Pacific Gas and Electric Company

Emerging Technologies Program

Application Assessment Report #0802

The Benefits of Ozone in Hospitality On-Premise Laundry Operations

Issued:	12 April 2009
Project Manager:	Wayne Krill Pacific Gas & Electric
Prepared by:	Global Energy Partners, LLC Lafayette, CA

ACKNOWLEDGEMENTS

Global Energy Partners, LLC wishes to acknowledge the individuals and organizations involved in this effort. Their enthusiasm for the use of ozone in on-premise laundry operations and its many benefits will result in a growing market for the technology.

Pacific Gas & Electric

- Shirley Fudge-Muller – for her help is locating a suitable host facility and providing utility data
- Steve Hutchison – for helping set the project in motion
- Wayne Krill – for his patience and determination to see this project through

Hilton Garden Inn – Emeryville

- Robert "Buck" Chisler – for his enthusiasm and willingness to try something new
- Jan Meck – for her foresight
- The entire housekeeping and laundry room staff – for their helpfulness

East Bay Municipal Utility District

- Joseph Lerma – for providing tariff information

Total Ozone Solutions, LLC

- Cal Eschbach – for data and technical assistance

ClearWater Tech, LLC

- Marc De Brum – for site identification and market and technical assistance

Mt. Hood Chemicals

- Steve Cauz – for providing information on laundry formulas

EXECUTIVE SUMMARY

Project Objectives

The objectives of this project were to showcase an innovative application of an available technology that has great potential for energy savings in hospitality facilities with on-premise laundry OPL operations in the PG&E service territory. Energy savings would commence immediately upon installation and would continue at the same rate of savings over the life of the equipment. A favorable demonstration of the ozone technology might warrant PG&E involvement to accelerate the adoption of this technology through promotional programs.

Project Background

This report describes the results of an assessment of the energy impacts resulting from use of ozone in an on-premise hotel laundry facility. While the use of ozone in on-premise laundry (OPL) operations is becoming more common, most of the available data on the energy impacts of ozone are from the equipment manufacturers themselves, which calls into question the objectivity of the values. The Pacific Gas and Electric (PG&E) market segment and product teams thought they needed data collected and analyzed by an impartial third-party to objectively promote the technology among their hospitality customers and to quantify the appropriate incentive level for the technology.

Technical Potential for Ozone in Hospitality On-Premise Laundry Operations in PG&E's Service Area

There are approximately 2,136 hotel properties possessing about 179,000 guest rooms in PG&E's service area.[1] Due to the size of PG&E's service area and the large number of hotel and motel rooms it contains, there is a significant opportunity for ozone in hospitality OPL operations. Secondly, the current trend towards "green" business is providing a fertile environment for technologies such as ozone; businesses can embrace and promote it among their customers.

The estimated electricity savings at the host facility due to the ozone system was 44 kWh per occupied guest room per year. Therefore, the annual electric technical potential for all the hotels in PG&E's service territory hotels is 5,230,204 kWh. The estimated natural-gas savings at the host facility due to the ozone system was 58 therms per year, per occupied room. Therefore, the annual natural gas technical potential for all the hotels in PG&E's service territory hotels is 7,455,051 therms.

Table ES-1 Maximum Technical Potential Electricity Savings from Ozone in Hotel Laundry Operations

	Electricity (kWh)	Natural Gas (therms)
Annualized savings per occupied room at host facility	40	58
Annual technical potential for all hotels in PG&E service territory	5,230,204	7,455,051

What is Ozone?

Ozone is a form of oxygen found naturally in the Earth's atmosphere. In its most stable form, oxygen exists as a gaseous diatomic molecule (O_2). Ozone is formed by the breakdown of

[1] Smith Travel Research (STR), California Tourism E-Outlook, July 2008, accessed September 11, 2008. <http://www.visitcalifornia.com/media/uploads/files/editor/CaliforniaTourism_Monthly_Reports08_07.pdf>

diatomic oxygen and the recombination of a percentage of the oxygen atoms into a gaseous triatomic molecule (O_3).

How Ozone Cleans

Being a powerful oxidizer, ozone cleans fabrics by chemically reacting with soils. Ozone removes electrons from the soils, causing the soils to break into smaller molecules; these become water-soluble and are released from the linen by ordinary agitation.

How Ozone is Produced

The most-common method of producing ozone for laundry applications is via corona discharge. Simply put, dry air is passed through an electrical field. The electric field causes some of the oxygen molecules to split into separate oxygen atoms. Individual oxygen atoms are unstable and attach to other oxygen molecules, forming ozone molecules.

The Benefits of Ozone in Laundry Operations

The quantifiable benefits of ozone in laundry operations are well-documented and include:

- reduced water and sewer costs,
- reduced hot water consumption,
- reduced drying time,
- increased linen life,
- reduced chemical and detergent costs, and
- reduced labor costs.

Host Facility

The host for this demonstration was the 278-room Hilton Garden Inn–Emeryville (Figure ES-1). The hotel is 13-stories high and features a full-service restaurant, lounge, pool, exercise facility, and meeting and banquet space. Owing to these amenities, the linens used and laundered on-premise include: sheets, blankets, bedspreads, towels, tablecloths, table skirts, napkins, and kitchen and cleaning rags.

The Hilton Garden Inn – Emeryville installed the ozone generator and associated plumbing at a cost of $14,000, including labor. The installation required minimal modifications to existing plumbing, which kept labor costs down.

Figure ES-1 Façade of 278-Room Hilton Garden Inn-Emeryville

Project Results

Table ES-2 summarizes the savings due to the installed ozone system at the Hilton Garden Inn–Emeryville. As expected, the value of the natural gas saved due to the replacement of hot water with cold was the leading component of total savings. The value of the electricity savings were minor, also as expected. The value of the water and sewer savings were larger than expected, which is significant since the ozone system vendor did not include that value in the pre-installation savings estimates upon which hotel management based their decision to install the ozone system.

Considering all the quantifiable savings resulting from the installation of the ozone system, the ozone system at the hotel has a simple payback of 7.5 months. With available rebates and incentives, the payback would be significantly shorter.

Table ES-2 Summary of Savings Resulting from Ozone in Laundry Operations

Cost Point	Value of Each Unit Saved	Units Saved per Year	Savings per Year	Percent of Total Savings
Water & Sewer	$5.92/ccf	1,154.5 ccf	$6,835	30.6%
Electricity (washer-extractors)	$0.0900/kWh	7,488 kWh	$674	3.0%
Electricity (dryers)	$0.0900/kWh	1.163 kWh	$105	0.5%
Natural gas (hot water)	$1.1940/therm	10,383 therms	$12,397	55.5%
Natural gas (dryer)	$1.1940/therm	1,948 therms	$2,326	10.4%
Total Quantifiable Savings	—	—	**$22,337**	—

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

PROJECT BACKGROUND

This report describes the results of an assessment by Global Energy Partners, LLC (Global) of the energy impacts resulting from use of ozone in an on-premise hotel laundry facility.

