable financial payback. The poor economics are a result of low system utilization and increased water use for this location.

Table 19. Simple Payback Period Calculation for Rogerson House

| Utility Component | Pre-Ozone Monthly Cost ($/month) | Post-Ozone Monthly Cost ($/month) | Cost Savings ($/month) |
|---|---|---|---|
| **Natural gas** | $126.54 | $46.62 | $79.92 |
| **Water/Sewer** | $389.89 | $463.08 | ($73.19) |
| **Electricity** | $0.00 | $5.24 | ($5.24) |
| **Total Monthly Cost** | **$516.43** | **$514.94** | **$1.49** |
| **Annual Cost Savings** | | | $17.88 |
| **Ozone System Cost** | | | $12,000 |
| **Simple Payback Period (years)** | | | **671** |

Calculation assumptions:

1. Each period represents 326 wash cycles over 30 days.
2. Negative savings for water/sewer and electricity indicates net cost increase on a monthly basis

## VIII. Conclusions

### A. Charleston Place Hotel

Figure 17 graphically summarizes the utility and cost savings attributable to the installation of the ozone laundry system at the Charleston Place Hotel.

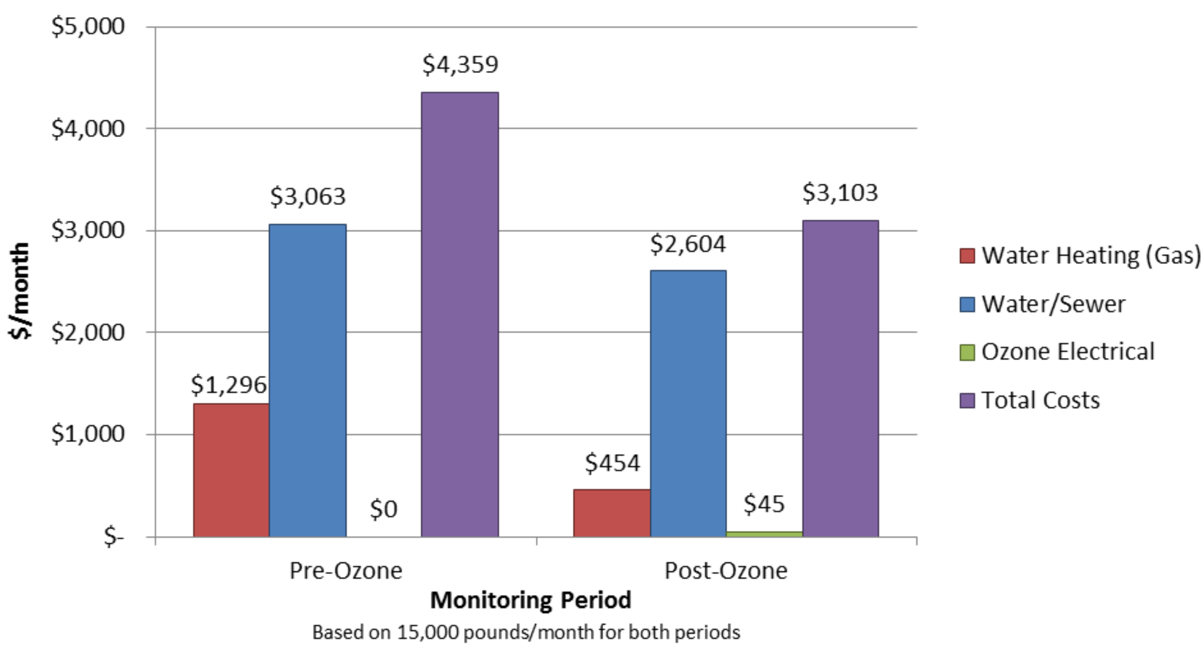


**Figure 17. Monthly Cost Summary for Pre-Ozone and Post-Ozone Periods**

The major conclusions from these results are as follows:

**Water Heating Energy Savings**

The ozone system installed at Charleston Place Hotel delivers significant water heater energy savings of 65%. This results in a cost savings of around $842 per month at their current natural gas rate. Water heating energy costs only reflect about one-third of the total utility cost associated with the laundry process at the site.

**Total Water Consumption**

As installed, the ozone system resulted in a decrease in total water consumption of 15%, which translates to a decrease of around $460 per month in water/sewer costs. Water/sewer costs represent around two-thirds of the total utility cost associated with the laundry process at the site.

As discussed earlier in this report, when using ozone, less rinse water is required in between the wash portion and the bleach portion of the cycle. At the Charleston Place Hotel, the ozone installer programmed the washer to perform a lighter rinse using less water, resulting in overall water savings after installing the ozone system.

