

The Potential of Water Saving and Water Capturing Innovations: A Case Study of Albuquerque Single Family Homes

By

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ABSTRACT

The need for innovative water saving and water capturing strategies in single family homes is evident by many U.S. cities' vulnerabilities to drought, climate change and population growth. The intrinsic value of modern innovations is that they offer the potential to produce the largest, most cost effective and environmentally sound alternative source of water required to meet current and future demand. Moreover, recognizing the intimate relationship between water use and the energy consumed in conveyance, treatment, end uses and waste treatment, may allow policy makers to meet water and energy use reduction goals simultaneously, as well as enhance water and energy security opportunity for current and future populations.

Using the City of Albuquerque as a case study, three innovations were examined to demonstrate the potential water, energy and monetary savings possible for the Albuquerque Bernalillo County Water Utility Department and its single family home customers. The usage of these three innovations was projected to 2030 and their associated benefits discussed with regard to their potential for enhancing water and energy security. Two in-home innovations, the dual-flush toilet and the Shower Water Conservation System, the latter an innovation designed by the author of this report, Andrew Funk, as well as one exterior innovation, rain water harvesting, were analyzed for their potential alternative source water production, and energy and monetary savings.

Using water saving and water capturing innovations in Albuquerque Bernalillo County Water Utility Department single family homes offers access to a significant volume of least cost alternative source water. These types of innovations empower the water utility and its customers to use water and energy resources more efficiently, save money and further decrease Albuquerque's reliance on groundwater, better equipping the City to manage future drought, climate change and population growth.

Key Words: Water Conservation, Water Efficiency, Energy Efficiency, Climate Change, Water Energy Nexus, Water Security, Energy Security

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Andrew Funk received his Bachelor of Science from the University of California at Davis in Environmental Policy, Analysis and Planning. While there, he worked in the Tahoe Research Group, contributing to research focusing on contributing factors to Lake Tahoe's declining water clarity. Mr. Funk then expanded his understanding of water resources at the University of New Mexico Water Resources Program. Mr. Funk's graduate research highlights the potential water, energy and monetary benefits associated with using water saving and water capturing innovations in an environment of drought, climate change and population growth. These benefits are quantified and discussed with regard to their potential for enhancing 21st Century water and energy security. His Professional Project report is accessible at:

<https://repository.unm.edu/dspace/handle/1928/2589>

While at UNM, Mr. Funk also worked at the New Mexico Office of the State Engineer. Here, he researched water conservation and climate change planning strategies used in other U.S. states and contributed to the Climate Change Water Impacts Work Group 2006 report to the State Engineer and Governor Richardson, "The Impact of Climate Change on New Mexico's Water Supply and Ability to Manage Water Resources". The latter is accessible at:

<http://www.ose.state.nm.us/PDF/ClimateChangeImpact/completeREPORTfinal.pdf>.

Mr. Funk graduated with a Master of Water Resources in December 2006. He now works in Boulder for Aquacraft Inc, a water engineering and management consulting firm.

NOTE: This paper is a summary of a Professional Project report by Andrew Funk, submitted in partial fulfillment of the requirements for the degree of Master of Water Resources at the University of New Mexico. This report was approved December 2006 by the following graduate committee: Professor of Economics Janie Chermak (co-chair), Professor of Environmental and Water Resources Engineering Julia Coonrod (co-chair) and Anne Watkins, Special Assistant to the New Mexico State Engineer.

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1.0 Introduction

According to the EPA, “more than 36 States expect to experience water shortages over the next 10 years, even without drought” (EPA, 2003). Thus, water resource managers across the U.S. are increasingly forced to acknowledge the severity of potential water shortages. Looming in this 21st Century are water resource challenges inherent in drought, climate change and population growth. These types of challenges, while daunting, are leading many to understand the benefits associated with using resources more efficiently. Clearly, the best hope for engaging this Nation’s future water supply challenges lies in a comprehensive approach to managing and conserving it. The research presented in this article evaluates the potential of innovations, as well as begins to enhance the understanding of their role in 21st Century comprehensive planning. This research, which used the City of Albuquerque as a case study, reflects the findings of Andrew Funk’s graduate research at the University of New Mexico’s Water Resource Program. The breadth of these findings may be downloaded at: <https://repository.unm.edu/dspace/handle/1928/2589> .

Using water saving and water capturing innovations in Albuquerque single family homes offers access to a significant volume of least cost alternative source water. These types of innovations empower the water utility and its customers to use water and energy resources more efficiently, save money and further decrease Albuquerque’s reliance on groundwater, better equipping the City to manage future drought, climate change and population growth.

This graduate research highlights the benefits of using three innovations as adaptive strategies for coping with the water scarcity challenges inherent in a 21st Century of drought, climate change and population growth. In doing so, these research findings are intended to enhance the understanding of the intimate relationships between water and energy demand in the urban environment. That is, there are inextricable linkages between the water purveyor’s treatment and delivery, the end user’s water demands and the energy resources consumed at each stage of the municipal water system. The significant benefits of recognizing these linkages, within the context of two innovations, are estimated in this study. Additionally, the benefits associated with using water saving and water capturing innovations offer the potential to enhance both water and energy security.

Water security is enhanced because water saving and water capturing innovations generate an Alternative Water Supply that may be used to meet current and future demands. That is, expanding above ground storage tank capacity, or (arguably) even better, aquifer storage and recovery systems may enhance water system flexibility. How these types of innovations enhance energy security may be less evident, but their ability to do so is equally important. An innovation that enables end users to use water more efficiently or one that captures rainwater where it falls directly impacts the energy demand connected to urban water supply systems.

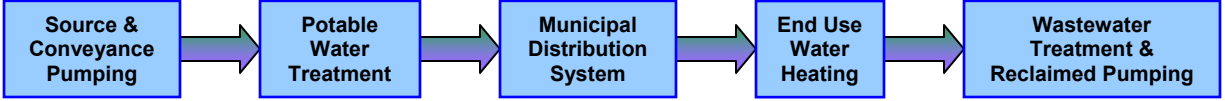


Figure 1 Stages of water supply where energy is used, Redesigned from (Cohen *et al.*, 2004)

Beginning at the source, energy resources are consumed to pump either surface or groundwater (or both) and move it to where it is needed via conveyance systems. At the drinking water treatment facility, energy is consumed to purify municipal water to National standards with a series of treatment processes and pumping. Energy is then consumed to distribute potable water throughout the municipal system. The largest energy demands occur at the end user level where water is heated for industrial, commercial and residential uses. Finally, energy is used to treat wastewater and dispose of (or reuse) the reclaimed water resource (Cohen *et al.*, 2004).

Using the City of Albuquerque, this research quantified the Alternative Water Supply accessible from using three innovations, the potential energy savings from decreasing the demands at each of the five stages in Figure 1 and the resulting monetary savings. To determine the water and energy security benefits, the analyses extent was narrowed to single family homes existing within the service area boundary of Albuquerque's largest water purveyor, the Albuquerque Bernalillo County Water Utility Department (ABWUD).