1.1 PROJECT IMPETUS

While the use of ozone in laundry operations is becoming more common, most of the available data on the energy impacts of ozone are from the equipment manufacturers themselves, which calls into question the objectivity of the figures. The Pacific Gas & Electric (PG&E) hospitality market segment and product teams prefer data collected and analyzed by an impartial third-party in order to objectively promote the technology among their hospitality customers.

1.2 TECHNICAL POTENTIAL FOR OZONE IN HOSPITALITY ON-PREMISE LAUNDRY OPERATIONS IN PG&E'S SERVICE AREA

On-premise laundry (OPL) operations are very common in the hospitality industry. There is little variation in the types of equipment used. What vary from site to site are the daily volumes of laundry and the type of laundry. Obviously, facilities with larger laundry volumes need more capacity, so they tend to use more and/or larger washing machines and dryers. Hotels with no on-premise restaurants, meeting facilities, pools, or spa facilities have the smallest average laundry load per guest. Their laundry types are also limited to sheets, pillowcases, bath towels, hand towels, and washcloths. Conversely, facilities with the extra amenities have the largest laundry loads per guest and the greater variety of laundry types. In addition to sheets and towels, they also have to launder tablecloths, cloth napkins, kitchen rags, and pool towels—often in a variety of colors and fabrics.

Because the laundry equipment in these facilities is so common, ozone can easily be added to the existing operations with few, if any, equipment modifications. Consequently, ozone is applicable in 100% of the market.

Due to the size of PG&E's service area and the large number of hotel and motel rooms within it, there is a significant opportunity for ozone in hospitality OPL operations. Secondly, the current trend towards "green" business is providing a fertile environment for technologies such as ozone that more and more businesses are embracing and promoting among their customers.

1.2.1 Number of Hospitality Facilities in PG&E's Service Area

In PG&E's service area there are approximately 2,136 hotel properties, possessing about 179,000 guest rooms.[2] This is an average of 84 guest rooms per property. The year-to-date occupancy rate through July 2008 for those 2,136 properties was about 65%.[3] This results in an average of 54 of the 84 guest rooms occupied at the average-sized hotel each day, or an approximate daily total of 116,000 occupied rooms in PG&E's service area. Clearly these figures will vary by day of the week, month of the year, and location. However, they provide a reasonable starting point for the analysis.

1.2.2 PG&E Energy Savings Technical Potential

The maximum technical potential for energy savings due to the use of ozone in hotel OPL operations in PG&E's service territory is based on the findings of the assessment profiled in this report. One should note that although the resulting energy savings at the host facility are typical, the facility is just one hotel among thousands in California. Thus, the technical potential estimates presented here are approximations.

Global made the assumption that the distribution of the number of rooms at each of the 2,136 hotels in PG&E's service territory is lognormal.[4] Splitting the hotels into two groups—small and large—and using the average number of rooms at the break point improves the accuracy of estimates. Therefore, 1,068 hotels (half of 2,136) have fewer than 84 rooms ("small" hotels) and the other 1,068 hotels have at least 84 rooms ("large" hotels). For each group, Global estimated the mean number of rooms as the first and third quartiles, respectively. Therefore, the mean number of rooms in small hotels was 53 and the mean number of rooms in large hotels was 134 rooms.

Table 1-1 summarizes the figures used to estimate the technical potential for electricity savings from the use of ozone in hospitality OPL operations in PG&E's service territory. The estimated electricity savings at the host facility due to the ozone system were 40 kWh per occupied guest room per year. Therefore, based on an average occupancy of 65%, the expected annual savings for the average small hotel is 1,388 kWh and 3,509 kWh for large hotels. The expected annual electric savings for all small hotels in PG&E's service territory is 1,482,357 kWh and 3,747,847 kWh for large hotels. Combined, these total of 5,230,204 kWh per year for PG&E's service territory.

Table 1-1 Maximum Technical Potential Electricity Savings from Ozone in Hotel Laundry Operations

Hotel Size	Small Hotels (<84 rooms)	Large Hotels (≥84 rooms)
Number of hotel properties in PG&E service territory	2,136	
	1,068	1,068
Average number of guest rooms	53	134
Annualized kWh savings per occupied room at host facility	40	
Expected electricity savings per hotel, per year (kWh)	1,388	3,509
Expected electricity savings per year (kWh)	1,482,357	3,747,847
	5,230,204	

Global believes that no significant electric-demand reductions would result from the use of ozone in hospitality OPL operations—regardless of the demand period during which the hotel operates

[2] Smith Travel Research (STR), *California Tourism E-Outlook*, July 2008, accessed September 11, 2008. <http://www.visitcalifornia.com/media/uploads/files/editor/CaliforniaTourism_Monthly_Reports08_07.pdf>
[3] Ibid.
[4] A lognormal distribution is a single-tailed probability distribution of any random variable whose logarithm is normally distributed with mean and standard deviation . Global selected this distribution to represent the number of rooms because the short tail to the left of the mean corresponds to the absolute limit of zero on the number of rooms a hotel can possess.

the ozone equipment. The motors in the laundry equipment are rather small, and only run-times are impacted.

Table 1-2 summarizes the figures used to estimate the technical potential for natural-gas savings from the use of ozone in hospitality OPL operations. The estimated natural-gas savings at the host facility due to the ozone system was 58 therms per year, per occupied room. Therefore, the expected annual savings for the average small hotel is 1,978 therms and 5,002 therms for a large hotel. The expected annual natural-gas savings for all small hotels is 2,112,929 therms and 5,342,122 therms for large hotels; this is a total of 7,455,051 therms per year for PG&E's service territory.

Table 1-2 Maximum Technical Potential Natural-Gas Savings from Ozone in Hotel Laundry Operations

Hotel Size	**Small Hotels (<84 rooms)**	**Large Hotels (≥84 rooms)**
Number of hotel properties in PG&E service territory	2,136	
	1,068	1,068
Average number of guest rooms	53	134
Annualized therm savings per occupied room at host facility	58	
Expected natural-gas savings per hotel, per year (therms)	1,978	5,002
Expected natural-gas savings per year (therms)	2,112,929	5,342,122
	7,455,051	

To summarize, the use of ozone in OPL operations in hotels in PG&E's service territory could result in annual electricity savings of as much as 5,230 MWh and annual natural-gas savings as much as 7.46 million therms (745,505 MMBtu).

1.3 ON-PREMISE LAUNDRY OPERATIONS

The basic equipment used in OPL operations is fairly standard. All hospitality facilities, except for the very largest, operate washer-extractor machines. Washer-extractors are large versions of the front-loading, horizontal axis washing machines commonly found in homes. The name washer-extractor comes from the fact that besides washing the linens, they extract water from the linens by spinning them, rather than the water extraction being completed by another piece of equipment. All facilities have dryers. Some facilities may also have folders and irons, but their energy use would not be impacted by the use of ozone.

After the housekeeping staff collects soiled linens and towels from the guest rooms, they are brought to the laundry room. There they are sorted, typically by color or type. This is because different linen types have different chemical, wash duration, and water temperature needs.