**Ozone Electrical Consumption**

The operation of the ozone system adds 483 kWh per month in additional electrical energy, or roughly $45 per month. This additional electrical energy is negligible compared to the water heating energy and monthly water/sewer costs.

**Payback Period**

The simple payback period for this ozone system installation is 2.8 years.

**Summary Conclusion**

The ozone laundry system used for this demonstration project delivered significant hot water energy savings of 65% and total water savings of 15%.

The demonstration site in Charleston, SC is characterized as having relatively moderate natural gas prices and water/sewer rates. The significant cost savings provided by the ozone system results in a simple payback period of 2.8 years. The results of this study indicate that ozone laundry technology is a financially attractive investment for hotels with similar laundry and utility characteristics as the Charleston Place Hotel.

### B. Rogerson House

Figure 18 graphically summarizes the utility and cost savings attributable to the installation of the ozone laundry system at the Rogerson House site.

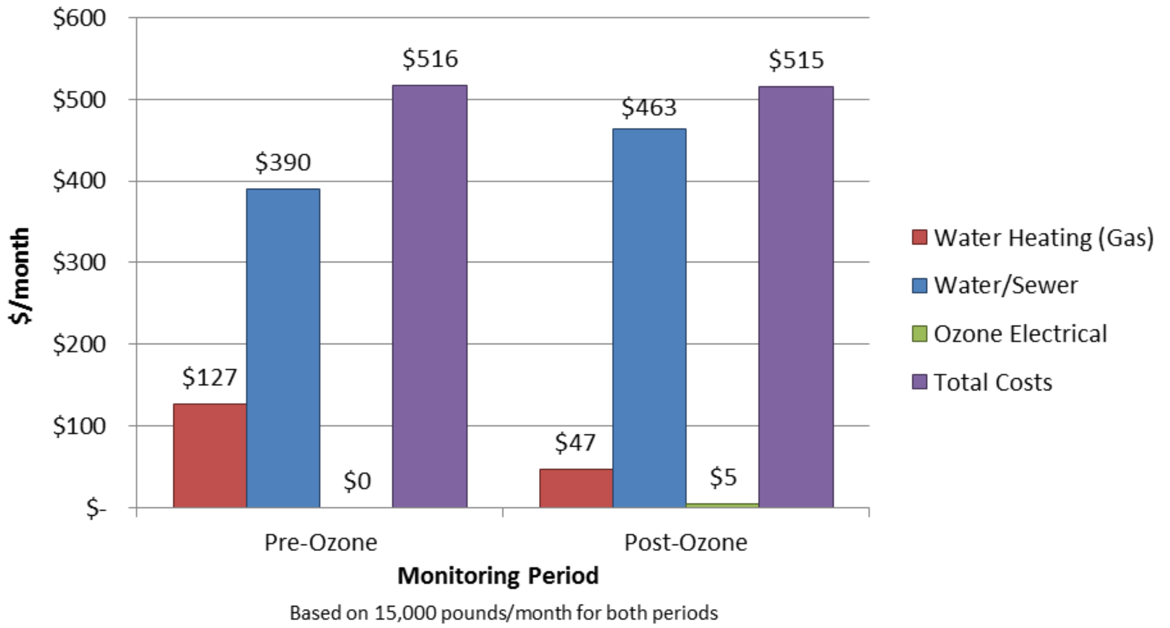


**Figure 18. Monthly Cost Summary for Pre-Ozone and Post-Ozone Periods at Rogerson House**

The major conclusions from these results are as follows:

**Water Heating Energy Savings**

The ozone system installed at Rogerson House delivers significant water heater energy savings of 63%. This results in a cost savings of around $80 per month at current natural gas prices. The water heating energy costs reflect about one-third of the total utility cost associated with the laundry process at the site.

**Total Water Consumption**

As installed, the ozone system resulted in an increase in total water consumption of 19%, which translated to an increase of around $73 per month in water/sewer costs. Water/sewer costs represent around two-thirds of the total utility cost associated with the laundry process at the site. The increase in water consumption was a result of the changes that were made to the wash cycle programs during the initial setup period in order to maintain satisfactory cleaning results after installation of the ozone system. The ozone installation and subsequent re-programming of the wash programs at Rogerson House reflected the typical ozone system installation process. These results indicate that careful attention is required during an ozone system installation to avoid changes in the wash programs that may increase total water consumption. The results of the Charleston Place Hotel demonstration project showed that net water savings are achievable by the installation of an ozone system; however, as demonstrated at the Rogerson House site, such savings are not assured.

### Ozone Electrical Consumption

The operation of the ozone system adds 38 kWh per month in additional electrical energy, or roughly $5 per month. This additional electrical energy is negligible compared to the water heating energy and monthly water/sewer costs.