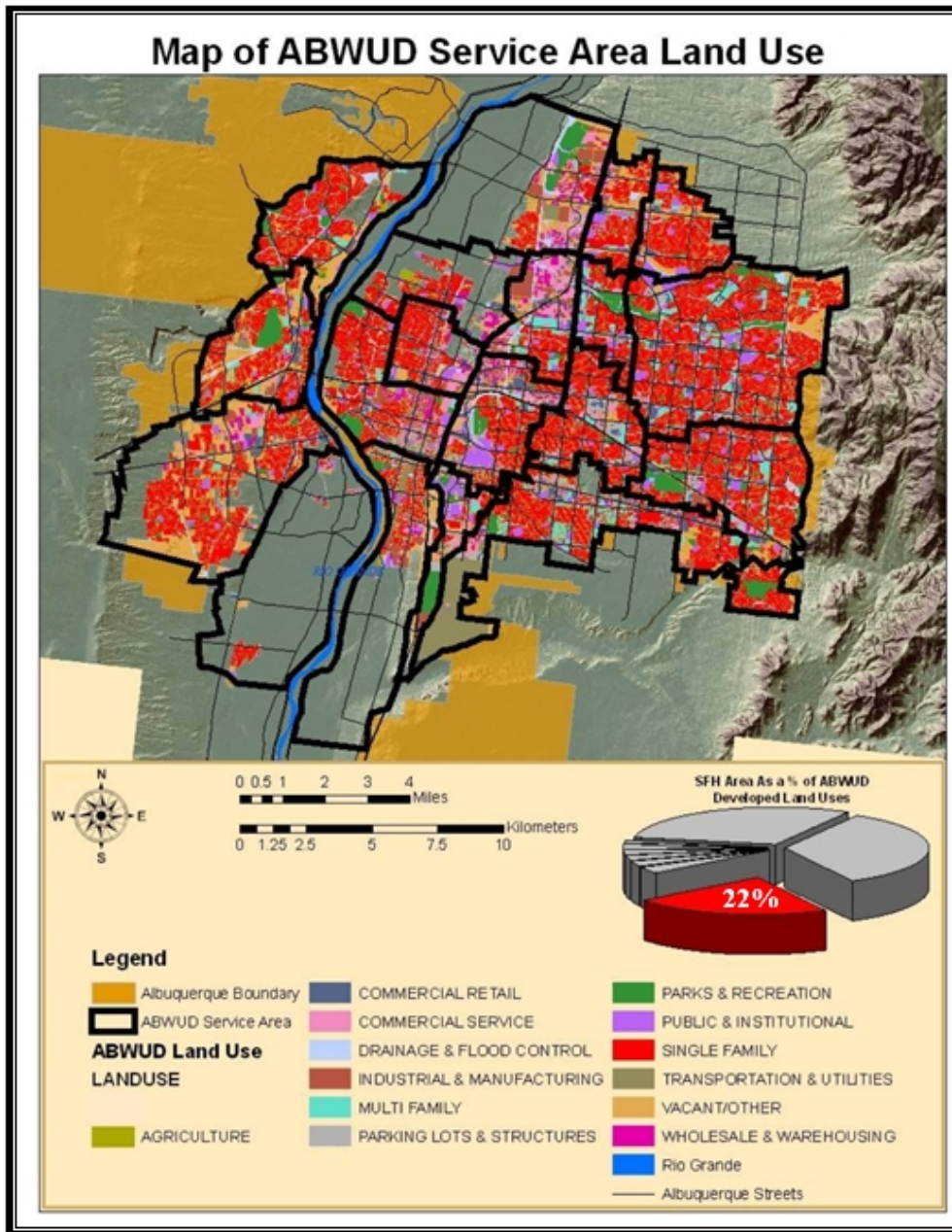


Figure 2 ABWUD 2003 service area and single family home zoned (land use) area

While ABWUD and its residential customers represent a relatively small portion of water and energy demand compared to the greater U.S., it is important to keep in mind that conservation and capture innovations and their potential water and energy benefits, as estimated in this study, could be estimated for a broader range of cities across the Nation. Stated differently, the water and energy security challenges inherent in drought, climate change and population growth are likely to impact much of the U.S.; thus, this study's innovation analyses may very well be transferred and used for other State water systems.

2.0 Albuquerque Faces 21st Century Water Security Risks

For many years now, Albuquerque has relied exclusively on groundwater from its underlying aquifer to meet municipal demand. However, 20th Century water managers recognized the imminent need for another source of water and secured a portion of upper Colorado River Basin (assumed average) flows. Therefore, beginning in 2008, Albuquerque will begin using 90% surface water (diverted from the San Juan Basin and channeled 26 miles under the Continental Divide) and 10% groundwater (Stomp, 2006). To be sure, this is a large scale, complex and expensive innovative solution to Albuquerque's water supply challenges. Unfortunately though, as we advance into the 21st Century, we are all faced with the new water supply challenges inherent in drought, climate change and population growth.

Drought has always occurred in the U.S., and always with some degree of variability. Climate modeling efforts however, are now predicting that there is a high likelihood that climatic changes, along with above average temperatures, will enhance the historic variability; thus, generating more extreme drought events (OSE, 2006). So what does this mean for water supplies?

Smaller winter snow pack accumulation with an earlier and faster spring snowmelt, coupled with more intense but possibly less frequent rainfall events, will likely impact reservoir flood control release regimes so that the volumes needed to meet peak summer demands may no longer be available. Higher temperatures are expected to enhance water supply risks by increasing sublimation, evapotranspiration, soil dryness and decreasing stream flows (OSE, 2006).

Adding to the water supply challenges is population growth. This variable alone may pose challenges beyond the capacity of many U.S. regions' water supplies. As urban populations increase, eventually so will the demand for potable water and the energy required to provide, treat and heat it.

For Albuquerque, these factors pose considerable 21st Century water security risks. The City has been mining groundwater unsustainably for some time now, resulting in drawdown of the water table and subsidence in some areas (City of Albuquerque, 2005). Moreover, its new surface water supply project may not be able to sufficiently meet the needs of a growing population. The source of Albuquerque's new surface water supply is diverted from the upper San Juan Basin, where the water resource impacts of drought and climate change are likely to reduce snow pack, runoff and surface flows (Saunders *et al.*, 2005). These conditions possibly would not pose too great a challenge if there weren't so many competing uses of surface flow in the San Juan Basin, and the greater Colorado River Basin. However, since there are competing demands for the source of Albuquerque's new surface water supply, then the City may be forced to share shortages (FWS, 2005). Therefore, there are no guarantees that the City will always have access to its full diversionary water right in the coming decades, possibly forcing a return to groundwater dependence.

3.0 What Can Be Done?

While Albuquerque's water resource future may appear grim, there are adaptive measures that can be adopted to empower ABWUD and its customers to manage water shortages. There

are water resource managers in the State of New Mexico who understand the need to engage in a comprehensive statewide urban (and agriculture) water conservation planning effort. This plan would clearly define and mandate by statute the State and Local Government and Water Purveyor roles in designing and implementing programs (Funk, 2007).

Comprehensive planning is an important topic that is likely to receive much more attention in the near future. This study's analyses highlight the benefits of innovative adaptation strategies which are expected to be included in a broader more comprehensive approach to coping with water resource challenges of drought, climate change and population growth. Two categories of innovative adaptation strategies, water conservation and water capture, hold the potential to generate significant opportunities for coping with these challenges.

4.0 Using Water More Efficiently

This study's analyses and discussions regarding water conservation focus on current and newly emerging technologies that decrease total per capita water demands by increasing efficient water use by end users, without negatively impacting the quality of life. The first innovation, the Dual Flush Toilet, enables end users to use considerably less potable water for flushing. The second innovation, the Shower Water Conservation System, makes it possible for users to not only use potable water more efficiently, but also use heated water more efficiently. Possibly the most attractive feature of these two innovations is that they do not require significant behavioral changes for their benefits to be realized. That is, end users can continue to use the toilet or shower with the same frequency and or duration as they normally do and still save water and energy resources and save money. Moreover, greater efficiency at the end user level translates into resource and monetary benefits at the water utility level.

The Dual Flush Toilet and Shower Water Conservation Systems' potential benefits were estimated using a four step process. According to Gleick *et al.* (2003, p.41), "the first step in evaluating the savings potential of water conservation options is to establish a reliable baseline of current water use patterns". Therefore, the first step this study took was to estimate the Albuquerque single family home baseline (or status quo) "per capita" toilet and shower water and energy demands and costs. This initial analysis exposed new and valuable information regarding the City's household indoor water use patterns. That is, due to the combined effectiveness of the 1992 National Energy Policy Act flush volume standards for toilets bought and sold in the U.S., and the ABWUD toilet rebate program, Albuquerque single family homes current per capita shower water demand exceeds that of current per capita toilet water demand. This new information, while contrary to what earlier studies' findings may have estimated almost a decade ago, provides insight into what type of targeted conservation strategies may be appropriate for ABWUD household customers today.

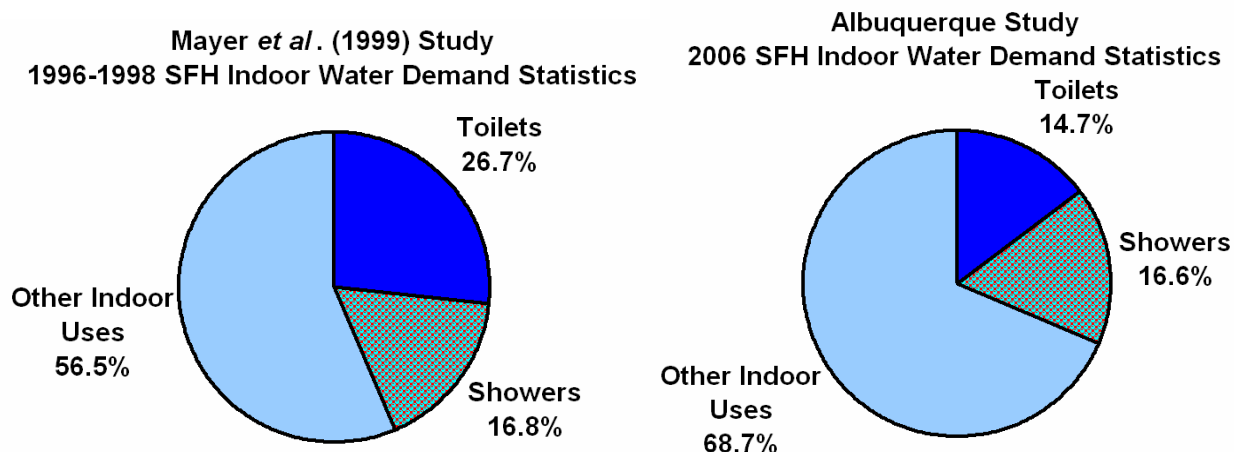


Figure 3 Mayer et al. (1999) & Albuquerque 2006 single family home per capita toilet and shower water demand statistics

The second step involved estimating the “per capita” toilet water and energy demand reductions and avoided costs under four different scenarios of single family home Dual Flush Toilet and Shower Water Conservation System usage. Third, this study generated ABWUD single family home population projections to estimate the toilet and shower water and energy demands and costs to the year 2030. Finally, the potential water, energy and monetary benefits from using the aforementioned innovations were estimated over the same 24 year time horizon. These benefits are discussed in terms generating an Alternative Water Supply to meet current and future demand, reducing demands on electricity production and natural gas; thus, demonstrating their ability to enhance water and energy security.

