# Saving Water with a Shower Orb

## Problem Statement

Across the United States, water consumption is a challenge facing many communities. Issues surrounding water come in the form of limited quantity, competing demands, infrastructure needs, and environmental impact. When the US is compared to other similarly developed countries, our water use inefficiencies present an unfortunate picture. According to UN Water, the US consumed over 17 trillion gallons of water for domestic purposes in 2005[1]. On a more local level, municipalities across New York State supplied more than 1.8 billion gallons to customers in 2012[2].

Our university consumed nearly 41,000,000 gallons during 2012[3]. As one of the major consumers of municipal water locally, any reductions in demand have the potential to benefit both our campus and the local community. Across the US, water use for showering is estimated to represent 16% of consumption[4]. This puts our shower-related consumption at approximately 6,500,000 gallons for 2012.

Generally, water is not considered a scarce resource in New York. The Northeast, and New York in particular, is dotted with some of the largest and most picturesque freshwater sources in the world. Despite this abundance, the Department of Environmental Conservation still makes water savings a priority, having sponsored programs including “Fix a Leak Week.”

In areas where scarcity is not an issue, motivation for reducing water consumption stems from the other tangible impacts of domestic water use: infrastructure for treatment and related maintenance and energy consumption involved in processing and delivering water. In the case of showers, water must also be heated. The second case for conservation is more ecologically focused. Our campus water demands are met by surface water. Campus water consumption and the discharge of treated wastewater disrupt the natural ecology. Reducing the footprint of water use lessens the impact on our environment.

## Project Summary & Background

The Shower Orb is a device that provides direct feedback to users about their shower duration. The Orb is mounted in the ceiling and glows different colors alerting users to their shower water use.  A simple green, yellow, red color scheme is used. Positioned either inside or just outside the shower, it is a non-invasive way to promote resource consumption. Twelve apartments were involved in the project with a total of 16 showers receiving Orbs.

Water use reduction is an important part of sustainability. Treated water embodies significant amounts of energy through treatment and processing. Ecological concerns, including disruption of surface water bodies, are also important. On our campus, water is heated with natural gas. With hot water making up the majority of water used in a shower, savings are realized not only in water but also in fuel.

There is currently no other product that uses actual water consumption to alert shower users of their resource impact. Because the Shower Orb is designed to work with in-line water meters, it is universally applicable to all types of showers. This makes the design unique in that it accommodates all shower heads too. The settings can be adjusted to change colors based on gallons consumed, rather than just minutes spent showering. The Orb does use approximately 100 mW to run, but remains in the off position the vast majority of the time. The controller that is used does remain powered continuously, but draws only three Watts.

Our decision to provide direct feedback to users in near real-time is based on established research. Numerous studies have focused on energy-related messaging and found that real-time feedback is most effective[5][6]. Similar approaches have been used successfully by non-water utilities to promote conservation, including the PriceLight, by CNT Energy and the Ambient Orb, by PG&E in California[7].

## Relationship to Sustainability

Reminding users about resource conservation while showering may also promote savings in other aspects of their lives. When one everyday activity is monitored, occupants may extend conservation behavior to electricity consumption or space heating use.

The impact on the local environment can be measured in a variety of ways. Qualitative benefits to shower use reduction include decreasing the demand on water infrastructure and saving energy from both treating and heating domestic water. Reducing the demand on the treatment systems prolongs facility life, and less water use reduces natural gas consumption associated with heating. Ecological and environmental benefits include reducing the “footprint” of our campus. Fewer gallons of water consumed equate to a smaller disruption to our local ecosystem.

## Materials and Methods

Each Shower Orb was handmade in the lab using inexpensive materials. Schematic design of the circuitry and control system was performed by the Project Manager/ Computer Engineer. Simultaneously, the Civil Engineer investigated installation conditions, as the Orbs were being deployed in existing apartment units. This planning phase of the project was completed in December of 2013.

