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

Andrew Funk

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By

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Committee Approval

The Master of Water Resources Professional Project Report of **Andrew Funk,** entitled **The Potential of Water Saving and Water Capturing Innovations: A Case Study of Albuquerque Single Family Homes,** is approved by the committee:

Julie Coonrod ____________________ 10/18/06 ____________
Co-Chair Date

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Anne Watkins ____________________ 10/18/06 ____________

ABSTRACT

The need for innovative water saving and water capturing strategies in Albuquerque single family homes (SFH) is evident by the city's vulnerability 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, allows 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.

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 generating future opportunity. Two in-home innovations, the dual-flush toilet and the Shower Water Conservation System (SWCS), 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.

ACKNOWLEGEMENTS

This report was made possible by the aid a several individuals. I would like to take this opportunity to express my gratitude to all who supported my efforts by guiding my analyses, sharing thoughts and ideas regarding conservation, providing me with necessary data and information and giving me encouragement throughout the entire process.

Professor Janie Chermak, Ph.D. in Economics at the University of New Mexico and co-chair to Andrew Funk's graduate committee was instrumental to this report's economic analysis and discussions regarding water saving innovations. Prof. Chermak's research focuses on Natural Resource and Environmental Economics, Applied Microeconomics, and Experimental Economics.

Professor Julia Coonrod, Ph.D. in Environmental and Water Resources Engineering and co-chair to Andrew Funk's graduate committee was a key influence to this report's GIS analysis and discussions regarding rainwater harvesting. Prof. Coonrod's research focuses on Middle Rio Grande Evapotranspiration, Open Channel Modeling for AMAFCA and Scaling Middle Rio Grande Evapotranspiration.

Anne Watkins, Special Assistant to the New Mexico State Engineer and Andrew Funk's third graduate committee person influenced many discussions in this report with her insights. She was Mr. Funk's supervisor at the New Mexico Office of the State Engineer for sixteen months and provided him with the opportunity to generate a deliverable highlighting what is needed in designing a comprehensive Statewide water conservation plan for New Mexico.

Several employees at the Albuquerque Bernalillo County Water Utility Authority were instrumental to my data gathering. Frank Roth, John Stomp, Katherine Yuhas, Doug Dailey and Bagher Dayyani were thoughtfully patient with my constant inquiries amid their own responsibilities. Their assistance is greatly appreciated.

Finally, I must express thanks to my wife, Diem. We were forced to live apart during my two year period at UNM due to our individual academic pursuits. Nevertheless, she remained a consistent voice of encouragement and praise. My practice explaining to her concepts and issues regarding conservation and capture innovations and drought, climate change and population growth aided my own understanding and enhanced my ability to articulate them.

ABOUT THE AUTHOR

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 lake profile particle size distribution and the potential of watershed runoff to impact Lake Tahoe water clarity. Mr. Funk then expanded his understanding of water resources at the University of New Mexico Water Resources Program. This report is his final Professional Project, completing the requirements for a Master of Water Resources degree. The Water Resources Program employs a multi-disciplinary approach to understanding the complexity of managing water resources. Throughout the process of designing this Professional Project report, Mr. Funk also worked at the New Mexico Office of the State Engineer as a graduate student researcher. Here, he researched water conservation and climate change planning strategies used in other U.S. states, prepared a deliverable highlighting a comprehensive list of strategies necessary in a New Mexico urban water conservation planning effort, and contributed to the Climate Change Water Impacts Work Group 2006 report, "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 .

NOTE: This work is based upon the Professional Project of 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 by the following graduate committee: Professor Janie Chermak (co-chair), Professor Julia Coonrod (co-chair) and Anne Watkins, Special Assistant to the New Mexico State Engineer.

ACRONYMS

ABWUA – Albuquerque Bernalillo County Water Utility Authority
ABWUD – Albuquerque Bernalillo County Water Utility Department
ac-ft – acre-foot
DFT – Dual Flush Toilet
gpcd – gallons per capita per day
HET – High Efficiency Toilet
KwHr – Kilowatt-hour
MwHr – Megawatt-hour
OSE – New Mexico Office of the State Engineer
SFH – Single Family Home
SJCP – San Juan-Chama Drinking Water Project
SWCS – Shower Water Conservation System
ULFT – Ultra Low Flow Toilet

DEFINITIONS

Acre-feet – The volume of water that can meet annual demand of two Albuquerque Single Family Homes of 3 persons each. 1acre-foot = 325,851 gallons
Dual Flush Toilets – Toilets with one flush mechanism (1.6gpf) for solid waste and one mechanism (0.8gpf) for liquid waste
End Use – Any water used at the point of delivery
Energy Conservation – Any action or technology that decreases energy usage at the water utility and end user levels, without negatively impacting the quality of life
Energy Intensity of Water – The amount of energy consumed per acre foot of water used
High Efficiency Toilet – Toilets that flush at 20% below the 1.6-gpf maximum or less, equating to a maximum of 1.28-gpf (CUWCC, 2005b).
Kilowatt-hour – A unit by which residential customers are billed for their monthly electricity usage. One Kilowatt-hour = 1000 Watts for one hour. Albuquerque single family homes use an average of 7,087 Kilowatt-hours per year (PNM, 2006b).
Megawatt-hour – A unit that represents the use of 1 million watts or 1,000 Kilowatts of electricity for one hour.
Single Family Home – Any attached or detached housing structure that has two or less units per structure (including duplex housing)
Therm – A unit by which residential and commercial customers are billed for monthly natural gas usage. One Therm = 96.7 cubic feet of natural gas or 100,000 British Thermal Units. Albuquerque single family homes use an average of 664 Therms per year (PNM, 2006b).
Ultra Low Flow Toilet – Any toilet that meets the National standard of 1.6 gallon per flush as required by the 1992 National Energy Policy Act
Water Capture – Any action or technology that facilitates the capture of rainfall from rooftops, without negatively impacting the quality of life
Water Conservation – Any action or technology that decreases water usage or increases efficient water use by end users, without negatively impacting the quality of life

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EXECUTIVE SUMMARY

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.

This study 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, this report's 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 three 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. 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.

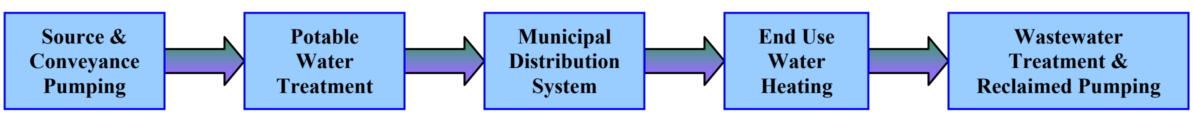


Figure ES-1 Stages of water supply where energy is used, Redesigned from (Cohen *et al.*, 2004)

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 the reclaimed water resource (Cohen *et al.*, 2004).

Using the City of Albuquerque, this study has quantified the Alternative Water Supply accessible from using three innovations and the potential energy resource savings from decreasing the demands at each of the five stages in Figure ES-1. 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).

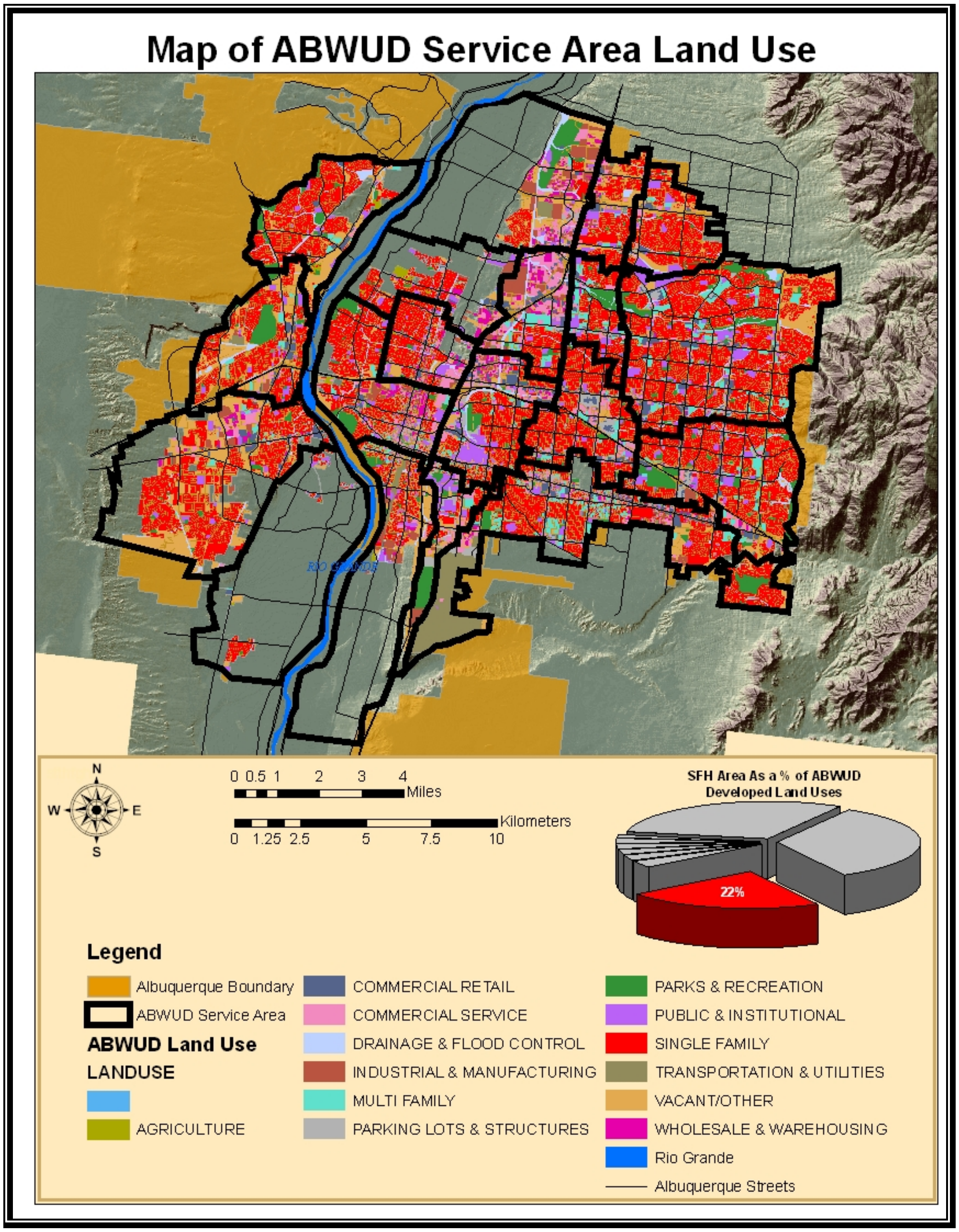


Figure ES-2 ABWUD service area and single family home zoned area

While the water utility and its residential customers represent a relatively small portion of water and energy demand in the greater U.S., it is important to keep in mind that the 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 the entire U.S.; thus, this study's innovation analyses may very well be transferred and used by additional city water managers.

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 water. 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 climactic 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 populations increase, 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. 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).

What Can Be Done?

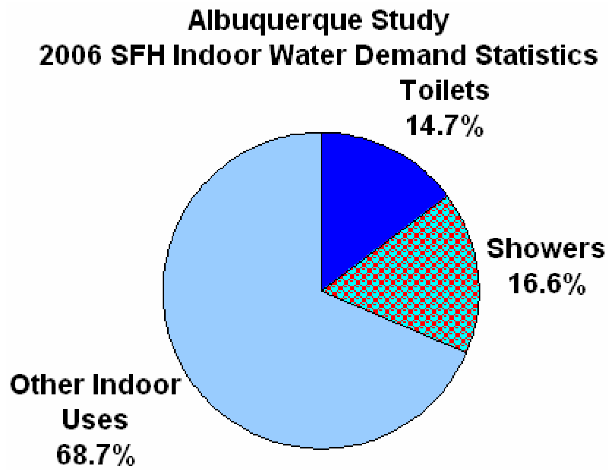
While Albuquerque's water resource future may appear grim, there are adaptive measures that can be adopted to empower ABWUD and its customers to manage water shortages. There are water resource managers in the State of New Mexico who understand the need to engage in a comprehensive statewide urban (and 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. This 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.

Using Water More Efficiently

This study's analyses and discussions regarding water conservation focus on current and newly emerging technologies that decrease total 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 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 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.

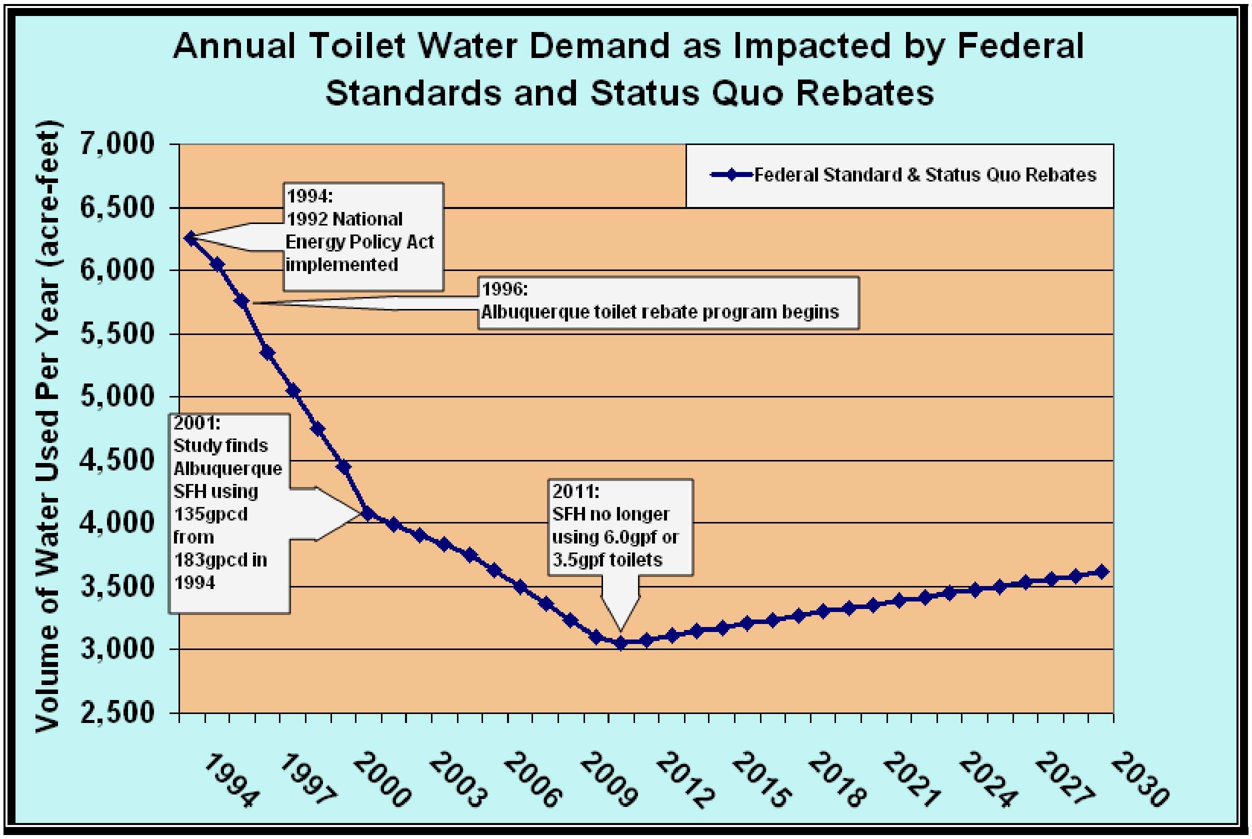


ES-3 Albuquerque 2006 Single family home per capita toilet and shower water demand statistics

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 throughout this report 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.