5.0 The Dual Flush Toilet

The Dual Flush Toilet offers significant resource and monetary benefits by presenting the user with the option of two flush volumes. That is, with each flushing event the user can choose between two flush volume buttons, 1.6 gallon per flush for solid waste and 0.8 gallon per flush for liquid waste. To determine the potential benefits the baseline single family home per capita toilet water demand was first estimated between 1994 and 2030.

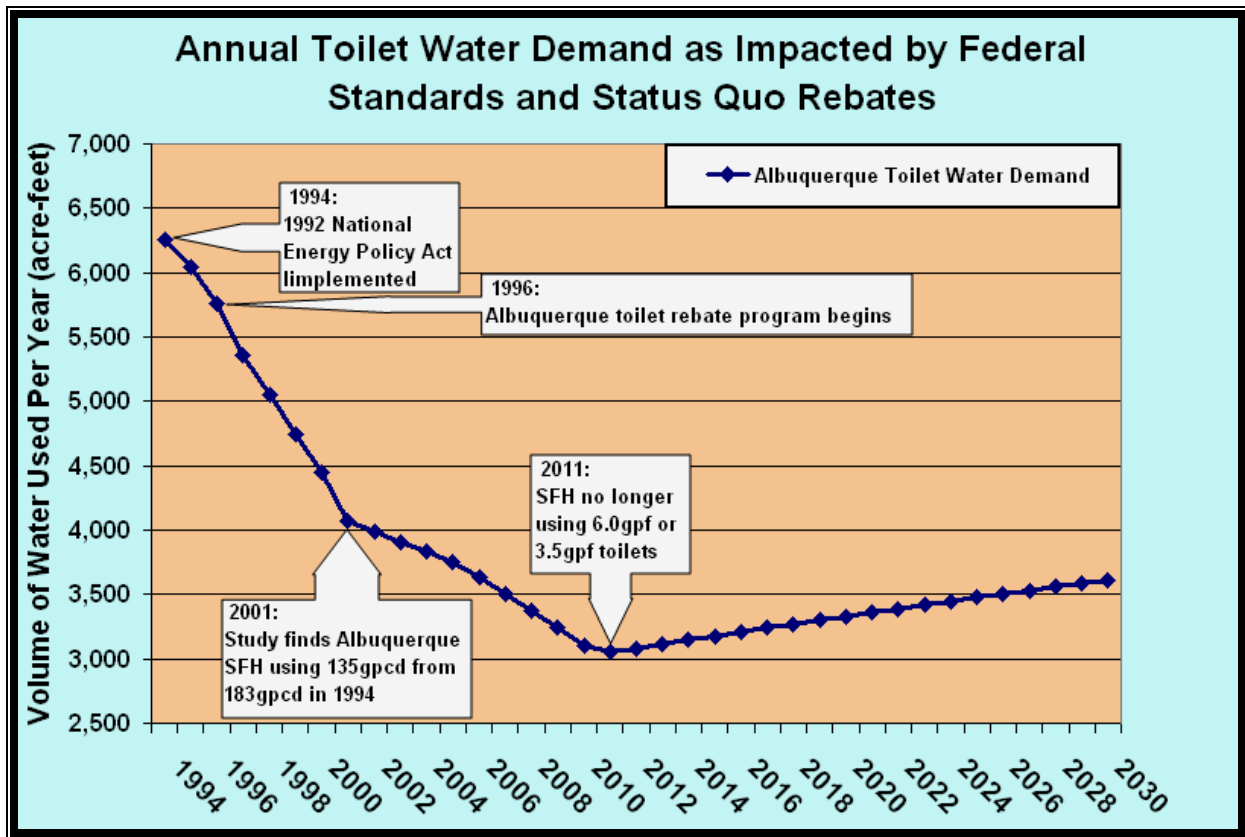


Figure 4 Estimated and projected Status Quo trend in single family home toilet water demand

The total per capita toilet water demand plot above tells an interesting story. 1994 is the year the 1992 National Energy Policy Act was implemented, requiring toilet model bought and sold in the U.S. be 1.6 gallon per flush. Prior to then toilet models were designed to use either 6.0 or 3.5 gallon per flush. Two years later, ABWUD implemented its toilet rebate program, offering its customers a rebate as an incentive to replace their older less efficient toilet model with a 1.6 gallon per flush model. In 2001, Western Resource Advocates released a study saying that Albuquerque single family homes had reduced their water use from 183 gallons per person per day (in 1994) to 135 gallons per person per day. After 2001, and looking a little to the future, this study estimates that by 2011 ABWUD single family home customers will no longer be using older 6.0 or 3.5 gallon per flush toilets. Beyond 2011, even though homes are only using 1.6 gallon per flush models, population growth is relentless with regard to its impact on total per capita toilet water demand.

Plotting the above baseline, or Status Quo, toilet water demand along side this study's most conservative retrofit scenario, where 60 % of ABWUD single family homes are using dual flush toilets and 40% are using a mix of 6.0, 3.5 or 1.6 gallon per flush toilet models, demonstrates the potential water resource benefits. Clearly, there is a volumetric difference in total water demand between the two plots. Possibly less clear are the slopes of these lines, which are also different.

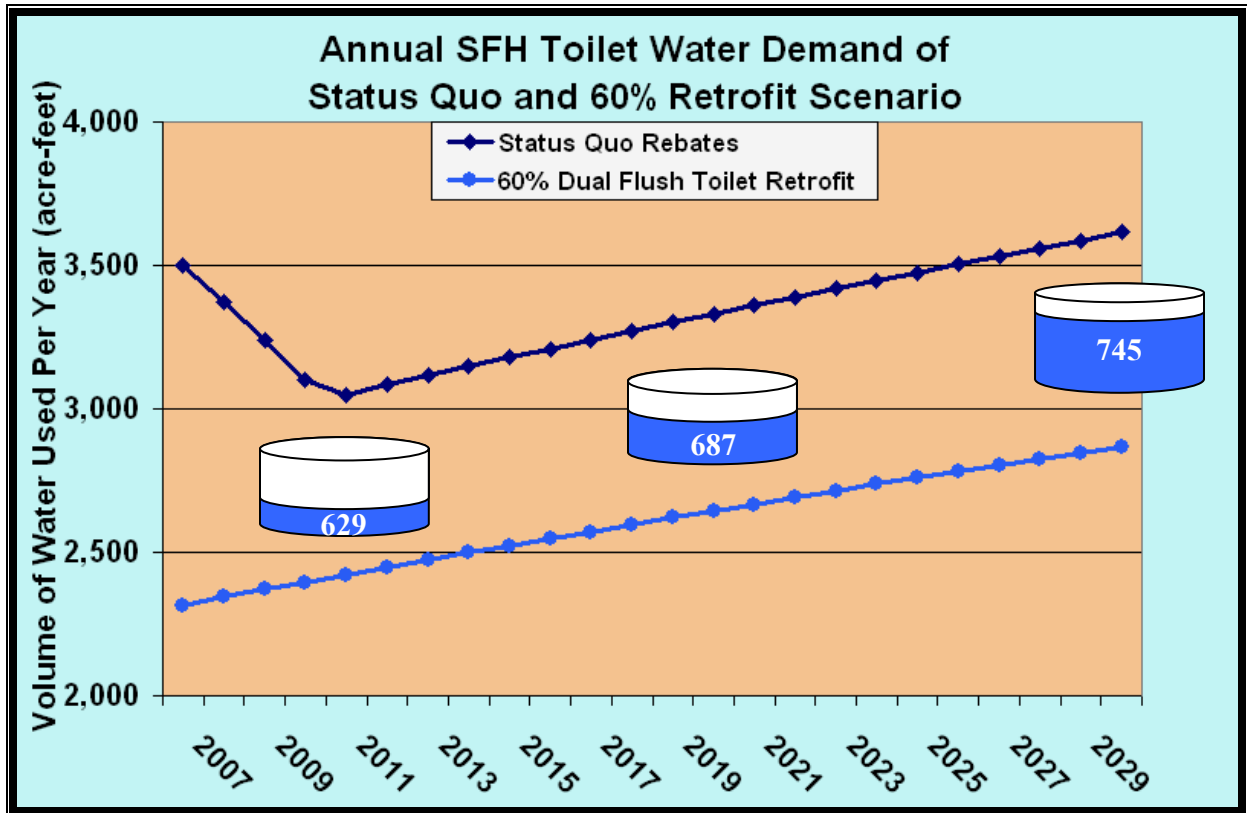


Figure 5 Projected single family home per capita toilet water demand

The difference between these two plots highlights the amplified water savings associated with using the dual flush toilet over time. That is, this study estimates a savings of 629ac-ft in 2011, 687ac-ft in 2020 and 745ac-ft in 2030. Each year these significant volumes of Alternative Water Supply may be used to meet current growing demands or stored to meet future demands.