### Payback Period

The ozone system at Rogerson House does not offer a financial payback in its current configuration due to the net increase in water consumption and the relatively low throughput of the system.

With this particular ozone installation, the increased water usage during the post-ozone period has a particularly strong impact on the financial viability of the system due to the relatively high water and sewer costs in the Boston area. As discussed above, achieving neutral or slightly reduced water consumption is likely achievable at the Rogerson House facility through further adjustments to the wash programs and thus the annual utility (primarily energy) savings would be approximately $900/year. In addition, because this facility processes a relatively small amount of laundry compared to other types of facilities, the overall cost savings is minimal which also impacts the economic viability. Under the above assumptions, a facility that processed around three times the laundry volume of Rogerson House (i.e., 1,500 pounds per day instead of 500 pounds per day) would have a simple payback period within the range of 3 - 5 years.

### Summary Conclusion

The ozone laundry system used for this demonstration project delivered significant hot water energy savings of 63%. However, as operated during the post-ozone period, the system resulted in an increase of total water usage of 19%. These results indicate that unlike energy savings, water savings is not assured by the installation of an ozone system. Careful attention is required during the reprogramming of the wash cycles to ensure that total water usage is not increased as a result of any wash program changes intended to maintain satisfactory cleaning performance.

The demonstration site in Boston, MA is characterized as having relatively low natural gas prices and high water and sewer rates. Despite the significant energy savings provided by the ozone system, the additional water usage resulted in an overall negligible cost savings on a monthly basis.

## IX. Projected Savings of Widespread Adoption

At the outset of this project, the team estimated that the primary annual energy consumption of commercial laundry facilities in the U.S. is 248 tera Btu/yr (Zogg et al., 2009). Based on the larger energy savings of 65% observed at the Charleston Place, the maximum energy savings potential of ozone laundry technology is estimated to be 161 tera Btu/yr. This represents the maximum possible savings if every laundry facility installed an ozone system, regardless of financial feasibility. This also assumes there isn't any ozone systems already installed and that every installation will achieve similar savings to what was observed at the Charleston Place. If a more modest estimate of 25% of total commercial laundry facilities in the U.S. installed an ozone system and achieved similar savings as the Charleston Place, the savings potential is estimated to be 40 tera Btu/yr.

## X. Barriers to Widespread Adoption

Based on the knowledge and experience gained throughout the course of this demonstration project, the team identified several barriers that are likely limiting the widespread adoption of ozone laundry technology across the commercial multi-load laundry industry. These include the following:

- **Lack of familiarity with the technology**
  Many laundry facility managers may not be aware of ozone laundry technology unless they are actively involved in the commercial laundry industry (by attending trade shows, for example). The lifetime of most commercial laundry equipment spans decades, so in a smoothly running laundry facility, the facility manager is likely to focus on day-to-day operational and maintenance needs, rather than the procurement of new capital equipment.
- **Resistance to changing "what works"**
  A well-functioning commercial laundry system is a highly-tuned operation involving customized wash cycles with detergent and bleach chemistries tailored to the specific needs of the facility. Laundry facility managers are likely to be hesitant to install a new technology such as ozone that would require reprogramming the washing machines, changing the chemical components, and potentially affecting the perceived quality of the laundered garments.
- **High upfront cost**
  The relatively large upfront cost of an ozone laundry system is likely to be a large barrier to adoption, regardless of the estimated payback period. The minimum investment for a relatively small-capacity ozone system would be approximately $10,000. Larger systems can cost over $40,000. These upfront costs may be reduced through utility incentive programs and would need to be investigated prior to making a decision to purchase.
- **Low energy costs**
  Todays' energy prices, particularly natural gas, make payback on energy savings alone difficult. Similarly, facilities with relatively small laundry throughput may not use enough energy in the laundry process to warrant an investment in ozone technology.
- **Resistance from detergent chemical suppliers**
  In many commercial laundry facilities, the detergent chemical suppliers are responsible for setting up and adjusting the wash cycle programs as necessary to maintain the desired level of cleaning performance over the lifetime of the equipment. After the initial installation of clothes washer equipment, the chemical supplier maintains a high level of interaction with the on-site laundry staff and the physical equipment on an ongoing basis. Many detergent chemical suppliers charge for their service based on the quantity of chemicals consumed. With most ozone laundry system installations, the amount of required detergent in each wash cycle is decreased, which may substantially decrease the chemical supplier's revenue. This creates a direct business conflict with one of the key stakeholders involved in maintaining the smooth operation of the overall laundry system.
- **Sanitization concerns**
  Although ozone is a natural disinfectant with proven sanitization properties, a facility manager may be reluctant to deviate from the traditional methodology of using high-temperature wash water for long periods of time to achieve sanitization.
- **Ozone health and safety concerns**
  A properly functioning ozone laundry system with appropriate safety controls poses little to no additional health or safety risks to the on-site laundry staff. However, failure to provide adequate

health and safety information to the facility management and on-site laundry staff may result in concerns about breathing ozone, ozone exposure to the skin, the Earth's ozone layer, or other health and environmental effects associated with ozone outside the context of the laundry process.