The Dual Flush Toilet

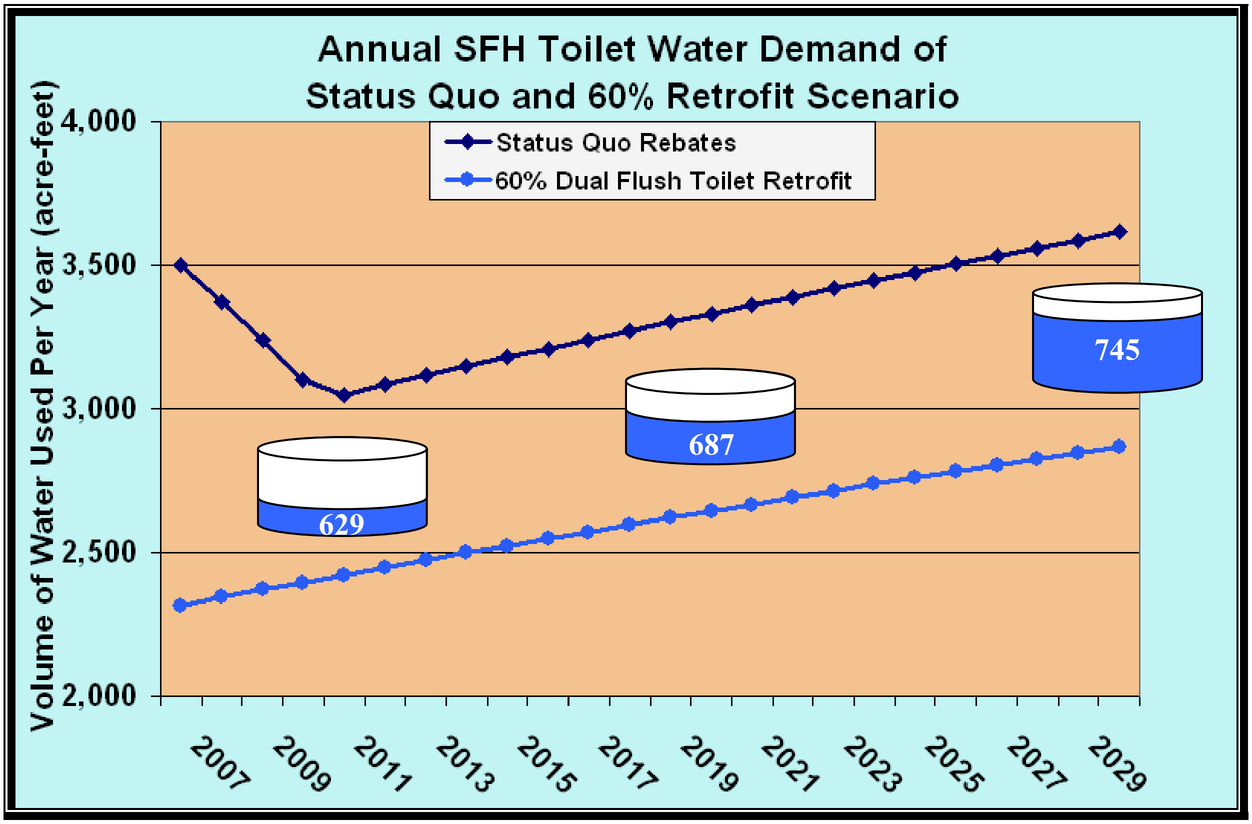
The Dual Flush Toilet offers significant resource and monetary benefits by presenting the user with the option of two flush volumes. That is, with each flushing event the user can choose between two flush volume buttons, 1.6 gallon per flush for solid waste and 0.8 gallon per flush for liquid waste.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



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

The 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 is toilet rebate program, offering its customer 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.

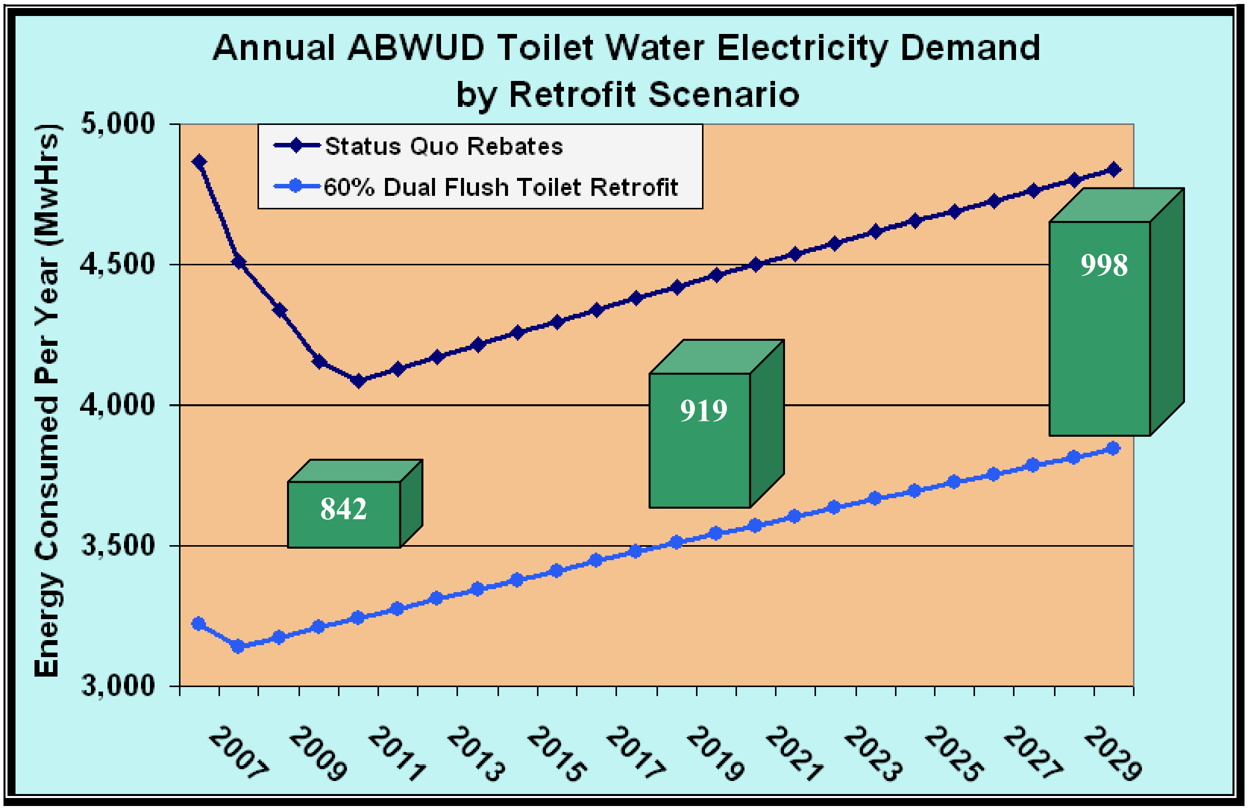
Plotting the above baseline, or Status Quo, toilet water demand along side this study's most conservative retrofit scenario, where 60 % of ABWUD single family homes are using dual flush toilets and 40% are using a mix of 6.0, 3.5 or 1.6 gallon per flush toilet models, demonstrates the potential water 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.



ES-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 (in above ground storage tanks or below ground in aquifer storage and recovery systems) to meet future demands.

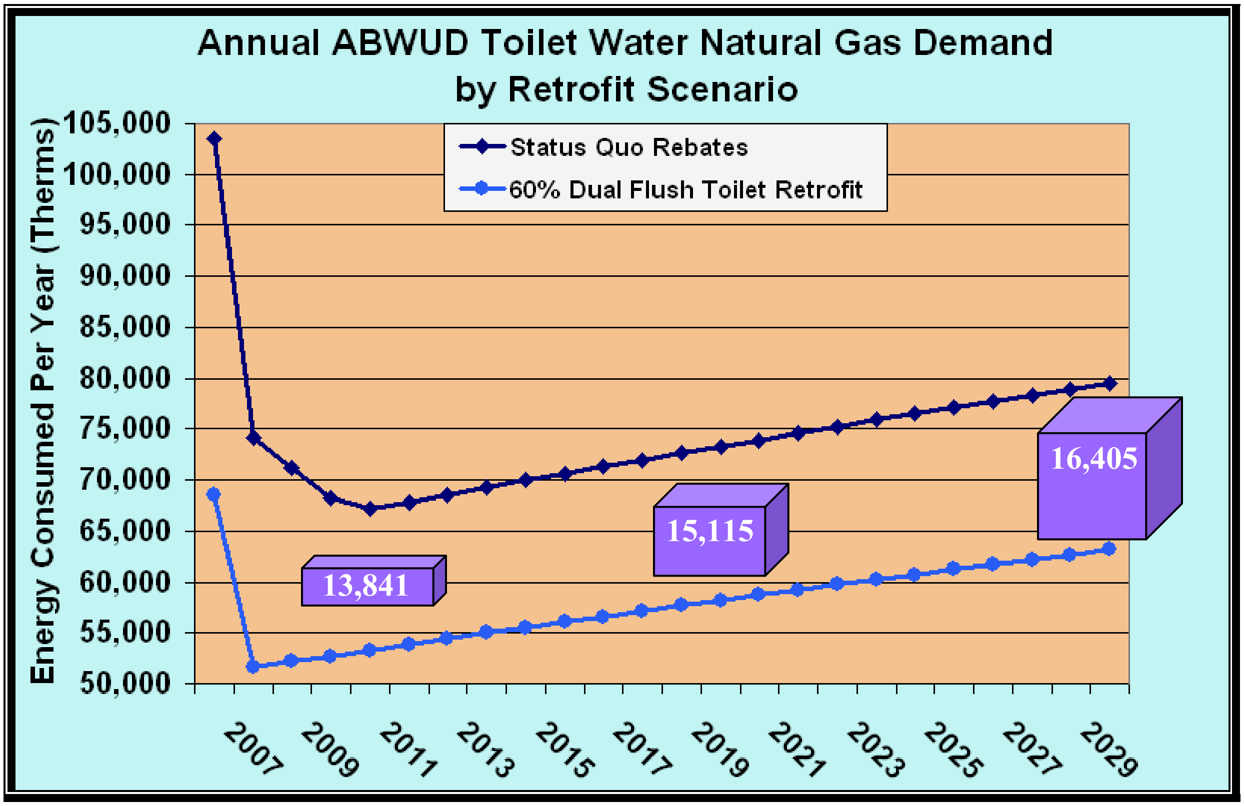
Increasing the efficiency of toilet water use also impacts energy demands. At ABWUD's facilities both electricity and natural gas are required to pump water, treat water to drinking water standards and treat wastewater. Thus, using the aforementioned Status Quo toilet water demand estimates, similar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



ES-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, 2006b). Thus, the electricity demand reductions revealed in this study are significant.



ES-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 treatment. Under the same 60% retrofit scenario, this study finds that natural savings are 13,841Therms in 2011, 15,115Therms in 2020 and 16,405 in 2030. To put these natural gas savings in perspective, Albuquerque single family homes used an average 664Therms per home in 2005 (PNM, 2006b). The volumes of natural gas saved each year may be used to meet other demands or stored to meet future demands.

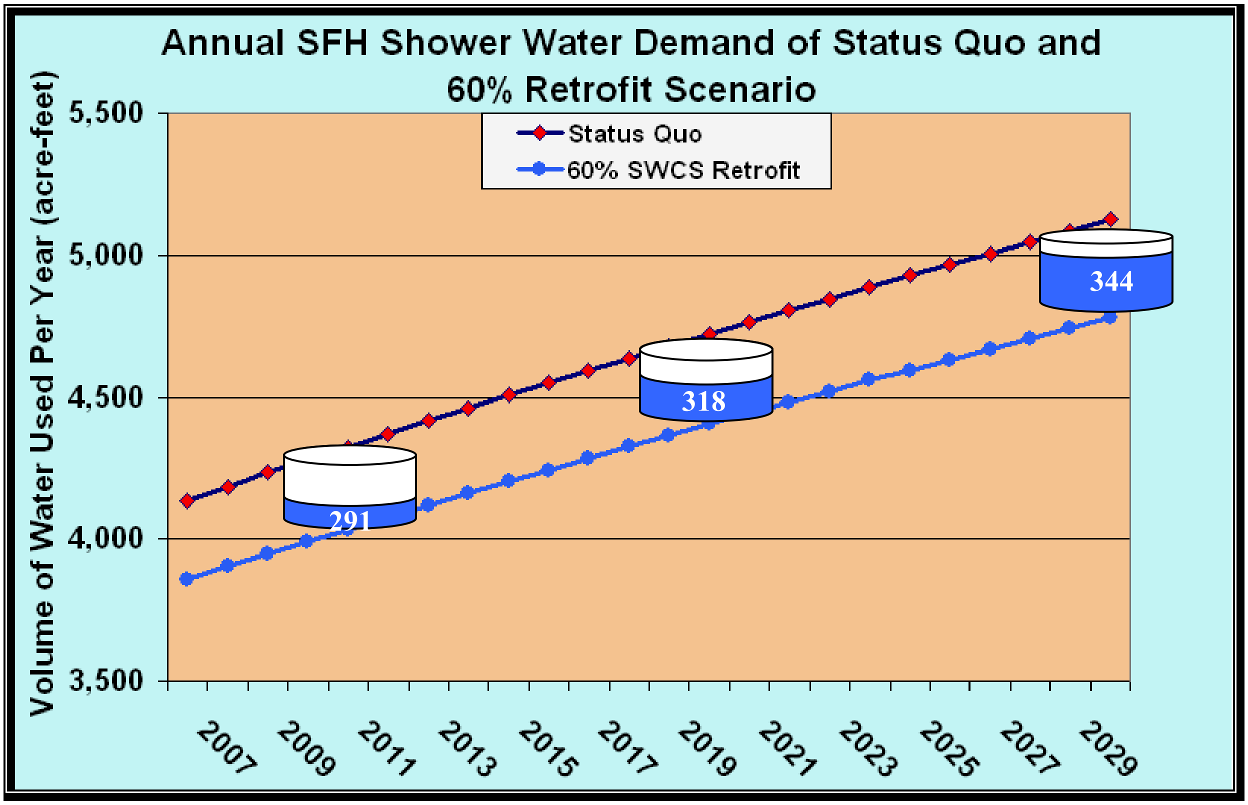
The Shower Water Conservation System

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 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. 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.

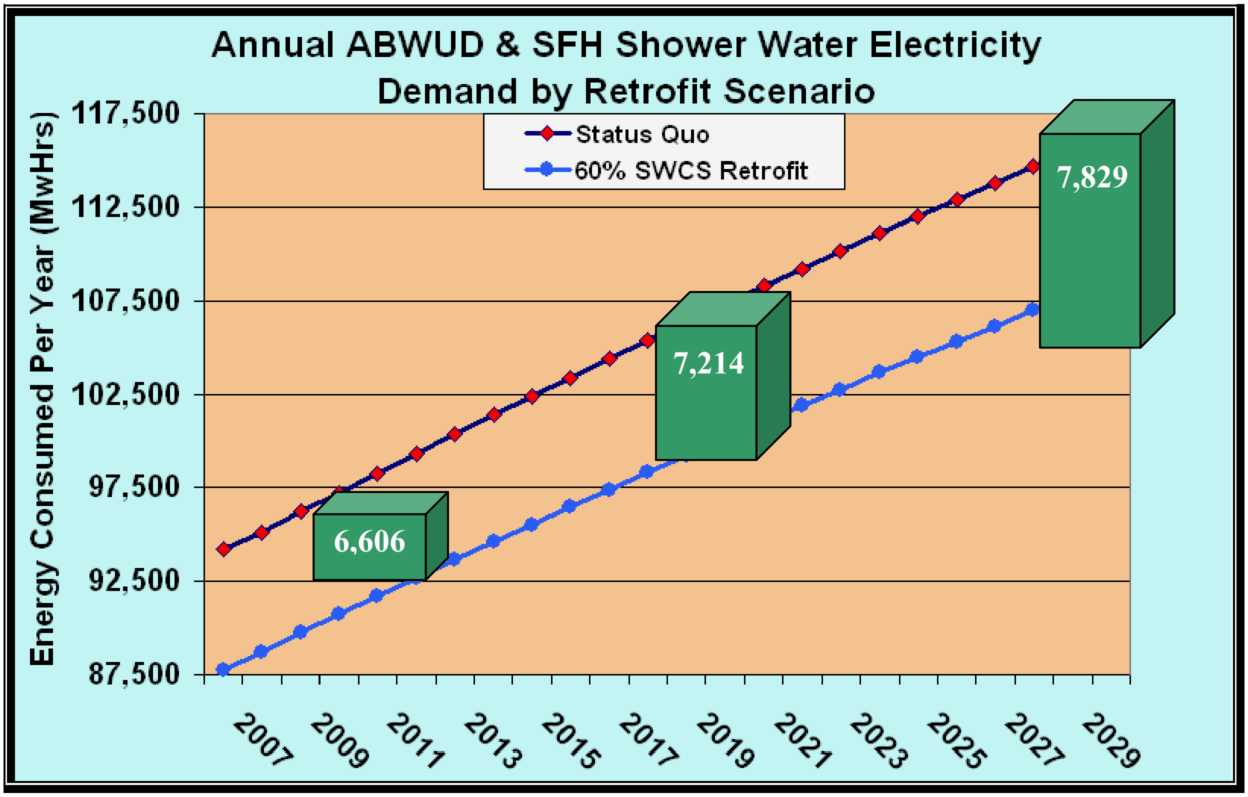
As with the toilet analysis, the Albuquerque SFH total per capita shower water demand was estimated and compared to four different retrofit scenarios. The comparison with this study's (more conservative) 60% retrofit scenario assumes that 60% of ABWUD single family home customers are using the system 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.



