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Update of Market Assessment for Capturing Water Conservation Opportunities in the Federal Sector

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U.S. Department of Energy
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Richland, Washington 99352

Summary

The Department of Energy's (DOE) Federal Energy Management Program (FEMP) requested an update of the original market assessment done by Pacific Northwest National Laboratory (PNNL) in 2001 [Parker et.al. 2001]. This original analysis evaluated water conservation opportunities and answered key questions necessary for FEMP to make recommendations on whether or not to proceed with strategies for water conservation, primarily through the development of water conservation Energy Savings Performance Contracts. The update's intent is to reevaluate the cost-effective water savings potential in the Federal sector, which incorporates new technologies and recent available data on Federal water use, and also to make recommendations on strategies that will assist FEMP in developing a path forward to assist Federal agencies in effective water management.

This updated assessment is based on a new analytical approach that utilizes newly available data and technologies. The new approach fine-tunes the original assessment by using actual Federal water use, which is now tracked by DOE (as compared to using estimated water use). Federal building inventory data is also used to disseminate water use by end-use technology in the Federal sector. In addition, this analysis also examines the current issues and obstacles that face performance contracting of water efficiency projects at Federal sites.

A summary table of the cost-effective savings potential results of this updated evaluation is found below in Table S.1. The following bullets are key findings and recommendations.

Key Findings:

- The total life-cycle cost-effective water conservation potential today in the Federal sector, assuming 100% penetration of efficient technology, based on appropriate "off the shelf"[1] domestic water technologies is estimated to be between 35 and 50 billion gallons/year. This represents approximately 17% to 24% of the total Federal water use. The original analysis estimated this savings to be between 33 and 49 billion gallons annually, or between 27% and 40% of the total Federal water use[2].

[1] "Off the shelf" technologies analyzed in this assessment are toilets, urinals, faucets, showerheads, and clothes washers – these technologies are considered domestic water technologies (used by humans for sanitary purposes), easily purchased and installed, and are non-engineered. Engineered retrofit technologies (e.g., for process water use, cooling towers, steam systems, and leak detection) are not analyzed in this assessment because of their site specific nature. Please see Section 3 and Appendix E for a detailed description of these technologies.

[2] The large discrepancy between the percentage savings between the original and updated assessment is a result of the following: 1) the original assessment used an underestimated Federal water use, while the updated assessment uses actual Federal water use as reported by Federal agencies to the Department of Energy; 2) the original assessment overestimated the percentage of water consumed by off-the-shelf fixtures, while updated assessment revised these assumptions that resulted in more accurate estimates. (See Section 1 for more information.)

- A number of new "off the shelf" technologies have emerged on the market since the original assessment. These include dual flush toilets, 1.0 gallon per flush toilets, 0.5 gallon per flush urinals, hydro-powered sensored faucets, and solar-powered sensored faucets. These technologies were analyzed in this updated assessment. For more information on each technology, go to Section 3.

- Half of the total Federal water use is consumed by these "off the shelf" fixtures – or domestic water consuming equipment. The remaining water consumption is used by engineered process water using equipment such as cooling towers, steam systems, and irrigation. Typically these process oriented technologies are very site specific in nature; therefore, savings have a wide variance among sites. These engineered technologies are not analyzed in this report but should not be discounted as large water savings opportunities in the Federal sector.

- Energy savings potential from reduction in hot water use in showers and faucets is estimated to be in the range of 602 to 1,550 billion British thermal units (Btus).

- If all these savings were captured under today's rates for water and energy savings, the dollar savings potential would be between $166 and $236 million annually.

- The majority of the water conservation technology retrofits (domestic water fixtures) analyzed in this assessment are found to be life-cycle cost-effective at a combined marginal[1] water/sewer cost of about $4/1,000 gallons or greater. The measures that are not cost-effective at this rate are certain faucet and toilet options, but only under certain scenarios – please see all results of the life-cycle cost (LCC) analysis in Section 4 in Tables 4.3 through 4.6.

- The energy savings from the hot-water-using fixtures (showers and faucets) drives the life-cycle cost-effectiveness such that in many cases, water savings are not even necessary to render the retrofit cost-effective.

- Based on the draft fiscal year 2003 *Report on Federal Agency Activities Under Executive Order 13123*, little progress has been made towards the Executive Order 13123 water efficiency goals by Federal agencies. Out of the 49,000 Federal sites, less than 4% have reported developing water management plans and less than 3% have reported implementing the required four FEMP Water Efficiency Best Management Practices.[2]

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[1] Marginal cost of water and sewer is the volumetric charge for water and sewer only (typically expressed as cost per thousand gallons) and does not include fixed or flat charges such as meter charges or taxes.

[2] Information obtained from draft report: U.S. Department of Energy. 2005. *Report on Federal Agency Activities Under Executive Order 13123, Efficiency Energy Management, Fiscal Year 2003 Draft*. Office of Energy Efficiency and Renewable Energy. Washington D.C.

- Since 2000, total water use in the Federal government has decreased almost 5% [U.S. DOE 2005]. It is unclear whether this decrease in water use is the result of efficiency improvements, reporting methodology, or changes in staffing or building inventory. Water is tracked by the Department of Energy in total million gallons consumed annually, as reported by each Federal agency. Because water is not tracked on a per unit basis like energy (on a Btu per square foot basis), it is difficult to truly measure how well the Federal government is performing in terms of water efficiency improvements. It would be a better indicator of water consumption trends or metrics if water consumption were tracked ideally by population or building occupancy, or more realistically by square footage rather than total gallons consumed.

- Although a considerable number of energy savings performance contract (ESPC) projects at Federal installations now include water conservation measures, many opportunities for cost-effective water savings - particularly opportunities in engineered projects - are not being captured. This is because most of the water projects are undertaken by water service providers through subcontracts to the energy service companies (ESCOs), and are focused on standard water-savings technology retrofits.

- The current industry standards for measurement and verification (M&V) for water measures as part of an ESPC were researched. For basic water consuming fixtures, (such as toilets, urinals, showers, and faucets), water savings are typically stipulated where savings are determined based on calculated pre- and post-retrofit water consumption agreed to by the facility. For water processes such as a cooling tower or single-pass cooling equipment, M&V is typically based on short term pre- and post-retrofit field measurement of the specific equipment. These are reasonable approaches to M&V for water efficiency retrofits given the dearth of building-level water meters and confidence and experience in technology performance.

- The institutional barriers and cost structure created by using water services as subcontractors to a performance contract tends to stifle innovation, reduces the cost-effectiveness of some technologies, minimizes the number of engineered projects, and slows down the implementation process. This results in considerable savings not captured. A standalone "water technology-specific" performance contracting would virtually eliminate all of these issues and result in more cost-effective water and associated energy savings for the Federal sector.

Table S.1. Summary Results of the Range[1] of Total Federal Annual Cost-Effective Savings

Federal Sector	Low End Water Savings (million gallons/yr)	High End Water Savings (million gallons/yr)	Low End Energy Savings (million Btu/yr)	High End Energy Savings (million Btu/yr)	Low End Total Cost Savings ($million/yr)	High End Total Cost Savings ($million/yr)
DoD	27,595	37,895	346,495	1,000,549	$123.28	$170.93
Civilian Agencies	7,796	12,347	255,174	549,578	$42.31	$65.35
Grand Total	35,391	50,242	601,669	1,550,128	$165.59	$236.28

Key Recommendations:

The following are key recommendations uncovered during this analysis that will provide FEMP direction on developing an effective water program to help Federal agencies manage water resources more effectively.

FEMP should:

- Reevaluate the water efficiency policies that are set in the Executive Order (EO) 13123. It is currently unclear whether the existing EO water efficiency goals are effectively motivating Federal sites to implement water savings measures and is properly tracking water consumption in the Federal sector. These polices are expected to be reviewed in FY 2005 as stated in FEMP's water efficiency website: "The Department of Energy will review agencies' progress in 2005, and may revise the water efficiency improvement goal at that time." (http://www.eere.energy.gov/femp/technologies/water_goals.cfm)

- Update and revise water efficiency related documents and resources that are have become out of date; these include: website materials, the section titled "M&V for Water Projects" in the FEMP's *M&V Guidelines: Measurement and Verification for Federal Energy Management Projects*, and energy/water cost calculator for water consuming fixtures, among other water related documents. (http://www.eere.energy.gov/femp/technologies/water_efficiency.cfm)

- Consider partnering with other Federal agencies such as Environmental Protection Agency, General Services Administration, and Department of Defense to develop a broad and effective water efficiency program for Federal agencies. FEMP could potentially act as the technical support arm of this partnership, providing technical information such as "fact sheets", case studies, and technical bulletins particularly

[1] The savings presented in Table S.1 represent a range of efficient technologies and penetration of these technologies in the Federal sector. Find detailed information on the analysis in Section 4 and 5.

relevant to the Federal sector. In addition, this partnership could draw on and develop the link between energy and water efficiency to further raise FEMP's visibility in a comprehensive program of water resource management.

- Consider developing a standalone water technology-specific performance contract as a solution to many of the barriers that are currently faced by the Federal sites implementing water efficiency projects. Allowing water service companies to work directly with Federal customers as part of a performance contract would result in reduced costs and enhance innovation of water efficiency measures, allowing more cost-effective water and energy savings.

- Provide support for and encourage the use of specific M&V plans for water measures in ESPCs. Water efficiency measures have unique characteristics (compared to energy measures); and therefore, require different verification methods. The water service contractor performing the work should be engaged in this process by the ESCO. With this approach, the water services contractor will also share with the ESCO the responsibility for the savings guarantee.

- Consider developing a detailed examination of current Department of Defense (DoD) water and sewer rates. This could provide important insight to cost-effectiveness of water efficiency projects for DoD sites that generate water on site. Normally, these sites undervalue water, which makes producing cost-effective water projects difficult. Ancillary savings such as energy, operations and maintenance, and chemical savings will most likely be the drivers for cost-effectiveness at these sites.

- Develop a component of the program focused on engineered-solutions to water efficiency. These would target large water-using activities and may include demonstrations of technologies focused on leak detection, steam systems, cooling towers, and irrigation systems. Successful demonstrations would serve as case study material for further promotion across the Federal sector.

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1.0 Introduction

In March 2001, Pacific Northwest National Laboratory (PNNL) performed a market assessment for the Federal Energy Management Program (FEMP) titled *Market Assessment for Capturing Water Conservation Opportunities in the Federal Sector* [Parker et al. 2001]. This assessment provided information to FEMP on whether there was a demand for a technology-specific water conservation performance contract. Specifically, the report identified the critical needs, requirements, and factors affecting successful implementation via an ESPC-type contract. Also, the analysis estimated the life-cycle cost-effectiveness of water-efficient technologies and also estimated the cost-effective potential for water savings in the Federal sector for domestic related water technologies (water consumed by humans for sanitary purposes) that are "off the shelf" fixtures (toilets, urinals, showerheads, faucets, and clothes washers).

FEMP requested that PNNL update this original assessment to reevaluate the cost-effective water savings potential in the Federal sector and the life-cycle cost-effectiveness of domestic fixtures. The original analysis findings show that the life-cycle cost-effective water conservation potential in the Federal sector, based on appropriate off the shelf technologies, was estimated to be 33 to 49 billion gallons annually, or between 27% and 40% of the total Federal water use. The findings of this update show a potential Federal water savings of off the shelf technologies to range between 35 and 50 billion gallons annually or between 17% and 24% of the total Federal water use.

The range in gallons saved is nearly the same between the original and updated analysis, while the percent savings is quite different. This is because the Federal water consumption used in the original analysis was significantly underestimated, while the percentage of water used by the "off the shelf" water technologies was overestimated. The original assessment used estimated Federal water use of about 122 billion gallons annually [Lombardo Associates 1997], while this assessment uses actual data on agency water use reported to the Department of Energy for fiscal year 2003: 209 billion gallons annually [U.S. DOE 2005]. Savings calculations in the original assessment assumed that 80% of total water use was consumed by domestic fixtures, while the updated assessment estimates this to be 51% based on the revised analysis (as described in Section 5).

The cost savings potential of the original analysis was estimated to be $132 to $196 million annually (if all savings were captured at the time of the original analysis at the average Federal water/sewer cost of $4/1,000 gallons). This represents water cost savings only (energy cost savings was not included in the original assessment). For the updated analysis, a water cost savings between $152 and $216 million annually is estimated, using an average combined water/sewer cost for DoD and civilian agencies of $4.25/1,000 gallons and $4.47/1,000 gallons, respectively. For the updated assessment, the energy cost savings is estimated to range from $13 to $20 million. For a complete description of these savings and costs, see Sections 4 and 5.

This updated assessment is based on a new analytical approach that utilizes newly available data and technologies. This new approach fine-tunes the original assessment by estimating total water use by end-use technology in the Federal sector. The assessment also analyzes two different settings, office and barracks, to determine the life-cycle cost-effectiveness of various technologies. Office and barracks have different water use patterns for domestic fixtures, therefore will have different life-cycle cost results.

The differences between the original and updated analyses are as follows:

- New types of “off the shelf” equipment have emerged on the market since the original assessment, which are included in this analysis.
- New price information is obtained for all technologies.
- Energy savings is included in the update and not incorporated into the original.
- Updated and more specific penetration rates of efficient technology in the Federal sector are used for this update.
- Annual water consumption data was obtained from the Department of Energy (DOE). The original analysis used an estimate of Federal water consumption.
- This updated assessment uses a new analytical approach that segregates water use between DoD and civilian agencies based on Federal inventory data, and also further breaks water use down by end-use. The original analysis did not break out water use to this level of detail.
- An updated Federal discount rate was used.

2.0 Federal Legislation, Rulings, Interpretations, and Action Toward Water Conservation Goals

2.1 Water Efficiency Goal Executive Order Overview

Executive Order 13123 encourages Federal agencies to reduce costs and implement cost-effective water efficiency improvements at Federal facilities [Executive Order 13123 1999]. The Department of Energy provided guidance to assist each agency to determine a baseline water consumption for FY 2000, track water consumption by Federal agency, and establish water conservation goals for Federal agencies, as required by the E.O. The water conservation goal is not a numerical reduction but rather the development of a water management plan and implementation of at least four of the FEMP *Water Efficiency Improvement Best Management Practices (BMPs)* [FEMP Website 2005]. The BMPs represent typical areas within the Federal government appropriate for efficiency improvements. The ten BMPs are as follows:

1. Public Information and Education
2. Distribution System Audits, Leak Detection and Repair
3. Water Efficient Landscape
4. Toilets and Urinals
5. Faucets and Showerheads
6. Boiler/Steam Systems
7. Single-Pass Cooling
8. Cooling Tower Systems
9. Miscellaneous High Water-Using Equipment
10. Water Reuse and Recycling

Find a full description of each BMP on the FEMP website at:
http://www.eere.energy.gov/femp/technologies/water_fedrequire.cfm

As reported in the FY 2003 *Report on Federal Agency Activities Under Executive Order 13123*, the Federal government baseline water use (FY 2000) was 219,114 million gallons. As of FY 2003, the Federal government reported consuming 209,055 million gallons. This is an overall drop of 5%. Because water is not tracked on a per unit basis like energy (Btu per square foot of building inventory), it is difficult to ascertain if this drop in water use is caused by efficiency improvements, inventory, or staffing changes.