Increasing the efficiency of toilet water use also impacts energy demands. At ABWUD's facilities both electricity and natural gas are required to pump water, treat water to drinking water standards and treat wastewater. Thus, using the aforementioned Status Quo toilet water demand estimates, similar Status Quo and 60% retrofit scenario benefits were estimated for the electricity and natural gas demands of toilet water.

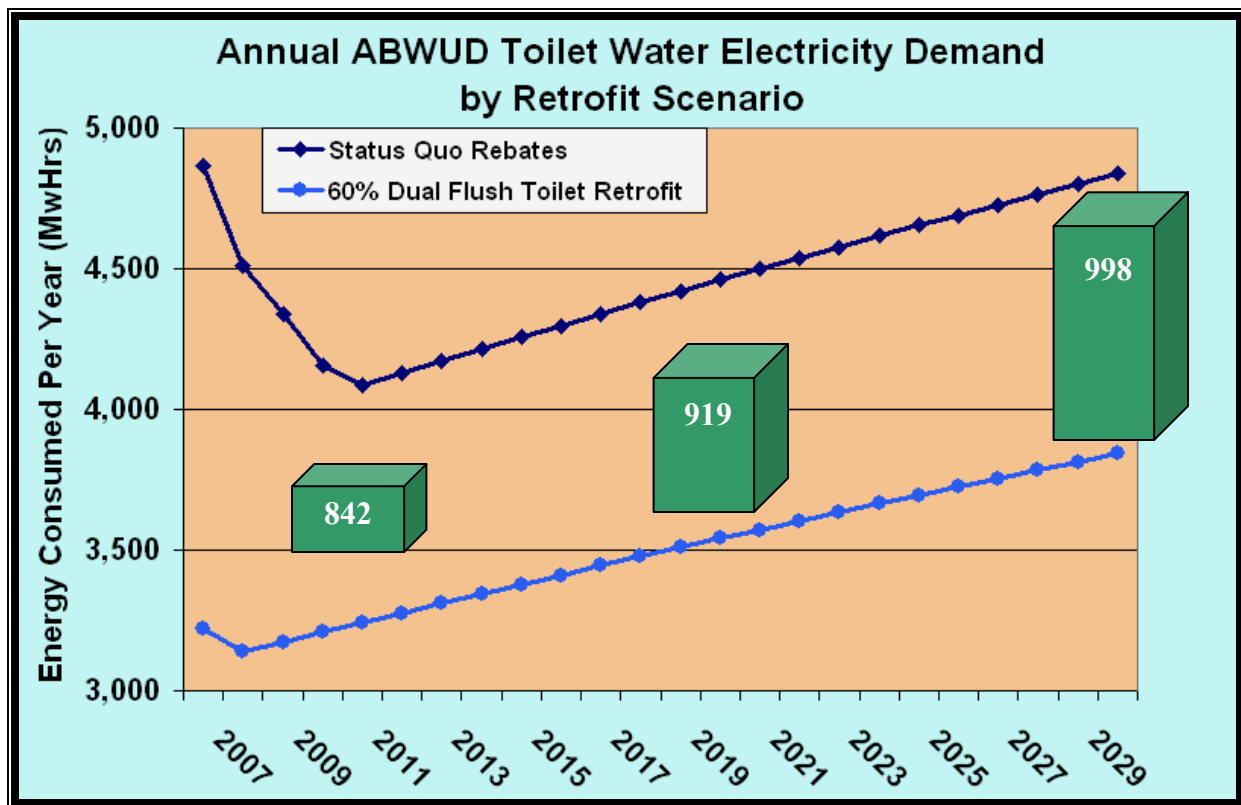


Figure 6 Projected single family home per capita toilet water electricity demand

Again the plots' differing slopes highlight the benefits associated with using the dual flush toilet over time. This study estimates an electricity demand reduction of 842 Megawatt-hours in 2011, 919 Megawatt-hours in 2020 and 998 Megawatt-hours in 2030. Under this scenario, every year offers the potential of a larger demand reduction as population increases and a consistent 60% of single family homes use the Dual Flush Toilet.

To begin to understand what these electricity savings may represent, it is helpful to know how much electricity a Megawatt-hour is in terms of household demand. In 2005, Albuquerque single family homes consumed an average 7.09 MwHrs per home (PNM, 2006a). Thus, the electricity demand reductions revealed in this study are significant.

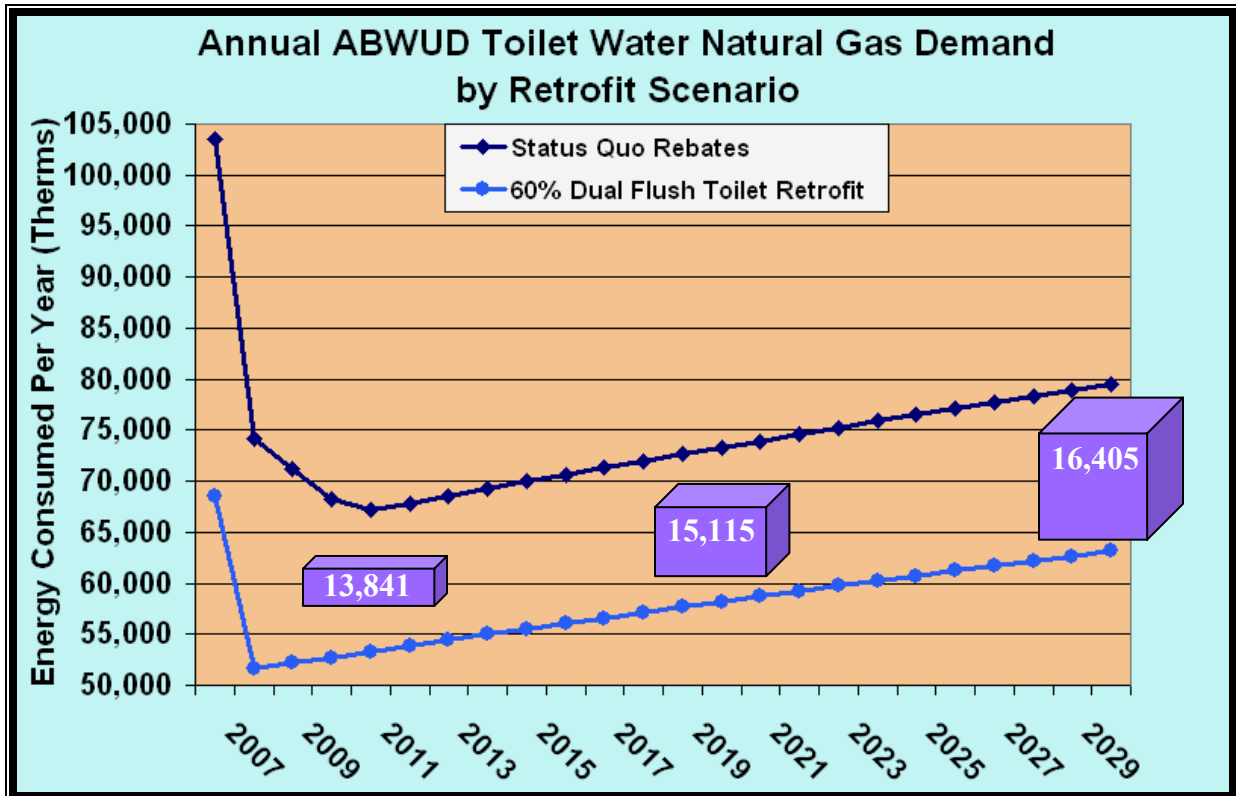


Figure 7 Projected single family home per capita toilet water electricity demand

As with electricity, Dual Flush Toilets offer the potential to reduce natural gas demands, since it is consumed in some of ABWUD’s pumping and wastewater treatment¹. Under the same 60% retrofit scenario, this study finds that natural gas savings are 13,841 Therms in 2011, 15,115 Therms in 2020 and 16,405 Therms in 2030. To put these savings in perspective, Albuquerque single family homes used an average 664 Therms per home in 2005 (PNM, 2006a). The volumes of natural gas saved each year may be used to meet other demands or stored to meet future ones.

6.0 The Shower Water Conservation System

The Shower Water Conservation System is a newly emerging innovation designed exclusively by (and U.S. Utility Patent Application Pending status held by) this report’s author, Andrew Funk. The potential water saving benefits of this innovation are not as substantial as those associated with using Dual Flush Toilets. However, since this innovation enables end users

¹ The sudden drop in natural gas demand in 2008 is partly a result of more toilet retrofits under the Status Quo condition, but is largely due to the opening of the San Juan Chama Drinking Water Treatment Plan & Finished Pump Station. In 2008 the city will only use 10% groundwater. Groundwater well and booster pumping in 2004 consumed 818,886 hundred cubic foot of natural gas. A 90% reduction in groundwater use will reduce ABWUD natural gas demand for providing water.

to not only use water more efficiently, but also use heated water more efficiently, then the potential for energy savings gets much more interesting.