Figure 1 - A Shower Orb installed in an apartment

The next phase was prototyping, which occurred throughout January and February. Minor setbacks were encountered with LED color mixing. This led to the simplification of the design to include two LEDs of each color; green, yellow, and red. The physical appearance of the orb was achieved using fillable plastic Christmas ornaments, spray paint, and plastic piping. Fabrication took place in March with assistance in fabrication from two other students. Deployment occurred over spring break with the units functional when students returned. An installed Orb is pictured in Figure 1.

## Results, Evaluation & Demonstration

The apartments that had Shower Orbs installed represented approximately 20% of the water consumption of the apartment complex. Using the American Water Works estimate of 16% domestic water use for showers, our study had the potential to impact the use of 144,000 gallons of water annually[4]. Our goal was to realize a 10% reduction in water use.

The preliminary results from our deployment are mixed. Due to the short duration of the study period (March 24 through April 6), statistical validity of the data is lower than desirable. On average, changes in shower duration and water consumption actually increased. Additionally, some apartments showed significant increases or decreases on the order of 25 to 30%. Results are summarized in Table 1 with full results tabulated in the Appendix. Given a study of longer duration, we feel that more consistent savings are possible.

| Table 1 - Results Summary | | | |
|---|---|---|---|
| shower duration (min/day) | total water use (gal/day) | hot water use (gal/day) | fraction hot water (%) |
| baseline period average | | | |
| 44.6 | 608.5 | 413.8 | 68.1 |
| experimental period average | | | |
| 48.1 | 620.9 | 449.7 | 72.2 |
| overall change (%) | | | |
| 3.5 (7.8) | 12.5 (2.0) | 35.8 (8.7) | 4.1 |

The results show that shower duration, total water use, and hot water use all increased from the baseline period, which is opposite of what was expected.

The impact of each gallon of water saved can be measured both quantitatively and qualitatively. Quantitative metrics include total gallons saved, treatment energy saved, heating energy saved, emissions savings from energy, and cost savings. Even with a modest 5% reduction in shower duration, which represents 30 seconds on a ten minute shower, savings accrue rapidly. Implemented at scale across a university, or across the state, the benefits scale tremendously. Potential per-gallon savings are summarized in Table 2 and full calculations are included in the Appendix.

The Shower Orb, as designed, is a highly transferable idea. Potential markets are nearly endless as showers are ubiquitous in homes, college dormitories, hotels, and with the increasing popularity of various green building standards, even the workplace. Estimating New York State's shower consumption at 288 million gallons, the potential for savings is enormous [2] [3]. The main obstacle to scalability is the infrastructure needed for optimum installation. The most impactful installation is one that permits real-time feedback to users based on water consumption. This scenario maximizes impact and accuracy of the feedback, however requires relatively expensive meters. The meters also need to be installed in-line which makes plumbing access a requirement.

| Table 2 - Quantitative Metrics | | | |
|---|---|---|---|
| Treatment Savings | energy savings[8] | 120 | kWh/ kgal |
| | $CO_2$ savings[9] | 65.5 | lbs/kgal |
| | $NO_x$ savings[9] | 0.048 | lbs/kgal |
| | $SO_x$ savings[9] | 0.132 | lbs/kgal |
| Heating Savings | gas savings | 7.81 | therms gas/kgal hot water |
| | $CO_2$ savings[10] | 91.6 | lbs/kgal hot water |
| | cost savings | 15.16 | $/kgal |

Notes: The heating energy and cost savings are specific to our campus, which uses natural gas for domestic water heating and has a fixed price per kilogallon. State-wide values for emission reductions would be different based on heating fuel. Cost savings include water and natural gas savings based on 70% hot water makeup of showers as seen in the data.

Demonstration of the Shower Orb will include a simulation. All of the components of the Orb will be on display, and data will be simulated to showcase how the Orb works. A poster with pictures of an actual installation and a summary of results will accompany the model to provide additional information.

## Conclusions

Contrary to research in the field of consumption feedback, the Shower Orbs actually produced a net increase in shower duration, total water usage, and fraction hot water used. While some units displayed significant savings, the 16 bathroom sample did not provide overall beneficial results. On average, shower time increased by 3.5 minutes per day and total water use in the shower went up by 35.8 gallons per day.