The draft FY 2003 *Report on Federal Agency Activities Under Executive Order 13123,* also reports there has been a total of 1,669 water management plans developed and 1,154 BMPs implemented at Federal sites.[1] Progress towards the EO 13123 water efficiency goals has been very slight. These numbers represent that only 3.4% of sites that are required to implement water management plans have done so and only 2.3% of the required BMPs have been implemented.

2.2 Alternative Financing for Water Efficiency Projects

There are two main methods that Federal sites can utilize to obtain alternative financing for water projects – energy savings performance contracts (ESPCs) and utility energy service contracts (UESCs). UESCs can be used to implement water efficiency measures as part of the energy project. These are typically contracted through an areawide agreement, basic order agreement (BOA), or model agreement with the local servicing utility.

There are two distinct types of ESPCs – the Department of Defense (DoD) ESPC and the DOE Super ESPC. DoD services can achieve water efficiency goals by including water conservation projects as part of additional ESPC strategy offered through DoD. Under DoD contracts, the ESPC approach can, and does, include water (only) conservation projects. Within its ESPC, DoD also allows bundling of water conservation projects with energy conservation projects to achieve an overall payback that falls within ESPC contract parameters.

Prior to October 2004, civilian agencies were not able to develop ESPC projects that were primarily driven by water conservation measures. The DOE Super ESPC did not allow water efficiency projects because of a legal opinion rendered by the Assistant General Counsel for Procurement and Financial Assistance. The opinion stated that water conservation projects can only be included in the DOE Super ESPC "… as long as the energy conservation or energy savings is the primary purpose of the contract, reduction in costs attributable to water conservation may be included as part of energy savings for purposes of calculating the contractor payment where such water conservation savings are integral parts of the energy project" [Masterson 2000][2].

However, on October 28, 2004, *National Defense Authorization Act for Fiscal Year 2005* (Act) was signed into law, extending the authority for Federal agencies to use the DOE Super ESPC contracts until September 30, 2006. Included in this provision is language that now allows

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[1] Information obtained from draft report: U.S. Department of Energy. 2005. *Report on Federal Agency Activities Under Executive Order 13123, Efficiency Energy Management, Fiscal Year 2003 Draft*. Office of Energy Efficiency and Renewable Energy. Washington D.C.

[2] Masterson M.A. Assistance General Counsel for Procurement and Financial Assistance, U.S. Department of Energy, to James J. Cavanagh, Director, Office of Headquarters Procurement Services. February 11. 2000.

projects that are dominated by water conservation measures. The Act establishes that water projects can be performed as a standalone project as stated in the Act: “a water conservation measure that improves the efficiency of water use, is life-cycle cost-effective, and involves water conservation, water recycling or reuse, more efficient treatment of waste water or storm water, improvements in operation or maintenance efficiencies, retrofit activities, or other related activities, not at a Federal hydroelectric facility” [http://www.eere.energy.gov/femp/newsevents/detail.cfm/news_id=8301].

It is fortunate and beneficial to have these contracts in place, but many suggested improvements in the ESPC contracting approach could be made, as detailed in Section 6.

3.0 Appropriate Water Conservation Technologies, Savings, and Applications

This update's intent includes reevaluation of "off the shelf" technologies' life-cycle cost-effectiveness. The off the shelf technologies, or domestic water consuming fixtures, that are assessed are toilets, urinals, showerheads, faucets, and clothes washers. The data used in the assessment for each fixture is described in this section.

It should be noted that kitchen water use is not examined in the analysis, including dishwashers[1] and faucet use. Kitchen faucet water use is very site specific, difficult to estimate, and is commonly "volume driven" (used for filling pots) instead of flow rate driven. There is significant opportunity for water and energy savings in kitchens from efficiency improvements in rinsing and dishwashing, but this is not examined in this update.

In addition, engineered technologies applicable to water use such as cooling towers, steam systems, irrigation, and leak detection may also present significant water savings opportunities in the Federal sector. These technologies are generally site-specific, and their application can result in significant cost-effective water savings. However, because of their site-specific nature, the potential savings are not easily quantified and thus are not included in this determination of water saving potential in the Federal sector. Thus, the savings potential determined below is conservative; significantly more water savings could be achieved by incorporating site-specific/process-oriented technologies. Please find information on these process water uses and efficiency improvements at the end of this section and in Appendix E.

3.1 Assessment Data

The information provided below describes the technologies analyzed in this assessment and provides data that was used to calculate the life-cycle cost-effectiveness of the different fixture options. This data includes:

- Fixture cost
- Installation cost
- Operation and maintenance (O&M) costs different from normal operations

Fixture cost data comes primarily from the General Services Administration (GSA) Advantage (found at www.gsaadvantage.gov). The GSA Advantage is a centralized on-line catalog of supplies by which Federal government facilities can purchase goods and services. Included in the GSA Advantage are many of the plumbing fixtures analyzed in this assessment.

[1] Energy use for hot water use in dishwashers is estimated in this analysis. The software tool utilized estimates hot water use for showers, faucets, dishwashers, and clothes washers. Go to Section 5.2 for a detailed explanation.

When fixtures were not available on the GSA Advantage, wholesale or bulk purchase prices were obtained directly from the manufacturer.

Also included for each fixture is the estimated cost to install the piece of equipment. Multiplying the time it takes to install the equipment by the hourly rate for a plumber results in the installation cost. A typical plumber's hourly rate is $43, which is obtained from *RS Means Residential Cost Data for 2003* [Reed Construction Data 2004]. The installation time was obtained by inquiring two different sources on typical installation times of these fixtures[1].

Operations and maintenance costs were also researched for each type of fixture. For the majority of the fixtures, there are no significant differences in the operations and maintenance. The only exception to this is with battery-powered sensored faucets, which require periodic battery changes.

3.2 "Off the Shelf" Technologies

The following section describes each off the shelf technology that is analyzed in this assessment. General information is provided on the standard technology available on the market, high efficiency versions, fixture cost, installation cost, and operation and maintenance information.

3.2.1 Toilets

Toilets are typically the largest water consumer of indoor water use at most facilities [Vickers 2001]. The Energy Policy Act (EPAct) of 1992 mandated that all toilets meet or exceed the standard of 1.6 gallons per flush (gpf). Technologies have since emerged on the market that have lower flush rates than this EPAct requirement, and are also examined in this analysis.

The basic types of toilets available on the market are tank toilets, typical in residential and light commercial applications, and flush valve toilets, typically found in commercial applications. An option for increasing efficiency of an existing toilet at a lower cost is a flush valve retrofit kit. This entails replacing the older valve with a high efficiency valve (not replacing the entire plumbing of the unit) and replacing the toilet bowl. This option is available on the GSA Advantage.

Another style of toilet on the market is a pressure-assisted toilet, which contains a chamber inside of the toilet tank that traps air. Once the chamber begins to fill with water, the trapped air becomes compressed, stored as "potential energy". When the toilet is flushed, the compressed air pushes out the water at a very high velocity providing a powerful flush and very good

[1] Obtained information on installation time from personal communications with Mr. Andrew Perrin, Water Engineer, of H2O Applied Technologies in January and February 2005 and Mr. Lonnie Burke, Water Conservation Specialist and Master Plumber with Resource Wise on January 13. 2005.

flushing performance. This high velocity water in pressure-assisted toilets creates a louder flush than traditional tank toilets. They may not be suitable for residential settings, but are acceptable for commercial buildings and barracks. A 1.0 gpf pressure-assisted toilet is now available on the market.

In addition, there is a relatively new type of tank toilet called a dual flush toilet. This toilet provides two flushing options: a full flush at 1.6 gpf and a partial flush option, which ranges from 0.8 gpf to 1.0 gpf depending on the brand. There are two brands that were analyzed: Caroma™ and Mansfield EcoQuantum™. The results from the analysis for these two toilets are averaged.   It should be noted that the dual flush toilet in this analysis is only analyzed for women's use. Dual flush toilets would not be practical in a men's restroom because in the Federal setting, men typically use urinals.

Table 3.1 summarizes the toilets that were studied in the analysis along with the cost information used in the life-cycle cost analysis presented in Section 4 of this document. For installation costs, it typically takes about 1 hour to install any type of toilet, totaling $43 per installation [Reed Construction Data 2004]. Also, there are no major differences in operations and maintenance between these efficient toilets compared with older toilets[1]. For existing flush rates of toilets, this analysis considers 3.5 gallons per flush typical. This is because in 1980, all toilets were required not to exceed 3.5 gallons per flush. Because toilets have, on average, about a 20-year life[1], it is assumed that most toilets have been retrofitted at least once since 1980. This assumption is considered conservative.

[1] Obtained information on maintenance costs and typical toilet life through personal communications with Mr. Lonnie Burke, Water Conservation Specialist and Master Plumber with Resource Wise on January 13. 2005.

Table 3.1. Toilet Data Used in the Analysis

Toilet Type	Flush Rate (gpf)	Water Savings Potential per use	Fixture Cost	Cost Data Source
Gravity Fed Tank	1.6	54%	$225	Average of typical price from GSA Advantage
Pressure-Assist	1.6	54%	$265	Average of typical price from GSA Advantage
Pressure-Assist	1.0	71%	$300	Wholesale price from manufacturer [Mansfield 2005]
Flush Valve	1.6	54%	$180	Average of typical price from GSA Advantage
Flush Valve Retrofit Kit	1.6	54%	$127	Average of typical price from GSA Advantage (includes cost of bowl)
Dual Flush	Range: 1.2 – 1.4 (average use) [Koeller 2003 and Veritec 2002]	60% - 64%	$200 - $246	Wholesale price from manufacturers[1] [Mansfield 2005]

3.2.2 Urinals

Urinals are typically only used in commercial applications. Similar to toilets, all current urinals must meet the EPAct 1992 standards of not exceeding 1.0 gpf. There are two basic types of urinals, flush valve toilets and no-water urinals –urinals that do not have a flushing system and therefore use no water. For flush valve urinals, there are 1.0 gpf and 0.5 gpf models on the market. The 0.5 gpf flush is relatively new. The no-water urinal was analyzed in the original market assessment; however, there are new brands that are now available and are considered in this analysis.

[1] Obtained typical cost range for Caroma dual flush toilet through personal communications with Mr. John Karas, Business Development Manager of Caroma USA, Inc. on January 18, 2005.

The no-water urinal is distinctly different from the flush valve urinal. As the name implies, no-water urinals do not use water for flushing. These urinals use a trap in the drain that contains a sealing liquid that is less dense than urine. This liquid floats on top of any urine in the trap, sealing the trap and preventing sewer vapors from escaping back into the restroom. Urine passes through the sealing liquid in the trap and into the drain line.

There are currently three major models of the no-water urinals on the market available to the Federal government: the Falcon Waterfree™ urinal, the Waterless No-Flush™ urinal, and, from a European company, the Uridan® Non-Water Urinal. No-water urinals come in different sizes and styles made with high-tech composites and fiberglass or traditional porcelain. The Waterfree and Waterless urinals have removable traps, while the Uridan uses a permanent trap.

For this analysis, maintenance of no-water urinals was investigated through a variety of sources because maintenance costs are different than flush valve urinals[1] [Uridan 2005, Waterless 2005, McMordie Stoughton and Chvala 2004]. No-water urinals have no valves to repair or replace, but do have other routine maintenance tasks. The sealant must be replaced in all no-water brands. For the Waterless and Falcon Waterfree urinals, traps need to be periodically replaced. There are other maintenance differences that are very hard to quantify. Some evidence points to maintenance savings with no-water urinals because there is a decrease in sewer line calcification. Other evidence points to the opposite; that no-water urinals can possibly cause line stoppage. So, after careful consideration and research, operation and maintenance costs of urinals is not considered in the analysis because reliable data on cost differences between flush urinals and no-water urinals was not obtained.

Installation time for replacing a flush valve urinal is typically about 1 hour[2]. No-water urinals can take longer because some adjustments are necessary to get the urinal to mount on the wall properly. Therefore, an installation time of 1.5 hours was used in the analysis[2]. For existing flush rates of urinals, 1.5 gallons per flush is considered typical for this analysis, as a conservative assumption. This is because in 1980, all urinals were required not to exceed 1.5 gallons per flush. Because urinals, like toilets, have on average about a 20 year life[3], it is assumed that most urinals have been retrofitted since 1980.

The table below summarizes the data on urinals that was used in the analysis.

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[1] Obtained information on maintenance of flush urinals and no-water urinals through personal communications with three sources: Mr. Lonnie Burke, Water Conservation Specialist and Master Plumber with Resource Wise on January 13. 2005; Mr. Bill Slaughter, Federal Account Representative, with Falcon Water Free Urinals on January 12, 2005; and Mr. Joe Romero with Uridan-USA Division of GDK International, Inc. on January 28, 2005.

[2] Obtained information on installation time for flush urinals and no-water urinals from Mr. Bill Slaughter, Federal Account Representative, with Falcon Water Free Urinals on January 12, 2005

[3] Obtained information on typical urinal life through personal communications with Mr. Lonnie Burke, Water Conservation Specialist and Master Plumber with Resource Wise on January 13. 2005.

Table 3.2. Urinal Data Used in the Analysis

Urinal Type/Brand	Flush Rate (gpf)	Water Savings Potential per use	Estimated Cost per Fixture	Cost Data Source
Flush Valve	1.0	33%	$125	Average of typical price from GSA Advantage
Flush Valve	0.5	67%	$125	Average of typical price from GSA Advantage
Falcon Waterfree	0	100%	$186 - $235	GSA Advantage: #GS-07F-0294L
Uridan	0	100%	$395	Wholesale price from manufacturer[1]
Waterless	0	100%	$393 - $429	GSA Advantage: #GS-O7F-0124J

3.2.3 Showerheads

Showers are typically used in Federal facilities in housing, barracks, hospitals, and prisons. The current maximum flow rate for showerheads, set by EPAct, is 2.5 gallons per minute (gpm), at a pressure of 80 pounds per square inch (psi). There are showerheads that go below this flow rate. However, for this analysis the two types of showerheads analyzed are 2.5 gpm and 2.0 gpm. (Find information on energy use for showerheads in Section 4.)

[1] Obtained information on typical Uridan costs from Mr. Joe Romero with Uridan-USA Division of GDK International, Inc. on January 28, 2005.

Installation time for replacing a typical showerhead is considered to be about 15 minutes[1]. There are no major operation and maintenance differences between the efficient fixtures and existing fixtures. The typical existing flow rate of showerheads was estimated to be approximately 2.75 gallons per minute for the purposes of this analysis. This is based on water audits performed [Solana and McMordie 2004, Chvala et al. 2004][2] and the *Handbook of Water Conservation* [Vickers 2001]. Information that was used in the analysis for showerheads is in the table below.