- **One more stakeholder**
  Finally, the installation of an ozone system introduces at least one more stakeholder (the ozone equipment manufacturer and the on-going service provider) to an already crowded process involving numerous other stakeholders, including:
  - General management of the organization
  - Laundry facility manager
  - On-site laundry workers
  - Machine equipment manufacturer
  - Machine maintenance provider
  - Detergent chemical provider

  The successful operation of a commercial laundry facility requires regular interaction and communication among all these stakeholders and an alignment of business goals and objectives. Resistance to adding yet another critical link to this system may create an intangible, yet real, barrier to adoption.

## XI. Recommendations for Advancing the Adoption of Ozone Technology

Based on the barriers to adoption described above, the team recommends the following to advance the adoption rate of ozone laundry technology:

- **Targeted outreach campaign**
  Increase overall knowledge and familiarity with ozone laundry systems by targeting organizations such the BBA with information on the benefits of ozone laundry systems. Such organizations are likely to have members that operate large, high-throughput laundry facilities that would have the greatest financial incentives for installing ozone systems. The targeting of small facilities (those with less than 1,500 pounds of laundry throughput per day) should be limited, as the laundry volumes may not be high enough to warrant investment in an ozone laundry system. Any outreach materials should highlight the sanitization properties of ozone, and should proactively address potential health and safety concerns regarding the use of ozone.
- **Simple financial feasibility calculator**
  Not all commercial laundry facilities are ideal candidates for ozone installations. As such, ozone product brochures that promise extreme levels of energy savings and financial payback may be met with skepticism, even from facilities that may be ideal target installations sites. To add legitimacy, transparency, and broaden the reach of ozone marketing claims, a simple online calculator should be developed that can be used to determine if ozone laundry technology is viable for a given laundry facility. The inputs to the tool should include "easily knowable" characteristics such as current laundry equipment type, laundry cycle types, daily laundry throughput, hot water heating fuel type, and local gas, electricity, water, and sewer rates. Such a tool would provide a laundry facility manager with a customized, legitimate estimate of potential energy, water, and financial savings potential.
- **Rebates from servicing utilities**
  As demonstrated in this report, ozone systems can provide significant water, sewer, and water heating energy savings. Rebates from water and gas utilities providers could incentivize the installation of ozone

systems, particularly for medium- and large-size laundry facilities where the payback period is favorable but the high first cost may still be too much of a barrier.

- **Modified business model for chemical suppliers**
  Encourage the adoption of modified business models for chemical suppliers, to alleviate the inherent risk to their business that the ozone system presents. For example, instead of charging for the quantity of chemical consumed, the chemical supplier could charge a fixed monthly service fee equivalent to its current average monthly proceeds before installation of the ozone equipment. This type of arrangement would eliminate the fundamental business conflict for the chemical supplier. The monthly chemical costs for the installation site would not change (even though the quantity of chemicals supplied would decrease), and the business goals of the chemical supplier and ozone provider would be aligned.

- **Greater collaboration between ozone system manufacturers and washer manufacturers**
  Commercial washer manufacturers are primarily large, national/multi-national companies that have been in business for decades. Ozone system manufacturers are small, regional companies that are relatively new to the market. Collaboration between two could provide the following:
  - Greater visibility for ozone technology
  - Business partnerships for creating washers with integrated ozone, or standard ozone add-on packages
  - Potential competitive advantage for washer manufacturers providing more energy-efficient technology packages

- **Careful attention to total water consumption**
  The results of this study indicate that careful attention is required during the reprogramming of the wash cycles to ensure that total water usage is not increased as a result of any wash program changes intended to maintain satisfactory cleaning performance. Energy savings can be assured by the installation of an ozone system because hot water heating energy is a direct function of the programmed wash water temperatures. However, water savings may not be assured because adjustments in the wash cycles intended to boost cleaning performance may result in an increase in total water usage.

## XII. References


Garlick, TF, Halverson, MA and MR Ledbetter, 1996. Wastewater Recycling and Heat Reclamation at the Red Lion Central Laundry, Portland, OR (1996). PNNL-11223. Pacific Northwest National Laboratory, Richland, WA 99352

Wyndham, 2010. Wyndham San Jose and Total Ozone Solutions Work. Available at: http://www.sustainableenergyassc.com/wp-content/uploads/Wyndham_Ozone_Washing.pdf.