While the preliminary results may be discouraging, there are a number of other factors to consider. For example, baseline data was taken during the fall semester. Comparing the average outdoor temperature for the experimental period (March 24 through April 6) to that of the baseline reveals a difference of over 10°F (40°F versus 28°F). This is one potential external cause of increased consumption.

The analysis did produce other interesting information. For example, across all apartments, hot water made up an average of 70% of the water consumed, with little variation. This knowledge can have beneficial applications beyond this project and may impact the way residential building systems are designed on campus going forward. More favorable results, with the potential for significant savings, are likely with an extended Shower Orb deployment. Additionally, implementation of the Shower Orb is feasible in a variety of situations. This is demonstrated in the successful implementation of the Orb for this study.

# Appendix

Included in the Appendix are calculations and results tables from all apartment showers.

## Summary Tables

| Table A.1 - Experimental Period Data | | | | | |
|---|---|---|---|---|---|
| Apt | Duration (minutes) | Total Use (gallons) | Hot Use (gallons) | Cold Use (gallons) | Fraction Hot (%) |
| Apt 10-1 | 25.0 | 362.7 | 247.8 | 114.9 | 68.3 |
| Apt 10-2 | 63.0 | 590.8 | 373.6 | 217.2 | 63.2 |
| Apt 10-3 | 30.4 | 453.0 | 275.9 | 177.1 | 60.9 |
| Apt 10-4 | 30.3 | 473.4 | 313.4 | 160.0 | 66.2 |
| Apt 80-1 | 37.4 | 504.7 | 370.0 | 134.7 | 73.3 |
| Apt 80-2 | 36.0 | 519.7 | 359.4 | 160.3 | 69.2 |
| Apt 80-3 | 39.3 | 530.5 | 382.9 | 148.5 | 72.2 |
| Apt 10-5 | 55.4 | 886.0 | 566.9 | 319.2 | 64.0 |
| Apt 10-6 | 62.9 | 1036.4 | 704.0 | 332.4 | 67.9 |
| Apt 80-4 | 60.8 | 597.9 | 437.6 | 160.3 | 73.2 |
| Apt 80-5 | 50.6 | 738.2 | 520.8 | 217.4 | 70.6 |
| average | 44.6 | 608.5 | 413.8 | 194.7 | 68.1 |
| stdev | 14.3 | 201.2 | 135.5 | 71.7 | 4.2 |

| Table A.2 - Experimental Period Data | | | | | |
|---|---|---|---|---|---|
| Apt | Duration (minutes) | Total Use (gallons) | Hot Use (gallons) | Cold Use (gallons) | Fraction Hot (%) |
| Apt 10-1 | 28.6 | 379.9 | 269.6 | 110.3 | 71.0 |
| Apt 10-2 | 64.1 | 522.3 | 366.9 | 155.4 | 70.3 |
| Apt 10-3 | 23.6 | 300.6 | 201.8 | 98.8 | 67.1 |
| Apt 10-4 | 36.2 | 485.9 | 345.9 | 140.1 | 71.2 |
| Apt 80-1 | 35.6 | 456.8 | 349.6 | 107.1 | 76.5 |
| Apt 80-2 | 40.7 | 546.4 | 403.5 | 142.9 | 73.9 |
| Apt 80-3 | 51.8 | 706.4 | 509.9 | 142.8 | 72.2 |
| Apt 10-5 | 52.9 | 708.7 | 480.1 | 228.6 | 67.7 |
| Apt 10-6 | 80.4 | 1169.8 | 823.4 | 346.4 | 70.4 |
| Apt 80-4 | 64.3 | 851.7 | 661.4 | 190.3 | 77.7 |
| Apt 80-5 | 51.4 | 702.0 | 534.3 | 167.7 | 76.1 |
| average | 48.1 | 620.9 | 449.7 | 166.4 | 72.2 |
| stdev | 17.2 | 244.4 | 178.9 | 70.7 | 3.5 |