Table 3.3. Showerhead Data Used in the Analysis

Showerhead	Flow Rate (gpm)	Savings Potential per use	Estimated Cost per Fixture	Cost Data Source
Standard EPAct Low Flow Showerhead	2.5	9%	$11	Average of typical price from GSA Advantage
High Efficiency Showerhead	2.0	24%	$11	Average of typical price from GSA Advantage

3.2.4 Faucets

Faucets are required to have a flow rate that does not exceed 2.2 gpm (at 60 psi) under the EPAct requirements. High efficiency faucets range from about 1.0 gpm to 0.5 gpm, both of which are considered in the assessment. Faucets that were analyzed for this report are for domestic use only: hand washing after restroom use and general hygiene (face washing and teeth brushing). Kitchen use was not analyzed. The types of faucets evaluated in this analysis are described below.

[1] Obtained information on showerhead installation time from Mr. Andrew Perrin, Water Engineer, with H2O Applied Technologies on January and February of 2005.

[2] Also Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Pacific Northwest National Laboratory*. PNNL-Letter Report. Pacific Northwest National Laboratory. Richland, Washington (not publicly available).

- *Low flow faucet aerator*: Retrofit of an existing faucet with a low flow faucet aerator. An EPAct standard aerator (2.2 gpm) and a high efficiency aerator (1.0 gpm) were analyzed.

- *Pedal activated faucet*: Retrofit to an existing faucet that allows the faucet to be turned on and off with a foot pedal. This was analyzed for the standard (2.2 gpm) and high efficiency aerators (1.0 gpm) because this is a retrofit of an existing faucet, not a replacement of the entire unit.

- *Self closing faucet*: Replacement of an existing faucet with a faucet that automatically shuts off after valve is compressed. Both single and double self closing faucets were analyzed. It was found that typically self closing faucets come at the EPAct standard flow rate of 2.2 gpm.

- *Sensored faucet*: Replacement of an existing faucet with a faucet that is operated by a sensor – either electronic or infrared – that turns on and off automatically when a person approaches the faucet. A battery-operated and hard-wired version of this faucet was included in the analysis. It was found that sensored faucets typically are standard at 0.5 gpm.

- *Hydro-powered sensored faucet*: Replacement of an existing faucet with a sensored faucet that is operated by a battery that is charged by a hydro-powered generator. The battery is charged from each use – flowing supply water causes a turbine to spin that creates a current, which is stored in the rechargeable battery. The battery is charged in as little as five uses per day, so it is considered applicable for most Federal applications. This faucet comes standard at 1.1 gpm. (Find more information at: http://www.totousa.com/toto/pagecontentview.asp?pageid=56&showimage=eco)

- *Solar- powered sensored faucet*: Replacement of an existing faucet by a sensored faucet that is powered by a small solar panel, which turns any ambient light source into electricity (similar to the way a solar-powered calculator works). This electricity is used to operate an infrared sensor which automatically controls the faucet. This faucet comes standard at 0.5 gpm.

As described above, both manual and automatic faucets were analyzed. Because the water automatically shuts off with automatic and sensored faucets, there is additional water and energy savings associated with reduced time the faucet is on. The typical savings from these automatic faucets is about 20% compared to traditional manual faucets [USGBC 2003]. This reduction was used in estimating the water and energy savings of the pedal activated, self closing, and sensored faucets. Typically, the operations and maintenance between the different types of faucets are similar. The only faucet that was found to have additional maintenance requirements was the battery-operated sensor faucet because the battery must be replaced approximately every 2 years [Sloan Valve 2005]. The increased annual maintenance cost of the battery-operated sensored faucet was estimated at $11.19. (This is based on an estimated labor time of 10 minutes, labor cost of $43/hour, and a battery cost of $15.)

The typical existing flow rate of faucets was estimated to be approximately 2.75 gallons per minute for the purposes of this analysis. This is based on water audits performed [Solana and McMordie 2004, Chvala et al. 2004[1] and the *Handbook of Water Conservation* [Vickers 2001]. (Find information on energy use in faucets in Section 4.)

Table 3.4 describes the data that was used in the analysis to estimate the life-cycle cost-effectiveness of these faucets. The flow rates are based on the standard flow rate that was available for the particular type of faucet. Because labor time varies among these different faucets, a column was added to this table to detail this information.

Table 3.4. Faucet Data Used in the Analysis

Faucet	Flow Rate (gpm)	Savings Potential per use	Estimated Cost per Fixture	Estimated Installation Labor Time (min)	Cost Data Source
Standard EPAct Low Flow Aerator Retrofit	2.2	20%	$3.20	5	Average of typical price from GSA Advantage
High Efficiency Low Flow Aerator Retrofit	1.0	64%	$3.20	5	Average of typical price from GSA Advantage
Pedal Activated Retrofit	2.2 and 1.0	36% - 71%	138	60	Average of typical price from GSA Advantage
Self Closing – Single Replacement	2.2	36%	$71.50	60	Average of typical price from GSA Advantage
Self Closing – Double Replacement	2.2	36%	$173.50	60	Average of typical price from GSA Advantage

[1] Also Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Pacific Northwest National Laboratory*. PNNL-Letter Report. Pacific Northwest National Laboratory. Richland, Washington (not publicly available).

Table 3.4. Faucet Data Used in the Analysis (cont)

Faucet	Flow Rate (gpm)	Savings Potential per use	Estimated Cost per Fixture	Estimated Installation Labor Time (min)	Cost Data Source
Sensored – Battery-operated Replacement	0.5	85%	$248	60	Average of typical price from GSA Advantage
Sensored – Hard Wired Replacement	0.5	85%	$248	120	Average of typical price from GSA Advantage
Hydro-Powered Sensored Replacement	1.1	71%	$500	90	Wholesale price from manufacturer [Toto USA 2005]
Solar-Powered Sensored Replacement	0.5	85%	$475	90	Wholesale price from manufacturer [Sloan Valve 2005]

3.2.5 Clothes Washers

The clothes washers in this study are a commercial-quality, soft-mount family-sized high performance Energy Star clothes washers (see http://www.energystar.gov/index.cfm?fuseaction=clotheswash.display_commercial_cw). These washers save considerable water and energy over standard family-sized soft-mount commercial washers. Because most of a clothes washer's energy use is tied to hot water use, any savings in hot water translates to energy savings. Additional energy savings are reported as a result of higher-efficiency motors and the high spin speeds achieved in the H-axis designs.

The assessment only examines retrofits of high performance washers for DoD barracks. There are other Federal applications for laundry in hospitals and prisons; however, these equipment are considered large process water use, which is not appropriate for soft-mount family-size high performance washer retrofits.

The typical existing clothes washer in a barracks setting at a DoD installation is estimated to consume 38 gallons per cycle, while high performance washers use typically ~15 gallons per cycle, saving 61% of laundry water consumption. Typically, a clothes washer can be replaced in about 1 hour. There are no operations and maintenance savings between these two types of washers. Table 3.5 provides the data used in the LCC analysis for clothes washers.

Table 3.5. Clothes Washer Data Used in the Analysis

Clothes Washer	Water Consumption per cycle (Gallons)	Savings Water Potential per Cycle	Estimated Installed Cost per Fixture	Cost Data Source
High Performance	15	61%	$1,500	[Sullivan et al. 2004]

3.3 Engineered Site-Specific Water Processes and Equipment

There are significant water savings opportunities from equipment and processes beyond the “off the shelf” technologies that are being examined in this assessment. These engineered solutions are significant water users in the Federal sector and offer large water efficiency improvements. Typically these technologies are site-specific in nature; therefore savings have a wide variance among sites. These engineered technologies are not analyzed in this report, but should not be discounted as large water savings opportunities in the Federal sector. These technologies can be applied to:

- Cooling towers
- Boiler and steam systems
- Irrigation
- Industrial laundry
- Leak detection and repair
- Single-pass cooling

A description of each technology and efficiency opportunities is included in Appendix E of this report.

4.0 Cost-Effectiveness of Implementing Water Conservation

A life-cycle cost (LCC) analysis was used to determine the cost-effectiveness of implementing the "off the shelf" technologies described in Section 3 at Federal facilities. This LCC analysis is consistent with the methodology outlined in the National Institute of Standards and Technology Manual 135, *Life-Cycle Costing Manual for the Federal Energy Management Program* [Fuller and Peterson 1995]. The results of the LCC analysis were used in two ways: 1) determined which fixtures were LCC effective and most appropriate for Federal applications and 2) determined the total cost-effective savings potential in the Federal government (see Section 5).

It should be noted that while engineered solutions (i.e., efficiency measures designed for a specific application or water-using process at a specific site) are acknowledged to hold significant potential for water savings in the Federal sector, their site-specific nature makes it difficult to analyze and quantify savings. Therefore, these were excluded from this analysis.

4.1 Introduction to Life-Cycle Cost Analysis Methodology

To determine at what marginal water/sewer rate the fixtures become LCC effective, the positive net present value (NPV) was calculated. NPV is the total net discounted dollar savings of owning, operating, and maintaining one piece of equipment as compared to another. So, the LCC results show at what marginal water/sewer rate the fixture becomes economical to replace the fixture as compared to existing equipment. This information is helpful because it can point to which technologies have the best opportunities for application in Federal facilities. The results of the LCC analysis are presented in the tables at the end of this section.

The LCC analysis assesses two different water use scenarios – water use patterns for office and barracks. This is because "off the shelf" fixtures in the Federal sector typically match an office setting or barracks setting. In other words, people typically use domestic fixtures at work and at their place of residence. It is considered that civilian agencies typically only use water in the office setting while DoD services use water both in the office and the barracks setting. DoD also has family housing, which closely matches the barracks use pattern, with the exception of urinal use.

To do the LCC analysis, an estimate of the installed and operations and maintenance costs of the water conservation technologies were developed along with the annual water and energy consumption of the existing and replacement equipment, as described in Section 3. With that information, and with assumptions on the remaining life of the current technology and the current discount rate, the cost-effectiveness range of water/sewer rates was determined. The primary assumptions used in the LCC analysis are shown in the following list. For a full description of the assumptions used in the LCC analysis, see Appendices C and D.

- Typical water use for office and barracks scenarios were modeled using the Facility Energy Decision System (see methodology in Appendices C and D) for all "off the shelf" fixtures described in Section 3.

- Replacement of fixtures are assumed to be installed immediately.

- Federal real discount rate of 3.0% is used [Schultz et al., 2004].

- Existing technologies are assumed to have a 50% remaining life. This assumes a normal distribution of building and equipment ages across the entire Federal sector.

- The cost of replacing the equipment is annualized over the life of the replacement.

- The LCC analysis determines at which combined marginal water/sewer rate the fixture has a positive NPV.

- Future water and sewer rates are *not escalated.*

- Future energy rates *are escalated*.

The rest of this section details the data that was used in the LCC analysis and the detailed results are shown in the tables at the end of this section.

4.2 Federal Water/Sewer Rates

The average Federal marginal water and sewer rates for both DoD and civilian agencies were determined so that the LCC results could be compared against these average marginal Federal rates. The cost-effective combined water and sewer cost for each fixture can be compared to the average rates in the Federal sector to determine if the technology is cost-effective at Federal sites, for both DoD and civilian.

Actual water rates across the Federal sector vary widely, and the variance is heavily influenced by whether water is purchased (most likely from a municipal supplier) or generated on site (common for DoD installations). Water rates are also influenced by geographic location and agency contracting mechanism. To estimate the typical marginal cost of water in the Federal government, the Raftelis 2002 *Water and Wastewater Rate Survey* was used [Raftelis 2004]. This water rate survey is a detailed investigation of water and sewer rates from water utilities across the continental U.S., serving both Federal and non-Federal sites. The water rate survey collected and analyzed data on residential, commercial, and industrial customers for varying meter sizes, including the marginal and fixed costs for water and sewer. This survey is a comprehensive examination of water and sewer rates across the Continental U.S., so it is considered a good representation of typical water rates that Federal facilities incur if water is purchased from a local municipality[1]. It is assumed that civilian agencies are typically charged commercial water and sewer rates by the serving municipalities and DoD installations are typically charged industrial water and sewer rates by the serving municipalities.

All data collected in the Raftelis *Water and Wastewater Rate Survey* for commercial marginal rates (the water costs that only represent the volumetric charge for water and not fixed costs and fees) were averaged, which represents a mean water/sewer rate for civilian sites. All data collected in the water rate survey was also averaged for industrial marginal rates to represent the mean water rate for DoD installations.

Table 4.1 shows the marginal water and sewer rates that are considered average for the Federal government:

Table 4.1. Mean DoD and Civilian Marginal Water Rates

Sector	2003 Marginal Water Cost ($/1,000 gallons)	2003 Marginal Sewer Cost ($/1,000 gallons)	2003 Marginal Total Water Cost ($/1,000 gallons)
DoD	$1.79	$2.46	$4.25
Civilian	$1.93	$2.54	$4.47

It should be noted that a significant number of DoD installations do not purchase water from a local municipality and pump and treat water on-site. Where this is the case, the cost of water may be significantly lower than the average marginal industrial rate that is reported in the Raftelis survey described above. This is because DoD installations that produce and treat their own water typically estimate water costs based on pumping, treatment, and chemical costs only, excluding capital amortization and labor costs in rate calculation [Lombardo 1997]. A detailed examination of current DoD water/sewer rates was not performed for this updated analysis (significant effort is required and therefore it was beyond the scope of this assessment). More information on actual DoD rates could provide important insight to cost-effectiveness of water efficiency projects for DoD. Historical water rate information on a select number of Army sites can be found in Appendix F.

4.3 Federal Energy Rates

For base year energy prices, the LCC analysis used 2004 national average energy rates obtained from a file, ENCOST04.TXT, created in support of the document *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – April 2004* [Schultz et al. 2004]. While these EIA-based average rates were not Federal-specific, industrial prices were used as a proxy for prices paid by DoD, and commercial prices for those borne by the rest of the Federal sector.

[1] Federal water rates outside the U.S. were not investigated.

Prices for subsequent years in the analysis period were escalated using fuel and sector-specific escalation rates provided in the same document.

While marginal rates are preferable for an LCC analysis, such national-level estimates for the Federal sector are not easily obtained. In the case of commercial and industrial rates, the impacts of using average rates as a proxy may be relatively minimal because fixed costs may represent a relatively small portion of the total energy bill. To provide the option of a truly conservative view of the savings potential of the analyzed equipment, the LCC results are presented both with and without energy savings. Table 4.2 provides the energy rates for electricity and natural gas for civilian and DoD.

Table 4.2. Base Year Energy Rate for LCC analysis

Sector	2004 Electricity Rate ($/kWh)	2004 Natural Gas Rate ($/therm)
Industrial (DoD)	$0.0469	$0.4750
Commercial (Civilian)	$0.0742	$0.7690

4.4 Life-Cycle Cost Analysis Results

The results of the LCC analysis show that most of the fixtures are cost-effective at the average combined marginal water/sewer cost for the Federal government: $4.25/1,000 gallons for DoD sites and $4.47/1,000 gallons for civilian sites. The most cost-effective fixtures were manual faucets and showerheads. It was found that the cost-effectiveness of these fixtures is greatly enhanced when incorporating energy savings from hot water savings. For some of these options, the LCC results calculated a negative water/sewer cost at which the fixture becomes cost-effective. In other words, a site could have free water and yet still find it LCC effective to install the particular water-efficient fixture by only including energy savings. This means that energy savings alone creates enough cost savings to render the fixture LCC effective.