Essentially, the Shower Water Conservation System eliminates the unnecessary water and energy waste normally lost down the drain, while individuals wait for the water to reach an acceptable temperature before stepping into the shower. One important feature that separates this system from Hot Water on Demand and Hot Water Recirculating Systems is that it functions completely independent of an energy source. The system's main function is to collect cold/lukewarm water before it flows from the shower head (or faucet) and to slowly re-inject it back into the hot water stream flow during showering.

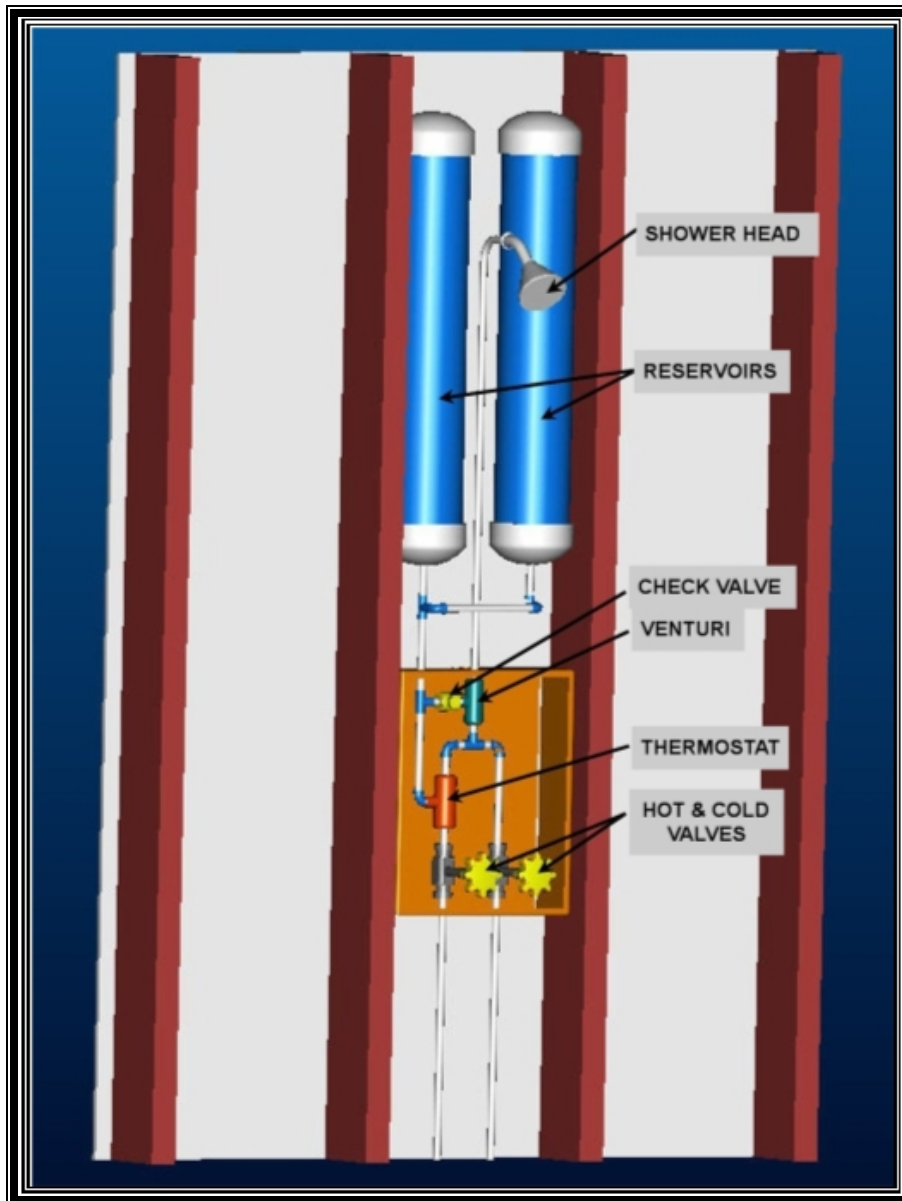


Figure 8 The Shower Water Conservation System (basic design)

As the hot water valve is opened the initial water temperature may be anywhere between 40°F to 120°F or higher. The average preferred showering temperature though, is 105°F (Gleick *et al.*, 2003). Thus, depending on the plumbing between the shower and the water heater, a significant volume of previously heated water is normally discarded down the drain while waiting for the preferred water temperature. This study estimates that a typical three person single family home loses over 1,400 gallons down the drain annually waiting for hot water from the water heater to reach the shower head. The Shower Water Conservation System eliminates this unnecessary wasting of water and energy resources in the following way.

When cold/lukewarm water flows through the Thermostat, the valve is open and the water is directed to the two Reservoirs. When the water reaches 105°F the Thermostat closes and hot water is then redirected toward the showerhead. On its way there it flows through a Venturi. The Venturi's narrow section is connected to the Reservoirs via a one way Check Valve. Since pressure is at its least in the Venturi's narrow section, then the stored cold/lukewarm water, with a greater force due to gravity and some suction, is injected into the hot stream flow. Here the heat energy of the hot water stream flow thermodynamically reheats and absorbs the cold/lukewarm water. Throughout the shower event the cold/lukewarm water is injected at a rate that has a negligible impact on the shower water temperature. Therefore, individual showering events may occur without wasting the initial (previously heated) cold/lukewarm water and the energy resources consumed for potable treatment, delivery, end-use water heating and wastewater treatment.

As with the toilet analysis, the Albuquerque single family home total per capita shower water demand was estimated and compared to four different retrofit scenarios. The comparison with this study's (more conservative) 60% retrofit scenario assumes that 60% of ABWUD single family home customers are using the system and 40% are not. Since shower water demands increase over time as population increases, then it is important to consider new and innovative solutions that increase efficiency of each showering event.

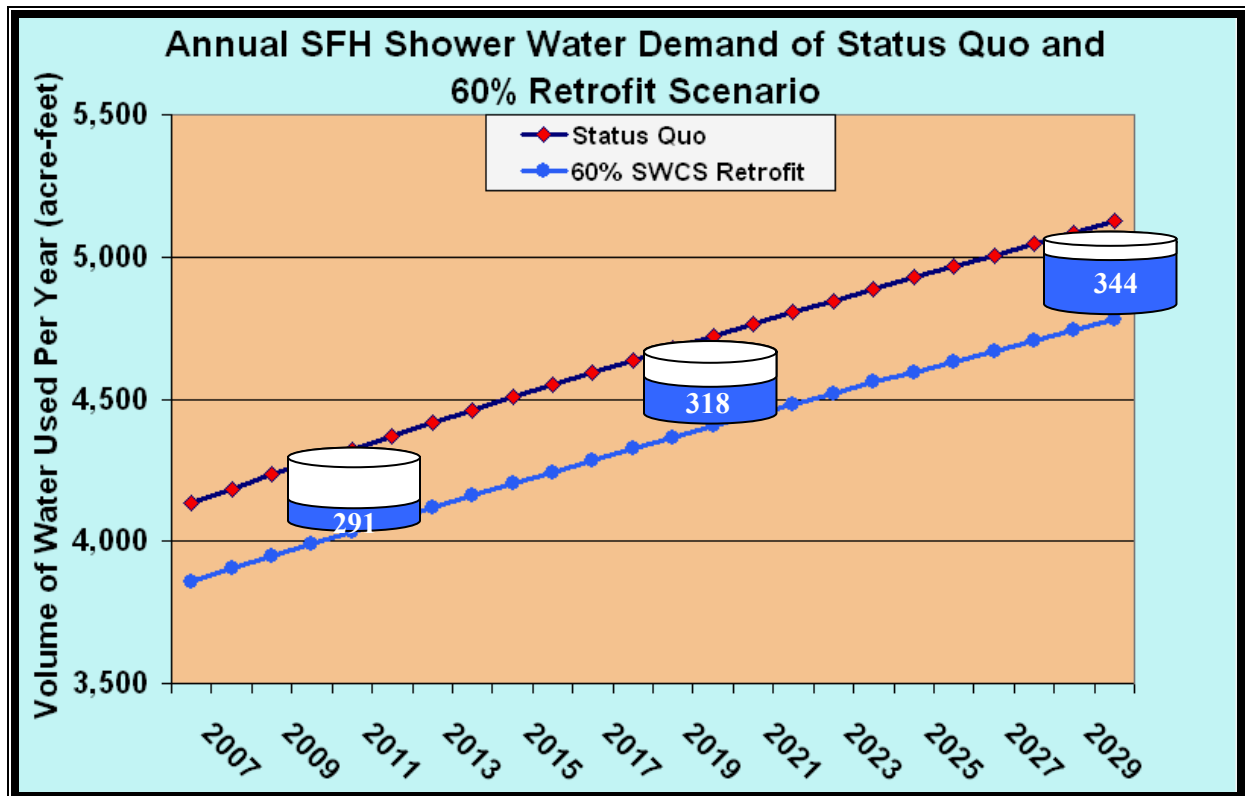


Figure 9 Projected single family home per capita shower water demand

This study finds that the water saving benefits of the Shower Water Conservation System translate into 291ac-ft in 2011, 318ac-ft in 2020 and 344ac-ft in 2030 of Alternative Water Supply that may be used to meet either current demand each year or stored to meet future years' demands.