Laundry personnel load the laundry into the washer-extractors by hand, select the appropriate wash program, and start the machine. All chemicals are automatically measured into the machine at the appropriate time. When the wash cycle is finished, laundry staff remove the laundry from the washer-extractor and place it into the dryers. Again, personnel select the appropriate drying cycle and start the dryer.

1.4 OZONE 101

1.4.1 What is Ozone?

Ozone is a form of oxygen found naturally in the Earth's atmosphere. In its most stable form, oxygen exists as a gaseous diatomic molecule (O_2). Ozone is formed by the breakdown of diatomic oxygen and the recombination of a percentage of the oxygen atoms into a gaseous triatomic molecule (O_3).

Although diatomic oxygen is a powerful oxidizing agent in its own right, ozone has much stronger oxidizing properties. It reacts more quickly, often in fractions of a second, with a wide range of substances. In addition, ozone is one of the most effective biocides known to science—better even than chlorine, bromine, and other commonly-used disinfectants. Once ozone has fully reacted with substances in water or air, excess ozone gas decomposes quickly to diatomic oxygen and mixes into the atmosphere.

1.4.2 How Ozone Cleans

Being a powerful oxidizer, ozone cleans fabrics by chemically reacting with soils. Ozone removes electrons from the soils, causing the soils to break into smaller molecules that become water soluble and are released from the linen by ordinary agitation.

1.4.3 How Ozone is Produced

The most common method of producing ozone for laundry applications is via corona discharge. Simply put, dry air is passed through an electrical field. The electric field causes some of the oxygen molecules to split into separate oxygen atoms. Individual oxygen atoms are unstable and attach to other oxygen molecules, forming ozone molecules.

Dry air is required for adequate and reliable ozone production. First, ozone production decreases quickly as the moisture level in the air increases. Second, moist air leads to the production of nitric acid, which is highly corrosive and can quickly damage the ozone generator. Therefore, the air stream is dried prior to entering the ozone generator.

1.5 TECHNIQUES FOR APPLYING OZONE TO THE LAUNDRY SYSTEM

Ozone is rarely generated and then stored, but instead is generated as needed and introduced into the wash water as the washer-extractor is being filled and/or while the washer-extractor is in operation. Different manufacturers of ozone equipment for laundry operations use a variety of techniques to apply or introduce the ozone gas into the washer-extractor. Each technique has its advantages and disadvantages. Overall, ozone—regardless of how it’s applied—will provide energy-savings benefits. The following are the four most common methods of introducing ozone into the laundry system.

1.5.1 Recirculation Injection

Recirculation-injection (RI) systems continuously circulate wash water between the washer and the ozone system. As a result, the wash water is continuously re-oxidized and ozone-enriched. An oxidation-reduction-potential controller or an ozone parts per million (PPM) controller is highly recommended for monitoring and controlling ozone concentration in the water. Even though the RI approach can handle heavy soil and microbe loads, and save water, it is seldom used because it is the most complex and expensive of the four design alternatives. In addition, RI systems require constant maintenance to keep lint filters clean for proper system performance, which further reduces their appeal.

1.5.2 Diffusion

As with the RI approach, diffusion systems continuously inject ozone directly into the sump of the washer throughout each step of the wash cycle. Therefore, diffusion systems omit the piping, pump, contact vessel, and filters required by RI systems. As a result, they are less complex and less costly than RI systems.

1.5.3 Direct Water Injection

Direct-water-injection (DWI) systems inject ozone by means of a venturi directly into the cold-water supply line leading to the washer. This is a single-charge system, so the wash water is ozonated only once just before it enters the washer-extractor. As a result, the ozone concentration of the wash water will decrease throughout the entire wash cycle—depending on the length of the wash cycle and the soil level of the laundry. This type of system is the simplest and, therefore, the least costly and easiest to maintain.

1.5.4 Charge System

A variant of the DWI approach, a charge system (CS) includes a recirculation loop from the ozone contact vessel to the ozone system. A charge system mixes ozone with cold water and then continually recycles it between a contact vessel and the ozone system to maintain a predetermined ozone level in the water. The CS approach makes it possible to achieve higher effective concentrations of ozone in the water prior to releasing it into the washer. However, like the DWI approach, the ozone-enriched water is not recharged once it enters the washer.

1.6 THE BENEFITS OF OZONE IN LAUNDRY OPERATIONS

The reported benefits of using ozone in laundry operations are so numerous as to be, at times, difficult to believe. This is one of the reasons that ozone system manufacturers and distributors have had a hard time breaking into the OPL market. In addition, many of the quantifiable benefits have not been quantified by unbiased third parties that would lend credibility to the figures. Additional qualitative benefits exist that can be very important to some facility operators.

1.6.1 Quantifiable Benefits

The quantifiable benefits of ozone in laundry operations are well documented. However, there is a considerable range of benefit values. In addition, there is a dearth of unbiased, third-party research to corroborate those values. The following paragraphs present some of the most significant quantifiable benefits of ozone in OPL operations.

1.6.1.1 Reduced Energy Costs

Undoubtedly, the most-important benefit for hospitality owners and operators is reduced energy costs. These typically result from reduced hot-water consumption and, to a lesser extent, reduced drying times. Energy savings are fairly easy to measure and valuate.

Reduced Hot-Water Consumption

Typically, sanitizing is achieved using hot water. However, ozone works best in cold water—resulting in considerable energy savings.

Reduced Drying Time

Ozone does not change the water’s pH like detergents and bleach, so less souring chemicals are needed. This in turn reduces the need for softener, which tends to coat the fibers and holds moisture in the fabric, extending the drying time.

1.6.1.2 Reduced Water and Sewer Costs

Ozone aids the effectiveness of traditional laundry chemicals, reducing the amount of chemicals necessary. With less chemicals in the wash, fewer rinse cycles are needed; this results in reduced water consumption and sewer discharge. The savings associated with reduced water and sewer demand are significant and easy to measure and valuate.

1.6.1.3 Increased Life of Linens

Ozone shortens washing and drying cycle times, reducing exposure to chemicals and heat, thus decreasing fabric wear. The water softening properties of ozone also improve fabric life. Linens are typically ordered only once or twice per year. As a result, it can be difficult to accurately assess the value of increased linen life without comparing purchase costs over a period of several years.

1.6.1.4 Reduced Chemical and Detergent Costs

Ozone is such an effective disinfectant that fewer chemicals are required in the wash cycle. Chemical costs vary month-to-month as occupancy rates change and laundry formulas are adjusted. Therefore, it can be difficult to accurately estimate chemical cost savings due to ozone.

1.6.1.5 Reduced Labor Costs

Since ozone cleans more effectively, re-washes of heavily-soiled or stained items are less frequent, reducing the labor needed to sort and re-wash items. Reduced labor costs are very difficult to estimate, because of continuous changes in staffing and assignments; laundry staff duties are not differentiated and measured separately among a variety of tasks.