Generally, toilets and urinals are cost-effective at average Federal water/sewer marginal rates. However, the results show that toilets used in men's restrooms are often not cost-effective at a water rate at or below the average Federal rates. This is because men typically use urinals more often than toilets in the Federal setting, so water savings is minimal for male toilets.

There are a number of scenarios where automatic and sensored faucets require a high water/sewer rate to become cost-effective. In these cases the installation is expensive and water savings is not significant enough to overcome the high installed cost. For example, a pedal activated faucet with a flow rate of 2.2 gpm does not generate enough savings over the life of the fixture to have good return on investment. Note that hot water generated by electric water heaters is cost-effective at lower water/sewer rates than compared to natural gas water heaters. This is because electricity is typically more expensive on a Btu basis than natural gas.

High performance (Energy Star) commercial clothes washers were cost-effective at the average Federal water/sewer rate. Similar to showers and faucets, electric water heaters results in the best LCC effectiveness for clothes washers. Where only water savings were considered, clothes washers are still cost-effective at average Federal marginal water/sewer rate.

A summary of the results of this analysis is presented in Tables 4.3 to 4.6 below. These results show the marginal rate of water where the technology has a positive NPV. In other words, it is the water rate at which the fixture will become LCC effective. These tables provide a convenient way to determine if a fixture is LCC effective at a given combined water/sewer marginal rate for different scenarios. The tables are broken out by the two water use scenarios that were modeled – office and barracks.

The results for toilets and urinals in Table 4.3 are shown for both female and male barracks. Because water use is different between these two facility types, the LCC results are different. The results for dual flush toilets are provided for female toilets only. This is because dual flush toilets in men's restrooms are not considered practical because men typically use urinals in the Federal setting. The results for both dual flush toilets and no-water urinals are an average across the brands that were analyzed.

For technologies that use hot water (showers, faucets, and clothes washers), there are three different scenarios provided in Tables 4.4, 4.5, and 4.6 below:

- Water savings and electricity savings from an electric water heater
- Water savings and natural gas savings from a natural gas water heater
- Water savings only with energy savings not included

In addition to these components, the results for faucets in Table 4.5 show the cost-effective water rate at the DoD and civilian energy rates for both electricity and natural gas (as described in Table 4.2). Because showerheads are primarily in DoD facilities, only DoD energy rates are used.

Table 4.3. Toilet and Urinal LCC Analysis Results

Technology Category (with installed cost)	Specific Type	Office: Combined Water/Sewer Rate w/ Positive NPV ($/kgal)	Office: Annual Water Savings per Fixture (kgal)	Female Barracks: Combined Water/Sewer Rate w/ Positive NPV ($/kgal)	Female Barracks: Annual Water Savings per Fixture (kgal)	Male Barracks: Combined Water/Sewer Rate w/ Positive NPV ($/kgal)	Male Barracks: Annual Water Savings per Fixture (kgal)
Toilets							
$269	Standard Tank 1.6 gpf	$1.99	9.08	$2.37	7.64	$4.75	3.81
$224	Standard Flush Valve 1.6 gpf	$1.65	9.08	$1.97	7.64	$3.95	3.81
$127	Flush Valve Retrofit 1.6 gpf	$0.94	7.64	$1.12	7.64	$2.24	3.81
$344	Pressure Assist 1.0 gpf	$3.37	11.96	$4.01	10.06	$8.04	5.02
$309	Pressure Assist 1.6gpf	$3.99	9.08	$4.74	7.64	$9.51	3.81
$267	Dual Flush (female only)* 1.3 gpf average	$1.39	12.95	$1.82	9.00	NA	NA
Urinals							
$169	Standard Flush Valve 1.0 gpf	$3.80	2.99	NA	NA	$4.52	2.52
$169	Efficient Flush Valve 0.5 gpf	$1.90	5.98	NA	NA	$2.26	5.03
See section 3	No-Water Urinal (average)	$3.03	8.97	NA	NA	$4.25	7.55

* Results for dual flush toilets are for female use only because men's restrooms typically contain urinals. Therefore, annual savings per fixture only accounts for female toilet use. Find information on data used in for dual flush toilets in Appendix C.

Table 4.4. Showerhead LCC Analysis Results

Specific Type (with installed cost)	Water Heating Fuel	Barracks: Combined Water/Sewer Rate w/ Positive NPV ($/kgal)	Barracks: Annual Water Savings per Fixture (kgal)	Barracks: Annual Energy Savings per Fixture (kWh or therms)
Standard EPAct Showerhead 2.5 gpm $27	Electric	$0.05	2.66	66.33 kWh
	Natural Gas	$0.72	2.66	3.00 therms
	None – water savings only	$1.19	2.66	
High Efficient Showerhead 2.0 gpm $27	Electric	-$0.64	6.92	166.00 kWh
	Natural Gas	-$0.02	6.92	8.00 therms
	None – water savings only	$0.46	6.92	

Table 4.5. Faucet LCC Analysis Results

			Office			Barracks		
Faucet Specific Type (with installed cost)	Federal Sector (DoD and Civilian)	Water Heating Fuel	Combined Water/Sewer Rate w/ Positive NPV ($/kgal)	Annual Water Savings per Fixture (kgal)	Annual Energy Savings per Fixture (kWh or therms)	Combined Water/Sewer Rate w/ Positive NPV ($/kgal)	Annual Water Savings per Fixture (kgal)	Annual Energy Savings per Fixture (kWh or therms)
Standard EPAct Faucet	DoD	Electric	-$4.66	1.10	124.20 kWh	-$0.37	0.99	20.63 kWh
2.2 gpm		Natural Gas	-$1.57	1.10	5.50 therms	$0.16	0.99	1.00 therms
$6.89		None – water savings only	$0.53	1.10	NA	$0.59	0.99	NA
	Civilian	Electric	-$7.42	1.10	124.20 kWh	NA	NA	NA
		Natural Gas	-$2.94	1.10	5.50 therms	NA	NA	NA
		None – water savings only	$0.53	1.10	NA	NA	NA	NA
High Efficient Faucet	DoD	Electric	-$3.85	3.49	306.00 kWh	-$1.26	3.14	99.25 kWh
1.0 gpm		Natural Gas	-$1.47	3.49	13.67 therms	-$0.45	3.14	4.75 therms
$6.89		None – water savings only	$0.17	3.49	NA	$0.18	3.14	NA
	Civilian	Electric	-$5.98	3.49	306.00 kWh	NA	NA	NA
		Natural Gas	-$2.54	3.49	13.67 therms	NA	NA	NA
		None – water savings only	$0.17	3.49	NA	NA	NA	NA
Self Closing Single	DoD	Electric	$3.03	1.10	139.50 kWh	$8.76	0.99	23.17 kWh
2.2 gpm		Natural Gas	$6.50	1.10	6.18 therms	$9.36	0.99	1.12 therms
$115.80		None – water savings only	$8.85	1.10	NA	$9.84	0.99	NA
	Civilian	Electric	-$0.07	1.10	139.50 kWh	NA	NA	NA
		Natural Gas	$4.95	1.10	6.18 therms	NA	NA	NA
		None – water savings only	$8.85	1.10	NA	NA	NA	NA
Self Closing Double	DoD	Electric	$10.78	1.10	139.50 kWh	$17.38	0.99	23.17 kWh
2.2 gpm		Natural Gas	$14.25	1.10	6.18 therms	$17.98	0.99	1.12 therms
$217.30		None – water savings only	$16.60	1.10	NA	$18.46	0.99	NA
	Civilian	Electric	$7.68	1.10	139.50 kWh	NA	NA	NA
		Natural Gas	$12.70	1.10	6.18 therms	NA	NA	NA
		None – water savings only	$16.60	1.10	NA	NA	NA	NA

Table 4.5. Faucet LCC Analysis Results (cont)

			Office			Barracks		
Faucet Specific Type (with installed cost)	**Federal Sector (DoD and Civilian)**	**Water Heating Fuel**	**Combined Water/Sewer Rate w/ Positive NPV ($/kgal)**	**Annual Water Savings per Fixture (kgal)**	**Annual Energy Savings per Fixture (kWh or therms)**	**Combined Water/Sewer Rate w/ Positive NPV ($/kgal)**	**Annual Water Savings per Fixture (kgal)**	**Annual Energy Savings per Fixture (kWh or therms)**
Pedal Activated Standard	DoD	Electric	$4.50	1.97	139.50 kWh	$8.01	1.77	23.17 kWh
2.2 gpm		Natural Gas	$6.43	1.97	6.18 therms	$8.34	1.77	1.12 therms
$182.30		None – water savings only	$7.74	1.97	NA	$8.60	1.77	NA
	Civilian	Electric	$2.78	1.97	139.50 kWh	NA	NA	NA
		Natural Gas	$5.57	1.97	6.18 therms	NA	NA	NA
		None – water savings only	$7.74	1.97	NA	NA	NA	NA
Pedal Activated High Efficient	DoD	Electric	-$0.12	3.89	343.80 kWh	$2.91	3.50	111.52 kWh
1.0 gpm		Natural Gas	$2.28	3.89	15.36 therms	$3.73	3.50	5.34 therms
$182.30		None – water savings only	$3.93	3.89	NA	$4.37	3.50	NA
	Civilian	Electric	-$2.27	3.89	343.80 kWh	NA	NA	NA
		Natural Gas	$1.20	3.89	15.36 therms	NA	NA	NA
		None – water savings only	$3.93	3.89	NA	NA	NA	NA
Sensor - battery	DoD	Electric	$3.44	4.68	427.40 kWh	$6.87	4.21	147.68 kWh
0.5 gpm		Natural Gas	$5.92	4.68	19.10 therms	$7.77	4.21	7.09 therms
$292.30		None – water savings only	$7.62	4.68	NA	$8.47	4.21	NA
	Civilian	Electric	$1.22	4.68	427.40 kWh	NA	NA	NA
		Natural Gas	$4.80	4.68	19.10 therms	NA	NA	NA
		None – water savings only	$7.62	4.68	NA	NA	NA	NA
Sensor - hardwired	DoD	Electric	$1.85	4.68	427.40 kWh	$5.09	4.21	147.68 kWh
0.5 gpm		Natural Gas	$4.32	4.68	19.10 therms	$5.99	4.21	7.09 therms
$336.60		None – water savings only	$6.02	4.68	NA	$6.69	4.21	NA
	Civilian	Electric	-$0.38	4.68	427.40 kWh	NA	NA	NA
		Natural Gas	$3.20	4.68	19.10 therms	NA	NA	NA
		None – water savings only	$6.02	4.68	NA	NA	NA	NA

Table 4.5. Faucet LCC Analysis Results (cont)

			Office			Barracks		
Faucet Specific Type (with installed cost)	**Federal Sector (DoD and Civilian)**	**Water Heating Fuel**	**Combined Water/Sewer Rate w/ Positive NPV ($/kgal)**	**Annual Water Savings per Fixture (kgal)**	**Annual Energy Savings per Fixture (kWh or therms)**	**Combined Water/Sewer Rate w/ Positive NPV ($/kgal)**	**Annual Water Savings per Fixture (kgal)**	**Annual Energy Savings per Fixture (kWh or therms)**
Hydro Powered	DoD	Electric	$8.37	3.79	343.80 kWh	$12.42	3.41	111.52 kWh
1.0 gpm		Natural Gas	$10.83	3.79	15.36 therms	$13.26	3.41	5.34 therms
$566.45		None – water savings only	$12.52	3.79	NA	$13.91	3.41	NA
	Civilian	Electric	$6.16	3.79	343.80 kWh	NA	NA	NA
		Natural Gas	$9.71	3.79	15.36 therms	NA	NA	NA
		None – water savings only	$12.52	3.79	NA	NA	NA	NA
Solar Powered	DoD	Electric	$5.51	4.68	427.40 kWh	$9.16	4.21	147.68 kWh
0.5 gpm		Natural Gas	$7.98	4.68	19.10 therms	$10.06	4.21	7.09 therms
$541.32		None – water savings only	$9.68	4.68	NA	$10.76	4.21	NA
	Civilian	Electric	$3.28	4.68	427.40 kWh	NA	NA	NA
		Natural Gas	$6.86	4.68	19.10 therms	NA	NA	NA
		None – water savings only	$9.68	4.68	NA	NA	NA	NA

Table 4.6. Clothes Washer LCC Analysis Results

		Barracks		
Specific Type	**Water Heating Fuel (Electric, Natural Gas, None – water savings only)**	**Combined Water/Sewer Price w/ Positive NPV ($/kgal)**	**Annual Water Savings per Fixture (kgal)**	**Annual Energy Savings per Fixture (kWh, therms)**
High Performance Commercial (Energy Star) Clothes Washer $1,500	Electric	$1.56	41.9	2,407.2 kWh
	Natural Gas	$3.02	41.9	134 kWh*, 103.5 therms
	None – water savings only	$4.19	41.9	NA

* Electric savings for water heated by natural gas result from to motor efficiency improvements.

5.0 Cost-Effective Savings Potential in the Federal Sector

The cost-effective savings potential in the Federal sector was determined by first estimating the amount of water currently used by domestic fixtures. Next, the cost-effective savings percentage (of the total water use) was calculated for each fixture to determine what percentage could be saved cost-effectively. This was done by identifying the fixtures that were determined to be LCC effective at the Federal average combined marginal water and sewer rate, as described in Section 4. The methodology used to determine the water consumption in the Federal government and cost-effective savings potential is described below.

5.1 Water Consumption Estimates in the Federal Sector

To ascertain the cost-effective water conservation potential in the Federal sector, the first step is to determine the total water use in the Federal sector that is available for water savings for each "off the shelf" technology, as described in Section 3.

The total Federal water use was obtained from the FY 2003 DOE *Report on Federal Agency Activities Under Executive Order 13123* [Executive Order 13123 1999]. All Federal agencies are required to report total annual water use and cost of water to DOE. These annual totals are summed for DoD and civilian agencies. The reported water use and cost is presented in Table 5.1 below.

Table 5.1. Total Water Use and Cost in the Federal Government [U.S. DOE 2005]

Sector	FY 2003 Water Use (million gallons)	% of Total Use	Water Cost ($ million)
DoD	162,096	78%	$292
Civilian Agencies	46,959	22%	$135
Total	209,056	100%	$427

The approach in this updated assessment examines water use in the Federal sector at the end-use level for each "off the shelf" domestic technology – toilets, urinals, showerheads, faucets, and clothes washers. This was accomplished by applying the Federal water use indices for specific building types to the Federal inventory data obtained from the General Service Administration 1999 Federal real property database [GSA 1999].

The GSA real property database provides square footage for each major building type in the Federal sector for all DoD and civilian agencies. However, water use is typically driven not by how big the building is, but rather by how many people occupy the building. Therefore, it is more accurate to base water use by occupancy level instead of by square footage. The total occupancy of each building type was estimated by multiplying the total square footage by an estimated occupancy density (occupant/sqft). The occupancy densities were obtained from

Facility Energy Decision System (FEDS) software [FEDS 2002]. A complete description of Federal inventory building types and occupancy densities used in the analysis are listed in Appendices A and B.