Zogg et al., 2009. Energy Savings Potential and RD&D Opportunities for Commercial Appliances, Navigant Consulting, Inc. Available at: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf

# XIII. Appendices

## A. Abbreviations and Acronyms

| | |
|---|---|
| BBA | Better Buildings Alliance |
| Btu | British thermal units |
| CBEA | Commercial Building Energy Alliance |
| DOE | U.S. Department of Energy |
| kgal | thousand gallons |
| klb | thousand pounds |
| kWh | kilowatt hours |
| MLW | Multi-load washer |
| PNNL | Pacific Northwest National Laboratory |

## B. Metering Equipment

### Water Flow Meters

DLJ100 1" with pulse output water meters were used for the cold water lines.[10] The minimum flow is 0.75 gallons per minute and the maximum flow is 50 gallons per minute. The accuracy is within 0.5%-1%. The water meters are also capable of emitting a pulse for every gallon of water consumed. DLJ100H 1" water meters were used for the hot water lines. Their specifications are the same as the cold water meters.

### Water Flow Data Loggers

HOBO UX120-017 pulse data loggers were used to log the water consumption at Rogerson House.[11] The water meters were connects to the data loggers, which logged each pulse the water meters emitted. The data logger is capable of storing 520,192 measurements, and has a range of -40°F to 158°F.

### Water Temperature Probes

Omega TC-J-NPT-G-72 thermocouple probes were used to measure the water temperature.[12] The probe can measure temperatures to 1200°F and can withstand pressures to 2500 psi at ambient temperatures.

### Water Temperature Data Loggers

Omega OM-EL-USB-TC-LCD thermocouple data loggers were used to log the water temperature.[13] The data logger can store up to 32,510 temperature readings from the thermocouple probe. The data logger plugs directly into a PC's USB port. Three different functions are available on the display, most recent logged temperature, maximum logged temperature and minimum logged temperature. The operating temperature range is 14°F to 104°F.

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[10] Information on the waters meters is available at http://watermeters.com/.
[11] Information on HOBO pulse data loggers is available at http://www.onsetcomp.com/products/data-loggers/ux120-017.
[12] Information on Omega thermocouple probes is available at http://www.omega.com/pptst/TC-NPT.html.
[13] Information on Omega temperature loggers is available at http://www.omega.com/pptst/OM-EL-USB-TC-LCD.html.

Omega SMPW-CC-K-M thermocouple connectors were used to connect the thermocouples to the temperature loggers.[14] The connectors can handle temperatures from -20°F to 425°F.

**Ozone Electrical Meter/Logger**

A Watts Up Pro power meter was used to measure the energy consumption from the ozone system.[15] This power meter has an accuracy of +/-1.5%. Memory storage depends on how many parameters are stored: 120,000 records can be stored if only logging watts. In automatic mode with all parameters recorded, approximately 4,000 records can be stored.

Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, and Figure 24 show the equipment used in the demonstration.

[14] Information on Omega thermocouple connectors is available at http://www.omega.com/pptst/SMPW-CC.html.

[15] Information on Watts Up Pro power meters is available at https://www.wattsupmeters.com/secure/index.php.

**Figure 19. DLJ100 1-inch Water Meter (Photo: Watermeters)**


**Figure 20. HOBO UX120-017 Data Logger (Photo: Onset)**

**Figure 21. Omega TC-J-NPT-G-72 Thermocouple (Photo: Omega)**

**Figure 22. Omega OM-EL-USB-TC-LCD Thermocouple Data Loggers (Photo: Omega)**

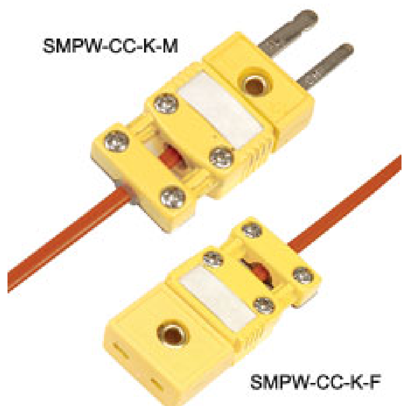


**Figure 23. Omega SMPW-CC-K-M Thermocouple Connectors (Photo: Omega)**


**Figure 24. Watts Up Pro Power Meter (Photo: Navigant)**

## C. Data Tables and Calculations

### Charleston Place

**Table 20. Water Temperature Measurements**

| Period | Cold Water Temp (°F) | Hot Water Temp (°F) |
|---|---|---|
| **Pre-Ozone** | | |
| Week 1 | 80.7 | 142.7 |
| Week 2 | 78.7 | 142.4 |
| Week 3 | 79.1 | 142.6 |
| Week 4 | 78.1 | 143.6 |
| Week 5 | 76.3 | 143.0 |
| Week 6 | 76.8 | 143.6 |
| **Post-Ozone** | | |
| Week 7 | 77.3 | 144.1 |
| Week 8 | 75.3 | 144.9 |
| Week 9 | 72.8 | 143.8 |
| Week 10 | 70.0 | 145.1 |
| Week 11 | 68.0 | 144.7 |