ES-8 Projected single family home per capita shower water demand

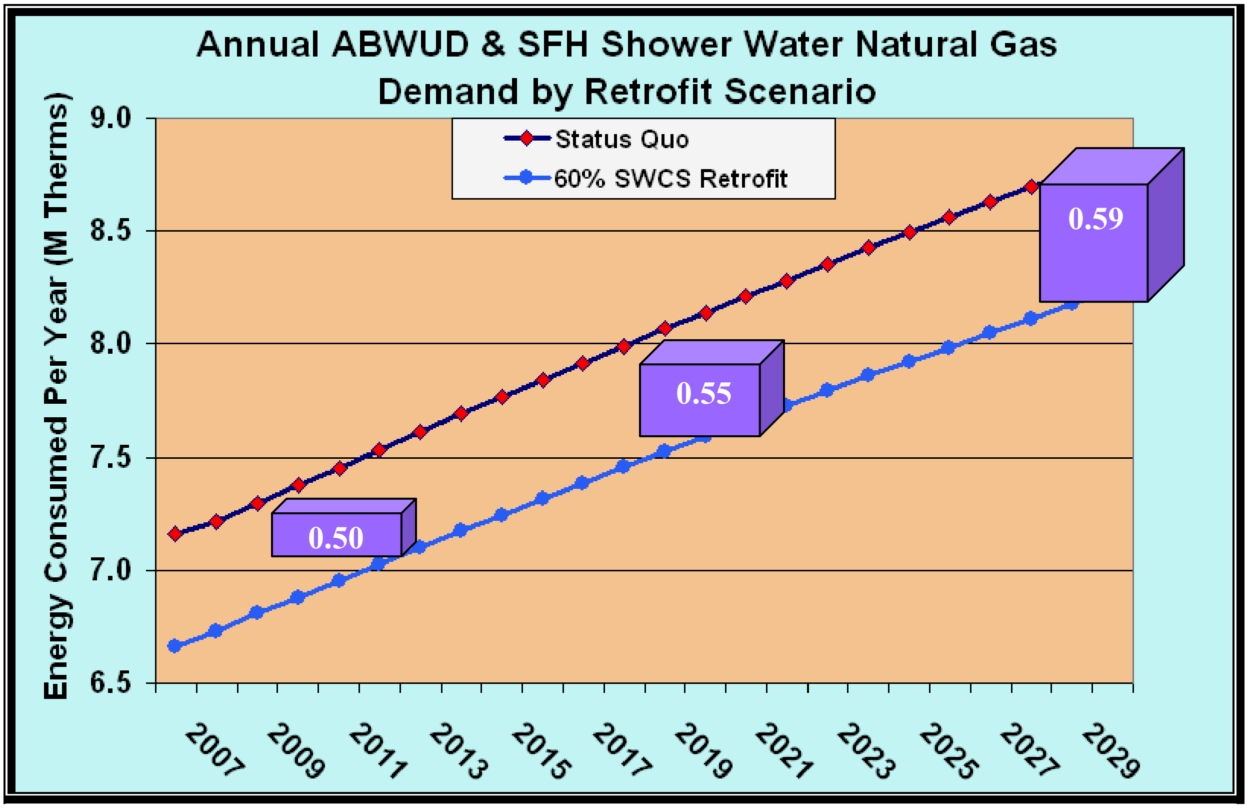
This study finds that the water saving benefits of the Shower Water Conservation System translate into 291ac-ft in 2011, 318ac-ft in 2020 and 344ac-ft in 2030 of Alternative Water Supply that may be used to meet either current demand each year or stored to meet future years' demands.

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.



ES-9 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, possibly lower greenhouse gas emissions.

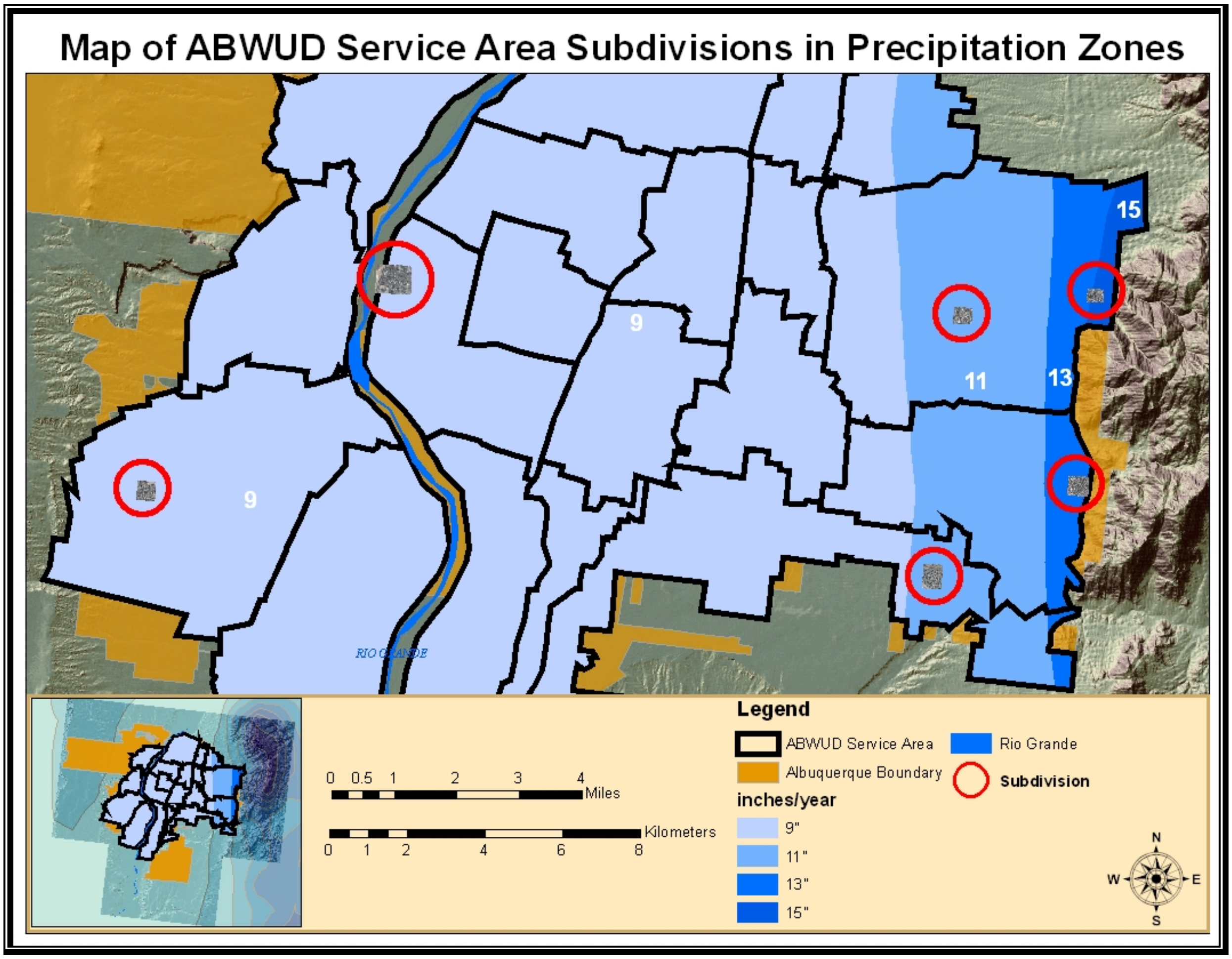


ES-10 Projected ABWUD & single family home per capita shower water natural gas demand

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 0.50Million Therms in 2011, 0.55Million Therms in 2020 and 0.59Million 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.

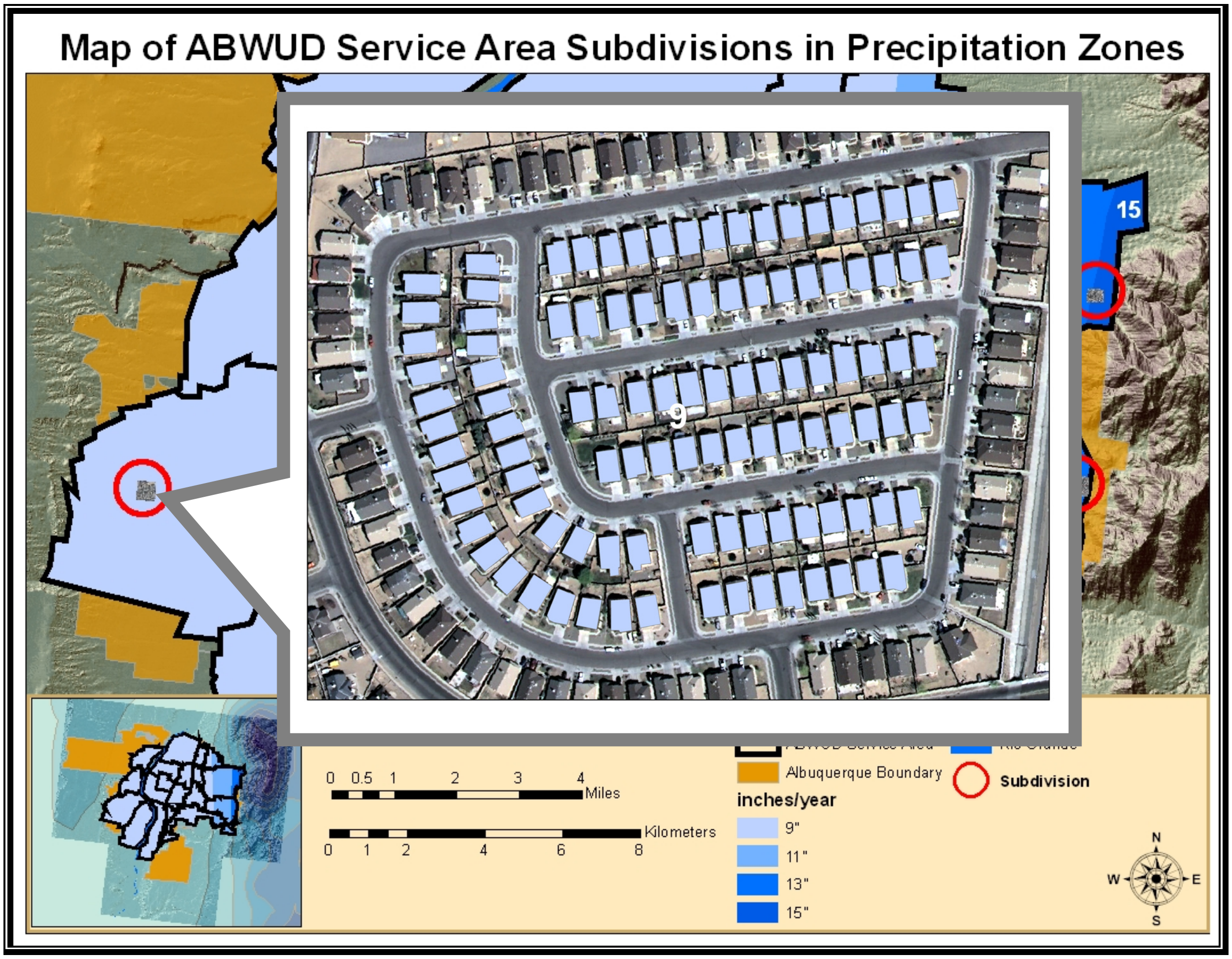
Capturing Rainwater

The second category of innovative adaptation strategies analyzed in this study is 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 again for ABWUD single family home customers.



ES-11 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 if average annual precipitation zones, with an increasing annual average closer to the 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.



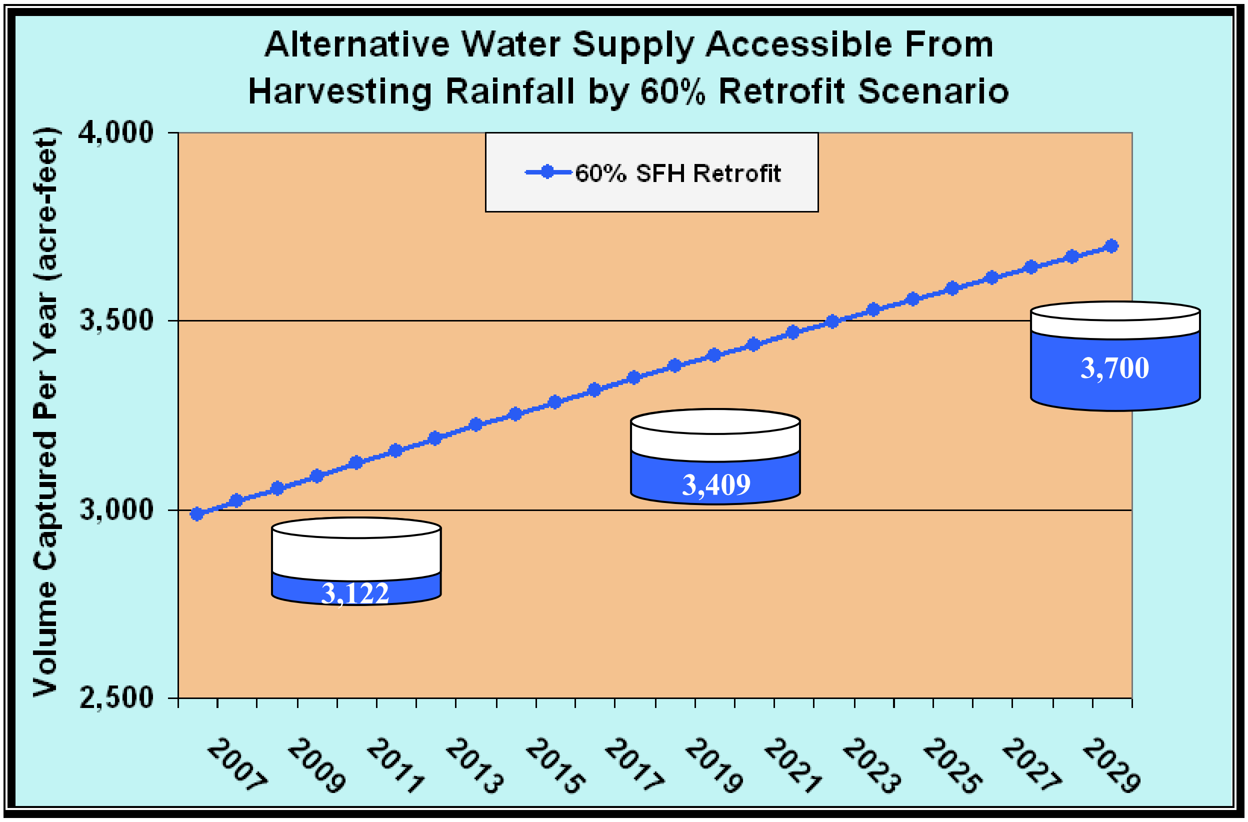
ES-12 Single family home rooftops digitized

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 are 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 finds 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 proposes 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.



ES-13 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 reservoirs to meet current and future demand or stored below ground in an aquifer storage and recovery program.

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 finds 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 (coal burning) thermoelectric power plants, then the resultant electricity demands reductions are enough to decrease the volume of water used by these facilities by 45ac-ft (PNM, 2006b). 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 $362,000. These funds may be used to further improve water conservation and capture programs or other programs that comprehensively may enable Albuquerque to meet the water resource challenges of drought, climate change and population growth.

This Report's Take Home Message

The following report demonstrates that there is power in efficient water use and water capture innovations beyond mere water conservation. These types of innovations may enable cities to 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". 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 report, 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 of drought, climate change and population growth.

> **"In the Southwest, water is absolutely essential to our quality of life and our economy. Addressing climate change now, before it is too late, is the responsible thing to do to protect our water supplies for future generations."**
> **- Governor Bill Richardson**

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1.0 INTRODUCTION

The need for new and innovative solutions to urban water scarcity may be no more apparent than in New Mexico's largest city, Albuquerque. Residing along the Rio Grande River, the city has grown and thrived despite the water resource limitations characteristic of its semi-arid climate. The current residential population of approximately 501,000 and the commercial, industrial and institutional sectors they support continue to persist in large part because of their reliance on the City's highly productive underlying aquifer. However, due to years of unsustainable pumping rates, the aquifer is experiencing significant drawdown, highlighting the reality of Albuquerque's water scarcity challenges and the need for new and innovative adaptation strategies (Gutzler *et al.*, 2005).

Hydrologic studies have demonstrated that the city groundwater mining has decreased the volume of water discharging to the Rio Grande surface water flows. Moreover, Albuquerque's pumping is not sustainable and has caused areas of subsidence (Hall, 2005). Thus, in the 1960's, Albuquerque engaged a planning effort to secure an added surface water supply that would allow it to decrease its reliance on groundwater. The city now owns the water right to 48,200 acre-feet per year of upper Colorado basin water, which is diverted from the San Juan Basin, channeled 26 miles under the Continental Divide and stored in the Rio Grande Basin's Heron Reservoir, and downstream reservoirs, for use in the San Juan-Chama Drinking Water Project (SJCP) (City of Albuquerque, 2005b).