The estimated occupancy for each building type was then multiplied by the associated Federal water use indices (WUI). The Federal WUI, obtained from the American Water Works Association (AWWA), is an estimate of the typical daily water use per occupant in gallons per person per day (gpd) [AWWA 1996]. See Appendix B for a full explanation on how WUIs were chosen and estimated for each building type in the GSA real property database. Also, a detailed methodology and breakout of water use in the Federal sector by building type is included in Appendices A and B.

The total water use for each building category was further broken down by end-use. This is done by applying the typical end-use profiles for each building type. A percent breakout of water use by end-use technology was obtained from two main sources, *Handbook for Water Use and Conservation* by Amy Vickers [Vickers, 2001], and *A Water Conservation Guide for Commercial, Institutional and Industrial Users* developed by the New Mexico State Engineers Office [NMOSE 1999]. A detailed explanation of how each building type's end-use profile was estimated can be found in Appendix B.

These water use percentages for "off the shelf" technologies for each building type were then multiplied by the total Federal water use obtained from the FY 2003 *Report on Federal Agency Activities Under Executive Order 13123*. DoD domestic water consumption was estimated to be 78,193 million gallons and civilian domestic water consumption was estimated at 27,862 million gallons, which totals 106,055 million gallons, or approximately 51% of all Federal water use. Detailed data is provided in Table 5.2 below.

Table 5.2. Estimated Water Use for Off the Shelf Technologies in the Federal Government

Technology	Annual DoD Water Use (million gallons)	Annual Civilian Water Use (million gallons)	Annual Total Federal Water Use (million gallons)	Percent Total Federal Water Use
Toilets	32,614	12,214	44,828	21%
Urinals	6,824	1,859	8,683	4%
Showers	12,162	7,920	20,082	10%
Faucets	13,081	3,488	16,569	8%
Clothes Washers	13,512	2,381	15,893	8%
Domestic Fixture Total	78,193	27,862	106,055	**51%**
Total Water Consumption	162,096	46,959	209,055	
% of Total Use	**48%**	**59%**	**51%**	

5.2 Energy Consumption Estimate in the Federal Sector

The energy used to heat water in the Federal government was estimated using the Facility Energy Decision System (FEDS), a building energy modeling tool [FEDS 2002]. The building inventory data from the GSA Real Property database that was used to estimate the water use in the Federal government was input into the FEDS software to model the amount of energy required to heat water in the Federal sector for domestic fixtures: showerheads, faucets, clothes washers, and dishwashers. FEDS accounts for energy consumed by standby losses[1], which are included in the total energy use, but are not accounted for in energy reduction as a result of efficiency improvements.

FEDS only accommodates efficiency improvements for faucets and showerheads. Therefore, the energy reduction potential for clothes washers and dishwashers in the Federal sector is not estimated in this assessment. However, it should be noted that there is significant opportunity for energy reduction from high performance clothes washers, as discussed above. There is approximately a 76% in energy reduction from high performance clothes washers compared to traditional equipment. This includes both hot water reduction and higher motor efficiency.

FEDS calculates energy requirements to heat tap water based on the difference between the groundwater temperature and the desired hot water temperature. The Federal inventory data was broken out by DOE Region, enabling buildings to be modeled by region to account for groundwater temperature differences throughout different parts of the country.

To estimate energy savings as a result of reduction in hot water for showers and faucets, varying flow rates for fixtures were modeled in FEDS to determine the amount of energy used by each. It was assumed that all water was heated using distributed water heaters. Water heated by steam or hot water from a central boiler and distributed system(common in DoD facilities) is not examined in this analysis. Because central boilers are typically less efficient than distributed water heaters as a result of distribution losses, the energy use and savings estimate in this analysis is conservative.

All water was assumed to be heated by either electricity or natural gas. Aside from central boiler hot water, a small percentage of water is heated in distributed systems using fuel oil, propane gas, or other fuels, and thus assumed to be negligible for the purposes of this assessment. The amount of water assumed to be heated using electricity versus natural gas was

[1] Standby losses occur through the walls of the hot water tank, as well as through pipes during transmission to the end-use. When hot water is not being used, it tends to cool to the ambient temperature; more energy is therefore needed to keep the stored water at the desired temperature, although water may not have been drawn from the tank. This wasted energy, lost to the surroundings instead of providing useful work, is called standby loss.

based on Commercial Buildings Energy Consumption Survey 1999 (CBECS) [CBECS 2005], Annual Energy Outlook 2003 (AEO) data [EIA 2005], and data collected on Federal sites for other analyses conducted by PNNL [Parker et al. 2005]. For more information on these assumptions, go to Appendix C.

The results from the FEDS analysis of the total required energy to heat water for domestic uses (faucets, showers, clothes washers, and dishwashers) in the Federal government is approximately 20,900 billion Btu, or about 2% of the total energy requirement of the Federal government [EIA 2005][1]. The amount of energy required to heat water for showers and faucets is estimated to be about 4,900 billion Btu or about 0.5% of the total energy requirement in the Federal sector. Detailed results are presented in the Table 5.3.

Table 5.3. Estimated Energy Requirements for Domestic Hot Water in the Federal Sector

Federal Sector	Annual Electricity Use (MWh)*	Annual Natural Gas Use (million Btu)	Total Annual Energy Use (million Btu)
DoD Faucets and Showers	469,033	2,212,825	3,813,166
Civilian Faucets and Showers	137,044	635,550	1,103,145
Total Faucets and Showers	606,077	2,848,376	4,916,312
DoD Total Hot Water	1,674,525	9,500,118	15,213,597
Civilian Total Hot Water	644,868	3,468,931	5,669,220
Total Federal Hot Water	2,319,393	12,969,049	20,882,817

* Conversion from MWh to MMBtu is 3.412

See Appendix D for a detailed explanation of the methodology used in estimating the energy use and savings in the Federal sector.

5.3 Cost-Effective Savings Potential Results

The water consumption and energy use estimated (presented in Tables 5.2 and 5.3) and the results of the LCC analysis (presented in Section 4) were used to estimate the cost-effective savings potential from the “off the shelf” fixtures in the Federal sector. This analysis was done at a very high level encompassing the entire Federal sector, so the results are not specific to any given site or Federal agency. Rather, they are general findings estimating total savings potential across the DoD and civilian sectors. This savings potential represents 100% penetration of cost-effective, efficient technologies in the Federal sector to show the true savings potential.

[1] The Federal government, as reported by Energy Information Administration (EIA) in 2003, used 1,051.6 trillion Btus.

Because of the complexity of the Federal sector, certain simplifying assumptions were made—these are discussed below. Note that the savings potential for any given site should be looked at given that site's specific situation, including specific equipment use and age, as well as the marginal water/sewer cost, and environmental issues, for example.

To estimate the cost-effective savings potential in the Federal sector, appropriate domestic fixtures were chosen from each category (toilets, urinals, showerheads, faucets, and clothes washers) that were determined to be LCC effective at or below the Federal average combined water/sewer marginal cost (4.25/1,000 gal for DoD and 4.47/1,000 gal for civilian). Two technologies were chosen from each category – a standard fixture that meets the current EPAct requirements and a high efficiency option that exceeds EPAct but is still LCC effective at the average Federal water rate. See Table 5.4 for a list of the fixtures chosen.

Table 5.4. LCC Effective Fixtures Used to Estimate Savings Potential

Technology	Standard EPAct Technology	High Efficiency Technology
Toilet	1.6 gpf flush valve	1.0 gpf pressure assisted
Urinal*	0.5 gpf	No-water urinal
Showerhead	2.5 gpm	2.0 gpm
Faucet	2.2 gpm	0.5 gpm
Clothes Washer	High Performance	NA

* Urinal EPAct standard is 1.0 gpf. However, 0.5 gpf was cost-effective below the average Federal rates; therefore, was used as the "standard".

The savings for each of the fixtures in Table 5.4 was calculated based on the difference between the average water consumption of current water-using equipment in the Federal sector and the more efficient retrofit water consumption (as described in Section 3).

The Federal government has already implemented some degree of water-efficient technologies, therefore a range of penetration rates of efficient technologies was assumed. This was based on previous work at Federal sites [Solana and McMordie 2004, Chvala et al. 2004][1], which estimates the percentage of efficient fixtures that meet EPAct standards and highly efficient fixtures currently installed at Federal sites as described above. Penetration of high efficiency fixtures was considered to be much lower than standard EPAct fixtures. The

[1] Also, Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Pacific Northwest National Laboratory*. PNNL-Letter Report. Pacific Northwest National Laboratory. Richland, Washington (not publicly available).

penetration rates used in this analysis are in Table 5.5, and more details are provided in Appendix B

Table 5.5. Penetration Rates of Efficient Technologies in the Federal Government

Fixture	EPAct Standard Technology	Penetration Rate in Federal Sector	High Efficiency Technology	Penetration Rate in Federal Sector
Toilets	1.6 gpf	20%	1.0 gpf pressure assist	0%
Urinals	1.0 gpf	50%	0 gpf	2%
Showerheads	2.5 gpm	70%	2.0 gpm	10%
Faucets	2.2 gpm	70%	0.5 gpm sensored	10%
Clothes Washer	High Performance (or use Energy Star)	4%	NA	NA

These penetration rates were multiplied by the corresponding cost-effective water and energy use savings. These values arrive at the realistic cost-effective water and energy savings that is currently available for water savings for each technology.

The final results of the cost-effective water savings potential in the Federal sector is estimated to be between 35,000 and 50,000 million gallons per year representing about 17% to 24% of total Federal water consumption. The corresponding cost savings due to water savings is between $152 and $216 million annually (based on water rates presented in Table 4.1). The energy savings potential from reduced hot water consumption in showers and faucets is estimated to range from approximately 601,700 to 1,550,000 million Btus. The corresponding energy cost savings represents between $13 and $20 million annually (based on energy rates presented in Table 4.2). Breakouts by end-use of these results are shown below in Table 5.6. Low-end savings represent retrofits using the EPAct standard fixtures; high-end savings represent installation of the high-efficiency technologies.

Table 5.6. Total Cost-Effective Range of Savings in the Federal Government

Federal Sector	Fixture	Low End Water Savings (million gal)	High End Water Savings (million gal)	Low End Water Cost Savings ($million)	High End Water Cost Savings ($million)	Low End Energy Savings (million Btu)	High End Energy Savings (million Btu)	Low End Energy Cost Savings ($million)	High End Energy Cost Savings ($million)
DoD	Faucet	3,351	7,893	$14.24	$33.55	322,267	821,044	$5.15	$7.75
	Clothes Washer	6,510	6,510	$27.67	$27.67	NA	NA	NA	NA
	Showerhead	131	1,034	$0.56	$4.39	24,228	179,506	$0.85	$2.12
	Toilet	13,684	16,212	$58.16	$68.90	NA	NA	NA	NA
	Urinal	3,919	6,247	$16.66	$26.55	NA	NA	NA	NA
DoD Total		27,595	37,895	$117.28	$161.06	346,495	1,000,549	$6.00	$9.87
Civilian	Faucet	1,203	2,139	$5.38	$9.56	250,886	519,224	$6.10	$7.89
	Showerhead	213	1,606	$0.95	$7.18	4,288	30,354	$1.36	$2.27
	Toilet	5,270	6,814	$23.56	$30.46	NA	NA	NA	NA
	Urinal	1,111	1,788	$4.96	$7.99	NA	NA	NA	NA
Civilian Total		7,796	12,347	$34.85	$55.19	255,174	549,578	$7.46	$10.16
Grand Total		35,391	50,242	$152.13	$216.25	601,669	1,550,128	$13.46	$20.03

6.0 Needs and Recommended Requirements for Successful Performance Contracting

Water conservation and efficiency measures have been incorporated into performance contracting of energy-efficiency projects as part of the Department of Defense ESPC and Super ESPC contracts. Thus, there is a considerable base of experience in water efficiency performance contracting at Federal sites. The majority of the water conservation projects have been developed and implemented through second-tier contractors to energy service companies (ESCOs). For these ESCOs, the water conservation projects are generally implemented through a water management specialist as a subcontractor and/or a technology supplier who has expertise in implementation. There are a few ESCOs that maintain staff with water conservation project development expertise, but this is not typical.

A number of challenges, observations or recommendations have been made by the providers of water conservation services who have designed and implemented a significant number of water conservation projects and verified the savings under ESPC for the Federal sector[1]. These observations and recommendations are described in this section under the subheadings “Project Design,” “Project Implementation,” and “Savings Verification”.

6.1 Project Design

The following bullets describe key findings that impact the design of water projects. These observations show limitations and barriers to designing effective water conservation projects.

- Given the requirements of the Super ESPC, water services (only) firms must be used as subcontractors. A water services subcontractor to an ESCO generally increases the cost of a water efficiency project and thus causes some technologies to no longer be cost-effective. A standalone water savings performance contract with a water services (only) firm would likely reduce the overall cost of a water project while at the same time allow more water projects to be cost-effective.

- Many ESCOs consider water projects to be primarily domestic or “off the shelf” technology retrofits (e.g., low flush toilets and urinals), and very often do not incorporate more complex or engineered water projects—particularly projects in industrial processes or facilities, such as single-pass cooling or steam system

[1] Information obtained on impacts of performance contracting for water efficiency projects from personal communications with the following: Mr. James Horner, President of Water Management Inc. on February 28, 2005; Mr. Tom Horner, Vice President of Water Management Inc. on February 28, 2005; and Mr. Andrew Perrin, Water Engineer, with H2O Applied Technologies on February 2005.

efficiency improvements. This creates a significant number of missed opportunities, especially if water conservation can be readily included in an energy conservation retrofit (e.g., retrofit of chillers or cooling towers).

- Water efficiency opportunities are many times the last set of projects or technologies identified in a more complete and comprehensive set of energy projects. ESCOs should bring in the water efficiency experts (if subcontracted) early in the identification of *all utility savings* project opportunities. Also, given most ESCOs do not maintain in-house expertise in water efficiency, bringing in a water services firm early in the process can help “sell” a cost-effective water efficiency project to an otherwise reluctant Federal agency.

- Water audits can generally identify equipment vintage and rated performance. In some cases (as with energy consuming equipment), the stated or manufacturer’s (label) performance is incorrect because of aging and/or improper maintenance. For example, a labeled 1.6 gpf toilet may have a worn or replaced valve that is allowing over 3 gpf. In many cases, the toilet cannot be included in a retrofit project because of the rating on the *label*. Allowance needs to be made for including retrofit projects in these types of situations.

- Currently, most water management projects’ economic analyses use an average (rather than marginal) water/sewer rate based on the water bill–without an escalation factor–for LCC analysis. This approach is flawed. There is a need for development of a method for determining the appropriate baseline rate to use for a water project cost-effectiveness assessment, as well as the escalation of that rate, similar to the way energy rates are determined and escalated in LCC analysis.[1]

- Some water services companies, as subcontractors to an ESCO, may not be willing to reveal proprietary measures or projects without a guarantee or some other certainty of being selected as part of the ESCO team of a Federal ESPC project. Water project opportunities that could be included as part of the ESCO bid and selection process are often missed because of proprietary nature of some technologies.