**Table 21. Water Consumption and Load Count**

| | Machine #1 (Braun) | | | Machine #2 (Braun) | | | Machine #3 (Braun) | | | Machine #4 (Washex) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reading Date** | **Cold (Gallons)** | **Hot (Gallons)** | **Load Count** | **Cold (Gallons)** | **Hot (Gallons)** | **Load Count** | **Cold (Gallons)** | **Hot (Gallons)** | **Load Count** | **Cold (Gallons)** | **Hot (Gallons)** | **Load Count** |
| **Pre-Ozone** | | | | | | | | | | | | |
| 8/15/2013 | 17 | 36 | 0 | 17 | 35 | 0 | 19 | 34 | 0 | 60 | 30 | 0 |
| 10/2/2013 | 39,500 | 107,000 | 336 | 30,900 | 113,100 | 345 | 31,635 | 112,563 | 330 | 11,720 | 26,160 | 127 |
| **Post-Ozone** | | | | | | | | | | | | |
| 10/2/2013 | 39,500 | 107,000 | 0 | 30,900 | 113,100 | 0 | 31,635 | 112,563 | 0 | 11,720 | 26,160 | 0 |
| 11/6/2013 | 117,900 | 146,000 | 314 | 97,500 | 148,100 | 330 | 120,500 | 142,300 | 298 | 28,394 | 36,650 | 92 |

To obtain ozone system electrical consumption data, the ozone vendor ran an ECO2 unit and an AEROUS-8 oxygen concentrator at the same settings used at the Charleston Place Hotel site (80% output). For a normal wash cycle of 30 minutes, the system consumed 0.17 kWh of electrical energy. The results will be the same regardless of the washers used. Because the ozone system at the Charleston Place Hotel consisted of three ECO2 units, one ECO1 unit, and two AEROUS-8 oxygen concentrators, the team multiplied the laboratory results by four to get a total system energy consumption per cycle of 0.68 kWh. This represents a conservative estimate of the ozone system energy consumption as only two oxygen concentrators were used in the actual installation (see Table 22).

Table 22 through Table 26 provide data collected on the ozone system and washer performance at the Rogerson House.

**Table 22. Ozone System Electrical Consumption**

| Period | Energy Use (kWh/month) |
|---|---|
| **Pre-Ozone** | 0 |
| **Post-Ozone** | 483 |

**Rogerson House**

**Table 23. Water Temperatures Measured at Rogerson House**

| Period | Cold Water Temp (°F) | Hot Water Temp (°F) |
|---|---|---|
| **Pre-Ozone** | | |
| Week 1 | 62.3 | 140.6 |
| Week 2 | 61.3 | 141.0 |
| Week 3 | 56.6 | 141.0 |
| Week 4 | 54.3 | 140.9 |
| Week 5 | 44.7 | 140.3 |
| **Post-Ozone** | | |
| Week 6 | 42.0 | 141.1 |
| Week 7 | 40.9 | 140.8 |
| Week 8 | 38.8 | 140.5 |
| Week 9 | 38.3 | 139.9 |
| Week 10 | 38.3 | 141.6 |
| Week 11 | 37.0 | 140.9 |
| Week 12 | 37.2 | 141.1 |

**Table 24. Water Consumption Measured at Rogerson House**

| | Washer 1 | | Washer 2 | |
|---|---|---|---|---|
| Period | Cold Water Consumption (Gallons) | Hot Water Consumption (Gallons) | Cold Water Consumption (Gallons) | Hot Water Consumption (Gallons) |
| **Pre-Ozone** | | | | |
| Week 1 | 1131 | 2068 | 929 | 1723 |
| Week 2 | 1107 | 1882 | 1044 | 1968 |
| Week 3 | 1127 | 1899 | 781 | 1558 |
| Week 4 | 1180 | 2134 | 587 | 1595 |
| Week 5 | 963 | 1929 | 846 | 1743 |
| **Post-Ozone** | | | | |
| Week 6 | 2659 | 599 | 1951 | 498 |
| Week 7 | 3296 | 611 | 1842 | 586 |
| Week 8 | 2677 | 734 | 2075 | 604 |
| Week 9 | 2957 | 551 | 1705 | 571 |
| Week 10 | 3041 | 767 | 1997 | 784 |
| Week 11 | 3589 | 690 | 1964 | 654 |
| Week 12 | 3307 | 797 | 1887 | 491 |