The city water purveyor, Albuquerque Bernalillo County Water Utility Department (ABWUD), is responsible for administering the water and wastewater utilities and therefore, has overseen the construction of a new diversion dam, Drinking Water Treatment Plant (DWTP),

Finished Water Pump Station as well as the already operational Southside Water Reclamation Plant. Upon completion, this system will divert SJCP water from the Rio Grande, purifying it with a series of treatment processes and pumping the potable water to storage reservoirs, where it will mix with the existing ABWUD groundwater distribution system (City of Albuquerque, 2005a). Initially, the distribution system will deliver a mix of 90% SJCP water and 10% groundwater to urban service connections. The mix is expected to decrease to 70% SJCP water and 30% groundwater 40 years after the project's inception (Stomp, 2006).

The SJCP is a large scale and complex and expensive innovative solution to Albuquerque's scarce water supply challenges. New and more intimidating challenges however, are likely to confront ABWUD and its ability to continue to deliver the volumes of potable water currently demanded by service connection customers. As the city advances into the 21st Century it is faced with the inherent water supply challenges of drought, climate change and population growth.

Drought is a far-reaching force in Albuquerque and the greater Southwest. That is, the impacts of drought can expect to be felt into the 21st Century (and beyond) throughout all urban sectors. Historically, Southwestern drought records, including more ancient tree ring data, illustrate varying severity of drought events. Moreover, climate change research draws attention to the high likelihood of enhanced drought variability and its potential impacts on the city's SJCP water supply (Woodhouse *et al.*, 2005).

The large consensus of climate research exposes a high likelihood that climactic deviations from average precipitation events, around which western cities, such as Albuquerque, have structured their planned growth, economy and reservoir management, will adversely impact

the available water supply. Smaller winter snow pack accumulation in the San Juan Basin and Upper Rio Grande Basins, together with more precipitation falling as rainfall is expected to alter the timing and volume of reservoir flood control releases; thus, adding to the risk of diminished storage capacity normally used to help meet summer peak urban, as well as agricultural, water demand (Saunders *et al.*, 2005).

Possibly even more important is the likelihood that average temperatures are raising in both the San Juan and Upper Rio Grande Basins. These higher temperatures may exacerbate the SJCP water supply risks associated with precipitation regime changes by effectively causing an earlier snowmelt and increasing sublimation, evapotranspiration, soil dryness and decreased stream flows (Saunders *et al.*, 2005). Snow pack is also necessary for replenishing groundwater supplies. As a result, in the San Juan Basin, the origin of SJCP water, disputes may arise over needed surface water due to the lack of accessible water below ground (Saunders *et al.*, 2005).

The four largest stakeholder demands on San Juan Basin surface waters are from municipal, in-stream uses, irrigated agriculture and power generation. Under drought conditions, agreements exist requiring these competing uses to share shortages, as determined by the Bureau of Reclamation. The SJCP is not immune from this agreement and therefore, is likely to have its diversion reduced if drought persists, further threatening Albuquerque water supply (FWS, 2005).

Amid all these factors is the looming inevitability of population growth. This single variable alone may pose challenges beyond the capacity of ABWUD current innovative (and expensive) water supply solution. The city’s population is projected to increase to 627,966 residents by 2030. That is, the current estimated population of approximately 501,000 will

increase by 25% in twenty four year's time (Appendix 1). Along with an increasing population will follow an increased demand on Albuquerque water supply. As stated by Gutzler *et al.* (2005), "…population is the single largest factor determining long-term trends in total water demand".

Since the water supply impacts associated with drought and climate change, as well as the ever-increasing water demand from a growing population, are likely to overstress the SJCP water supply and affect the ability of the ABWUD to reduce its groundwater mining, then it is prudent for the city water resource managers to continue to design and implement new and innovative adaptation solutions to its 21st Century urban water scarcity. This study finds that innovative planning solutions, designed to alter how Albuquerque uses and acquires its water supply, significantly enhance ABWUD capacity to meet increasing water demands.

The two strategic methods this report analyses involve innovative solutions that are characterized as providing an alternative source of water that will aid in meeting the current and future ABWUD water demand. The benefits of technological advances in water using and water capturing innovations are that they allow people to perform tasks more efficiently without any significant changes in behavior, as well as secure an alternative source of water to meet future demand. Moreover, their ability to do so with fewer water and energy resources makes them highly cost effective to implement.

This report examines the potential of two innovations that enhance water use efficiency and one innovation that captures water. Within the boundary of the ABWUD service area, this study estimates the largely untapped potential for water, energy and monetary savings. Narrowing the focus of this analysis to one urban sector, Single Family Homes (SFH), facilitates

a greater understanding (and evaluation) regarding the outcome of status quo policies and the potential savings associated with Dual Flush Toilets (DFT), the Shower Water Conservation System (SWCS) (a newly emerging innovation) and Rainwater Harvesting. 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.

Motivating this study was the fact that the lack of understanding for the intimate relationships between water use and energy consumption and the potential savings of one from reducing the demand of the other are largely systemic Nationwide. Moreover, U.S. water resource planning efforts have largely not recognized the intimate connections between water and energy demand (Cohen *et al.*, 2004). Therefore, the objectives of this study could have been satisfied using many other U.S. city municipal water utilities as the analysis extent. Stated differently, the analysis in this report is appropriate across a broad range of cities. The City of Albuquerque was selected largely out of convenience and accessibility. In no way is this report designed as an assault on ABWUD, its staff and implemented policies. Undeniably, the water utility, its conservation officers and management staff have been very successful in reducing Albuquerque water demand.

The sections that follow discuss and estimate the inherent water, energy and monetary benefits associated with SFH water conservation and capture technologies. Beginning with a

literature review, several previous studies are discussed with regard to their contribution to this report. The background of ABWUD SFH water use and projections for the next 24 years previews this study's maximum potential savings and avoided costs. Here, the importance of recognizing the intimate relationship between water use and energy consumption is discussed with regard to the benefits associated with using water more efficiently. This study's population projection procedures are explained with regard to how the number of SFH existing within the ABWUD service area boundary was estimated over a 24 year period.

The bulk of this report analyzes the potential savings of three innovations in ABWUD single family homes. The per capita reduced water and energy demands and monetary savings from using dual flush toilets are quantified against ABWUD's Status Quo mix of older models and modern low flow toilets resulting from National standards and rebate programs. A second innovation (one designed exclusively by this report's author, U.S. Utility Patent Application Pending) the SWCS, is explained in detail and its water and energy savings and avoided monetary costs are also quantified in Albuquerque SFH according to the quantified baseline per capita shower water demand. These two innovations are discussed not only in terms of their potential savings, but also as new and cost effective sources of alternative water supply that may be used to meet current and future ABWUD water demand amid a backdrop of drought, climate change and population growth. The opportunity generated by using water and energy resources more efficiently is then discussed with regard to its impact on 21st Century water and energy security. The third innovation, rainwater harvesting, is then examined in this report. A GIS analysis provides a telling story of the significant volume of alternative source water this underutilized innovation has to offer, as well as the potential water and energy security

opportunities it may generate. Finally, specific recommendations are offered that clearly define what the State Government and Water Purveyor roles are to ensure that ABWUD and its single family home customers are equipped with the innovations necessary to enable them to cope with the water scarcity challenges posed by drought, climate change and population growth.

2.0 LITERATURE REVIEW

This study draws from the insights of and methodologies developed in several previous research efforts. The report most influential on discussions and analysis was produced by the Pacific Institute for Studies in Development, Environment and Security in Oakland, California. "Waste Not Want Not: The Potential for Urban Water Conservation in California" provides a comprehensive look into California urban water use and the water saving potential of conservation technologies. Both indoor and outdoor technologies are analyzed to demonstrate how significantly the State (California) may cost effectively reduce its urban demand. A similar approach is used in this study, but the scope of the analysis is more narrowly focused to SFH within the service area of ABWUD. The Pacific Institute's methodology for determining the level of technology penetration in urban sectors and whether technologies are cost effective is used in this report, as are various assumptions regarding water use behavior (Gleick *et al.*, 2003).

A second report, "Residential End Uses of Water" (REUW), published by the American Water Works Association Research Foundation, is considered by many as the most comprehensive collection of SFH survey and data logger information assembled to date. The study collected survey and disaggregated end water use data from 12 cities in Colorado, Florida, Arizona, Ontario and California. The participant sample consisted of a total of 1,188 households. Data analysis demonstrated that the ranges in the amount and frequency of water use for toilets,

showers, washing machines and other fixtures across all the studied cities was statistically/significantly similar. Therefore, this study takes advantage of the noteworthy transfer value of the REUW study data and uses it to explain ABWUD single family home water use behavior for toilet flushing and showering (Mayer *et al.*, 1999).

Finally, “Energy Down The Drain, The Hidden Costs of California Water Supply”, a joint report by the Natural Resources Defense Council and Pacific Institute, takes a different approach towards identifying the potential savings associated with using water more efficiently. Here, the links between water use and energy consumption are recognized. That is, the report highlights the fact that energy is needed to divert water, treat water for potable purposes, pump water, heat water and treat wastewater. This study draws from these insights and quantifies the energy and monetary savings to the ABWUD and its SFH customers from decreased volumes demanded, pumped, treated and heated (Cohen *et al.*, 2004).

3.0 BACKGROUND

Faced with the water resource limits imposed by an environment where drought is the norm, climate change is imminent and water demand is increasing with population growth, this study recommends Albuquerque water managers consider a wide array of policy alternatives. One alternative the City has implemented utilizes rebates as customer incentives to purchase and retrofit a range of low flow appliances and fixtures, as well as rainwater harvesting equipment. Beginning in 1996, the Albuquerque Water Utility began providing rebates for low flow toilets. Rebates for xeriscaping began the following year. In 2000 showerheads and washing machines were added to the list of possible rebates. By 2003, rainwater harvesting equipment, hot water re-

circulating systems, dishwashers, sprinkler timers and refrigerated air rebates were available to customers (Yuhas, 2005).

ABWUD rebate programs are touted as contributing to large decreases in Albuquerque per capita water demand. Since the program's inception, the City water demand has decreased from 251 gallons per capita per day (gpcd) to 174 gpcd (WRA, 2003). Albuquerque SFH water demand was quantified in 2001 to have reduced to 135 gpcd (WRA, 2003). While these successes are noteworthy, three still remains a large untapped potential for program enhancement, increasing SFH customer participation and realizing a broader range of savings associated with using less water.

Water conservation and capture technologies offer Albuquerque the largest, most cost effective alternative supply of water to meet current and future demands. Surprisingly though, the potential savings associated with using water efficiently and harvesting rainfall remain largely unrealized. That is, not only are the benefits underestimated, but the subsequent energy and monetary savings are not considered by Albuquerque water managers. Moreover, recent economic analyses of ABWUD implemented rebate programs completely excludes energy saving benefits linked with using less water (Gates, 2004). Consequently, more effective (and needed) demand reducing conservation and capture programs that are clearly cost effective when analysis is inclusive of both water and energy savings are likely to not be implemented when the latter is omitted (Cohen *et al.*, 2004). Prior to this report, no known analysis has attempted to demonstrate that the city of Albuquerque may cost effectively implement conservation and capture programs to address water supply scarcity, reduce urban energy demand and generate

monetary savings for both ABWUD and its customers, notwithstanding the challenges posed by drought, climate change and population growth.

3.1 The Water Energy Nexus

There are inextricable links between end uses of water, energy consumed in water treatment and delivery and water needed for generating energy to both provide and heat water. It is estimated that approximately 3 percent of the energy generated in the U.S. is consumed in the conveyance, treatment, delivery and disposal of municipal water resources. Moreover, about 39 percent of total U.S. fresh surface and groundwater withdraws – close to the 40 percent of freshwater withdraws for U.S. irrigation - is used (some of it consumptively) for thermoelectric power generation (Hutson *et al.*, 2004).

An argument often made against urban conservation planning is that agriculture uses the most water, and therefore, policy should address it first. At this level of analysis it is true, agriculture conservation planning should occur before urban planning. However, and as this study highlights, when one recognizes the significant "energy intensity" of water used in urban sectors – due to energy used in conveyance, treatment, delivery, heating and wastewater treatment and disposal of water resources – and that water is used to generate (some of) that energy, then the importance of urban conservation planning is clear. U.S. projected energy demand for supplying and treating municipal water are estimated to increase about 50% from 2000 to 2050 as population grows (EPRI, 2002). Additionally, targeted urban water use efficiency looks even more attractive when one considers that the majority of the energy consumed in the urban environment occurs in the residential sector for heating water (and drying cloths) (CEC, 2005). In a 21st Century environment of drought, climate change and population

growth, urban (and agricultural) conservation and capture planning is a necessity for U.S. water and energy security.

Nationwide, energy is used to provide water and water is used to generate energy. In Albuquerque, energy costs represent one third (about $5.8M) of the ABWUD operating budget. These costs are the result of pumping only and do not include energy costs associated with potable treatment (as will be required by the SJCP), and wastewater treatment (ECC, 2004). The city residential end users also demand an even larger amount of energy for heating water. Consequently, the combination of supplying the city's potable water, heating it and treating the waste is highly energy intensive. This study identifies the energy intensity of ABWUD toilet and shower water demand and highlights the avoided costs associated with providing, using and heating less water; therefore, decreasing the electricity and natural gas demand and the water needed for thermoelectric power generation. These benefits are projected to 2030 to demonstrate the effect water saving and water capturing technologies have on the demand of a growing population.

3.2 Water Conservation

Water conservation technologies are the "cheapest and most cost effective method" for Albuquerque to maintain a sufficient water and energy supply to meet current and future demands; thus, possibly enabling its continued economic growth and development in New Mexico (Gleick *et al.*, 2003; Lucero *et al.*, 2003). However, the linkages between water and energy must be understood if ABWUD planners are to take full advantage of the potential benefits associated with using less water. Therefore, this study finds that traditional (now insufficient) conservation policy directives would better serve ABWUD customers if they were

modified to embrace the intimate relationship between water and energy. Full recognition of the nexus of these two resources may dictate Albuquerque's ability to adequately prepare for, and meet the challenges of drought, climate change and population growth into the 21st Century and beyond.

This study estimates the in-home end use benefits of using two water saving technologies. Toilets were selected due to their being reported as the single largest water using fixture in SFH. Showers are reported to be the second largest water user (or third depending on which study looked at) and tend to be much more energy intensive than toilets due to hot water use[1]. Both the dual flush toilet and the Shower Water Conservation System present ABWUD and its SFH customers with significant savings when compared to this study's "Status Quo" scenario[2]. Four different scenarios are evaluated against the Status Quo to estimate the potential benefits when 60%, 80%, 100% and an Incremental% of SFH are retrofit or constructed with these two innovations.

This study also forecasts the water and energy demands from toilet flushing and showering on a 24 year time horizon, ending in 2030. For example, in 2020 the total annual Status Quo scenario water and energy demands for toilet and shower use events combined are estimated at 8,053 acre-feet (ac-ft), 111,780 Megawatt-Hours (MwHrs), and 8,212,427 Therms[3]. The latter two estimates reflect the electricity and natural gas demand of ABWUD to provide potable water and treat wastewater and electricity and natural gas demand of SFH to heat water.

[1] Mayer *et al.* (1999) report toilets as the largest user, Clothes Washing as the second and showers as the third. Gleick *et al.* (2003) found toilets the largest, Showers the second and faucets third.
[2] The Status Quo scenario reflects SFH past, present and future demands for toilet and shower water, energy and monetary costs.
[3] This estimate reflects SFH use within the service area boundary of the ABWUD and assumes that SFH water treatment, pumping and heating methods remain unchanged.

The estimates below show the maximum potential savings (from the 100% retrofit scenario) in 2020 associated with retrofitting and building homes with dual flush toilets and the SWCS. The benefits generated by these two innovations exhibit their potential not only to reduce urban water and energy demand, but also facilitate discussion of how they may aid in reducing Albuquerque's reliance on groundwater, meet future demand and help the city prepare for the challenges related to drought, climate change and population growth.

