EXECUTIVE SUMMARY

Integrated Water Planning through Building Level Cascade of Water Use

ESTCP Project EW-201155

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1.0 INTRODUCTION

Department of Defense installations used 85.5 billion gallons of potable water in fiscal year 2016. At the same time, installations generated nearly an equivalent amount of sewage and paid for its treatment. Nearly all of the water used by installations is potable, though that level of purity is not required for all applications. Across the U.S. it is estimated that 30% of potable water is used for toilet flushing alone. Using the appropriate level of purity for each application, in some cases using water for several applications, preserves fresh water resources for required uses, supports sustainable water supplies for the future, reduces energy and chemicals required to process and pump potable water and sewage, reduces hydraulic load on existing sewer systems, and reduces cost for both purchased water and sewage treatment services. In addition, water reuse strategies support achievement of mandated water conservation targets (2%/year from 2007 through 2025) and increase water resilience and security. This report includes information on the water, energy, and operations and maintenance savings that may be gained through the use of efficient plumbing fixtures and graywater reuse systems.

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2.0 OBJECTIVES

This demonstration project investigated the integration of state-of-the-art water-saving technologies for reducing water demand at the building level. A cascade approach was used, whereby technologies were considered for treating and reusing water to meet demands more efficiently by matching the appropriate water quality with the appropriate use. The study investigated the integration of the cascade approach with the more conventional but not yet fully implemented approach of water conservation, which allowed for measurement of the relative benefits and costs of emerging versus more proven technologies.

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3.0 TECHNOLOGY DESCRIPTION

The project considered a range of water saving technologies that building managers could consider. Based on demonstration site factors, the project focused primarily on efficient water fixtures and graywater reuse technologies. Most of the technologies studied were at the bathroom-scale, though one building-scale system was evaluated as well. For bathroom retrofits, the technologies investigated included 0.5 gpm sink faucets with infrared auto-off sensors, an under-sink graywater reuse system, low flush toilets and/or alternate toilet sensor settings, and 2 gpm showerheads in building locker rooms. The building-scale system that was investigated was a graywater reuse system that treated graywater from sinks and showers such that it could be reused for toilet flushing. The primary metric for the project was to reduce water demand at the building level by 30%. Impacts on operations and maintenance, as well as energy consumption, were also measured.

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4.0 PERFORMANCE ASSESSMENT

In the case of a building comprising primarily office space, conservation fixtures achieved a reduction in overall facility water use of 7% as compared to the target rate of 30%[1]. An additional 7% reduction was realized by adjusting toilet automatic flush mechanisms, for a total building potable water reduction of 14%. Several factors contributed to this lower than projected reduction. First, faucets and showers represented a small fraction of the building water demand, which included specialized research facilities with high water needs, so associated improvements had limited overall impact. Second, recommendations for toilet retrofits were limited to flush valve sensor adjustments, with toilet and flush valve replacements planned by the facility for an upcoming remodel. Despite this low figure, the faucet and shower retrofits paid for themselves in less than a year with the cost of water alone. Lastly, the under-sink graywater system did not recover enough water from the sinks to support the toilet flushing.

[1] The US Army Construction Engineering Research Laboratory would achieve a 47.2% reduction with both plumbing fixture and toilet retrofits. Implementation of waterless urinals and under-sink scale graywater reuse system would save water by 51.3%

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5.0 COST ASSESSMENT

The graywater reuse systems studied in this project require further improvement before their widespread adoption can be recommended. For the building-scale graywater reuse systems, the product water quality in the storage tank was acceptable for reuse activities, but this may be dependent on the amount of makeup (dilution) water that was injected into the product tank at the particular test site. Additionally, the building-scale system was susceptible to down times due to controls or sensor malfunction, which were difficult to troubleshoot by support staff. Once these issues are addressed, such systems could eliminate toilet water flushing demand in building types such as barracks and gymnasiums. From a cost perspective, this practice faced challenges and would be most effective for new structures or structures in which shower drain plumbing is easily accessible to perform the necessary plumbing retrofits for segregating gray and black water. For improving future deployments of similar systems, pre-validation of the systems using protocols based on the American National Standards Institute/ National Sanitation Foundation 350 standard should be required, with modifications made to reflect the expected graywater generation schedule for the building and design. A more extensive level of treatment should be targeted in the validation phase in order to avoid water quality concerns. On-site performance and automation validation over a three-month startup period, as well as the first year's maintenance, should be included in contracts for installing these systems in buildings in order to ensure that systems do not fail after installation. Systems that can reuse a larger fraction of the building water demand should be explored to improve life cycle costs. Life cycle cost analysis tools should be used up front to project return on investment to ensure the payback period will be acceptable. Non-market valuation factors, such as emergency operation of critical facilities, need to be considered, and associated models to support this analysis need to be developed.

For the bathroom-scale under-sink graywater reuse system, further technical improvements are required to meet some of the water quality requirements for toilet flushing. While the system generally worked well to clarify and disinfect the water, the level of organics removal of 83% fell short of the 90% removal level that would be needed to bring the biochemical oxygen demand below 10 mg/L. In addition, physical system modifications are necessary to improve the energy efficiency, self-cleaning capability, chlorine dosing levels, and controls. These improvements are key for making the system cost-effective. The approval process and retrofit times for installing the under-sink system were also longer than expected, and the associated costs may be a limiting factor for achieving a target payback period. To improve future deployments of similar technologies, the pre-validation phase should target a more extensive level of treatment than the standards in order to provide a margin of safety, and the validation testing should be performed under flow conditions representative of bathroom usage (i.e., weekend downtimes). Overall, the challenges faced with autonomous performance and cost require improvements before such a bathroom-scale water reuse approach can be considered.

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6.0 IMPLEMENTATION ISSUES

This study confirmed that conservation technologies such as efficient fixtures can improve sustainability and resiliency in a cost-effective manner. On the other hand, water reuse at the building-scale is still a maturing technology space, and challenges with automation, retrofit cost, and a relatively low ratio of water cost to capital costs still present barriers to the adoption. Higher levels of water reuse through advanced treatment could be one option for improving payback, though regulatory challenges may limit that approach in the near term. Alternatively, non-market-cost valuations based on the need for DoD facilities to meet water demand reduction targets within Executive Order 13693, Net Zero policy, and water security capabilities described in Army Directive 2017-07, could still drive technology adoption. During the study, it was also noted that some facilities at installations, such as off-grid training areas, incur very high water and wastewater costs that are on the order of 100-fold the cost for on-grid buildings. Targeting these areas may provide an alternative cost-effective approach for maturing water reuse technology for future building-scale applications. Overall, there is considerable work remaining to provide building-scale solutions to support integrated capabilities that can fully address current DoD guidance and policies for water resilience and security.