1.6.2 Qualitative Benefits

Some benefits of ozone in OPL operations cannot be measured at all and, therefore, are qualitative in nature. However, even qualitative benefits can sometimes still be established.

1.6.2.1 Increased Fabric Softness, Fluffiness, and Brightness

Ozone helps prevent the re-deposition of soil onto the linens (one of the major causes of fabric graying), which eliminates the need for further bleaching and chemical use. Reduced chemical usage results in softer, fluffier linens.

1.6.2.2 Improved Fabric Smell

Ozone deodorizes by breaking molecular bonds of most organic and inorganic compounds that cause odors.

1.6.2.3 Ability to Mix White and Colored Linens

Ozone reduces the need for bleach in many applications. As a result, white and colored linens can be washed together, which saves labor necessary for separating.

1.6.2.4 Improved Linen Availability

Many OPL facilities have observed fewer laundry items needing to be re-washed after laundering in ozone, which improves the availability of existing linens.

CHAPTER 2

PROJECT OBJECTIVES

The objectives of this project were to showcase an innovative application of an available technology that has great potential for energy savings in hospitality facilities with OPL operations in PG&E’s service territory. Energy savings commence immediately upon installation and continue at the same rate over the life of the equipment. A favorable demonstration of the ozone technology would allow PG&E to accelerate the adoption of this technology through promotional programs.

Ozone technologies for OPL operations are commercially available from a variety of manufacturers and are relatively easy to install and operate. The technology and the application have been available for several years. However, penetration rates are low due to perceived high costs and the technically-conservative nature of the OPL facility operators and the laundry industry, in general.

While the project took place at a hotel, the use of ozone has applications in almost any commercial facility having OPL operations, such as: hospitals, nursing-care facilities, gymnasiums, schools, and prisons—regardless of their location.

CHAPTER | 3

PROJECT METHODOLOGY

3.1 METHODOLOGY

The methodology used in this project established a baseline of energy consumption prior to the installation of the ozone equipment and then compared that to post-installation energy use to establish total energy savings. The methodology followed a five-step process.

1. Identify a hospitality facility within PG&E's service area that would be willing to host a monitored demonstration of the technology. Ideally, the host facility would be part of a well-recognized hospitality chain. Positive project results at a facility belonging to a well-recognized chain would accomplish two objectives: 1) it would attract more attention and interest; and 2) with many similar facilities throughout the chain, replicating the results would be made easier.

   The host facility was responsible for the full installed cost of the equipment. However, management of the host facility would be encouraged to apply for rebates available through PG&E and other organizations, such as its local water and sewer district.

   The host facility identified for this project was the Hilton Garden Inn–Emeryville. At the beginning of the project, management at the hotel was already in discussions with both PG&E and the East Bay Municipal Utility District (EBMUD) regarding the installation of an ozone system in their OPL facility.

2. After identifying the host facility and prior to installation of the ozone system, Global established a one-month baseline of water consumption by metering the hot and cold water supplies for each of the washer-extractors. This provided information on water consumption, sewer outflows, and water heating energy impacts. Global established dryer operating times to measure dryer energy use, but found that dryer run-times are highly variable due to the dryer control systems that set run-time automatically based on the temperature of the exhaust air.

3. At the end of the one-month baseline monitoring period, the ozone equipment distributor installed the ozone generator and ozone supply lines to each of the washer-extractors. The hotel's laundry chemical vendor then re-programmed the washer-extractor formulas and wash cycle settings to account for the addition of ozone to the chemical and detergent array.

4. Once the ozone equipment distributor calibrated the ozone equipment, determined it was working properly, and the new ozone-based formulas were producing suitable results, the one-month post-installation monitoring period began.

5. Initial plans were to have an independent laboratory conduct comparative measurements and analyses of the ozone-treated laundry and the laundry washed with standard systems. However, Global abandoned those plans when it learned that laboratory tests of laundry cleanliness are not standard in the hospitality industry.

6. Before, during, and after the monitoring periods, Global conducted oral interviews—both in-person and by telephone—with several staff members at the host facility. The purpose was to assess their views of equipment operations, effectiveness, laundry results, and economics.

7. Prepare a final report that included: estimated annual energy savings results, expected adoption rates, estimated energy and non-energy savings potential in PG&E's service territory, and recommendations for further program development and/or incentives.

3.2 PROJECT HOST & LAUNDRY EQUIPMENT

Initially, two months were set aside to find and recruit a host facility. Based on discussions with PG&E, the desired locale for the host facility was the San Francisco Bay Area. Three high-profile, four-star hotels and one local four-star hotel were initially selected as potential host sites. However, it was quickly determined that the three high-profile hotels had very small OPL operations, and the local hotel was told by their chemical vendor that ozone could not be used with their washer-extractors.[5] Table 3-1 summarizes the characteristics of the four initial candidate hotels.

Table 3-1 Initial Possible Host Sites and Dispositions

Facility	Location	Rooms	Part of Well-Known National Chain?	Outcome
High Profile 4-Star Hotel	San Francisco	591	Yes	Small OPL operations
High Profile 4-Star Hotel	San Francisco	380	Yes	Small OPL operations
High Profile 4-Star Hotel	Alameda County	279	Yes	Small OPL operations
Local 4-Star Hotel	Contra Costa County	138	No	Ozone not acceptable

Soon thereafter, several opportunities arose among hotels participating in a water conservation program offered jointly by PG&E and two local water/wastewater agencies in the San Francisco Bay Area. Through this ongoing program, several hotels had already installed ozone systems or were to install it very soon. Eventually, the facilities manager of the 278-room Hilton Garden Inn–Emeryville (see Figure 3-2) expressed strong interested in participating. In mid-May 2008, Hilton's corporate management confirmed their participation in PG&E's joint water conservation program. The manager of the Hilton Garden Inn–Emeryville also agreed to allow the monitoring of the laundry equipment for this project.

Figure 3-2 Façade of 278-Room Hilton Garden Inn – Emeryville

[5] While no specific reason was given at the local hotel to decline participation, chemical vendors are often barriers to the use of ozone technologies in OPL operations due to the vendor's fear of losing sales to a "competing" technology. On the other hand, several chemical manufacturers and vendors have embraced ozone and even offer detergents and other laundry chemicals suitable for use with ozone.

The hotel, located in the San Francisco Bay Area, is 13-stories high and features a full-service restaurant, lounge, pool, exercise facility, and over 9,000 square feet of meeting and banquet space. Owing to these amenities, the linens used and laundered on-premise include: sheets, blankets, bedspreads, towels, tablecloths, table skirts, napkins, and kitchen and cleaning rags.

The opportunity to use the Hilton Garden Inn–Emeryville, a hotel belonging to a worldwide chain, as the host facility met both of the stated objectives of selecting a facility belonging to a well-recognized chain. The high visibility of the Hilton name would likely attract more attention and interest and the large number of similar facilities would ease replication of the results.