Table 3.2-1 Maximum Conservation Potential in 2020

Benefits	Beneficiary	Dual Flush Toilet		Shower Water Conservation System	
		Status Quo Demand	100% Retrofit Scenario Savings	Status Quo Demand	100% Retrofit Scenario Savings
Water (acre-feet) [1]	ABWUD	-	-	-	-
	SFH	3,331	**1,145**	4,722	**529**
Electricity (MwHrs)	ABWUD	4,460	**1,533**	6,323	**708**
	SFH	-	-	100,997	**11,315**
Natural Gas (Therms)	ABWUD	73,303	**25,193**	104,425	**12,003**
	SFH	-	-	8,034,669	**900,213**
Costs (In 2006 $, r = 5%)	ABWUD	$113,735	**$39,088**	$161,223	**$18,175**
	SFH	$1,537,596	**$528,435**	$9,229,826	**$1,034,086**

[1] Water savings occurs at the SFH end user level

The estimated savings under the 100% retrofit scenario (and the other 3 scenarios) should also highlight additional, less intuitive benefits. Two important benefits examined in greater detail in section 4.3 this report are the enhanced opportunity to meet current and future demand by enhancing water and energy security. That is to say, it is one thing to suggest that Albuquerque's climate and population growth has resulted in demand outpacing sustainable supply, yet it is quite different to propose maintaining a sustainable demand via efficient innovations (and other policies) to supply future opportunity. The water and energy savings

associated with SFH conservation technologies assist users in curbing their appetite for scarce resources without imposing restrictions on every day household tasks (such as flushing and showering). Moreover, the savings contribute significantly to maintaining a supply for both current and future demands; thus delaying growth management programs (Gleick *et al.*, 2003; Lucero *et al.*, 2003).

3.3 Water Capture

The practice of capturing rainfall for domestic uses is not new. Recent research reveals evidence that early Indus Valley human civilizations developed rainwater harvesting systems over 4,500 years ago to adapt to extreme climactic changes. The ancient Mayans were also confronted with changing climate conditions and responded to severe droughts between AD 810 and 910 by constructing rainfall collecting reservoirs and storing water to cope with scarcity (Pandey *et al.*, 2003). Now, and as Albuquerque and its residents advance into the 21^{st} Century, with a high likelihood of similar or even more extreme climate impacts to water (and energy) resource capacity, water resource planners may benefit from the lessons of the ancients.

Current climate change predictive modeling efforts, while still unable to predict with a high level of certainty, precipitation impacts at the local or watershed level, perform well at lower resolution regions, such as the Southwestern U.S. The consensus of climate forecasts demonstrate the high likelihood that less precipitation will contribute to snow pack and more as rainfall. Moreover, earlier snow melts due to above average temperatures are likely to enhance issues associated with urban water supply (Saunders *et al.*, 2005).

Beginning in March 2008, 90% of Albuquerque's water supply is planned to come from the San Juan Chama Project and the remaining 10% from groundwater. This system is reliant on

a San Juan Basin diversionary right of 48,200 ac-ft per year which is stored for use and released from a series of four reservoirs (City of Albuquerque, 2005b). The security of Albuquerque's SJCP water supply, released from upstream reservoirs may however, be compromised by an extreme climate's impact on the timing of precipitation events.

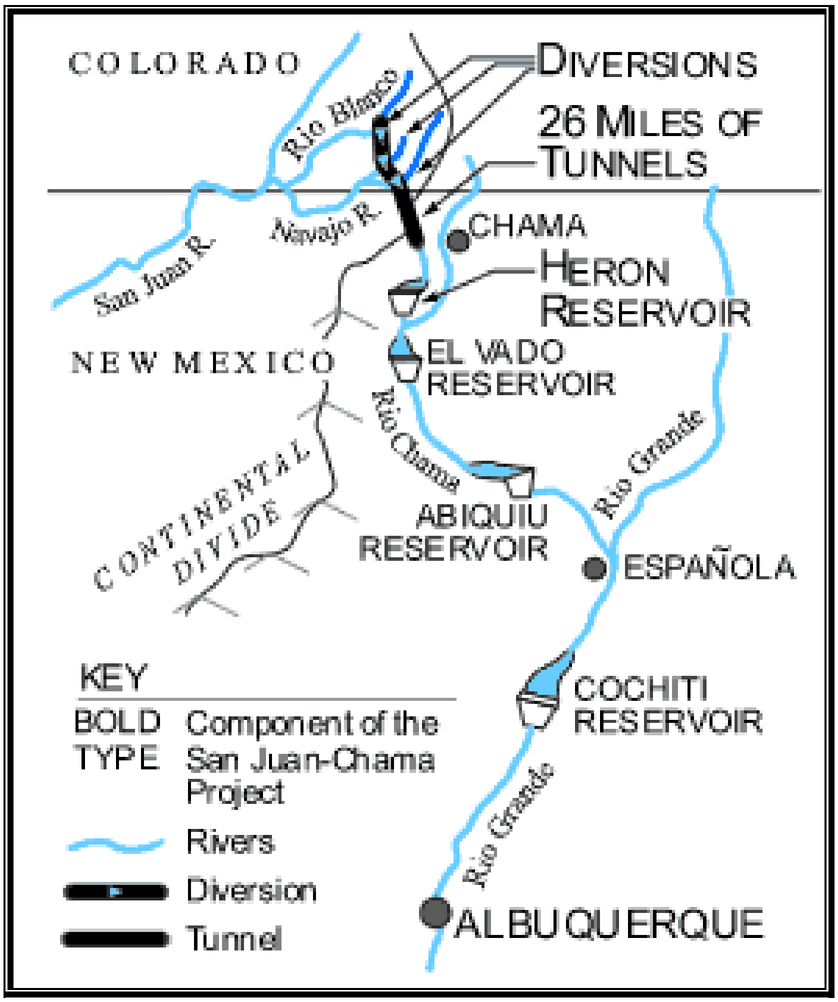

Figure 3.3-1 San Juan Chama Project Diversion and Reservoir Storage System, From (City of Albuquerque, 2005a)

Under normal conditions a slow and steady snowmelt begins in the spring and progresses into the early summer. But, as forecasted by climate models, higher temperatures and rainfall when there used to be snowfall is likely to send early season flood flows to SJCP reservoirs.

Additionally, SJCP water right diversions, managed (and quantified) by the Bureau of Reclamation in the San Juan Basin, may not be able to receive its full annual entitlement when mid to late summer peak demands exceed existing reservoir stocks and river flows; thus, forcing the BOR to quantify shortage sharing between the basin's water users (FWS, 2005). The foreseeable problem is that there may not be enough reservoir storage capacity to meet the downstream demands throughout the summer peak demand season and Albuquerque may have to rely more on groundwater mining. Or, the city water managers could begin to look to the insights of past civilizations and harvest rainfall.

This study examines the rain water harvesting potential from the ABWUD service area SFH customer rooftops. Unlike the previous section which discussed conservation as a method of managing demand to secure alternative source water, this section introduces rainwater harvesting as new means of capturing and delivering alternative source water. However, the prospective water captured is not discussed in terms of rain barrels, but as alternative source water to meet Albuquerque's municipal demand under pressures of drought, climate change and population growth. As a new and alternative source of water, the capturing potential quantified in this study estimates its significant volume of water that may be harvested to offset demands on an uncertain SWCP water supply and an over mined groundwater supply.

Even though rainwater harvesting has enabled early civilizations to endure drought and offers modern urban sectors a significant potential for securing an alternative source of water supply at a relatively inexpensive cost, it is not largely used. This oversight is likely due to incomplete information as to what the potential benefits are. So, as with the two conservation technologies discussed above, this study quantifies the SFH water harvesting potential under four

retrofit scenarios: 60%, 80%, 100% and an Incremental% scenario. Again a 24 year forecast is used to determine SFH rainwater capturing potential as both the demand of an increasing population and the number of homes, or rooftop surface area, increases.

Under the Status Quo scenario, the 2020 total ABWUD single family home water demand is estimated at 55,543ac-ft[4]. If (in 2020) ABWUD and its SFH customers were to take full advantage of the water capturing potential of household rooftops, then the capacity to offset demands on surface and groundwater resources is significant. The estimates below show the maximum potential 2020 water capture from the 100% retrofit scenario. The quantifiable benefits of harvesting water from the sky demonstrate that not only may Albuquerque secure a new alternative water source, but it represents a significant portion of total SFH water demand and would help the City better prepare for the water supply challenges likely to occur due to drought, climate change and population growth.

Table 3.3-2 Maximum Rainwater Capture Potential in 2020

Benefits	Status Quo Demand	100% Retrofit Scenario Capture Potential	Captured Water as % of Status Quo Demand
Water (acre-feet)	55,543	**5,682**	10%

Here the benefits to SFH are not immediately apparent. Nevertheless, there are considerable advantages for homeowners participating in rainwater harvesting programs. Capturing rainwater translates into more viable future groundwater resources, contributing to the water security of future generations. Enhanced water security may encourage economic growth and development; perhaps raising the value of SFH and expanding home owner equity (Koenig,

[4] This estimate reflects SFH use within the service area boundary of the ABWUD and assumes 3.06 persons per SFH and135gpcd.

2003). Above, the maximum potential for capturing rain water is estimated at 10% of the total 2020 SFH demand. Recall that after March 2008 the City will acquire 10% of its water supply from the underlying aquifer. Therefore, further reductions to groundwater pumping due to rainwater harvesting would advance aquifer recharge and recovery[5]. Possibly even more important is that SFH owners' contributions to meeting the challenges of drought, climate change and population growth may encourage what is desperately needed in Albuquerque (and the greater Western U.S.), a conservation ethic.

4.0 SINGLE FAMILY HOME POPULATION PROJECTIONS

This study's toilet, shower and rainwater harvesting analyses all required estimates of Albuquerque SFH populations and the number of SFH existing within the service area of ABWUD each year. Several sources' data were used to generate population projections necessary for this study. Projection data is summarized in Table 4.0-1.

Table 4.0-1 Population Projection Sources and Data

Data Source	Data
Bureau of Business & Economic Research, UNM http://www.unm.edu/~bber/	1.) Bernalillo County Population Growth Rate 2000-2030
Katherine Yuhas, "Water Conservation Officer" Albuquerque Bernalillo County Water Utility Dept. kyuhas@cabq.gov	1.) Albuquerque population estimates 2000-2005 2.) ABWUD service area population 1990-2005 3.) 3.06 person per single family home
2000 Census "Fact Finder" http://factfinder.census.gov	1.) 65.68% of Albuquerque homes are single family homes

The Bureau of Business & Economic Research (BBER) provided Bernalillo County growth rate and population projections from 2000 to 2030 (BBER, 2006). Albuquerque

[5] Harvesting rainwater from rooftops may impact the amount of water infiltrating into the City's underlying aquifer through lawns and landscapes surrounding SFH. Moreover, harvesting will decrease the volume of urban runoff contributing to the Rio Grande River flows. Therefore, future analyses may wish to compare potential recharge and flow regime losses against the benefits of reduced groundwater mining.

population estimates between years 2000 and 2005 came from Yuhas (2006), who had the five year population estimates update annually by BBER. Years 2006 to 2030 were estimated using Bernalillo County growth rates. The resultant population numbers each year fall between those used in the 1997 “City of Albuquerque Water Resource Management Strategy (WRMS)” and more recent City of Albuquerque Planning Dept. projections from "The Planned Growth Strategy (PGS) 2006 Part 2". The former WRMS projections are consistently larger than those in the PGS.

The WRMS population estimates use City of Albuquerque population data, adds in the population served in the unincorporated areas and subtracts the New Mexico Utilities service area (Roth, 2006). The PGS assumes that Albuquerque's population is 80% of the County population (City of Albuquerque, 2006b). There is not a significant difference between the WRMS & PGS population projections and this study's forecast. This study chose a more conservative, and updated projection to avoid potential overestimating or underestimating savings. Thus, the potential water, energy and monetary savings identified in this analysis, although significant, are estimates. Albuquerque population projection assumptions and methodology are in Appendix 1.

This study has narrowed its analysis to ABWUD single family homes only. Since the population projections above do not give any indication of the number of SFH existing within the ABWUD service area boundary, or the population in these homes, then several assumptions were made to estimate projections of service area SFH populations. ABWUD service area population data from 1990 through 2005 was obtained from Yuhas (2006). During this six year period, an annual average of 97% of Albuquerque’s population lived within the ABWUD service

area. Thus, 97% of the aforementioned Albuquerque population projections were assumed customers of ABWUD.

According to Yuhas (2006), ABWUD assumes 3.06 persons per home in their billing and water use analysis. Additionally, the 2000 Census Fact Finder website shows that 65.68% of Albuquerque homes are SFH (US Census, 2000)[6]. These two numbers were used with the service area population to estimate the number of ABWUD service area SFH Customers. ABWUD service area SFH population projection assumptions and methodology are in Appendix 2.

5.0 WATER CONSERVATION POTENTIAL

Water conservation technologies offer ABWUD and its service area customers a large potential for water, energy and monetary savings, and would best serve the public if they were to become a common paradigm in policy regarding the City (and other New Mexico cities) water supply. Additionally, water conservation can produce "the largest, least expensive and environmentally sound" supply of alternative source water required to meet current and future needs (Geick *et al*., 2003, p.1). Without a clear understanding of the potential savings associated with the type of innovations discussed in this report, the ABWUD service area demands for water and energy will likely increase as pressures of drought, climate change and population growth force development or transfer of larger scale and more expensive supply options.

To estimate the potential benefits possible with conservation and capture innovations this study narrows the analysis, focusing on ABWUD single family homes. Realizing the prospective demand reductions on surface and groundwater resources requires that there first be reliable

[6] According to the 2000 Census, Albuquerque had 198,714 housing units. This study counted categories "1 unit attached", 1 unit detached and "2 units" (or duplexes) as single family homes.

information regarding the real potential for enhancing water use efficiency[7]. Without realistic information on the potential for water conservation, questions regarding Albuquerque water use goals, the ABWUD Water Resource Management Strategy, mitigating drought, water and energy security, economic growth and development, Safe Drinking Water Act compliance, watershed management, funding options, etc. are much more difficult to answer. Moreover, without this knowledge, the policy solutions to these questions may be wrong (Gleick *et al.*, 2003).

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". Typically, Albuquerque SFH water use is determined by water delivery and service connection data (Stomp, 2006). While total water delivery may be useful when evaluating the overall ABWUD household use, it does not offer clear insight into the effects of individual conservation measures, such as toilet rebates. Thus, this report identifies the Status Quo (baseline) water and energy demands and monetary costs as a means to highlighting the value of disaggregating end uses to evaluate their individual impact on demand and costs (Gleick *et al.*, 2003).

The Status Quo toilet and shower water demands in 1998 Albuquerque SFH, identified in this study, are similar to the demands of 12 separate U.S. cities reported in Mayer *et al.* (1999). The two analyses' pie charts below clearly demonstrate that toilets constitute the largest percentage of indoor SFH water demand around 1998[8]. However, Albuquerque household water use patterns have changed over time due to persistent National toilet standards and ABWUD

[7] Further steps towards realizing prospective demand reductions on imported water and groundwater are discussed in the Policy Recommendations section of this report.
[8] Mayer *et al.* (1999) determined "Other Indoor Uses" per capita SFH demand from clothes washers, faucets, leaks, other domestic, baths and dishwashers. Toilets and Shower water demand are singled out for comparison with this study.

toilet rebate (and other rebate and educational) programs. Consequently, this study finds that total per capita toilet water demand, which is traditionally considered to be the largest indoor water use, now (seen in the in 2006 pie chart below) falls below total per capita shower demand in Albuquerque SFH.

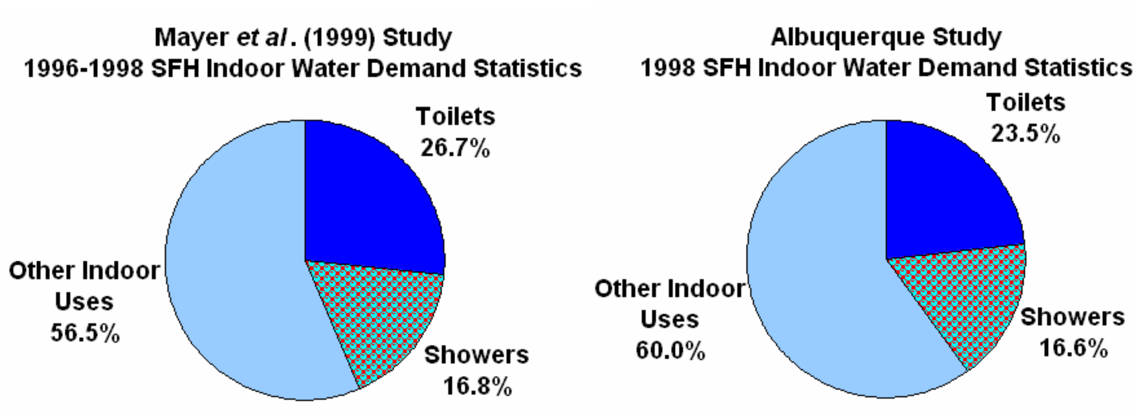

Figure 5.0-1 Comparison of Per Capita Toilet and Shower Water Use Statistics from Mayer *et al.* (1999) and This Study's 1998 Estimates

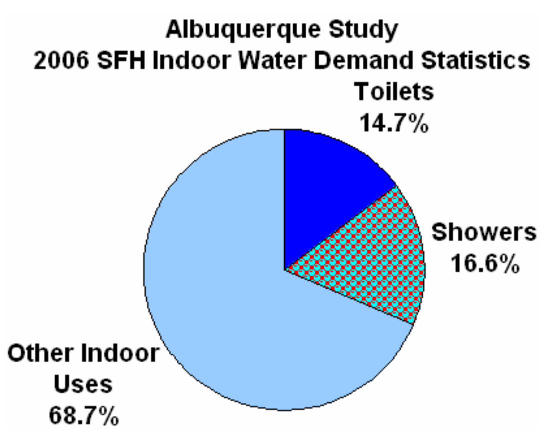

Figure 5.0-2 Albuquerque 2006 SFH per Capita Toilet and Shower Water Use Statistics

The above finding does not necessarily contradict those of other studies referenced in this report. That is, prior research by Mayer *et al.* (1999) and Gleick *et al.* (2003) show that toilet flushing constitutes the larger share of per capita water use in years 1998 and 2000 respectively.