Since this system enhances efficient use of heated water with each showering event, then the total electricity and natural gas demand reductions extend beyond those that occur at the utility level for pumping, drinking water treatment and wastewater treatment. Moreover, heating water is highly energy intensive, so the estimates under this study's 60% retrofit scenario, even though conservative, are noteworthy.

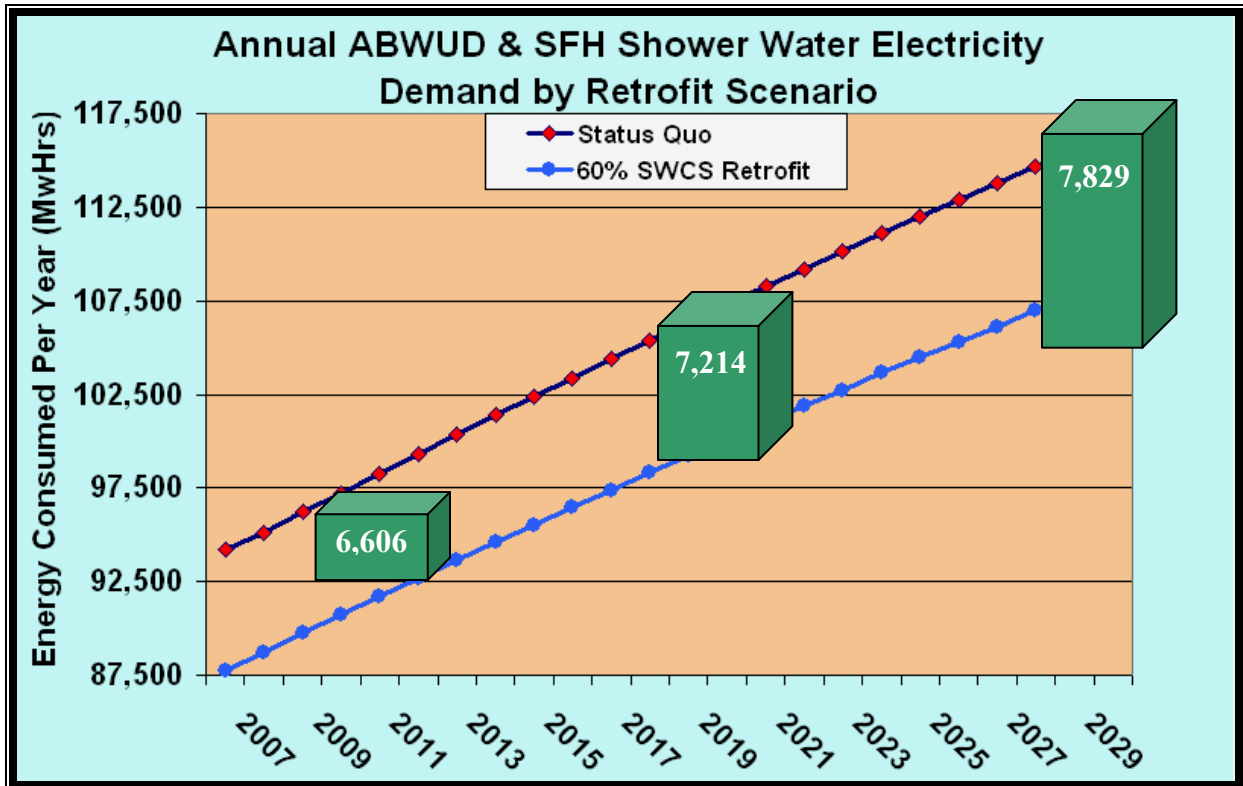


Figure 10 Projected ABWUD & single family home per capita shower water electricity demand

This study estimates that the combined ABWUD and single family home electricity demand reducing potential under the above scenario is 6,606MwHrs in 2011, 7,214MwHrs in 2020 and 7,829MwHrs in 2030. These significant reductions are eight times the electricity demand reducing potential offered by single family homes using Dual Flush Toilets. These reductions lead to less demands on thermoelectric power generation and thus, lead to lower greenhouse gas emissions².

² Albuquerque's electricity largely (about 46%) comes from the San Juan Generating Station. This closed loop system consumptively uses water and burns coal to generate electricity.

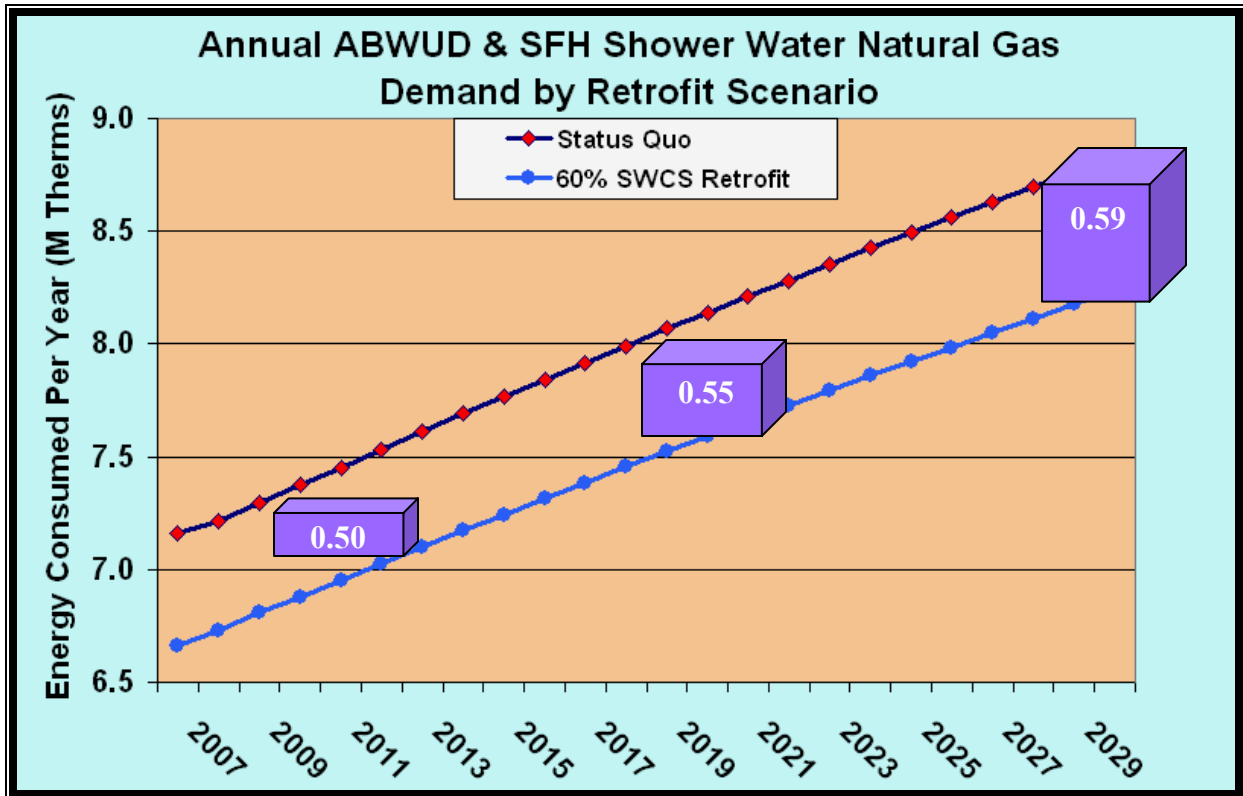


Figure 11 Projected ABWUD & single family home per capita shower water natural gas demand

When one considers that about 60% of U.S. households use natural gas water heaters to heat their shower water, it is clear that any innovation that increases hot water use efficiency is mutually beneficial to both the water utility and its customers (Wendt *et al.*, 2004). Here, the combined ABWUD and single family home natural gas savings are estimated at 0.50 Million Therms in 2011, 0.55 Million Therms in 2020 and 0.59 Million Therms in 2030. These savings are thirty six times the estimated potential natural gas savings when single family homes use Dual Flush Toilets; thus, decreasing demand and potentially contributing to fossil fuel and green house gas reduction goals.