The principal laundry room equipment at the Hilton Garden Inn–Emeryville consists of three washer-extractors and four gas-fired dryers, as detailed in Table 3-2.

Table 3-2 Laundry Room Equipment at Host Facility

Equipment	Units	Manufacturer	Model	Capacity (lbs)	Year Manufactured
Washer-Extractor	3	Pellerin Milnor	36026Q6J	95	1998
Gas Dryer	4	Pellerin Milnor	MLG130HS	120	1997

Laundry operations at the Hilton Garden Inn–Emeryville typically occur between 3 pm and 11 pm each day. Laundry staff manually separate the linens based on which of the six washer-extractor programs each type of linen requires. Table 3-3 shows the six formulas programmed into each washer-extractor at the Hilton Garden Inn–Emeryville for this study.

Table 3-3 Washer-Extractor Formulas with Ozone at Host Facility

Formula	Water Temperature	Ozone Used?
#1 – New Linen	Cold	Yes
#2 – Whites (sheets and towels)	Cold	Yes
#3 – Bedspreads	Cold	Yes
#4 – Tablecloths - Color	Hot	No
#5 – Tablecloths - White	Hot with Bleach	No
#6 – Power Wash (re-wash)	Hot	No

Formula #2 described in Table 3-3 is the most commonly-used formula at the Hilton Garden Inn–Emeryville, since sheets and towels account for 80% of the linens used each day. Table 3-4 compares the differences between the traditional and ozone versions of Formula #2 at the Hilton Garden Inn–Emeryville. After the changeover to ozone, there is no need for a bleach step. Without a bleach step, the ozone formula requires fewer rinse steps and combines the sour/soft step with a final rinse.[6] As a result of the change to ozone, each load of sheets and towels takes 5-1/2 minutes less to wash than before. Also, the ozone formula consumes 117 gallons less hot water and 30 gallons less water overall, in spite of consuming 87 gallons more cold water.

Two gas-fired Laars Pennant automatic circulating tank water heaters (model PNCV1750NACL2BXN) provide the hotel's hot water, including the hot water used in laundry operations. These two units are able to supply just over 2,200 gallons per hour (GPH) of 140°F water. With rated input power of 1.75 MMBtuh each, recovery efficiency of 0.85, and a water temperature increase of 80°F, the two water heaters consume 0.0078 therms (781 Btu) per gallon of water heated.

[6] The sour/soft step involves a combination of a slightly acidic chemical—the sour—that neutralizes residual alkalinity leftover from the suds (detergent) step and a softening chemical in one step.

Table 3-4 Comparison of Traditional (Before) and Ozone (After) Formula #2 for Sheets and Towels

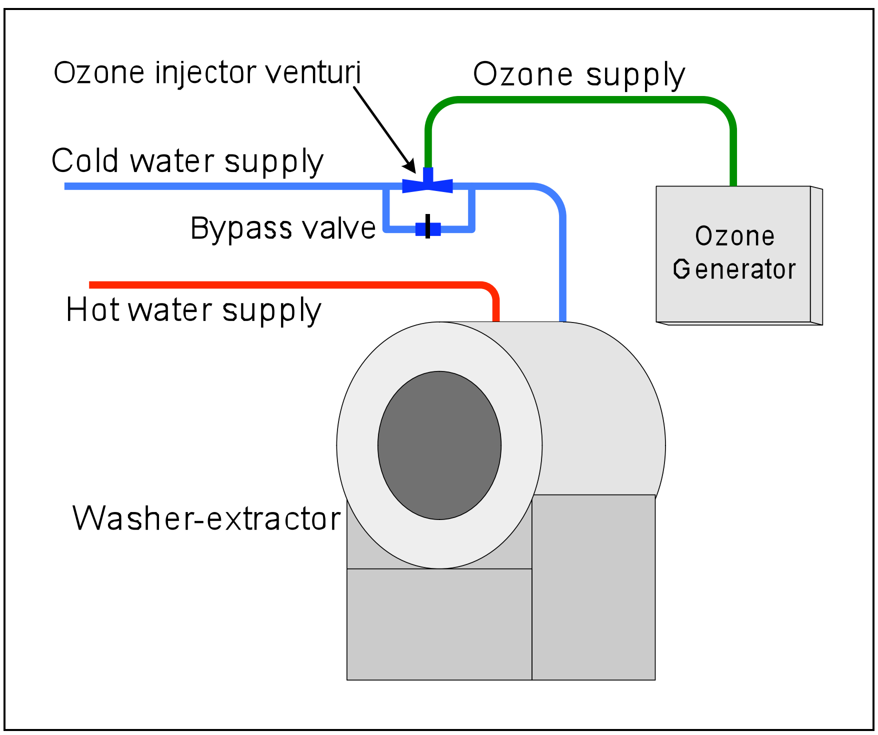
Laundry Step	Traditional Formula #2 (Sheets & Towels)			Ozone Formula #2 (Sheets & Towels)		
	Cold Water (gallons)	**Hot Water (gallons)**	**Run Time**	**Cold Water (gallons)**	**Hot Water (gallons)**	**Run Time**
1) Suds	0	47	8 mins	47	0	10 mins
2) Bleach	0	15	8 mins			
3) Rinse	0	22	2 mins	22	0	2 mins
4) Rinse	11	11	2 mins			
5) Spin	—	—	0.5 mins	—	—	2 mins
6) Rinse	22	22	2 mins	44	0	2 mins
7) Sour/Soft	15	0	4 mins	22	0	4 mins
8) Spin	—	—	4 mins	—	—	5 mins
Totals	**48 gallons**	**117 gallons**	**30.5 minutes**	**135 gallons**	**0 gallons**	**25 minutes**
	165 gallons			**135 gallons**		

3.3 OZONE EQUIPMENT

Total Ozone Solutions of Bridge City, TX installed a direct-water-injection ozone system manufactured by Nu-Tek International of Edgewater, FL. Figure 3-3 illustrates the layout of the ozone system installed at the Hilton Garden Inn–Emeryville. The system injects gaseous ozone directly into the cold-water supply line that provides water to each of the three washer-extractors.

Consisting of a single self-contained, wall-mounted ozone generator, the installed ozone system is simpler than most ozone systems installed for laundry operations. The only utility requirement for the installed system is 110V electrical service.