Possible reasons for the disparity may be explained by fact that the SFH study by Mayer *et al.* (1999) quantified SFH per capita usage using flow trace analysis across 12 U.S. sites, but did so from 1996 to 1998. The findings of Gleick *et al.* (2003) were estimated from all California per capita end uses (commercial, industrial, institutional and residential) in 2000. Thus, the temporal and urban sector distinction between research efforts are likely to play a part in isolating Albuquerque Status Quo per capita SFH water use, since it is after 2003 that household showering overtakes toilet flushing[9].

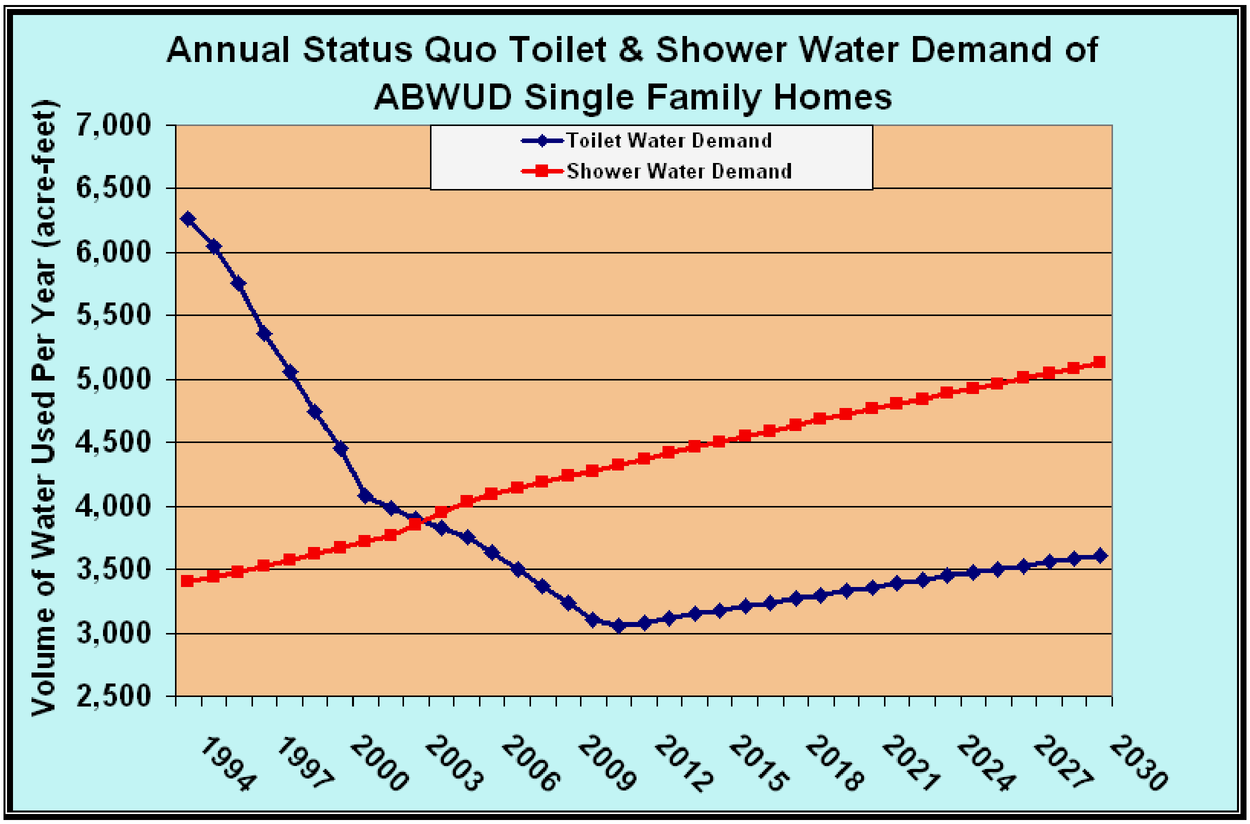

Figure 5.0-3 ABWUD Single Family Home Estimated and Projected Toilet and Shower Water Demand

[9] Prior to 2003 Albuquerque SFH per capita toilets water use maintains a dominant demand over per capita shower water use.

Moreover, the ABWUD service area SFH customers constitute a much smaller sample of residential end users and this study may simply be highlighting the previously unknown successes of combined Federal mandates and ABWUD rebate programs.

What ever the reasons for the disparity between this reports finding and those of AWWA and the Pacific Institute research, it is clear that ABWUD per capita SFH toilet and shower water use patterns are different than what previous measures (prior to 2004) would have concluded in the New Mexico's largest city. This new information should begin to provide insight into what type of targeted conservation strategies are appropriate for ABWUD service area customers. However, as emphasized in this report, it is important to also understand the benefits associated with per capita water use reductions. This study recommends the potential of dual flush toilets and the SWCS for saving water, energy and money at both the utility and household level be recognized, to realistically begin shaping targeted conservation programs that help prepare the city for future drought, climate change and population growth.

The ABWUD service area per capita toilet flushing and showering events in SFH provide the basis for determining Status Quo water and energy demand as well as monetary costs at the utility and household levels. Additionally, understanding the Status Quo demands and costs associated with per capita toilet and shower water use makes it possible to evaluate the potential savings of this study's four retrofit scenarios.

Several sources of information were combined to determine the current penetration of toilets and shower and water heating fixtures in Albuquerque SFH. Toilet data (and assumptions) originated in part from Gleick *et al.* (2003), but mostly from manually counting ABWUD rebates

recorded on paper from 1996 to the present[10]. Shower and water heater information were gathered from the Department of Energy and reports by the Rocky Mountain Institute and Oak Ridge National Laboratory. Empirical values of actual per capita SFH toilet and shower usage and household usage came from Mayer *et al.* (1999), Gleick *et al.* (2003) and Western Resource Advocates. Equations derived in Gleick *et al.* (2003) are used to quantify the mix of volumetric toilet flush types existing in Albuquerque SFH and to quantify the cost of conserved water in cost effective analyses.

ABWUD specific data regarding the energy consumed and associated costs in treating drinking water, pumping, and treating wastewater was obtained through personal communication with several water utility employees. Their individual contributions to this study's information gathering process were both essential and considerate. Their willingness to assist a graduate student researcher amid their daily duties is greatly appreciated.

So the question still remains, what is the potential of water saving innovations in ABWUD single family homes? The following sections demonstrate the methods and discuss assumptions, data and models used to quantify the water energy and monetary savings associated with using dual flush toilets and the SWCS in ABWUD single family homes.

5.1 The Dual Flush Toilet

According to several previous research efforts, toilet flushing is the single largest water use in homes. The Status Quo finding of this report however, illustrates that Albuquerque SFH per capita toilet water demand, the energy required to treat and provide toilet water and the costs

[10] ABWUD toilet rebate records are not currently transposed into electronic format. The utility focuses on total water deliveries and does not use rebate records to determine individual urban sector program participation.

linked to providing and using it have declined due to successful federal laws, implemented rebate programs and normal replacement. While the Status Quo conditions are a good example of policy impacts on per capita usage, much more is possible with new toilet innovations such as the dual flush toilet.

5.1.1 Toilet Innovation History

Using innovative toilet designs is not a new idea. Effective in 1994, the 1992 National Energy Policy Act required all toilets sold in the U.S. be Ultra Low Flow Toilets (ULFTs) using a standard flush volume of 1.6gpf. Prior to this National standard both 6.0gpf and 3.5gpf toilets dominated the U.S. toilet market. The 6.0gpf models were the standard until 1978 when California mandated toilets not exceed 3.5gpf. Consequently, 3.5gpf models were adopted by most U.S. State plumbing codes (CUWCC, 2005a). The ABWUD implemented its toilet rebate program in 1996. Customers can now receive up to $125.00 to replace an existing inefficient (6.0gpf or 3.5gpf) model with a 1.6gpf ULFT. Currently however, the program does not specify which models, or types of toilets, should be used for a rebate, limiting the potential water, energy and monetary savings to ABWUD and its SFH customers (Yuhas, 2005)[11].

Even though ULFTs use significantly less water per flush than their predecessors, they tend to not always perform well. That is, they often require more than one flush per use. According to the Mayer *et al.* (1999) study, SFH using 1.6gpf toilets flush more frequently than homes using 6.0 or 3.5gpf toilets. The result of encouraging ABWUD SFH to use any ULFT rated at 1.6gpf is that the added water use increases both the energy demand of toilet water and

[11] Several months prior to completing this report the ABWUD adopted a new resolution that enhanced the toilet rebate program examined in this study. Beginning July 1, 2006 water utility customers may receive an additional $50.00, on top of the normal $125.00 rebate, for the purchase and certified installation of a dual flush toilet or any other HET (ABWUD, 2006a).

imposes extra and unnecessary monetary costs on the water utility and its customers. Therefore, this study shows that SFH per capita toilet water use, the energy it consumes and costs may be reduced significantly by Albuquerque SFH retrofitting with dual flush toilets.

There are many low flow toilet innovations currently available in the US market, but not all of them perform well enough to meet performance testing standards. High Efficiency Toilets (HET) are those toilet makes and models that either meet or exceed such standards. HET and the focus on them is relatively new and many toilets that have been sold since the 1994 National Energy Policy Act standards began have been ULFT that may not perform well (Gauley *et al.*, 2005). Since it is not known whether ABWUD rebates have been used in SFH to acquire HET, which decrease the frequency and flush volume per capita, this report separates ULFT from HET in assuming no (or a negligible number of) dual flush toilets (or other HET) have been purchased though the ABWUD rebate program (Yuhas, 2005).

5.1.2 Toilet Water Methods and Estimates

The data and assumptions required in this study's spreadsheet model to generate estimates of SFH toilet water demands under the Status Quo and Retrofit Scenarios originate from several sources. Table 5.1-1 summarizes these data sources.

Table 5.1-1 Toilet Water Sources and Data	
Data Source	Data
This Study's SFH Population Projections (section 4.0)	1.) ABWUD service area SFH customer population projections
Katherine Yuhas, "Water Conservation Officer" Albuquerque Bernalillo County Water Utility Dept. kyuhas@cabq.gov	1.) ABWUD service area newly built single family homes 1990-2005 2.) 3.06 person per single family home
AWWA Research Foundation "Residential End Uses of Water" http://www.awwa.org/bookstore/product.cfm?id=90781	1.) 0.77 toilets per person 2.) Number of flushes per person per day for 6.0gpf and 3.5gpf toilets are 4.92; 1.6gpf toilets are 5.06 3.) % of single family homes using 6.0gpf, 3.5gpf and 1.6gpf toilet models 1996-1998
California Urban Water Conservation Council	1.) Typical toilet life = 25years = 4% natural replacement rate
Albuquerque Bernalillo County Water Utility Department rebate history files[1]	1.) Single family home toilet rebates 1996-2005
Pacific Institute, "Waste Not, Want Not: The Potential For Urban Water Conservation in California" http://www.pacinst.org/reports/urban_usage/	1.) Mix of SFH population using either 6.0gpf, 3.5gpf toilet models or a combination of both 1990-1994
[1] Rebate history was manually counted since rebate forms are not electronically recorded.	

Unfortunately, the ABWUD rebate program has not kept record of the types of toilets (6.0gpf and 3.5gpf) that have been replaced. Accurate information regarding the existing mix of toilets in homes is common across U.S. cities (CUWCC, 2005a). So, the method for quantifying SFH per capita toilet water use relies on methods used in Gleick *et al.* (2003). These methods' equations combined with this study's population and housing data and rebate history data were used to estimate what portion of the Albuquerque SFH population is using what type of toilet each year. Here, the Status Quo distribution of 6.0, 3.5 and 1.6gpf toilets used by ABWUD single family homes was estimated each year by determining the population living in newly built homes, the population using ULFTs retrofit due to the rebate program and the population using

ULFTs that have been swapped out by normal replacement due to the natural replacement rate of 4%, representing the typical 25 year life of a toilet (CUWCC, 1992; Gleick *et al.*, 2003) (Appendix 3).

The ABWUD service area newly built SFH constructed between 1990 and 2005 was provided by Katherine Yuhas, the department's Water Conservation Officer. The average percentage of new SFH customers from 1994 to 2005 was used with earlier discussed estimates of annual ABWUD single family home customers to estimate future "new" SFH customers for each year. Assuming 3.06 persons per home, the number used by the water utility to estimate customer water use, the ABWUD newly built home population was estimated each year (Yuhas, 2005).

The SFH population using ULFTs due to the ABWUD toilet rebate program was determined by manually counting rebate reports from 1996 to the present and again assuming 3.06 persons per home, as well as assuming 0.77 toilets per person (Mayer *et al.*, 1999). Estimating the Albuquerque SFH population each year using ULFTs due to normal replacement required use of the equation below from Gleick *et al.* (2003):

$$\mathbf{P_{nr\,(CURRENT\ YEAR)} = (P - \sum P_{nr\,(PREVIOUS\ YEARS)} - \sum P_{nh} - \sum P_{rp}) * LT}$$

here:
$\mathbf{P_{nr\,(CURRENT\ YEAR)}}$ is the current SFH population that is already using ULFTs that have been replaced due to normal replacement
P = SFH population in any year
$\mathbf{\sum P_{nr\,(PREVIOUS\ YEARS)}}$ = sum of the previous year SFH population and the current year SFH population using ULFTs that have been replaced due to normal replacement
$\mathbf{\sum P_{nh}}$ = sum of SFH population living in newly built homes in any year
$\mathbf{\sum P_{rp}}$ = sum of SFH population using toilets acquired by ABWUD rebate program
LT = typical life of a toilet, which is assumed to be 25 years (CUWCC, 1992).

The above equation and estimates of SFH population living in new homes as well as the population using toilets acquired through the ABWUD rebate program were combined to estimate the total SFH population using ULFTs each year. Therefore, to estimate the population using ULFT's each year the following equation was used,

$$\mathbf{P_{ULFT} = \sum P_{nr} + \sum P_{nh} + \sum P_{rp}}$$

where:
$\mathbf{P_{ULFT}}$ is the current SFH population using ULFTs.

Using the equations above with the different flush volumes and number of flushes per capita per day (pcpd) as empirically determined by Mayer *et al.* (1999), this study estimated the Status Quo volume of water demanded for toilet flushing each year by ABWUD single family homes form 1994 to 2030. From 1990 to 1994 the mix of SFH population using either 6.0gpf, 3.5gpf or a combination of both was assumed to be similar to the percentage of the California population, in the same years, using each as determined by Gleick *et al.* (2003). The assumption that those four early years of toilet penetration were similar to those of California was also calibrated against statistics from the Mayer *et al.* (1999) study that monitored 289,000 flushes from 1996 to 1998. Here 8.5% of SFH used 1.6gpf (ULFT) toilets almost exclusively, 26.2% of SFH used a mix of 1.6gpf and Non ULFT, 65.3% of SFH use Non ULFT exclusively. Moreover, According to the Mayer *et al.* (1999) study, which used flow trace analyses, ULFT are flushed an average of 5.06 times per person per day while Non-ULFT, or 6.0gpf and 3.5gpf toilets are flushed an average of 4.92 times per person per day (Appendix 3). Since this study's Status Quo and four retrofit scenarios were projected to 2030 to demonstrate the potential water, energy and

monetary savings, then this study's SFH population projections were used with the equation and estimates described above to estimate the toilet water demands each year.