**Table 25. Wash Cycles Measures at Rogerson House**

| Period | Washer 1: Total Number of Wash Cycles | Washer 2: Total Number of Wash Cycles |
|---|---|---|
| **Pre-Ozone** | | |
| Week 1 | 39 | 39 |
| Week 2 | 38 | 43 |
| Week 3 | 37 | 35 |
| Week 4 | 42 | 39 |
| Week 5 | 33 | 35 |
| **Post-Ozone** | | |
| Week 6 | 36 | 33 |
| Week 7 | 41 | 32 |
| Week 8 | 36 | 36 |
| Week 9 | 33 | 31 |
| Week 10 | 34 | 38 |
| Week 11 | 39 | 36 |
| Week 12 | 39 | 34 |

**Table 26. Ozone System Electrical Energy Consumption at Rogerson House**

| Period | Ozone Energy Consumption (kWh) |
|---|---|
| **Pre-Ozone** | |
| Week 1 | 0 |
| Week 2 | 0 |
| Week 3 | 0 |
| Week 4 | 0 |
| Week 5 | 0 |
| **Post-Ozone** | |
| Week 6 | 8.1 |
| Week 7 | 8.8 |
| Week 8 | 7.4 |
| Week 9 | 7.0 |
| Week 10 | 9.2 |
| Week 11 | 8.6 |
| Week 12 | 8.3 |

### D. Signed Site Agreements

**Better Buildings Alliance Commercial Laundry Ozone Demonstration**

**Host Site Agreement**

The undersigned ________________________ ("Participating Organization"), agrees to participate fully in the Better Buildings Alliance Commercial Laundry Ozone Demonstration being implemented by Navigant Consulting Inc. ("Navigant"). Participating Organization agrees that its participation will consist of installing one new ozone system at the designated location, and cooperating with Navigant and any Navigant subcontractors so that they can schedule times to install the necessary monitoring equipment on the current water heater and remove the monitoring equipment after the completion of the demonstration. Additionally, Participating Organization agrees to cooperate with Navigant to provide feedback after the demonstration period, either through e-mail or over the phone.

Specifically, Participating Organization agrees to the following:

1. Participating Organization will coordinate with Navigant to schedule a site visit by a Navigant representative to install monitoring equipment on the commercial washer(s) and to remove the monitoring equipment at the end of the demonstration.

2. Participating Organization will take delivery and install the new ozone system according to the manufacturer's instructions on the agreed upon date.

3. Participating Organization provides permission for Navigant to share any and all information related specifically to Participating Organization's participation in this demonstration with other organizations involved with the demonstration, including U.S. Department of Energy and other consultants specifically working on the demonstration.

4. Participating Organization provides permission for Navigant or the U.S. Department of Energy to publish (for example, by posting on an internet website) a technical report summarizing the findings of the demonstration, and to disseminate that report, in part or in whole, among the Better Buildings Alliance, the high performance buildings community.

5. If at any time Participating Organization has questions about the monitoring equipment, Participating Organization will contact [Name] at Navigant, [email], or [phone]. Questions regarding the installation, maintenance, or technical support for the ozone system must be directed to the ozone system vendor. Navigant, Pacific Northwest National Lab, or U.S. Department of energy will not provide expertise on the vendor technology installation, maintenance, or troubleshooting. [Note that it is important for the demonstration that you contact Navigant if the ozone system does not appear to be functioning properly at any time during your participation, so that the success of the demonstration project is not jeopardized.]

6. Participating Organization shall indemnify and hold harmless all organizations involved with the demonstration, including Navigant, U.S. Department of Energy, Pacific Northwest National Lab, and consultants specifically working on the demonstration on behalf of these companies, as well as their affiliated companies and their officers, directors, employees, customers, successors, and assigns (collectively "Demonstration Sponsors"), from and against any and all liabilities, costs, expenses, demands, claims, lawsuits, causes of action, damages, penalties, and forfeitures (including, but not limited to, those relating to or based upon property damage or personal injury, including death) (collectively, "Claims"), to the extent arising from or in any way connected with (i) the Navigant demonstration, (ii) the breach of any of the terms of this Agreement by Participating Organization, or (iii) the negligent or willful acts by Participating Organization or anyone acting on Participating Organization's behalf in, or related to, including use or misuse of the ULF(s) or performance of Participating Organization's obligations under this Agreement.