7.0 Capturing Rainwater

The second category of innovative adaptation strategies analyzed in this study was rainwater harvesting. Typically, when one hears “rainwater harvesting” the first thing that comes to mind is rain barrels. While using water stored in rain barrels is an efficient and responsible use of water for irrigation and even toilet flushing, they cannot capture the annual maximum potential rainfall. The potential Alternative Water Supply accessible from harvesting rainwater from rooftops is significant. To demonstrate this claim a GIS analysis was performed for ABWUD single family home customers.

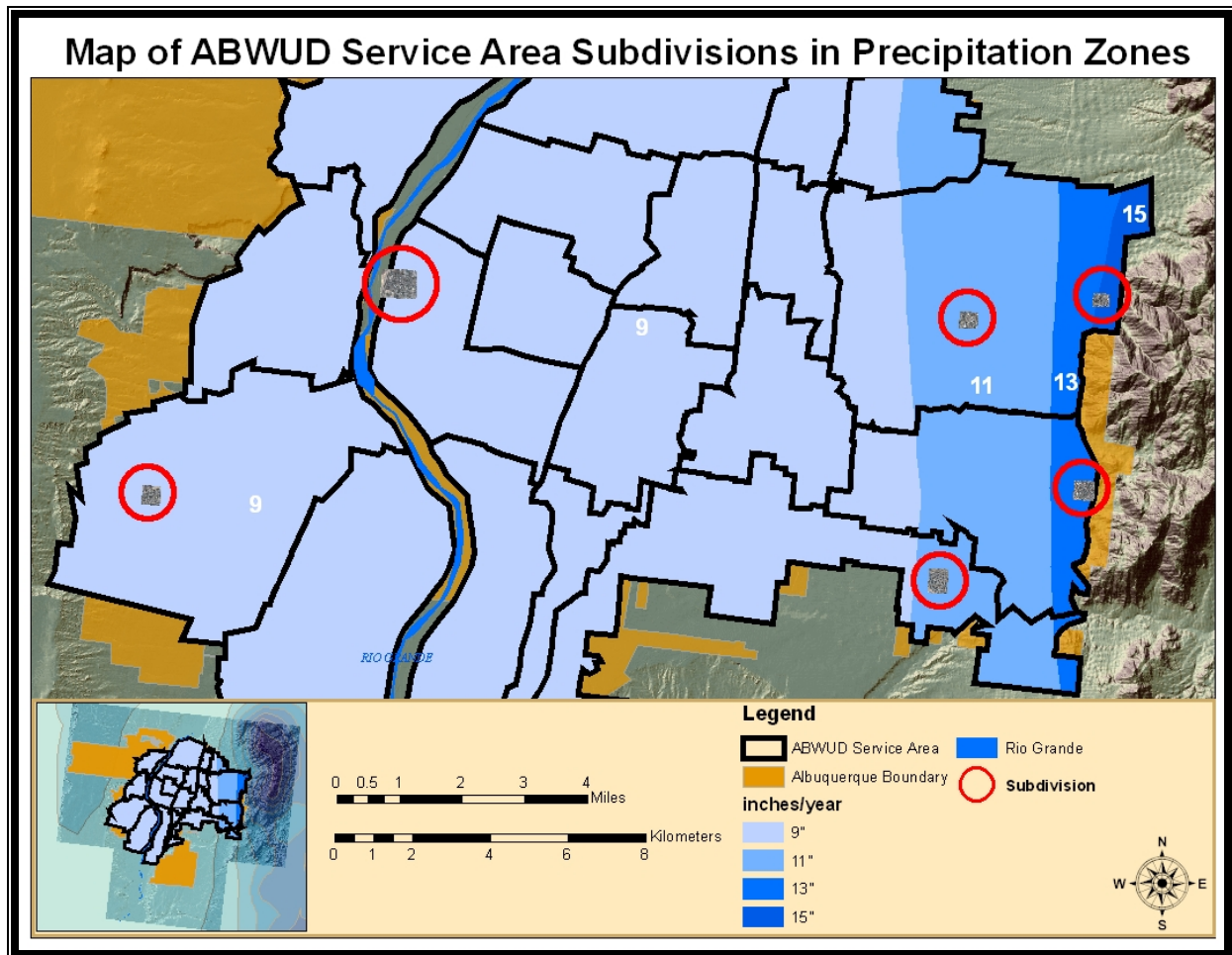


Figure 12 Geographic Location of Subdivisions & Average Annual Precipitation Zones (1971-2000)

The City of Albuquerque resides along the western base of the Sandia Mountains in north-central New Mexico. Its location gives it a unique range of average annual precipitation zones, with an increasing annual average closer to the Sandia Mountain base, on the City’s east side. Averaged between years 1971 to 2000, these zones were used to estimate the volume of water that may potentially be harvested from household rooftops. Six single family home subdivisions were selected within the ABWUD service are boundary. Two were selected in the 9 inch per year zone, two in the 11 inch per year zone and one in each of the 13 and 15 inch per year zones.

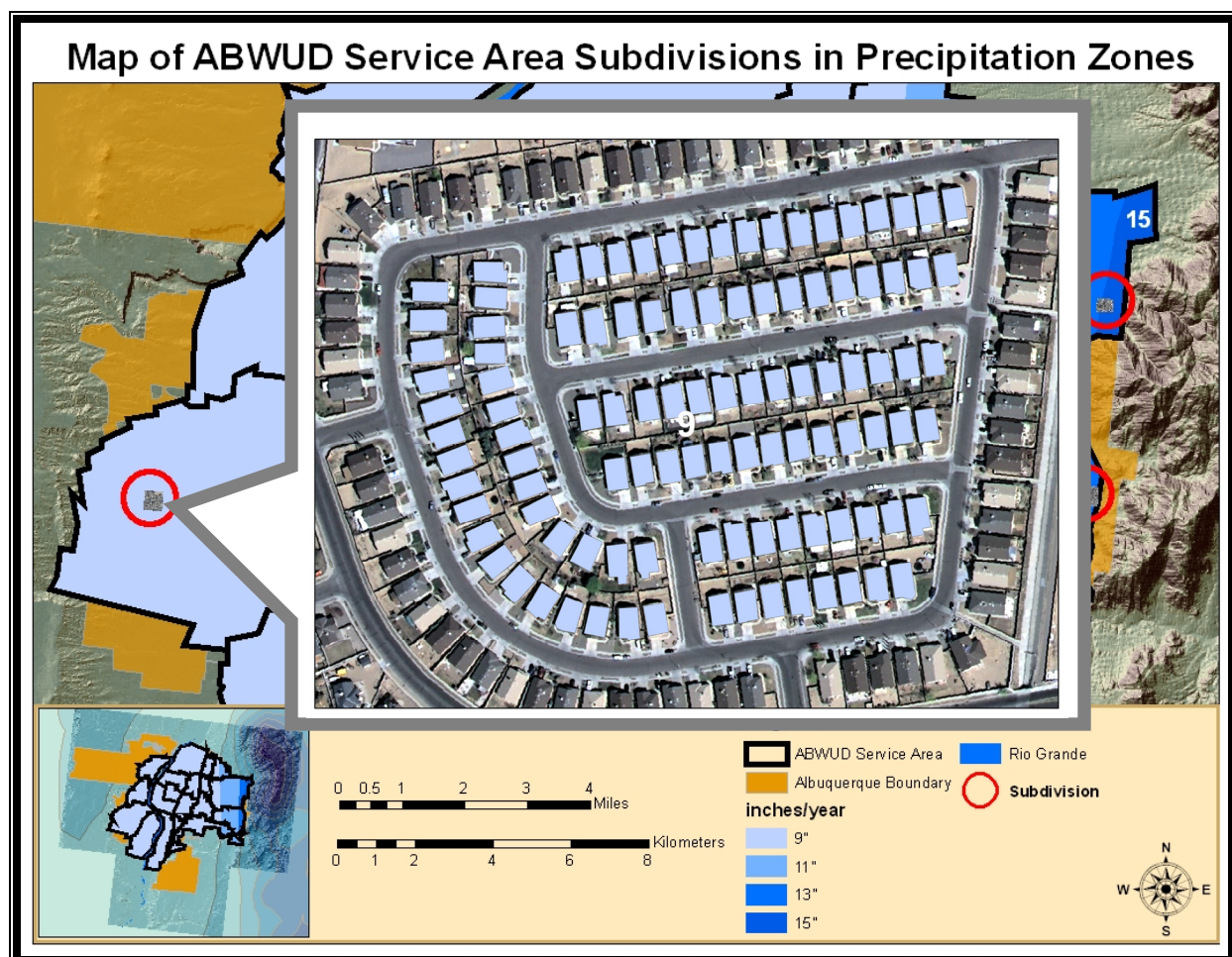


Figure 13 Single family home rooftops digitized

Orthoimages provided a bird’s eye view of single family home rooftops in each precipitation zone. Rooftop boundaries were digitized and their surface areas calculated. This surface area data, precipitation zone data and other single family home zoned area data were used to extrapolate estimates of the volume of harvestable water per home per year. Thus, this study found that in the 9 inch per year zone approximately 15,000 gallons is harvestable per single family home rooftop per year. Homes in the 11 inch zone can harvest close to 17,000 gallons per home per year. The 13 inch and 15 inch precipitation zones offer the potential for single family homes to harvest about 28,000 and 28,500 gallons per home per year respectively.