Figure 3-3 Plumbing of Direct Water Injection System at Host Facility



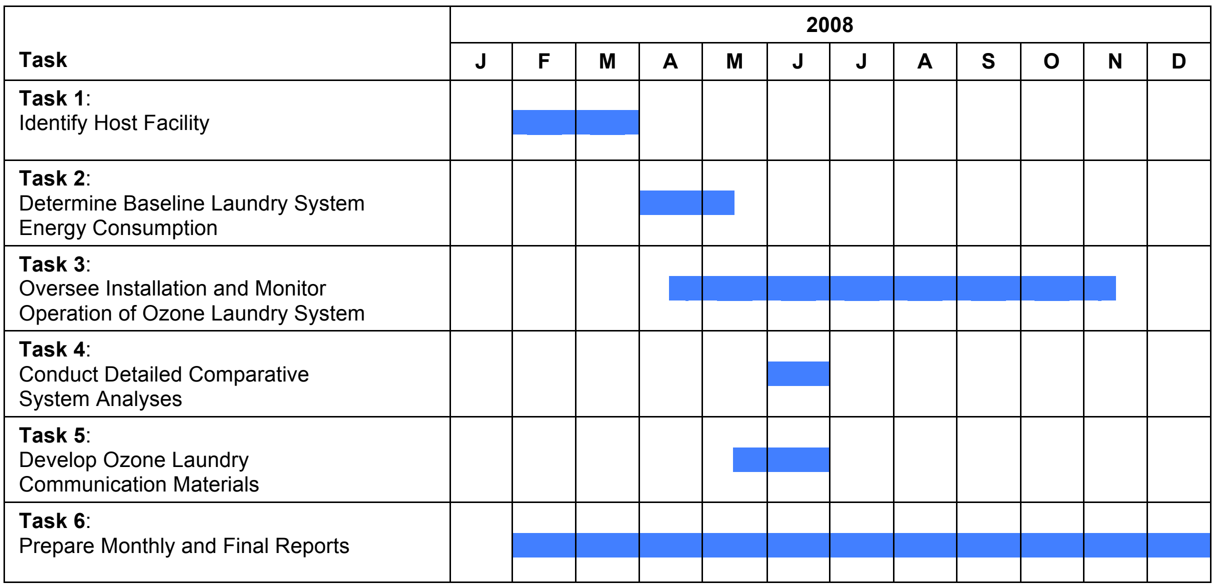
The installed ozone system is simple to operate, requiring only that laundry staff manually switch on the ozone generator when laundry operations begin and turn it off when they cease. The generator produces ozone only when cold water flowing through the ozone injection venturi creates a vacuum on the ozone supply line. Because the generator is vacuum-controlled, there is no chance of an ozone leak. Regular maintenance consists only of weekly cleaning of the lint screens on the two cooling fans located on the generator's housing.[7]

The Hilton Garden Inn–Emeryville installed the ozone generator and associated plumbing at a cost of $14,000, including labor. The installation required minimal modifications to existing plumbing, which kept labor costs down. Available incentives and rebates from PG&E and EBMUD should cover almost the entire project cost.

3.4 PROJECT TIMELINE

The project commenced in late January 2008. Two months were allotted to locate and register a host facility. The sequence included: a one-month baseline monitoring period, two weeks to install and calibrate the new ozone equipment, and a one-month post-installation monitoring period. Several more months were allocated to establish values for some of the more difficult-to-quantify benefits. Figure 3-4 illustrates the overall project timeline by month.

Figure 3-4 Project Timeline



[7] The manufacturer recommends that every five years the customer return the ozone generator for a cleaning and complete overhaul of the corona chambers. This service is typically included under the equipment warranty.

CHAPTER 4

PROJECT RESULTS

As presented earlier, there may be several sources of cost savings and environmental benefits resulting from the use of ozone in laundry operations. This study emphasized the measurement and substantiation of utility cost savings: water and sewer, electricity, and natural gas. The savings from utility costs alone resulted in a simple payback that, even without utility rebates or other incentives, should generate significant interest in the use of ozone for laundry operations—not only in the hospitality industry, but in any industry with OPL operations.

4.1 WATER & SEWER SAVINGS

Global monitored the flow of hot and cold water into each of the 3 washer-extractors for 30 days prior to installation of the ozone system and for 30 days after installation. Table 4-1 compares daily average hot and cold water consumption for laundry operations during those two periods. The use of ozone in the laundry operations reduced hot water consumption by over 91%. Cold water use increased by over 41%, because the use of ozone calls for cold water instead of hot. Overall water consumption for laundry operations decreased an average of 2,432 gallons per day, or more than 35%. This savings is equivalent to over 863,000 gallons per year. During the 60 days represented by the 2 consecutive 30-day monitoring periods, occupancy at the hotel was stable at about 75%. Therefore, a change in the number of guests accounts for little, if any, of the variation in water consumption for laundry operations.

Table 4-1 Comparison of Average Daily Water Consumption by Washer-Extractors, Pre- and Post-Installation

Monitoring Period	Cold Water – Average Daily Use (gallons)	Hot Water – Average Daily Use (gallons)	All Water – Average Daily Use (gallons)
30-Day Pre-Installation	2,902.9	3,990.1	6,893.0
30-Day Post-Installation	4,112.7	348.0	4,460.7
Difference	1,209.8 (41.7%)	-3,642.1 (-91.3%)	-2,432.3 (-35.3%)
Annualized Difference (gallons per year)	452,867	-1,316,420	-863,553
Annualized Difference (hundred cubic feet)	605.4	-1,759.9	-1,154.5

A decrease in water consumption also means a decrease in water sent down the sewer. The Hilton Garden Inn–Emeryville's combined costs for water and sewer costs are $5.92 per hundred cubic feet (ccf).[8] Based on the measured water consumption reductions, the hotel will realize water and sewer cost savings of $18.72 per day or $6,835 per year.

4.2 ENERGY SAVINGS

Because ozone works best at ambient water temperatures, most types of linens can be washed in unheated water, which reduces water heating costs. Electricity is not a big part of overall laundry energy use at the Hilton Garden Inn–Emeryville, since water is heated there using

[8] One hundred cubic feet (ccf) is equivalent to 748 gallons.

natural gas and the dryers are also natural-gas fired. As a result, the most significant energy savings at the Hilton Garden Inn–Emeryville resulted from reduced natural-gas consumption for water heating and clothes dryer operation.

4.2.1 Electricity Savings

Electricity savings at the Hilton Garden Inn–Emeryville resulted from shorter washer-extractor operating cycles and shorter drying times, which reduced the operating times of the motors within that equipment.

Each of the three washer-extractors contains a single 10 hp motor that spins the cylinder and operates the water pump. The motor operates nearly continuously during washer-extractor operation, with only short pauses between laundry steps and changes in direction. With the changes in Formula #2 (the wash cycle used for sheets and towels, as shown previously in Table 3-3), washer-extractor motor run-times decreased 16%, resulting in electricity savings of approximately 0.5 kWh per load. Typical laundry operations result in about 40 washer-extractor loads per day, corresponding to savings of 20.5 kWh per day or 7,488 kWh per year. Analyzing the hourly energy charges for the periods during which the host facility operates its laundry facility, Global established that the average energy cost to the Hilton Garden Inn–Emeryville is $0.09 per kWh. Therefore, the value of the washer-extractor motor savings is $674 per year.

Each of the four dryers has two motors: a 1 hp basket motor drive and a 3 hp blower motor. Both operate continuously while the unit is in operation. Calculating a change in dryer run-times due to the use of ozone proved to be quite difficult. Metering the electricity usage was not feasible because of the number of dryers. Metering only one dryer would not provide sufficient data to establish consumption; laundry staff randomly use any of the four identical dryers to dry a given load.