- Because many ESCOs do not have experience and expertise in water efficiency, particularly in those projects that are engineered, they often limit the development/identification of projects to those that are standard or proven retrofits and do not include potential projects that are small or more complicated—even if economic. Significant savings opportunities are thus lost.

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[1] Note the Department of Housing and Urban Development (HUD) has established a 3%/year escalation rate for water/sewer rates in all performance-based water conservation projects under HUD.

6.2 Project Implementation

The way that ESPCs are currently structured has an influence on how water projects can be implemented. The following bullets describe these major impacts on implementation of water projects.

- Water conservation measures/projects are almost always a part of a larger set of task or delivery orders that include energy conservation measures (ECMs). Generally, the ECMs take longer to design and implement than water conservation measures. Though, in most cases, the water conservation measures can be more quickly implemented than the ECMs, they are staged with the ECMs, thus unnecessarily delaying the more immediate capture of water savings.

- ESCOs often limit communication and interaction by water services subcontractors directly with the Federal client during design and implementation. Direct communication by the water subcontractor with the Federal client will generally lead to identification of additional opportunities, minimal disruptions, and increased client satisfaction.

- An ongoing or long-term water management/ maintenance program as part of a water conservation project is crucial to assure savings are sustained over the long term. Operations and maintenance is often included in energy conservation projects but neglected in water conservation projects, when in fact the water savings are just as dependent upon proper equipment maintenance as in energy projects.

6.3 Savings Verification

ESPCs require a guaranteed savings and thus require measurement and verification (M&V) to assure that savings are being met. The following list summarizes the issues revolving around savings verification for water projects and some recommendations for improvements.

- The current industry standard for measurement and verification (M&V) for water measures as part of an ESPC was researched. For basic water consuming fixtures, (such as toilets, urinals, showers, and faucets), water savings are typically stipulated where savings are determined based on calculated pre- and post-retrofit water consumption agreed to by the facility. For water processes, M&V is typically based on short term pre- and post-retrofit field measurement of the specific equipment.

- It is vital to have a reasonable and appropriate level of savings verification protocol commensurate with the type of project or type of retrofit. As stated in the above bullet, stipulated (calculated rather than measured) water savings is a common approach in the Federal sector; however, stipulated water savings should be applied to technologies only with well established water savings. Most domestic-related fixtures have reliable performance and stipulated M&V is most likely adequate. For process-related measures, such as cooling towers or single-pass cooling, the favorable M&V approach is short term and spot measurement because savings is dependent on the site specific nature of the measure.

- The ESCO should strive to engage the water services subcontractor in the development of the savings verification approach for the water conservation measures. Even if the water conservation retrofits are a small portion of the task or delivery order, and thus a small portion of the savings, a responsible savings verification plan needs to be developed and implemented proportionate to the M&V plan. With this approach, the water services contractor will also share the responsibility for the savings guarantee with the ESCO.

- All servicing utility (water, sewer, and energy) incentives for water saving (and water/energy saving) technologies and strategies should be allowed to be captured by the contractor and included in the cost-effectiveness analysis.

Overall, the most important issue is to create the contract requirements and a process that will be attractive to all potential water service providers in a highly competitive environment. This environment should allow the water service providers a wide and flexible range of water-related conservation and cost saving opportunities that bring innovation and creativity to the Federal sector customers.

7.0 References

American Water Works Association (AWWA). 1996. *Federal Water Use Indices*. Obtained from FEMP Website at: http://www.eere.energy.gov/femp/technologies/water_useindices.cfm

Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Fort Buchanan, Puerto Rico.* PNNL-14533. Pacific Northwest National Laboratory, Richland, Washington.

Commercial Buildings Energy Consumption Survey (CBECS) Website. 2005. Accessed February 2005. Website can be found at: http://www.eia.doe.gov/emeu/cbecs/contents.html.

Energy Information Administration (EIA) Annual Energy Outlook Website. 2005. Accessed February 2005. Website can be found at: http://www.eia.doe.gov/oiaf/aeo/

The Energy Policy Act of 1992 (EPACT). 1992. Public Law 102-486. Washington DC.

Executive Order 13123: *Greening the Government Through Efficient Energy Management*. 1999. Federal Register 30851. Volume 64. Number 109. Washington DC.

Facility Energy Decision System (FEDS) software Release 5.0.2. 2002. Pacific Northwest National Laboratory, Richland, Washington.

Federal Energy Management Program News and Events Website. Accessed on January 26, 2005. Summary of the National Defense Authorization Act of Fiscal Year 2005. Website can be found at: http://www.eere.energy.gov/femp/newsevents/detail.cfm/news_id=8301

Federal Energy Management Program Water Efficiency – Federal Requirements Website: http://www.eere.energy.gov/femp/technologies/water_fedrequire.cfm Accessed on January 26, 2005.

Federal Energy Management Program Water Efficiency – Water Goals Website: (http://www.eere.energy.gov/femp/technologies/water_goals.cfm)

Federal Energy Management Program Water Efficiency Website: (http://www.eere.energy.gov/femp/technologies/water_efficiency.cfm)

Fitzpatrick, Q.K., K.L. McMordie, F.V. Di Massa, and D.R. Dixon. 1995. *FORSCOM Installation Characterization and Ranking for Water Efficiency Improvement*. PNNL-10541. Pacific Northwest National Laboratory, Richland, Washington.

Fuller, S.K., and S.R. Petersen. 1995. *Life-Cycle Costing Manual for the Federal Energy Management Program*. NIST Handbook 135. National Institute of Standards and Technology, Gaithersburg, MD.

General Service Administration (GSA) Advantage Website. 2005. Accessed January 2005. Website used to estimate average fixture costs. Website can be found at: www.gsaadvantage.gov

General Services Administration. 1999. *Summary Report of Real Property Owned by the United States Throughout the World as of September 30, 1998*. General Services Administration, Washington, D.C.

Harrison H. and J. Beck. 2004. *Prisoners in 2003*. Bureau of Justice Statistics Bulletin. U.S. Department of Justice, Washington D.C.

International Association of Plumbing and Mechanical Officials (IAPMO). 2003. *Uniform Plumbing Code* IAPMO/ANSI UPC 1-2003. Ontario, CA.

Koeller, J. 2003. *Dual-Flush Toilet Fixtures – Field Studies and Water Savings.* Koeller and Company. Yorba Linda, California.

Lombardo Associates. 1997. *Federal Facilities Water Use and Water/Energy Conservation Potential*: Final Report. Prepared for the National Renewable Energy Laboratory. Newton, Massachusetts.

Mansfield Plumbing Products. 2005. "Wholesale Price List." Perrysville, Ohio.

McMordie Stoughton, K.L. and W.D. Chvala. 2004. *Southeast Region Energy Program Technical Bulletin: Water Saving Toilets and Urinals*. PNNL-SA-40945. Pacific Northwest National Laboratory, Richland, Washington.

New Mexico Office of the State Engineer (NMOSE). 1999. *A Water Conservation Guide for Commercial Institutional and Industrial Users.* Santa Fe, New Mexico.

Parker, G.B., K.L. McMordie, G.P. Sullivan, and D.B. Elliott. 2001. *Market Assessment for Capturing Water Conservation Opportunities in the Federal Sector.* PNNL-13511. Pacific Northwest National Laboratory. Richland, Washington.

Parker, G.B., A.E. Solana, and D.R. Dixon. 2005. "Facility Energy Decision System (FEDS) Assessment Report for Blue Grass Army Depot, Kentucky." PNNL-15075. Pacific Northwest National Laboratory, Richland, Washington.

Raftelis Financial Consulting, PA. 2004. *Water and Wastewater Rate Survey*. Charlotte, North Carolina.

Reed Construction Data, Incorporated. 2004. *RS Means Residential Cost Data - 2005*. Kingston, Massachusetts [plumbing labor costs]

Service Employees International Union Website. Accessed on February 15, 2005. Obtained nurse to patient ratio. Website can be found at: www.SEIU.org

Schultz, L.I., A.S. Rushing, and S.K. Fuller. 2004. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - April 2004*. NISTIR 85-3273-19. National Institute of Standards and Technology. Gaithersburg, MD.

Sloan® Valve Company Sensor Faucets Website. 2005. Accessed January 2005. Website can be found at: http://www.sloanvalve.com/index_2450.htm.

Solana, A.E. and McMordie, K.L. 2004. *Water Management Plan for Blue Grass Army Depot.* PNNL-14880. Pacific Northwest National Laboratory. Richland, Washington.

Sullivan, G.P., G.B. Parker, and J. W. Currie. 2004. *Wisconsin Focus on Energy Resource-Efficient Laundry (REL) Room Demonstration: Final Report.* PNDW-3445. Battelle - Pacific Northwest Division, Richland, Washington.

Toto Plumbing USA. 2005. "Wholesale Price List." Morrow, Georgia. Website can be found at: http://www.totousa.com/toto/pagecontentview.asp?pageid=56&showimage=eco

United States Green Building Council (USGBC). 2003. *Leadership in Energy and Environmental Design ™ Reference Guide for New Construction and Major Renovations*. Version 2.1 Second Edition. Washington D.C.

Uridan® Non Water System Website. 2005. Accessed in January of 2005. Website can be found at: http://uridan.com

Veritec Consulting Inc. 2002. *Dual Flush Toilet Project.* Canada Mortgage and Housing Corporation. Canada.

Vickers, A. 2001. *Handbook of Water Use and Water Conservation.* Amy Vickers and Associates, WaterPlow Press, Amherst, Massachusetts.

Waterless® No-Flush™ Urinal Website. 2005. Accessed in January of 2005. Website can be found at: http://waterless.com

Appendix A

Federal Inventory Data to Estimate Federal Water Use by Building Types

Appendix A – Federal Inventory Data to Estimate Federal Water Use by Building Types

To analyze water use in the Federal government, it is important to understand which building types are the predominant water users in civilian and Department of Defense (DoD) facilities. Federal inventory data was obtained from the General Service Administration 1999 Federal real property database [GSA 1999]. This data is broken down by agency, square footage, and building type. The building categories are as follows:

- Hospital: medical clinics and hospitals
- Housing: barracks and Federal housing
- Industrial: process related facilities
- Office: administrative buildings
- Other Institutional: research oriented space with no laboratories
- Post Office: postal facilities
- Prison: detention and prisons
- R&D (Research and Development): laboratory
- School: training facilities
- Service: maintenance shops
- Storage: warehouse
- All Other: miscellaneous buildings that do not fit into the above categories

The predominant building types by square footage in DoD and civilian facilities based on the GSA real property data are shown below in Figures A.1 and A.2. Housing, service, and storage take up the most floor space in the DoD, while offices, hospitals, and storage dominate civilian floor space.

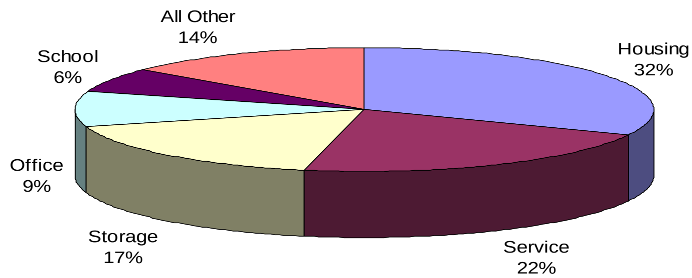

Figure A.1. Breakout of DoD Square Footage by Building Category

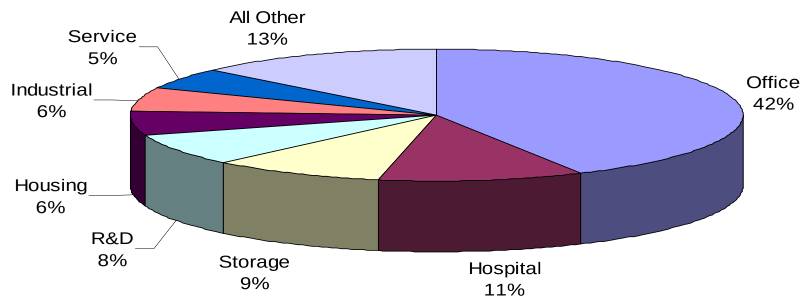

Figure A.2. Breakout of Civilian Square Footage by Building Category

However, water use is typically driven by how many people occupy a building and not by the square footage of a building. Therefore, it will be more accurate to base the Federal inventory by occupancy level instead of by floor space.

The total occupancy of each facility category can be estimated by multiplying the total square footage (as stated above) by the occupancy density (occupant/sqft), which is obtained from Facility Energy Decision System (FEDS) software [FEDS 2002]. (Find occupancy density factors in Appendix B.) It should be noted that not all of the facility categories in FEDS match perfectly with the facility categories provided in the Federal inventory. Therefore, the closest corresponding category was used (see Appendix D for details on building categories).

The estimated occupancy for each facility type was then multiplied by the associated Federal water use indices (WUI). The Federal WUI, obtained from the American Water Works Association (AWWA), is an estimate of the typical daily water use per person in the units of gallons per person per day (gpd) [AWWA 1996]. See Appendix B for a full explanation on how WUIs were chosen and estimated for each building type.

By multiplying the occupancy of each facility type by the corresponding WUI, a daily water use for each building type was estimated. These values were used to estimate the predominant water using building categories for DoD and civilian facilities, shown in the pie charts below. These charts are significantly different than the previous pie charts showing a breakout of Federal floor space (by square footage). For DoD, the top water users are housing, schools, and hospitals. For civilian agencies, the predominant water users are hospitals, offices, and prisons, as shown in Figures A.3 and A.4.

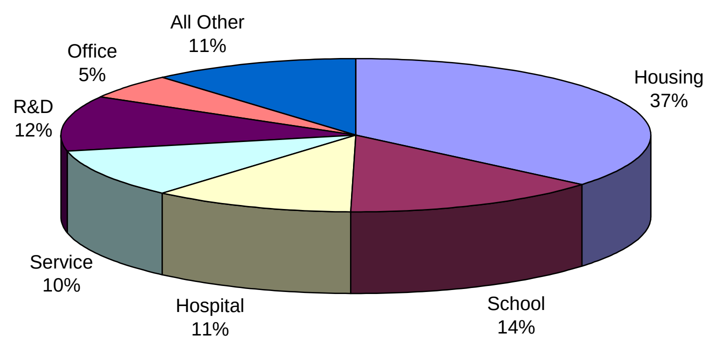

Figure A.3. Breakout of DoD Daily Water Use by Building Category

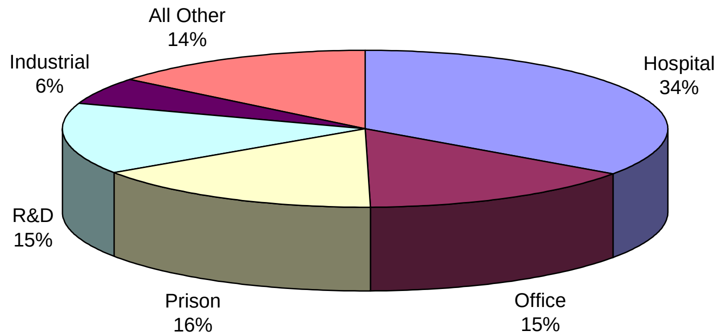

Figure A.4. Breakout of Civilian Daily Water Use by Building Category

Appendix B shows the next steps of assumptions used in the analysis to further estimate the Federal water use by these Federal building types and end-use fixtures.