Clearly, these large volumes of Alternative Water Supply are beyond the capacity of rain barrels. Additionally, it is unlikely that home owners would want to invest in and place large water storage tanks around their home. Therefore, this study proposed taking full advantage of the rainwater harvesting potential from Albuquerque household rooftops by capturing rainfall throughout the year and adding it to the municipal supply system.

The engineering, social and legal issues surrounding a large scale rainwater harvesting program in Albuquerque are beyond the focus of this study. What is estimated though, are the

annual volumes of water that are harvestable from such a large scale program that could significantly aid in meeting current and future water demands.

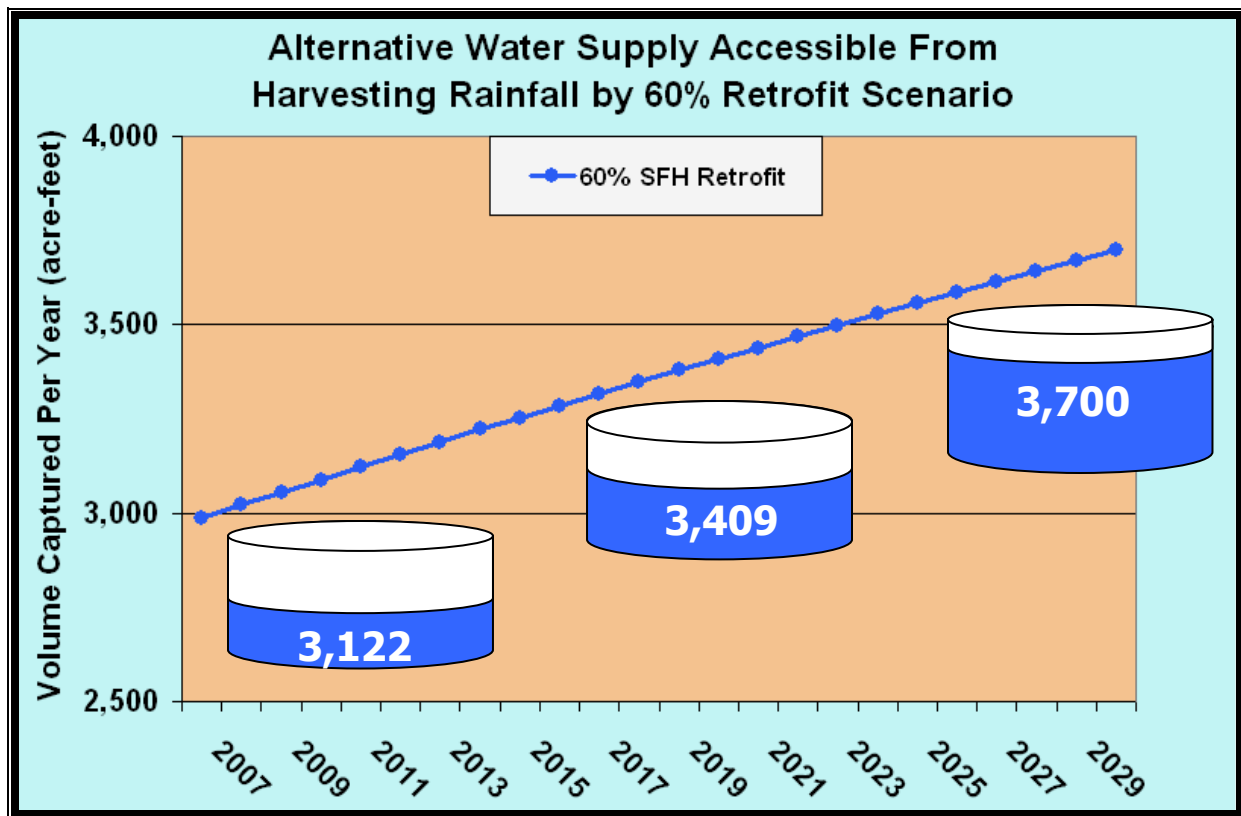


Figure 14 Annual single family home harvestable volumes

This analysis assumes the same retrofit scenario as in the prior water use efficiency analyses, where 60% of ABWUD single family home customers are harvesting rainwater from their rooftops and 40% are not. Here, this study estimates that in 2011 a total of 3,122ac-ft could be added to the municipal supply. As Albuquerque’s number of single family homes increases, estimates grow to 3,409ac-ft in 2020 and 3,700ac-ft in 2030. Each year these volumes of potentially harvestable Alternative Water Supply could be added to ABWUD storage tanks/reservoirs to meet current and future demand or stored below ground in an aquifer storage and recovery program.

8.0 Benefits Generate Opportunity

The water use efficiency and rainwater harvesting estimates presented above demonstrate that there are significant volumes of Alternative Water Supply and energy resource savings possible with this study’s three innovations. But what do those benefits translate into? The answer is opportunity. As Albuquerque advances into the 21st Century, where ABWUD ability to meet demands will become increasingly difficult under pressures of drought, climate change and population growth, it may be possible to maintain a more sustainable water and energy demand,

while at the same time acquiring an Alternative Water Supply; thus, enhancing water and energy security.

Looking to the 60% retrofit scenarios presented above and assuming a new scenario where 60% of ABWUD single family homes are using the Dual Flush Toilet, Shower Water Conservation System and harvesting rainwater, then the opportunities generated are substantial. This study found that from year 2008 through 2012 the water saved and captured is enough to meet the annual demand of about 40,100 homes. Since 46% of Albuquerque's electricity comes from the (coal burning) San Juan Generating Station, then the resultant electricity demands reductions are enough to decrease the volume of water used by the closed-loop facilities by 45ac-ft (PNM, 2006a)³. The natural gas savings are enough to meet the annual demand of 3,685 of Albuquerque's single family homes.

Continuing with the same aforementioned 60% retrofit scenario and five year period, the homes using these three innovations collectively save an estimated \$7,535,440. This is money that would likely contribute to other local economies. ABWUD would also enjoy monetary benefits of about \$362,000⁴. These funds may be used to further improve water conservation and capture programs or other programs that collectively may enable Albuquerque to meet the water resource challenges of drought, climate change and population growth.

Quantifying the monetary benefits from both water and energy savings emphasizes that new and creative conservation programs, especially those that distribute or rebate single family home innovation retrofits, are highly cost effective. A rainwater harvesting cost effective analysis of the large scale capture system introduced here was beyond the scope of this study. However, it is likely that energy costs avoided by shortened conveyance, decreased treatment process needs and reduced surface water diversion and groundwater pumping will enhance the cost effectiveness of such a plan; notwithstanding the avoided costs related to developing or transferring more traditional supplies from long distances.

9.0 The Take Home Message

Water saving and water capturing innovations offer ABWUD and its customers the opportunity to maintain an Alternative Water Supply to meet current and future demand as well as adapt to and cope with the challenges of drought, climate change and population growth. As with the greater U.S., Albuquerque's current water supply is likely to face shortages in the future due to the water supply impacts associated with climactic changes and a growing demand. However, the types of innovative solutions examined in this report (and many others not analyzed) demonstrate a large potential for generating an Alternative Water Supply, as well as for abating future adverse impacts to supply due to green house gas emissions.

Dual flush toilets offer the water utility and its customers significant savings beyond the status quo water and energy use reductions experienced since implementation of the 1992 National Energy Policy Act and rebate programs. The savings translate into an alternative water supply and energy savings that may be used meet current and future demand. Moreover, both ABWUD and its single family home customers save money.

³ Assumes 740 gallons of water consumptively used per MwHr (PNM, 2006b).

⁴ In 2006 dollars, Discount Rate = 5%

The Shower Water Conservation System is a newly emerging innovation that also facilitates water savings. However, since it saves hot (or previously heated) water used in each showering event, then considerably more energy resources are conserved. Again the Alternative Water Supply and avoided energy demand offer the opportunity to meet current and future demands, while simultaneously saving money and reducing green house gas emissions.

Rainwater harvesting is an old innovation that would significantly enhance Albuquerque water security if it were used on a much grander scale to supplement the City water supply. The potential volume of water captured from single family home rooftops may allow ABWUD to meet both current and future water demands.

This research demonstrates that there is power in efficient water use and water capture innovations beyond mere water conservation and rain barrel use. These types of innovations may enable cities to cost effectively enhance water and energy security in the 21st Century. Therefore, it is important to understand and take full advantage of the potential benefits associated with existing, newly emerging and modified innovative solutions to water and energy resource challenges.

Aldo Leopold said, “Conservation is a positive exercise of skill and insight” (Leopold, 1999). The message readers should gather from this study is the following: If 21st Century water resource managers understand and take full advantage of the types of insights presented in this study, and skillfully exploit them within the context of a larger, more comprehensive approach to enhancing water and energy security, then they may enable future generations to cope with the resource challenges associated with drought, climate change and population growth.

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