7. Participating Organization hereby releases all organizations involved with the demonstration -- including Navigant, Pacific Northwest National Lab, U.S. Department of Energy, and consultants specifically working on the demonstration on behalf of these companies, as well as their affiliated companies and their officers, directors, employees, customers, successors, and assigns (collectively "Demonstration Sponsors") – from any and all Claims of any kind arising out of Participating Organization's participation in the demonstration, except those arising due to the gross negligence or willful misconduct of the Demonstration Sponsors. Participating Organization further assumes the risk of all injuries to it and damage to and loss of Participating Organization's property, including loss of use thereof and any other indirect or consequential damages resulting directly or indirectly from Participating Organization's participation in the demonstration.

Participating Organization affirms all of the above by the signature of its authorized representative on this agreement below.

Participating Organization: ______________________________________________

By:__________________________________________________________________

(Signature)

Its: __________________________________________________________________

(Title)

Address:______________________________________________________________

Telephone Number:_____________________________________________________

Date: __________________________________________

## E. Promotional Flier

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# BUILDING TECHNOLOGY OFFICE: DEMONSTRATION PROJECT

A Call for Hospitality and Healthcare Industry Participation:

## Demonstrate How Efficient, Multi-Load Laundry Retrofit Saves Energy and Water

Typical multi-load washers used in moderate sized hotels (~250 rooms) can use up to 11,000 million (MM) Btu to heat water and up to 1.3 million gallons of water per year; that adds up to more than $100,000/year in water and energy costs![1] Retrofitting with a laundry ozonation system would save up to $17,000 per year in utility costs, while reducing laundry (washing + drying) energy use by ~11% and water consumption by ~35%, more than enough savings to pay for the ozonation system in less than a year.[2] To help develop solutions that will reduce energy and water use for commercial building owners and operators, the U.S. Department of Energy (DOE) frequently supports demonstrations to assess technologies' performance, installation procedures, and operations and maintenance characteristics. DOE is now seeking to engage hospitality and healthcare industry participation in a project to demonstrate resource-saving multi-load laundry technologies.

### Technology Demonstration

Technologies such as laundry wastewater recycling, low-temperature detergents, ozone generation, and polymer bead cleaning will be considered for demonstration in hospitality and healthcare laundry facilities that feature multi-load washing machines. The 3- to 5-month-long demonstrations will be conducted to confirm the technologies' long-term reliability and performance, quantify savings, and develop specifications for wide-scale deployment and market adoption.

### DOE is Seeking Research Partners

Successful demonstrations require the partnership of participating site and operations management, servicing utilities, equipment providers, and DOE's research team.

- Site managers provide site access and assistance.
- Servicing utilities assist with metering, incentives, and technology transfer.
- Vendors provide equipment, installation, commissioning, and troubleshooting.
- The research team matches the best technology for the selected demonstration site and oversees the demonstration.

**Commercial multi-load washers and ozone generator**

As part of a demonstration and proof of concept, the Crowne Plaza in Arlington, Virginia, installed a laundry ozone generator and connected it to three multi-load clothes washers. The demonstrated performance of the system clinched its purchase. Staff report detergent use is down by one-third, towels and sheets are coming out cleaner, dryer cycles are shortened, and hot water use is greatly reduced. Analysis indicates an average natural gas savings of 1.02 MMBtu per day.

DOE provides leadership for the demonstration project activities, including selection, installation, and commissioning of equipment; data collection and analysis of performance; development of technical specifications for deployment of efficient multi-load laundry technologies; and documentation of the demonstration results.

### Expectations of Participating Multi-load Laundry Operators:

- Provide site access for the demonstration.
- Assist with equipment installation and commissioning.
- Assist with data collection (e.g., detergent use).
- Ascertain customer satisfaction.
- Participate in documenting staff experience with the efficient system.

### Contact Information

If you are interested in joining our research team and gaining a technological edge in water, energy, and cost savings for your multi-load laundry operations, please contact Graham Parker (graham.parker@pnnl.gov).

1. Based on $0.80/therm and $8/1,000 gallons water+sewer rates.
2. Pacific Gas and Electric Company. 2009. *Ozonated Laundry Systems in Hospitality Facilities*. PG&E Hospitality Fact Sheet, San Francisco, California.

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

For more information, visit:
www.energy.gov

PNNL-SA-94595 • April 2013
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## F. Ozone Vendors Contacted

| Vendor | Contact |
|---|---|
| DEL Ozone | General Inquiry |
| Aquawing Ozone Laundry Systems | Ralph Daniels |
| ClearWater Tech, LLC | Ed Knueve |
| The Ozone Company | Andrew Rupnow |
| Ozone Laundry Systems | Randy Zorn |
| Total Ozone Solutions | General Inquiry |
| Ozone Water Technologies Inc. | Jim Gross |
| ArtiClean Ozone Laundry Systems | Danny Kirk |
| Ozotech Inc. | Jeff Schaub |

Energy Efficiency & Renewable Energy

Building Technologies Program
techdemo@ee.doe.gov

PNNL-23536 • August 2014

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