5.1.3 Status Quo Toilet Water Demand

The methods for estimating toilet water demand discussed above generated results that tells an interesting story of how Albuquerque SFH Status Quo toilet water use has changed and will continue to change over time if current policies are maintained. Beginning in 1994, the year the 1992 National Energy Policy act was implemented, 6.1gpf toilets became the National standard. As a result the estimated SFH per capita toilet water demand decreased by 8.7%. When ABWUD rebate program began in 1996, the rate of per capita demand declined even faster due to an enhanced penetration of ULFTs and a departure from SFH using Non Low Flow toilets. In 2001, the same year this study estimates that 6.0gpf toilets were eradicated from ABWUD single family homes, Western Resource Advocates conducted a study that estimated Albuquerque SFH water use. The report said that "total SFH water use" had decreased from 183gpcd (in 1994) to 135gpcd in 2001, a reduction of 36% (WRA, 2003). This study finds that "SFH toilet water use" decreased by 53% during the same time period. After 2001 this study estimates that only a mix of 3.5gpf and 1.6gpf toilets are being used by homes. Here, and up until 2011, the rate of decline in total SFH toilet water demand is diminished. Even though the per capita toilet water use continues to decline, the effects of population growth on total toilet water demand are clear.

It is also important to recall that after 2003 toilet water demand falls below shower water demand. According to the study's (spreadsheet model) findings, in 2011 3.5gpf toilets are fully removed from ABWUD single family homes. At this juncture, it is clear that SFH population

growth effectively increases the total per capita toilet water demand every year, regardless of the finding that all homes are using ULFTs.

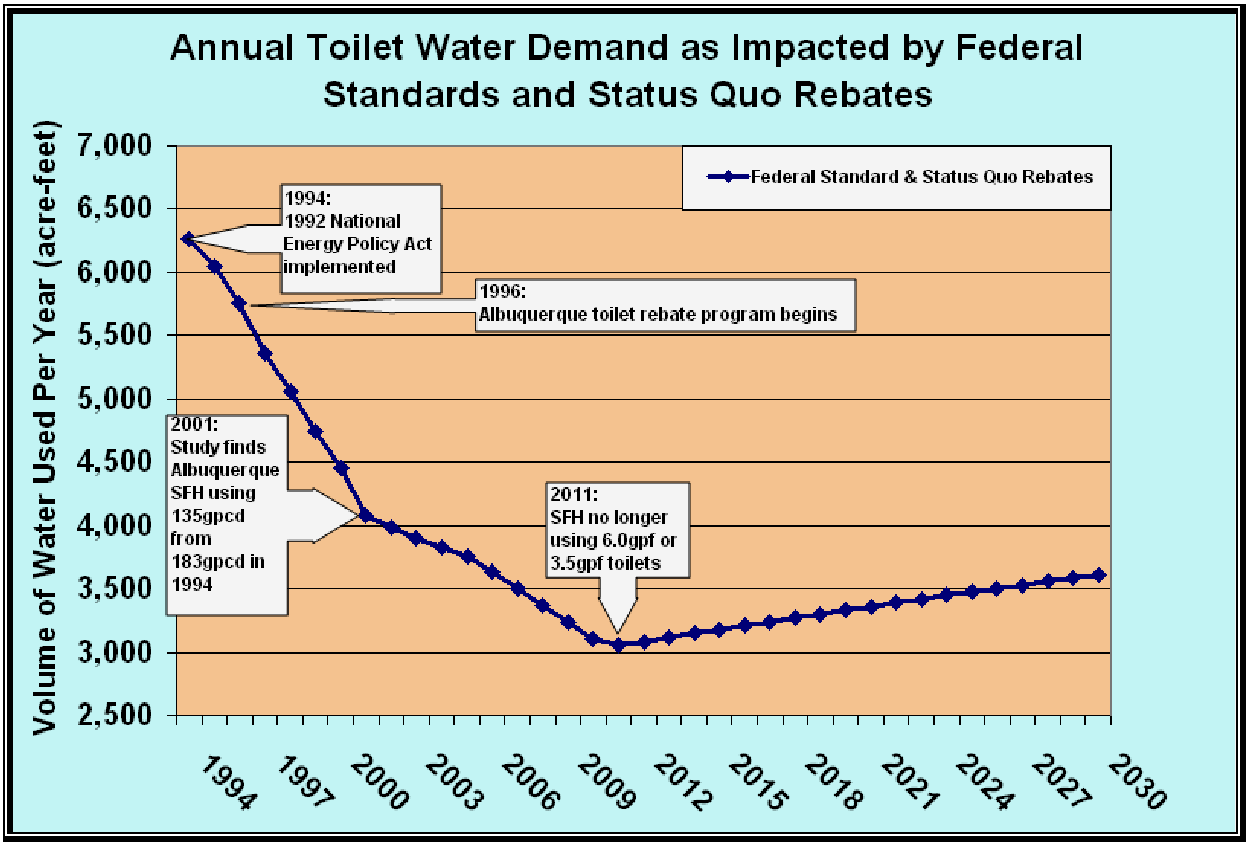

Figure 5.1-1 Estimated and Projected Trend in SFH Toilet Water Demand

5.1.4 Dual Flush Toilet Potential Water Savings

The SFH toilet water story above begins to highlight the importance of modify existing rebate programs to realistically begin reducing toilet water demand as much as possible. Four dual flush toilet retrofit scenarios were analyzed alongside the Status Quo projections to demonstrate the potential savings associated with this modern HET. Starting in 2006 and forecasting toilet water demand to 2030, it is clear that no matter what type of toilet is used after 2011, the effect of population growth on total usage is persistent.

One important distinction to recognize between the Status Quo and other retrofit scenarios is that when SFH populations are using dual flush toilets, the total demand is increasingly smaller over time. Between 2011 and 2030 the Status Quo and 60% Dual Flush Toilet retrofit scenarios' total water demands increase at slightly different rates. So, the plotted slope between these two scenarios demonstrates the potential for significant water savings over time. The figure below shows the demand as well as the water savings at 2011, 2020 and 2030 between the Status Quo and 60% Retrofit Scenarios[12]. The toilet water demand projection estimates and methodology can be found in Appendix 4.

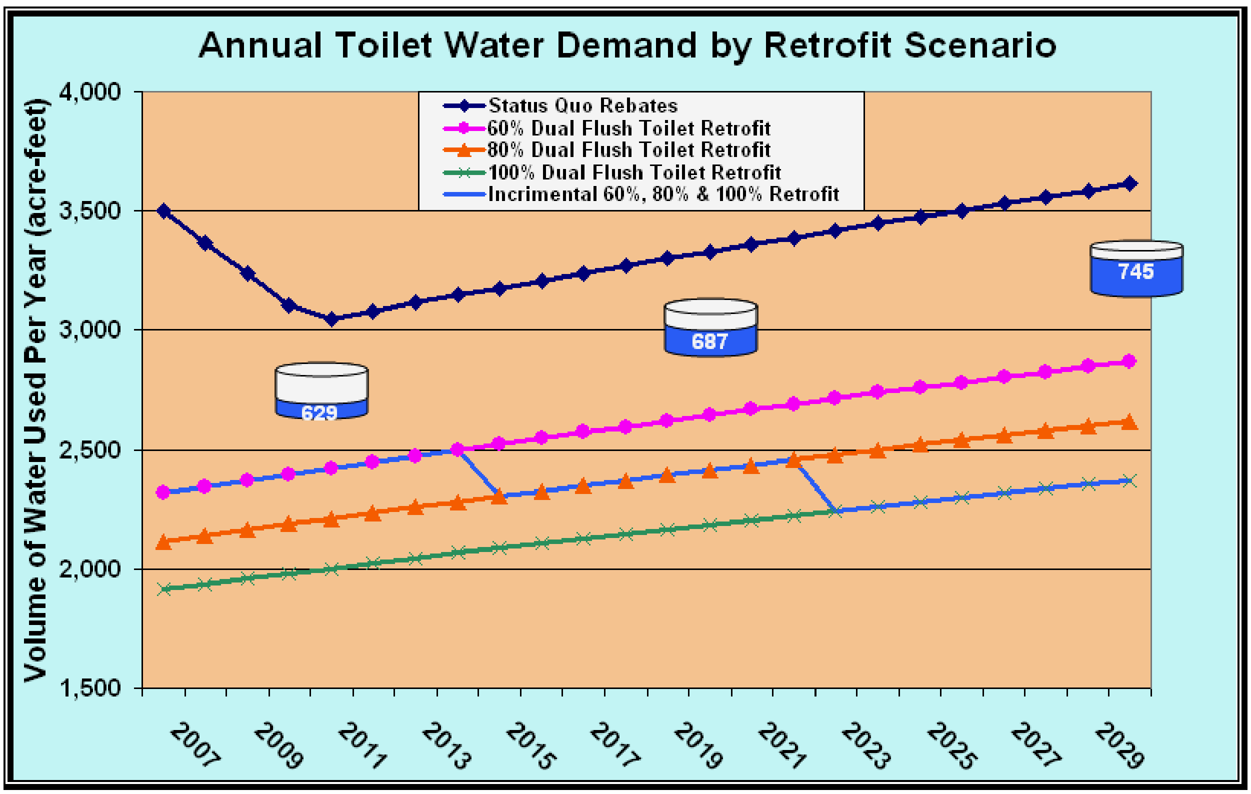

Figure 5.1-2 Projected SFH Total Toilet Water Demand

[12] Here 2011 was selected rather than 2010 to present and discuss a more conservative water savings. Prior to 2011, this study predicts SFH are still using 6.0gpf toilets.

5.1.5 Toilet Water and Energy Nexus

Understanding the above water demand trend also brings to light the fact that the energy required to provide SFH with toilet water will also increase in time. That is, energy is consumed at the ABWUD to pump groundwater from the ground and to city reservoirs, divert San Juan Chama water from the Rio Grande and treat it to potable standards at the new SJCP treatment facility, pump treated water from the Finished Water Pump Station to city reservoirs to mix with groundwater and treat wastewater at the Southside Water Reclamation Plant[13].

In Albuquerque, where the main source of urban water supply has traditionally been groundwater, both well and booster pumping is required to deliver potable water to city storage reservoirs. Electricity and natural gas are used to perform these tasks.

Beginning March 2008, only 10% of ABWUD customer water supply will come from groundwater. The remaining 90% will come from the new (currently under construction) San Juan Chama Drinking Water Plant. After treatment the water will be pumped to the Finished Water Pump Station and then pumped to city storage reservoirs to mix with groundwater. While the energy demand at the treatment plant is not yet fully known, and will likely fluctuate according to the changes in Rio Grande water quality, estimates were provided for this study.

Once toilet (and other end use) water is used it is treated at the Southside Water Reclamation Plant. Here the wastewater treatment process collects digester gas as the waste breaks down. The gas is used to generate electricity for plant operation and sometimes is sold back to PNM. However, the plant still needs to purchase both electricity and natural gas to treat wastewater throughout the year. The facilities contract with PNM has peak and off peak rates

[13] ABWUD water distribution system is largely gravity fed, so the city benefits from not having the added energy cost of pressurizing pipelines.

and natural gas prices that change monthly. Therefore, the mix of electricity and natural gas purchased depends on the month, day and time.

5.1.6 Toilet Energy Methods and Estimates

The above connections between toilet water and energy demand were determined by personal contact with ABWUD staff, who provided estimates of the electricity and natural gas purchased per gallon at well and booster pumps, the SJCP treatment facility and Finished Water Pump Station and at the Southside Water Reclamation Plant. Given these energy use estimates and the previously discussed water use methods and estimates, this study's spreadsheet model compared the 24 year Status Quo ABWUD energy demand for providing toilet water to single family homes, and treating it, to the same four dual flush toilet retrofit scenarios. The data, sources and assumptions required in this study's spreadsheet model to generate ABWUD toilet energy demand estimates under the Status Quo and Retrofit Scenarios is summarized in table Table 5.1-2.

Table 5.1-2 Toilet Energy Sources and Data

Data Source	Data
Bagher Dayyani, SCADA Manager, Water Systems Division, City of Albuquerque. BDayyani@cabq.gov	1.) 0.003406 KwHr/gallon & 0.00002589 Therms/gallon pumped form Albuquerque production wells and booster pumps
John Stomp, Water Resources Director, Albuquerque Bernalillo County Water Utility Authority JStomp@cabq.gov	1.) 0.003234 KwHr/gallon treated at the New San Juan Chama Drinking Water Plant and pumped to reservoirs from the Finished Water Pump Station 2.) SJCP will supply 90% of the ABWUD water and wells 10% after March 2008
Doug Dailey, Wastewater Utility Manager, Albuquerque Bernalillo County Water Utility Department DDailey@cabq.gov	1.) 0.0008584 KwHr/gallon & 0.00006495 Therms/gallon of wastewater treated at the Southside Water Reclamation Plant

In 2004, the city groundwater production wells and boosters pumped 32,600 million gallons and consumed 111,047 MwHrs and 844,036 Therms [14]. So, this study used 0.003406 KwHrs per gallon and 0.00002589 Therms per gallon of water pumped from wells and delivered to reservoirs by booster pumps to estimate toilet water energy demand (Dayyani, 2005) (Appendix 5).

The City's future drinking water treatment plant energy demand estimate was forecasted by Ch2MHill under an expected water treatment volume of 32,850 million gallons. At this volume the SJCP is expected to consume approximately 0.003234 KwHr per gallon of water treated and pumped to the Finished Water Pump Station (Stomp, 2006) (Appendix 6).

This study generated estimates of electricity and natural gas purchased per gallon at the Southside Water Reclamation Plant by looking at the total amount purchased in 2005. Here, the city's wastewater treatment facility treated 20,476.5 million gallons and purchased 17,578 MwHrs and 1.33 Million Therms[15]. Thus, roughly 0.0008584 KwHr and 0.00006495 Therms (of purchased gas only) are assumed to be required per gallon of wastewater treated (Dailey, 2006) (Appendix 7).

The energy demand at each of the three aforementioned toilet water supply and treatment arenas was quantified according to 100% groundwater and booster pumping plus wastewater treatment from 2006 to 2008. Beginning in 2008, estimates of energy demand assumed 10% groundwater and booster pumping and 90% SJCP treatment and pumping, along with the same wastewater treatment demand (Stomp, 2006).

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[14] Chlorine and Fluoride are also used to treat groundwater, but are not included in this study's analysis.

[15] Albuquerque's Southside Water Reclamation Plant uses a process that collects digester gas as the waste breaks down. It uses this gas to generate electricity to use at the plant and sometimes sells it back to PNM. However, the plant still needs to purchase both electricity and natural gas to treat waste water throughout the year.

5.1.7 Dual Flush Toilet Potential Energy Savings

Again, the rate of increase between scenarios' energy demands is different as population grows, when compared to the Status quo demand, demonstrating the potential for considerable savings over time. For example, the difference (or energy savings) between the Status Quo and 60% Retrofit Scenario electricity and natural gas demands in 2011, 2020 and 2030 are 842, 919 and 998 MwHrs and 13,841, 15,115 and 16,405 Therms respectively (Appendix 8 & 9).