To establish dryer run-times, Global staff observed the dryers in operation during two days and noted the run-time—which the control panel displays—when the dryer stops tumbling. The weighted average drying time before ozone was 26 minutes and the post-ozone weighted average was just under 24 minutes. The resulting reduction was smaller than anticipated and results in a savings of just 0.08 kWh per load. Based on 40 dryer loads per day, daily savings are 3.2 kWh or 1,163 kWh per year. At a cost of $0.09 per kWh, the value of the dryer motor savings is $105 per year.

It is possible that the smaller-than-expected decrease in drying time was due to the retention of the sour/soft step in the ozone formula. Frequently, ozone formulas eliminate the sour/soft step, which results in shorter drying times.

The total annual washer-extractor and dryer electricity savings due to the ozone system is 8,651 kWh, with a value of $779 to the Hilton Garden Inn–Emeryville. As expected, electricity savings accounted for a relatively small share (3.5%) of the overall energy savings.

4.2.2 Natural-Gas Savings

A majority of the natural-gas savings resulted from reducing hot water consumption in the washer-extractor; a small portion of the savings resulting from shorter dryer run-times.

As stated previously, hot water consumption fell 91%, or 3,642 gallons per day, as a result of the ozone system. On an annual basis, this is almost 1.32 million gallons. The natural-gas savings resulting from this decrease is 28.4 therms per day or 10,383 therms per year. The 12-month weighted average cost of natural gas for the Hilton Garden Inn–Emeryville is $1.19 per therm. Thus, the value to the Hilton Garden Inn–Emeryville of the natural-gas savings due to reduced hot water consumption alone is $12,397, or nearly 89% of the cost to install the ozone system.

Due to various factors, each drying cycle tends to differ in length. Each dryer contains a control system that determines the length of run-times. The operator loads the dryer, then starts the drying cycle by selecting cycle “B” (sheets, pillowcases, and towels) or cycle “C” (tablecloths & bedspreads) on the dryer’s control panel. The dryer’s control system then monitors the temperature of the exhaust air to determine the proper length for the drying cycle. At the beginning of the cycle, the exhaust air is comparatively cool due to the high moisture content of the linens. As the linens dry, the temperature of the exhaust air increases until there is insufficient moisture left in the linens to cool the exhaust air further. At this point, the controller shuts off the burner, but continues to tumble the linens for a short “cool down” period. In addition, laundry staff can manually add drying time if they feel the linen is still too damp once the dryer shuts off.

The reduction in natural-gas use due to the shorter dryer run-times was 0.133 therms per load. Based on 40 dryer loads per day, daily savings are 5.34 therms or 1,948 therms per year. With a natural-gas cost of $1.19 per therm, the value to the Hilton Garden Inn–Emeryville of the dryer natural-gas savings is $2,326 per year.

The total annual natural-gas savings due to the ozone system are 12,331 therms, having a value of $14,723 to the Hilton Garden Inn–Emeryville. Thus, the natural-gas savings represent two-thirds of the savings resulting from the ozone system and more than cover the cost of the ozone system.

4.3 SUMMARY OF SAVINGS

Table 4-2 summarizes the savings due to the installed ozone system at the Hilton Garden Inn–Emeryville. As expected, the value of the natural gas saved due to the replacement of hot water with cold was the leading component of total savings. The value of the electricity savings were minor, also as expected. The value of the water and sewer savings were larger than expected, which is significant—the ozone system vendor did not include the value of water and sewer savings in the pre-installation savings estimates upon which Hilton Garden Inn–Emeryville management based their decision to install the ozone system.

Considering all the quantifiable savings resulting from the installation of the ozone system, the ozone system has a simple payback of 7.5 months. With available rebates and incentives, the payback is significantly shorter. The Hilton Garden Inn–Emeryville applied for, and received, incentives from the East Bay Municipal Utility District for $1,740 and from PG&E for $7,086, for a total of $8,826 in incentives. These incentives reduced the payback period to just 83 days.

Table 4-2 Summary of Savings Resulting from Ozone in Laundry Operations

Cost Point	Value of Each Unit Saved	Units Saved per Year	Value of Savings per Year	Percent of Total Savings
Water & Sewer	$5.92/ccf	1,154.5 ccf	$6,835	30.6%
Electricity (washer-extractors)	$0.0900/kWh	7,488 kWh	$674	3.0%
Electricity (dryers)	$0.0900/kWh	1,163 kWh	$105	0.5%
Natural gas (hot water)	$1.1940/therm	10,383 therms	$12,397	55.5%
Natural gas (dryer)	$1.1940/therm	1,948 therms	$2,326	10.4%
Total Quantifiable Savings	**—**	**—**	**$22,337**	**—**

4.4 DEMAND IMPACTS

The demand impacts due to the use of ozone at the Hilton Garden Inn–Emeryville were not significant, even when the equipment use coincided with peak-demand periods. While ozone reduces equipment run-time, it does not change when the equipment is used or significantly reduce its demand.

4.5 ENVIRONMENTAL IMPACTS

In addition to the energy and utility savings due to the ozone system, there are environmental benefits as well. Besides the greenhouse-gas benefits from reduced power-plant emissions and reduced direct combustion of natural gas (from the decreased use of electricity and natural gas, respectively) there are other environmental benefits. The significant reduction in water consumption opens the saved water to other uses and end-users. In addition, less water down the sewer reduces strain on wastewater treatment systems—especially considering the chemical load associated with laundry water.

CHAPTER | 5

CONCLUSIONS

As shown in Section 1, the use of ozone in OPL operations in hotels in PG&E's service territory could result in annual electricity savings as much as 5,230 MWh and annual natural-gas savings as much as 7.46 million therms. The value of the electricity savings at the Hilton Garden Inn–Emeryville were about as expected. However, the value of the water and sewer savings was significantly greater than expected. The overall value of the savings due to the ozone system were higher than anticipated, resulting in a payback short enough to make the technology attractive in any on-premise laundry.

Ozone systems for use with OPL operations are now available on the market (see Appendix A). A few of the manufacturers and their distributors are marketing actively within the hospitality market and are becoming better known within the hospitality industry. With more studies such as this one, there will soon be adequate information available regarding the costs and benefits of ozone laundry system to further remove barriers to their widespread penetration of the OPL market.

It was not difficult to find a hospitality facility with OPL operations that was open to installing ozone. However, without knowing that up-front incentives are available to help defray first costs, most facility managers were no longer interested in what they viewed as an "experimental" technology.

Due to the wide availability of ozone equipment for OPL operations, the view that many OPL operation managers have of ozone, and the sizeable natural-gas savings offered by ozone, Global recommends that PG&E expand its marketing of ozone for OPL operations with its rebate/incentive programs. In addition, Global recommends that PG&E market ozone for OPL operations in cooperation with water/sewer utilities, due to the considerable water savings that result from the use of ozone—–especially considering recent worries about water shortages due to long-term drought conditions.