APPENDIX B

Federal Water Use Estimate Assumptions

Appendix B – Federal Water Use Estimate Assumptions

This appendix describes the assumptions used to estimate the Federal water consumption by building type and end-use described in Section 5 of this document.

Water Use Indices:

Federal water use indices (WUI) were used to estimate water use by building type in the Federal sector. Table B.1 below describes the WUI used in this assessment. Some are found on the FEMP website at http://www.eere.energy.gov/femp/technologies/water_useindices.cfm, and the rest are based on FEMP's WUI, as explained below.

Table B.1. Federal Water Use Indices used in the Analysis

Building Type	WUI – gallon per person per day	Data Source
Hospital	83.4	Adjusted from Federal WUI
Office	15.0	Federal WUI
Prison	120	Federal WUI
R&D	80	PNNL Water Plan
Industrial	80	Based on R&D WUI
Housing/Barracks	35.0	Federal WUI for dormitory
School	16.7	Average of Federal School WUI
Service	15.0	Based on Federal Office WUI
Other Institutional	16.7	Based on Federal School WUI
Storage	10.0	Adjusted based on Federal Office WUI
Post Office	15.0	Based on Federal Office WUI
All Other	15.0	Based on Federal Office WUI

The methodology below explains how WUI were estimated where no Federal WUI was provided for the given category or it was adjusted to provide a better estimate.

R&D: The R&D WUI was estimated by using data from the Pacific Northwest National Laboratory Water Plan[1]. Individual laboratory facilities at PNNL are metered for water consumption, and square footage and occupancy numbers are known for these facilities. The WUI used in this analysis is based on the average WUI for these laboratory facilities.

Industrial: Because reliable data was not obtained for industrial facilities WUI, it was assumed that R&D has a fairly similar use pattern with relatively low occupancy and intensive process water use.

Hospital: Hospital WUIs are provided in water use per bed and water use per employee. The typical employee to patient ratio for hospitals is 6 to 1 [SEUI 2005]. This is based on an average ratio of current mandated standards for nurse to patient ratios in hospitals that was found in the Service Employees International Union Website. So this ratio was used to "prorate" the WUI for patients and employees. The WUI was also adjusted based on an 80% occupancy rate because it is based on the number of beds, not patients. So the WUI of 120 gallons per bed per day and the WUI of 10 per employee was adjusted to equal 83 gallons per occupant per day.

Housing: It is assumed that the majority of the housing for both civilian and DoD are predominantly barracks type facilities. The WUI that best matched the barracks use pattern is assumed to be the Dormitory WUI.

Service, Post Office, and All Other: These categories are assumed to have a similar use pattern as the Office category.

Storage: Storage was adjusted to 10 gallons per person per day. This was based on the Office WUI of 15 gal/person/day, but reduced because typically storage has decreased heating and cooling requirements and no irrigation.

Occupancy

The occupancy densities, which were used to calculate the daily water use of Federal buildings based on building type, were obtained from the Facility Energy Decision System (FEDS) with the exception of prisons. The FEDS building categories do not match exactly with the Federal inventory categories. See Table D.1 (in Appendix D) for an explanation of how the FEDS categories were matched to the Federal inventory categories.

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[1] Also, Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Pacific Northwest National Laboratory*. PNNL-Letter Report. Pacific Northwest National Laboratory. Richland, Washington (not publicly available).

The Federal occupancy densities do not have a category for prison nor does it have a category with a close fit. Therefore, occupancy of Federal prisons was obtained from a Bureau of Prisons document that provides the total number of Federal inmates in 2003 [Harrison and Beck 2004]. Table B.2 lists the occupancy densities for each building type.

Table B.2. Occupancy Densities for Building Categories

Building Type	**Occupancy Densities (occ/ksf)**
Hospital	5.2129
Office	3.1156
Prison	4.600
R&D	3.1156
Industrial	1.7086
Housing	2.5216
School	10.3796
Service	2.4326
Other Institutional	10.3796
Storage	1.1726
Post Office	2.4326
All Other	3.1153

FEDS uses a typical number of occupants for individual building types; Table B.3 shows the occupied hours assumed for each building type. Occupancy hours are necessary inputs for FEDS to model water consumption because the longer a person occupies a building, the more times they will use the facilities.

Table B.3. Building Occupancy Hours

Building Type	**Weekdays**		**Saturdays**		**Sundays**	
	Start	End	Start	End	Start	End
CIVILIAN						
Office	700	1800	0	0	0	0
Health Care	0	2300	0	2300	0	2300
Public Order	0	2300	0	2300	0	2300
Education	700	1700	0	0	0	0
Single Family Attached Housing	1400	2300	700	2300	700	2300
Lodging	1500	2300	700	2300	700	2300
Warehouse / Storage	600	1800	0	0	0	0
Other	600	1800	0	0	0	0
Mercantile and Service	800	2100	900	1600	0	0
Assembly	1100	2200	1400	2300	1400	2000
DOD						
Office	700	1800	0	0	0	0
Hospital	0	2300	0	2300	0	2300
Schools and/or Training	700	1700	0	0	0	0
Duplex Federal housing	1400	2300	700	2300	700	2300
Barracks	1500	2300	700	2300	700	2300
Storage	600	1800	0	0	0	0
Production and/or Process	600	1800	0	0	0	0
Exchange Facilities	800	2100	900	2000	0	0
Lab	700	1800	0	0	0	0
Morale, Welfare, and Recreation	1100	2200	1400	2300	1400	2000
Security	700	2100	700	2100	700	2100

End-Use Breakouts

The sources for end-use breakouts were obtained from Water Use and Conservation by Amy Vickers, and *A Water Conservation Guide for Commercial, Institutional and Industrial Users* developed by the New Mexico State Engineers Office [NMOSE 1999]. However, these two sources do not have the water use breakout for all facility types that are characterized in this analysis. Also, these end-use breakouts do not distribute the water use by technology but rather by generic category such as "restroom" use (instead of toilet, urinal, faucet, and shower). Therefore, some assumptions were made to help characterize Federal water use by end-use based on these two sources.

Office: Office breakout is from the New Mexico Water Conservation guide [New Mexico Office of the State Engineer 1999], which breaks out the water use in the following manner:

- Restrooms: 40%
- Cooling/Heating: 28%
- Landscape: 22%
- Other: 9%
- Kitchen: 1%.

For the restroom category, toilet, urinal, and faucet use was broken out by characterizing the typical use patterns for females and males in an office setting. (Shower water use was assumed to be zero.) Typically people use the restrooms three times per day; women use toilets for all three uses and men use the urinal twice and toilet once [Vickers 2001]. Both men and women wash their hands after each use, and it is assumed that it takes 20 seconds for each hand washing. This use pattern gives the following breakout of total restroom use assuming that there are 50% women and 50% men in the building:

- Toilets: 61%
- Urinals: 17%
- Faucets: 22%.

These percentages were applied to the 40% restroom use to give the following breakout for each “off the shelf” technology for the office category.

- Toilets: 24%
- Urinals: 7%
- Faucets: 9%.

Service and All Other: The “service” and “all other” categories were assumed to have the use pattern similar to office buildings. Therefore, the same end-use breakouts were used for these types of buildings.

Hospital: End-use breakout for hospitals is from the New Mexico Water Conservation guide. The split is the following:

- Restrooms: 40%
- Cooling/Heating: 13%
- Laundry: 10%
- Sterilizers: 10%
- Kitchen: 8%
- Other: 8%
- X-ray: 6%
- Landscape: 5%.

For the restroom category in Hospital building types, toilet, urinal, showerhead, and faucet use was broken out by characterizing the typical use patterns hospitals. Patient "restroom" water use was estimated based on 5.1 toilet and faucet uses per day [Vickers 2001] and one shower per day. Employee water use was estimated based on comparing the Federal WUI for hospital employees and patients. Patient WUI is typically 120 gallons per patient per day. For employees, the typical WUI is 10 gallons per employee per day [AWWA 1996]. So, employee use is about 8% of the patient use. This gives the following breakout for restroom fixtures:

- Toilets: 49%
- Urinals: 0% (very small water use for only male employees assuming that patient rooms do not have urinals)
- Showers: 41%
- Faucets: 10%.

Housing: It is assumed that the majority of the housing building type is barracks. Therefore, the end-use breakout for housing is estimated based on data from hotel and motel water use patterns because this more closely matches water use patterns in barracks than residential style housing. The following split of water use for hotels/motels is from *A Water Conservation Guide for Commercial Institutional and Industrial Users* prepared by the New Mexico Office of the State Engineer.

- Guestrooms: 30%
- Kitchen: 25%
- Laundry: 20%
- Cooling/Heating: 15%
- Landscape: 10%.

To split the guestroom water use by fixture end-use, residential water use was obtained from the Handbook of Water Use and Conservation [Vickers 2001]. This breakout shows water use by bathroom fixtures:

- Toilets: 45%
- Showers: 26%
- Faucets: 26%
- Baths: 3% (baths were not analyzed for this study because this is minimal and not an area of efficiency improvements).

These percentages were multiplied by the guestroom percentage to get the breakout of water use for bathroom fixtures for housing:

- Toilets: 13%
- Showers: 8%
- Faucets: 8%.

School: School breakout is assumed to have a similar use pattern as Office buildings. Therefore, the split is from the New Mexico Water Conservation guide. The split is the following:

- Restrooms: 40%
- Cooling/Heating: 28%
- Landscape: 22%
- Other: 9%
- Kitchen: 1%.

The bathroom fixture usage is broken down accordingly, as described for Office buildings:

- Toilets: 24%
- Urinals: 7%
- Faucets: 9%.

Prison: Prison end-use breakout was estimated based on the hospital end-use breakout because the operating hours are similar and there are other major water users (like kitchen among other processes). It was assumed that 40% of the water use in prisons is from bathroom fixtures – same as hospital use. To further divide this, restroom use by each fixture – it was assumed that inmates have the same use patterns as the general public of 5.1 restroom uses per day and one shower per day [Vickers 2001]. There are an estimated number of 170,000 inmates in Federal prisons and 7% of these are women [Harrison and Beck 2004]. This percentage was used to estimate urinal use of the male inmates assuming male inmates have 4 urinals uses per day and 1.1 toilet uses per day. The end-use split of the 40% restroom use is as follows:

- Toilets: 7%
- Urinals: 10%
- Showers: 17%
- Faucets: 6%.

R&D and Industrial: Under the scope of this analysis, there was no sound data found for R&D and Industrial type facility water use patterns. Therefore, restroom water use was estimated based on assuming that restroom use pattern among staff in an R&D and industrial facility will be the same as an office setting. The total restroom use in an office facility, based on information described above for Office WUI, is 6 gallons per person per day (gpd). Therefore, the percentage of restroom use in an R&D facility is 7.5% (6 gpd dived by 80 gpd). The restroom breakout for R&D is as follows:

- Toilets: 5%
- Urinals: 1%
- Faucets: 2%.

Penetration Rates of Existing Efficient Technology

The penetration rates in the Federal sector of existing efficient water using equipment was estimated based on a range of rates. The penetration rates are based on field experience [Solana and McMordie 2004, Chvala et al. 2004] [1] and life of the equipment. The highest level of penetration of efficient technology in the Federal sector was based on the implementation of water using fixtures that meet EPAct flow rate standards, shown in Table B.4 below. Many showerheads have been replaced with EPAct standard fixtures because the life of showerheads is generally 5 years. Starting in about 1994, most showerheads were rated at 2.5 gpm. Therefore, the majority of existing showerheads have been replaced since 1994. For faucets, it is very easy and inexpensive to retrofit faucets with low flow aerators. Based on field experience, it is assumed that the majority of faucet aerators meet the EPAct standard flow rate.

EPAct standard 1.6 gpf toilets have been required since 1994. Toilets last about 20 years. Therefore it is assumed that the majority of these fixtures have not been replaced and do not meet EPAct flush rates. Urinals are easy to retrofit to use about 1.0 gpf by replacing the older higher consuming flush valve with a 1.0 gpf flush valve. It is assumed that about half of all urinals have been replaced with a 1.0 gpf flush valve[2].

For high efficiency fixtures, as described in Section 3, it is assumed that the penetration rate is very low. This is because they are recent to the market, and field experience verified the low penetration [Solana and McMordie 2004, Chvala et al. 2004][1]. Table B.4 shows the penetration rates that were used in the analysis.

Table B.4. Penetration Rates of Efficient Fixtures in the Federal Government

Fixture	EPACT Standard Flow/Flush Rate	Penetration Rate in Federal Sector	High Efficiency Flow/Flush Rate	Penetration Rate in Federal Sector
Toilets	1.6 gpf	20%	1.0 gpf	0%
Urinals	1.0 gpf	50%	No-water urinal	2%
Showerheads	2.5 gpm	70%	2.1 gpm	10%
Faucets	2.2 gpm	70%	0.5 gpm	10%

[1] Also Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Pacific Northwest National Laboratory*. PNNL-Letter Report. Pacific Northwest National Laboratory. Richland, Washington (not publicly available).

[2] Obtained information on penetration rate of urinals from personal communications with Mr. Bill Slaughter, Federal Account Representative, with Falcon Water Free Urinals on January 12, 2005.

APPENDIX C

Building Characteristics and Use Profile for Life-cycle Cost Analysis

Appendix C – Building Characteristics and Use Profile for Life-cycle Cost Analysis

To determine the LCC effectiveness of individual technologies, an average Federal office building and barracks were modeled. The building size and age were averaged from Federal inventory data, and other building characteristics were obtained from Facility Energy Decision System (FEDS) software. A female and male barracks were modeled separately because women and men have different water use patterns (women do not use urinals).

Water savings were calculated for each efficient, off the shelf technology, described in Section 3 in the main body of the report. The assumptions used to estimate the water and energy savings are described below in the series of tables. Table C.1 describes the building characteristics – its size, number of occupants, gender split of the building and the number of occupied days for each building type.

Table C.1. Building Characteristics Office and Barracks

Building Type	Square Feet	Number of Occupants	Gender split	Occupied Days
Office	18,889	46	50-50	260
Barracks	8,180	16.5	Modeled separately for male and female	365

Also, the number of fixtures in each building was estimated to calculate the water and energy savings per fixture for the LCC analysis. The number of fixtures, shown in Table C.2, are based on several different sources: the Uniform Building Code [IAPMO 2003], on-site experience from water audits [Solana and McMordie 2004, Chvala et al. 2004] [1], and information from the FEDS model. The most appropriate fixture count was chosen based on careful consideration of all three sources.

[1] Also, Chvala, W.D., G.P. Sullivan, and K.L. McMordie. 2004. *Water Management Plan for Pacific Northwest National Laboratory*. PNNL-Letter Report. Pacific Northwest National Laboratory. Richland, Washington (not publicly available).