| Table A.3 - Changes | | | |
|---|---|---|---|
| Apt | Time Change | Total Use Change | Hot Use Change |
| Apt 10-1 | 14.7% | 4.7% | 8.8% |
| Apt 10-2 | 1.7% | -11.6% | -1.8% |
| Apt 10-3 | -22.5% | -33.6% | -26.9% |
| Apt 10-4 | 19.6% | 2.6% | 10.4% |
| Apt 80-1 | -4.8% | -9.5% | -5.5% |
| Apt 80-2 | 13.1% | 5.1% | 12.3% |
| Apt 80-3 | 31.9% | 33.2% | 33.2% |
| Apt 10-5 | -4.6% | -20.0% | -15.3% |
| Apt 10-6 | 27.8% | 12.9% | 17.0% |
| Apt 80-4 | 5.7% | 42.5% | 51.2% |
| Apt 80-5 | 1.7% | -4.9% | 2.6% |
| average | 7.7% | 1.9% | 7.8% |
| stdev | 15.8% | 22.1% | 21.6% |

## Water Treatment Emissions Savings

### $CO_2$ Savings

$$\left|546\,\frac{lb\ CO_2}{MWh}\right|\left|\frac{120\ Wh}{1\ gallon}\right|\left|\frac{1\ MWh}{10^6\ Wh}\right|\left|\frac{1{,}000\ gallons}{1\ kgal}\right| = 65.52\,\frac{lb\ CO_2}{kgal\ saved}$$

### $NO_x$ Savings

$$\left|0.4\,\frac{lb\ NO_x}{MWh}\right|\left|\frac{120\ Wh}{1\ gallon}\right|\left|\frac{1\ MWh}{10^6\ Wh}\right|\left|\frac{1{,}000\ gallons}{1\ kgal}\right| = 0.048\,\frac{lb\ NO_x}{kgal\ saved}$$

### $SO_x$ Savings

$$\left|1.1\,\frac{lb\ SO_x}{MWh}\right|\left|\frac{120\ Wh}{1\ gallon}\right|\left|\frac{1\ MWh}{10^6\ Wh}\right|\left|\frac{1{,}000\ gallons}{1\ kgal}\right| = 0.132\,\frac{lb\ SO_x}{kgal\ treated}$$

## Natural Gas Savings

$$\left|\frac{(130-55)°\mathrm{F}}{1}\right|\left|\frac{8.33\ lb}{gallon}\right|\left|\frac{1\ Btu\ into\ water}{1\ lb°\mathrm{F}}\right|\left|\frac{1\ Btu\ into\ boiler}{0.8\ Btu\ into\ water}\right|\left|\frac{1\ therm}{100{,}000\ Btu}\right|\left|\frac{1{,}000\ gallons}{1\ kgal}\right| = 7.809\,\frac{therms}{kgal\ hot\ water\ saved}$$

### Natural Gas Emissions

$$\left|\frac{0.102\ lb\ CO_2}{1\ cf\ natural\ gas}\right|\left|\frac{1\ cf\ gas}{1{,}023\ Btu}\right|\left|\frac{100{,}000\ Btu}{1\ therm}\right|\left|\frac{7.809\ therms}{1\ kgal}\right| = 91.6\,\frac{lb\ CO_2}{therm}$$

## Cost Savings

### Gas

$$\left|7.809\ \frac{therms}{kgal\ hot\ water\ saved}\right|\ \frac{\$1.00}{therm\ average}\left|\frac{0.7\ gallons\ hot\ water}{1\ gallon\ total\ water}\right| = \$5.46\frac{gas\ savings}{kgal\ water\ saved}\left|\frac{120\ Wh}{1\ gallon}\right|\left|\frac{1\ MWh}{10^6\ Wh}\right|\left|\frac{1{,}000\ gallons}{1\ kgal}\right|$$

### Water

$$\frac{\$9.70}{kgal\ average} = \$9.70\frac{water\ savings}{kgal\ water\ saved}$$

### Total

$$\$5.46\frac{gas\ savings}{kgal\ water\ saved} + \$9.70\frac{water\ savings}{kgal\ water\ saved} = \$15.16\frac{savings}{kgal\ water\ saved}$$

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