Perhaps one of the most valuable indications of the benefits of ozone in OPL operations was a statement made by Buck Chisler, Chief Engineer at the Hilton Garden Inn–Emeryville. When asked what he thought of the ozone system after just one month of operation he said, "I'm ecstatic. Everything that was promised is happening."

OZONE EQUIPMENT MANUFACTURERS

Aquawing Ozone Injection Systems
45 Priscilla Lane
Auborn, NH 03032
Phone: (888) 296-4777
Fax: (603) 644-0498
Email: info@awois.com
Web: www.awois.com

ArtiClean
129 Fieldview Drive
PO Box 455
Versailles, KY 40383
Phone: (859) 873-1341
Fax: (859) 873-9196
Email: info@articlean.com
Web: www.articlean.com

ClearWater Tech, LLC
850 Capitolio Way, Ste. E
San Luis Obispo, CA 93401
Phone: (800) 262-0203
Fax: (805) 549-0306
Email: sales@cwtozone.com
Web: www.cwtozone.com

EnviroCleanse Systems, Inc.
6653 Powers Avenue, Suite 4
Jacksonville, FL 32217
Phone: (888) 420-4262
Email: info@envirocleanse.com
Web: www.envirocleanse.com

Guardian Manufacturing
2971-A Oxbow Circle
Cocoa, FL 32926
Phone: (321) 631-4580
Fax: (321) 631-4517
Email: jimbaker@guardianmfg.com
Web: www.guardianmfg.com

IndustrOzone Technologies, LC
9650 Strickland Road Suite 103-250
Raleigh, NC 27615
Phone: (800)736-1351
Fax: (919)847-3677
Email: industrozone@industrozone.com
Web: www.industrozone.com

Nu-Tek International, Inc.
704 West Park Ave
Edgewater, FL 32132
Phone: (800) 322-5776
Email: info@ozonelaundry.com
Web: www.ozonelaundry.com

Ozone Laundry Systems, Inc.
3838 So. State Street
Salt Lake City, UT 84115
Phone: (888) 283-0306
Fax: (801) 747-3315
Email: rz@ozonelaundrysystems.com
Web: ozonelaundrysystems.com

Ozone Solutions
Phone: (800) 454-0863
Web: www.ozonesolutionsonline.com

Pacific Ozone
6160 Egret Court
Benicia, CA 94510
Phone: (707) 747-9600
Fax: (707) 747-9209
Email: sales@pacificozone.com
Web: www.pacificozone.com

Pure n Natural Systems, Inc.
PO Box 1137
Streamwood, IL 60107
Phone: (800) 237-9199
Fax: (847) 470-1686
Web: www.purennatural.com

Water Energy Technologies, Inc.
9741 Tappenbeck Drive
Houston, TX 77055
Phone: (713) 464-7117
Email: info@waterenergy.com
Web: www.waterenergy.com

Wet-Tech
1102 Pleasant St.
Worcestor, MA 01602
Phone: (508) 831-4229
Fax: (508) 791-4966
Email: JackReiff@Wet-Tech.com
Web: www.wet-tech.com

APPENDIX | B

ENERGY SAVINGS POTENTIAL CALCULATIONS

Technical Potential – Electricity Savings – PG&E

	Value	Description	Calcs	Notes	Source
A	179,000	Hotel rooms in PG&E service territory (1)		Smith Travel Research (STR), *California Tourism E-Outlook*, July 2008	www.visitcalifornia.com
B	2,136	Number of hotel properties in PG&E service territory (1)		Smith Travel Research (STR), *California Tourism E-Outlook*, July 2008	www.visitcalifornia.com
C	84	Average number of rooms per property in PG&E service territory	[A/B]		
D	53	Average # rooms - small hotels		Assumes distribution is lognormal — used as proxy for average size of "SMALL" hotel	Lognormal Dist.xls
E	134	Average # rooms - large hotels (use as average # rooms for large hotels)		Assumes distribution is lognormal — used as proxy for average size of "LARGE" hotel	Lognormal Dist.xls
EE	64.8%	Estimated average hotel occupancy in PG&E service territory		Smith Travel Research (STR), *California Tourism E-Outlook*, July 2008	www.visitcalifornia.com
F	8,651	kWh saved per year due to ozone use (Hilton Garden Inn-Emeryville)		Electricity use reduction due to ozone use at HGI-Emeryville	Annualized results from Hilton Garden Inn - Emeryville
G	278	Room facility in which savings were measured (Hilton Garden Inn-Emeryville)			Per Buck Chisler, Facilities Manager, Hilton Garden Inn-Emeryville
FF	77%	Average estimated occupancy (Jan-Oct 2008 at Hilton Garden Inn-Emeryville)			Per Buck Chisler, Facilities Manager, Hilton Garden Inn-Emeryville
GG	214	Average number of rooms occupied each night (Hilton Garden Inn-Emeryville)	[G*FF]		
H	40	kWh savings/room/year (Hilton Garden Inn-Emeryville)	[F/GG]		
I	1,388	kWh savings/property/year due to ozone use (SMALL hotel)	[D*EE*H]	Average savings for "average" small property	
J	3,509	kWh savings/property/year due to ozone use (LARGE hotel)	[E*EE*H]	Average savings for "average" large property	
K	1,482,357	Total kWh savings per year in PG&E service territory due to ozone use (SMALL hotels)	[B*I*0.5]		
L	3,747,847	Total kWh savings per year in PG&E service territory due to ozone use (LARGE hotels)	[B*J*0.5]		
M	**5,230,204**	Total kWh savings per year in PG&E service territory due to ozone use	[K+L]	Maximum technical potential annual electricity savings	

Technical Potential – Natural-Gas Savings – PG&E

	Value	Description	Calcs	Notes	Source
P	12,331	Therms natural-gas savings/property/year due to ozone use		NG reduction due to ozone use at Hilton Garden Inn-Emeryville	Annualized results from Hilton Garden Inn - Emeryville
Q	58	Therms natural-gas savings/room/year due to ozone use (Hilton Garden Inn-Emeryville)	[P/GG]		
R	1,978	Therm savings/property/year due to ozone use (SMALL hotel)	[D*EE*Q]		
S	5,002	Therm savings/property/year due to ozone use (LARGE hotel)	[E*EE*Q]		
T	2,112,929	Total therm savings per year in PG&E service territory due to ozone use (SMALL hotels)	[B*R*0.5]		
U	5,342,122	Total therm savings per year in PG&E service territory due to ozone use (LARGE hotels)	[B*S*0.5]		
V	**7,455,051**	Total therm savings per year in PG&E service territory due to ozone use	[T+U]		

PROJECT PHOTOS

Figure D-1 Three Pellerin Milnor Model 36026Q6J 96 lb Capacity Washer-Extractors

Figure D-2 Four Pellerin Milnor Model MLG130HS 120 lb Gas Dryers

Figure D-3 Total Ozone Solutions Ozone Generator, Manufactured by Nu-Tek International, Inc

Figure D-4 Detail of Ozone Supply Line (top) and Venturi Connection with Cold Water Supply