Table C.2. Fixture Count for Office and Barracks

Building Type	Number of Female Toilets	Number of Male Toilets	Number of Urinals	Number of Faucets	Number of Showers
Office	3	2	2	6	0
Barracks	4	3	2	8	3

Average use of fixtures in an office building was based on 3 restroom visits per day. For barracks, it was assumed that 5 days per week, there were 2.1 restroom uses and 2 days per week, there were 4.1 restrooms uses to average out to 2.67 uses per day [Vickers 2001]. To calculate the water use for showerheads it was assumed that showers are 5.3 minutes long. Typical hand washing after a toilet use was assumed to be 20 seconds. Barracks water use assumed one face wash and 2 teeth brushings per person per day, which last 30 seconds each. Therefore, the total faucet water use in barracks each day is approximately 2.38 minutes. This data is shown in Table C.3.

Table C.3. Water Use Pattern

		Average Uses per Person per Day			
Building Type	**Gender**	**Toilets**	**Urinals**	**Faucets**	**Showers**
Office	Female	3	0	3	0
Office	Male	1	2	3	0
Barracks	Female	2.67	0	2.38 min total	1
Barracks	Male	1	1.67	2.38 min total	1

Source: Vickers 2001

APPENDIX D

Methodology Used to Estimate Federal Energy Use

Appendix D - Methodology Used to Estimate Federal Energy Use

Energy savings from reduced hot water use was calculated using the Facility Energy Decision System (FEDS), a building energy modeling tool [FEDS 2002]. For the entire Federal sector, varying flow rates for faucets and showerheads were modeled in FEDS to determine the amount of energy used. (Other domestic hot water consumers, dishwashers and clothes washers, do not have retrofit options in FEDS.) The Federal sector was represented by the GSA real property data [GSA 1999], which contains Federal building inventory floor space, described above.

FEDS calculates energy requirements to heat tap water based on the difference between the groundwater temperature and the desired hot water temperature. The Federal inventory data was broken out by DOE Region, enabling buildings to be modeled by region to account for groundwater temperature differences throughout different parts of the country.

Federal buildings were also modeled according to building type in order to allow FEDS to make assumptions for water consumption, fixture count, and water heating equipment based on building type and size. The building type categories in FEDS do not exactly correlate with the Federal inventory building categories. Table D.1 below shows which FEDS categories were used to represent the Federal categories. These were chosen based on the most similar water use pattern of the particular building type, which depends on occupancy numbers and hours.

Table D.1. FEDS Building Types Used to Represent Federal Building Types

Federal Inventory Building Type	FEDS Building Type
CIVILIAN	
Office	Administration
Post Office	Mercantile and Service
Hospital	Health Care
Prison	Public Order
School	Education
Other Institutional	Education
Housing	Lodging; Single Family Attached
Storage	Warehouse / Storage
Industrial	Other
Service	Mercantile and Service
R&D	Office
All Other	Assembly
DOD	
Office	Administration
Post Office	Exchange Facilities
Hospital	Hospital
Prison	Security
School	Schools and/or Training
Other Institutional	Schools and/or Training
Housing	Barracks; Duplex Federal housing
Storage	Storage
Industrial	Production and/or Process
Service	Exchange Facilities
R&D	Labs
All Other	Morale, Welfare, and Recreation

It was assumed that all water was heated using either electricity or natural gas. Small percentages of water are heated using fuel oil, propane gas, or other fuels, but these were assumed to be negligible for the purposes of this assessment. Additionally, many DoD sites use central systems to heat water, which typically use natural gas or fuel oil to heat water to very high temperatures or to steam, which then exchange heat with potable water for building use. This is generally less efficient than standalone water heaters in each building; therefore, the projected savings in this assessment are conservative. The amount of water assumed to be heated using electricity versus natural gas was based on Commercial Buildings Energy Consumption Survey 1999 (CBECS) [CBECS 2005] and Annual Energy Outlook 2003 (AEO) data [EIA 2005]. Both of these sources are not Federal-specific. Therefore, adjustments were made to these values according to field experience specifically in the Federal sector. The values used for this assessment, according to building and fuel type, are listed below in Table D.2a. The values gathered from CBECS and AEO are shown for comparison in Table D.2b. Please note that the data in Table D.2b does not accurately represent the Federal sector; electrical use is extremely low and so the values were adjusted appropriately for this analysis.

Table D.2a. Percent of Fuel Use for Water Heating by Building Type *used in the Analysis*

Building Type	% Electricity	% Natural Gas	Total % with Hot Water
Education	49%	49%	98%
Health Care	46%	54%	100%
Lodging	47%	53%	100%
Mercantile & Service	55%	40%	95%
Office	60%	40%	100%
Warehouse	50%	36%	86%
Other	45%	41%	86%
All Others	50%	50%	100%

Table D.2b. Percent of Fuel Use for Water Heating by Building Type *from CBECS / AEO*

Building Type	% Electricity	% Natural Gas	Total % with Hot Water
Education	34%	51%	94%
Health Care	36%	54%	100%
Lodging	36%	53%	98%
Mercantile & Service	30%	44%	82%
Office	33%	50%	91%
Warehouse	24%	36%	67%
Other	30%	44%	82%
All Others	32%	50%	57%

To determine the amount of annual Federal energy savings potential for a given retrofit fixture, energy consumption was determined for a base case scenario as well as for each retrofit scenario. The base case represented the average current flow rate in the Federal sector, which was estimated at 2.75 gpm for both faucets and showerheads [Vickers 2001]. Each retrofit scenario reduced this flow rate to represent a hypothetical situation, where every fixture in the Federal sector was replaced with 2.5 or 2.0 gpm for showerheads, and 2.2, 1.0, or 0.5 gpm for faucets. The difference in energy use between each of these scenarios and the base case approximates the total potential for energy savings in the Federal sector.

APPENDIX E

Conservation Opportunities with Site-Specific Water Process

Appendix E - Conservation Opportunities with Site-Specific Water Process

E.1 Cooling Towers

Cooling towers are often one of the largest water users for large office buildings, hospitals, and industrial-type facilities. Water is lost in a cooling tower through evaporation, bleed-off, and drift. As water is evaporated through the tower, dissolved solids remain in the system and build up over time. To maintain proper water quality, the water must be purged through the "bleed-off." Drift is water lost through large water droplets that are carried by wind. Several technologies and techniques can be used to maintain proper water quality and reduce bleed-off. These are briefly described below.

- Chemical Treatment: sulfuric acid or absorbic acid adjusts the pH of the system, limiting scale build-up, thus reducing bleed-off.

- Side Stream Filtration: filters out sediment and returns filtered water back to tower to reduce the amount of bleed-off needed.

- Copper Silver Ionization and Zeolite Media: an alternative to chemical treatment—copper/silver ions kill bio-matter to reduce scale build-up and also act as seed crystals for the formation of scale (calcite); crystallization is completed in the zeolite media and backwashed out of system daily.

- Ozonation System: an alternative to chemical treatment—ozone disinfects water supplies to reduce bleed-off (reduced chemical cost is an added benefit to the ozone method).

E.2 Boilers and Steam Systems

Large Federal facilities often use boilers and steam systems in central plants, hospitals, large office buildings, barracks, research and development facilities, and industrial and process plants. The amount of water that is consumed by the system depends on the size and water quality, and whether a condensate return is installed and maintained properly. The following bullets briefly describe the techniques that can be used to save water in boilers and steam systems.

- Proper Maintenance: Routinely inspect and maintain steam traps, steam lines, and condensate pumps.

- Leak Detection and Repair: Routinely inspect for leaks in condensate return line and steam lines.

- Condensate Return: Properly maintain condensate return, which recycles condensate for reuse in the system thus reducing water and chemical consumption and cost.

- Blow-down: Minimize blow-down by maintaining adequate water quality through routine inspection and maintenance of boiler water and fire tubes (reducing scale build-up), continuous monitoring and skimming of the blow-down, and automatic chemical treatment to control water quality of makeup water.

- Steam Tracers: Shut off steam tracers in the summer. (Steam tracers are used for freeze protection in the winter.)

- Boiler Efficiency and Size: Replace boilers that are inefficient or over-sized to reduce water requirements.

E.3 Efficient Irrigation

Many Federal facilities have irrigated landscape—office buildings and hospitals usually have peripheral turf or landscaped beds, and military bases commonly have recreation fields and golf courses. These irrigated areas are often sources of large water consumption and are prime targets for efficiency measures. Following is a list of typical technologies and techniques that can help to significantly decrease water irrigation consumption. This is commonly undertaken through Xeriscaping™.

The seven principles of Xeriscaping are:

1. Appropriate Design: Use a design that considers soil types and drainage, limits turf area, etc., so that landscaping requires limited irrigation.

2. Soil Improvements: Apply appropriate nutrients to soil to help maintain healthy plants, which results in more resilient and drought resistant plants.

3. Reduced Turf Area: Limit turf to areas for recreation purposes only.

4. Mulching Beds: Mulch reduces moisture evaporation off surface of beds and controls weed growth.

5. Efficient Irrigation: (also see retrofit options below)

- Early morning or late evening watering reduces evaporation.
- Automatic irrigation controls.
- Appropriate watering schedule to fit plant need and climate.
- Deep watering less often.
- Soil moisture sensor (tensiometer) or rain sensor connected to controls to avoid over-watering.

6. Climate-appropriate plants: Native and other low-water-demand plants that are specifically geared for the particular region reduce both water requirements and maintenance.

7. Maintenance:

   - Proper maintenance and adjustments of sprinkler heads ensures appropriate watering.
   - Routine inspection of irrigation system for leaks and broken heads.
   - Maintain weeds, fertilize properly, and prune as recommended.

Efficient Irrigation Retrofit Options:

- Low-Volume Drip System: Applies water at a constant rate directly to the root zone of the plant, eliminating runoff and over-spray and limiting evaporation

- Sub-Surface Drip System: Delivers water to root zone of the plant through underground piping, eliminating runoff, over-spray, evaporation and reducing maintenance requirements.

- Weather Based Irrigation System: Control system that irrigates based on the evapotranspiration rate requirement of the landscape by downloading this information from a local weather station. This type of system can be fine tuned to deliver the exact water needs of the plant.

- Reuse System: Reuses water from other applications, such as cooling tower bleed-off or other reclaimed water, to irrigate recreational fields or golf courses. (For example, Fort Carson Army Base uses treated water from the sewer treatment plant to irrigate the Base’s golf course.)

E.4 Ozonated Laundering

Ozone acts as a biocide destroying bacteria by rupturing cell membranes. In this way, ozonated laundering systems act as a bleaching agent that disinfects fabric. Ozonated laundering systems are most appropriate for applications where laundry does not get overly soiled and where disinfection is an important feature that is needed, such as hospitals. Also, ozone laundering is appropriate for facilities that launder large amounts of towels and sheets, such as barracks and other lodging type buildings.

Key benefits to ozonated laundering are:

- Water Savings: Ozone process requires no rinsing.
- Energy Savings: Heated water is not required in the ozone process because cold water absorbs more ozone.
- Elimination of Detergent: Ozone replaces the need for detergent (except in heavily soiled clothing, where detergent is combined with ozone).

E.5 Leak Detection and Repair

Water distribution systems often are huge sources of water loss, especially in the case of military bases that have old (pre-1940s) systems. Leaks often occur from loose joints or service connections in the system and corrosion, splits, and cracks along the piping wall. Typically, leak detection is done as part of a comprehensive water audit to help determine the source of unaccounted-for water consumption at the site. Leak detection is often done by outside contractors because determining the exact location of a leak requires training and appropriate tools. Sample leak detection technology includes listening devices (sonic for metal piping or ultrasonic for PVC piping) aerial thermal imaging, and sub-floor water leak alarm systems.

Some of the key benefits to regular system audits, leak detection, and repair programs are as follows:

- Reduced water loss
- Lowered cost for high-quality water (pumping, treating, etc.)
- Reduced operating costs
- Increased knowledge of the system

- Reduced legal liability and potential property damage caused by leaks, thus lowering insurance costs
- Safer and more reliable system (less likely to have contaminated water supply, increased reliability of fire protection systems)
- Better use of resources that ensure more reliable supply for the future.

E.6 Single-Pass Cooling

Single-pass or once-through cooling systems provide an opportunity for significant water savings. In these systems, water is circulated once through a piece of equipment and then disposed to drain. By comparison, to remove the same heat load, single-pass systems use 40 times more water than a cooling tower operated at 5 cycles of concentration.

Operations and Maintenance Improvements:

- Ensure that procedures are in place to turn off the water supply when the single-pass cooling equipment is not in operation. Some equipment, both old and new, allows water to constantly run, even when the equipment is turned off.
- Check entering and leaving water temperatures and flow rates to ensure they are within manufacturer's recommendations. For maximum water savings, the flow rate should be near the minimum allowed by the manufacturer. This can produce significant water savings.
- Balancing valves are sometimes not installed, or they are not properly adjusted and left in the "wide open" position. Once the valves are properly set, they should be marked (or fixed) in position to avoid future adjustment.
- Ensure that all appropriate employees are trained in O&M procedures.

Retrofit/Replacement Options:

- Modify equipment to operate on a closed loop that recirculates the water instead of discharging it.
- When the opportunity arises, replace the water-cooled equipment with more efficient air-cooled equipment.
- Find another use for single-pass effluent, such as boiler make-up, cooling tower make-up, supply or landscape irrigation. Savings for this reuse include both the associated water procurement costs as well as the sewer charges.

- Be aware that some effluent may be contaminated (such as that coming from degreasers, hydraulic equipment, or cooling systems) and not fit for reuse. Contaminated effluent should never be used in boilers because of the potential to hamper proper boiler operation.

APPENDIX F

Water and Sewer Historical Rate Data at DoD Sites

Appendix F - Water and Sewer Historical Rate Data at DoD Sites

A study of DoD rates [Fitzpatrick et al. 1995] in the U.S. Army Forces Command (FORSCOM) sites found combined water and sewer rates at 10 Army bases vary between a low of $0.55/1,000 gal to a high of $4.34/1,000 gal. The study found the variance to be more a function of inconsistencies in rate calculation from site to site than in actual cost of water. The weighted (by daily water consumption) average combined cost from these 10 FORSCOM sites is $1.29/1,000 gal. Table F.1 shows the findings of this study. It should be noted that rates provided in this study are not current, and further investigation into varying water rates among military installations should be examined because it greatly affects the cost-effectiveness of water efficiency technologies. However, this investigation is out of the scope of this report.

Table F.1. FORSCOM Average Water and Sewer Rates

Installation	Average Water Use (million gal/day)	Water Rates ($/1,000 gal)	Sewer Rates ($/1,000 gal)	Combined Water Sewer Rates ($/1,000 gal)
Fort Bragg	6.06	$0.34	$0.21	$0.55
Fort Campbell	4.67	$0.43	$0.54	$0.97
Fort Carson	2.84	$1.82	$1.42	$3.24
Fort Dix	1.92	$1.81	$2.53	$4.34
Fort Drum	2.02	$0.34	$1.12	$1.47
Fort Hood	6.22	$0.27	$0.32	$0.59
Fort Lewis	6.01	$0.23	$0.45	$0.68
Fort Polk	5.02	$0.92	$0.91	$1.83
Fort Sam Houston	3.40	$0.34	$1.42	$1.76
Fort Stewart	3.11	$0.14	$0.44	$0.58
Weighted Average		**$0.55**	**$0.74**	**$1.29**

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