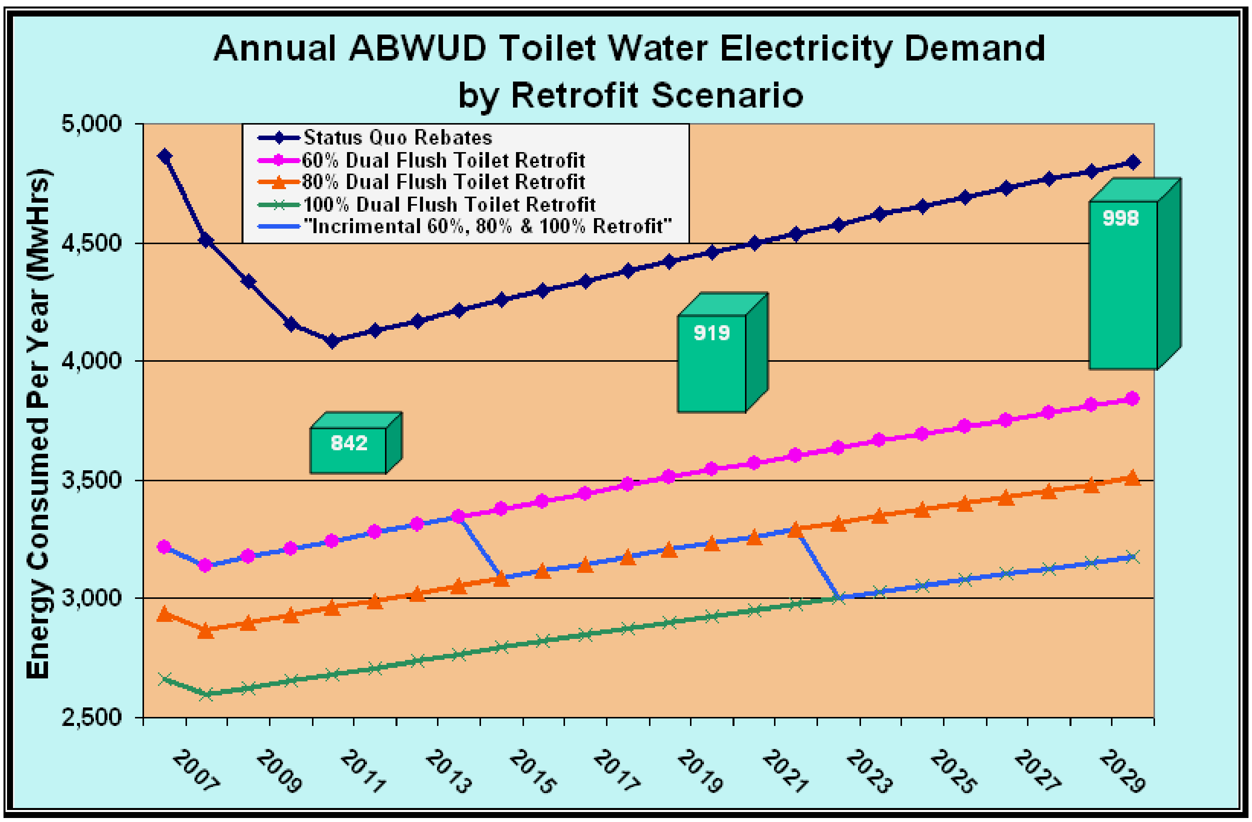

Figure 5.1-3 Estimated and Projected Trend in SFH Toilet Water Electricity Demand

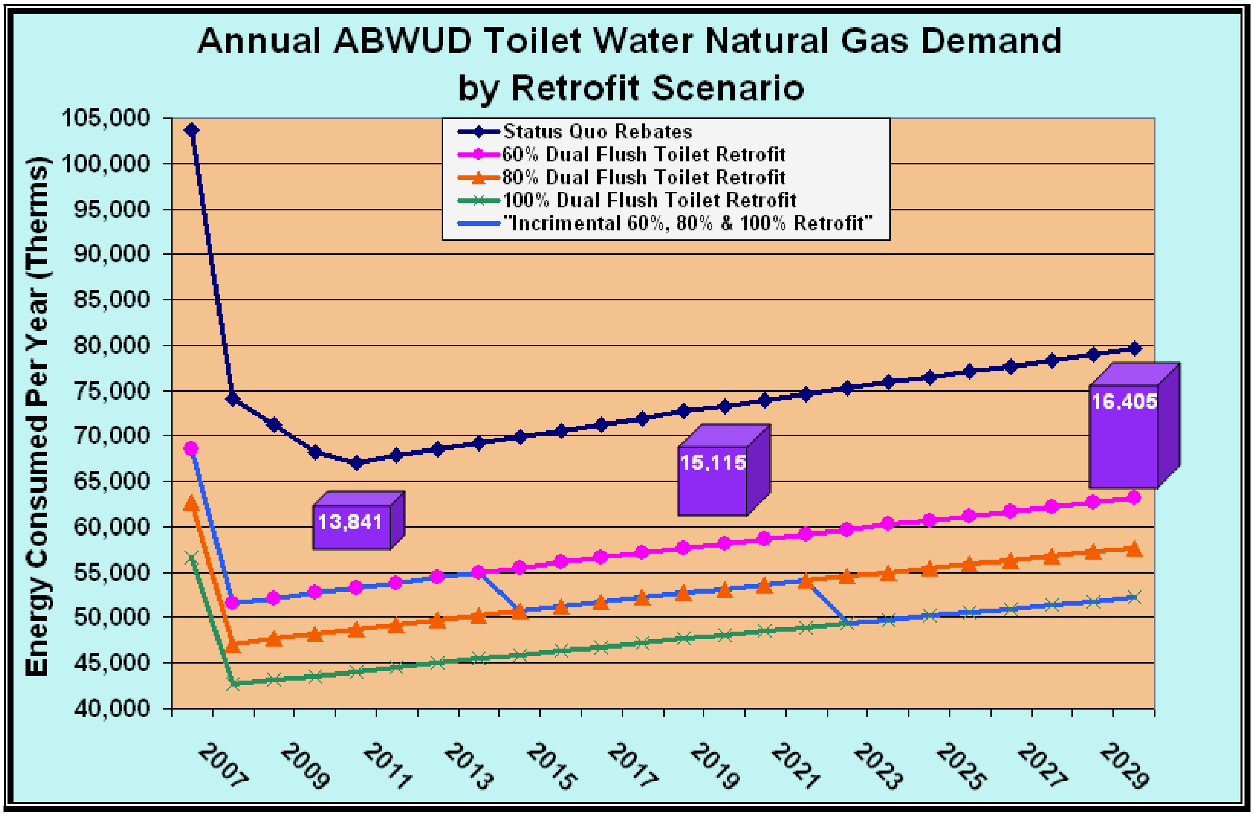

Figure 5.1-4 Estimated and Projected Trend in SFH Toilet Water Natural Gas Demand

5.1.8 Toilet Water and Energy Costs

Quantifying the resource benefits associated with using water efficient toilets also draws attention to the costs associated with per capita toilet water use. There are considerable costs coupled to providing water to SFH that is ultimately used for toilet flushing and then requires wastewater treatment. Moreover, households themselves also pay water and sewer costs. These costs are relatively small however, due to the current (low) price of water. So, what exactly are monetary costs of pumping, treating and using toilet water toilet water?

5.1.9 Toilet Water and Energy Cost Methods and Estimates

Information regarding both the ABWUD and SFH cost of toilet water and energy demands was collected from various sources. The costs of providing and using toilet water and

the aforementioned water and energy demands were used in this study's dual flush toilet spreadsheet model to estimate the costs to both the ABWUD and its SFH customers. A summary of cost sources and data is in table 5.1-3.

Table 5.1-3 Toilet Costs Sources and Data	
Data Source	Data
Bagher Dayyani, SCADA Manager, Water Systems Division, City of Albuquerque. BDayyani@cabq.gov John Stomp, Water Resources Director, Albuquerque Bernalillo County Water Utility Authority JStomp@cabq.gov	1.) ABWUD Monetary Savings & Costs calculated using: Electricity Rate = $0.042/KwHr Natural Gas Rate = $0.67/Therm
City of Albuquerque, Water Rates website http://www.cabq.gov/customerservices/rates.html	1.) SFH Monetary Savings and Costs calculated using: Water/Commodity Rate = $1.381/unit of water Sewer/Commodity Rate = $0.822/unit of sewerage
Jacques Blair, City of Albuquerque Economist	1.) 5% discount rate

The price ABWUD pays for electricity and natural gas was estimated using 2005 usage and cost data from the Southside Water Reclamation Plant. Here the utility purchased 17,577,545 KwHr and 1.33 Million Therms at a cost of $722,000 and $1,330,000 respectively (Dailey, 2006) (Appendix 7). Therefore, this study used $0.042 per KwHr and $0.67 per Therm. It is important to keep in mind that this study's cost projections are conservative since electricity and natural gas prices are likely to increase.

Costs incurred by SFH for flushing toilets reflect their current rate for both potable water and wastewater treatment. In 2006, SFH customers paid $1.381 per unit of water and $0.822 per unit of sewerage (City of Albuquerque, 2006c)[16]. SFH cost projections are also conservative

[16] 1 unit of water equals 748 gallons

since appropriate water rate structures are currently being considered as a method to encourage conservation in New Mexico (OSE/HJM86, 2005).

5.1.10 Dual Flush Toilet Potential Avoided Cost

A ten year period from 2008 through 2017 of total toilet water costs to ABWUD show a 23%, 30%, 36% and 25% cost reduction (or avoided cost) when 60%, 80% , 100% and an Incremental% of SFH respectively, are retrofit with dual flush toilets (Appendix 10). A discount rate of 5%, which is the same as the borrowing rate used by the City of Albuquerque, was used to project future value in 2006 dollars (Blair, 2006).

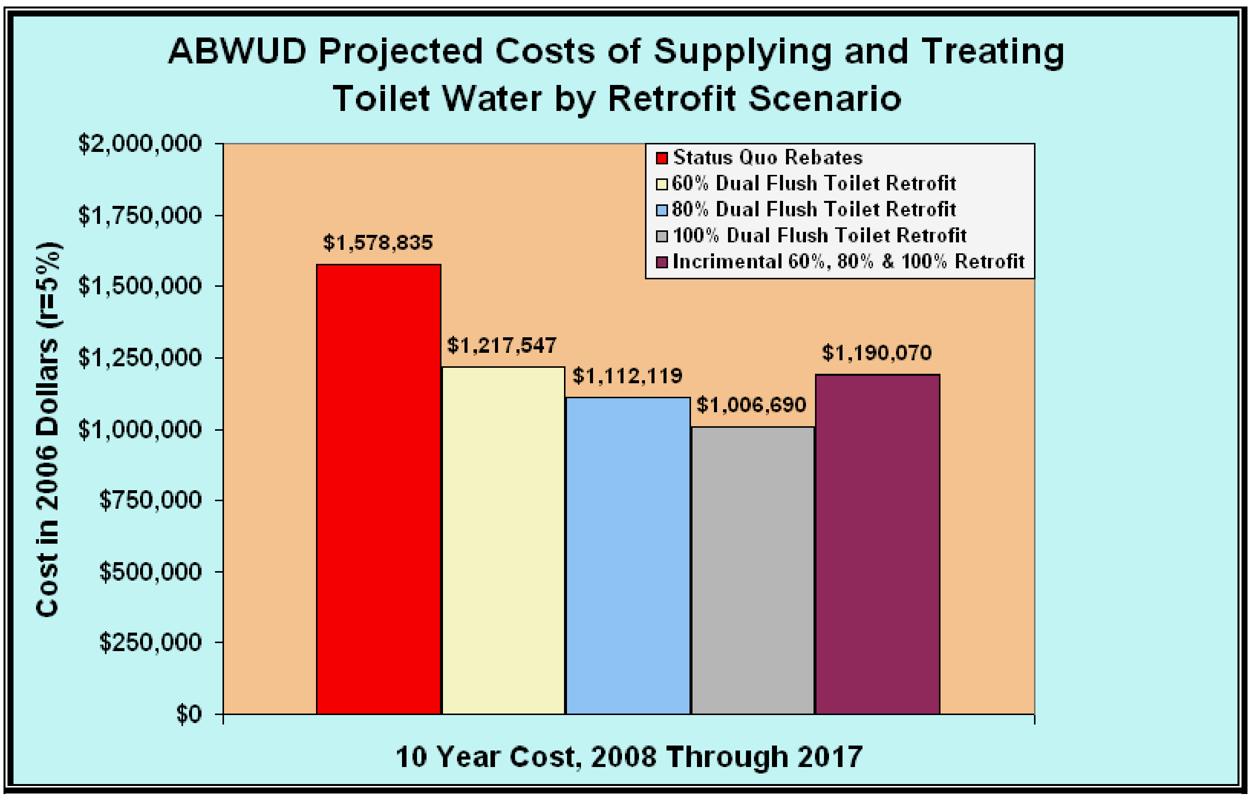

Figure 5.1-5 ABWUD Projected 10 Year Cost

SFH experience similar cost avoidance when using dual flush toilets, but are not paying for energy use, at least directly. The SFH costs for water and wastewater service for the same ten

year period and retrofit scenarios are also reduced by 23%, 30%, 36% and 25% (Appendix 11). The difference being however, that these avoided costs are divided between all the SFH customers each year that have retrofitted their homes with dual flush toilets.

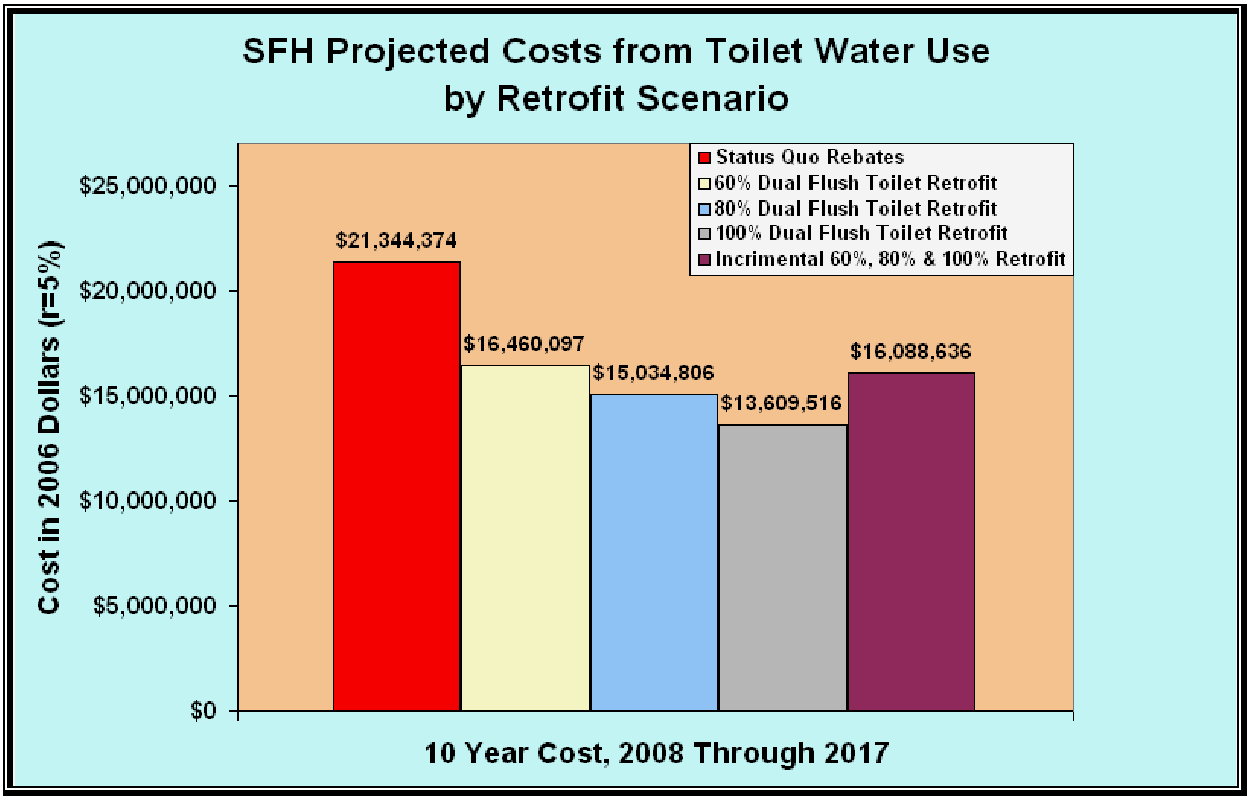

Figure 5.1-6 SFH Projected 10 Year Cost

The cost reductions quantified above for the ABWUD and SFH under each retrofit scenario are obtainable over a relatively short time period. The benefit inherent in retrofitting SFH with dual flush toilets is that the water and energy demand reductions per capita are permanent (for the lifetime of the toilet) for those homes that retrofit with dual flush toilets (Gleick *et al.*, 2003). Thus, the greater the participation by SFH in ABWUD dual flush toilet programs, the greater the water, energy and monetary savings. The important question for the

water utility to determine then, is whether a dual flush toilet distribution program is cost effective.

5.1.11 Dual Flush Toilet Cost Effectiveness

One implicit purpose of this study is to exhibit water saving innovations as conservation alternatives to Albuquerque developing larger, more expensive water supply projects or programs. As an alternative, it is important to show that using these types of technologies is cost effective so ABWUD may design polices implementing their use (Gleick *et al.*, 2003).

The cost effective analysis performed here for dual flush toilets and later in section 4.2 (p.71) for the SWCS uses methods from Gleick *et al.* (2003). One major difference between this study's cost effective analysis and that of Gleick *et al.* (2003) is that in this study Distribution programs are assumed the policy means by which SFH customers acquire dual flush toilets for free. Gleick *et al.* (2003) discussed rebate programs; from which SFH receive a rebate for a portion of their initial investment. Therefore, this report uses a modified version of the equation used in Gleick *et al.* (2003) since there is no SFH net investment in dual flush toilets retrofit by normal replacement. Essentially, a conservation measure that enhances the penetration of water saving innovations, such as the dual flush toilet, in ABWUD single family households is cost effective if the "cost of conserved water" is less than the cost of attaining a new source of water supply (Gleick *et al.*, 2003). To determine the cost of conserved water the following equation is used[17]:

[17] Even though the equation here considers a Distribution program, which requires no net investment by the SFH customer, the entire equation as used by Gleick *et al.* (2003), which uses rebates and requires a net investment by homes, is provided. This study's use of Distribution programs forces several terms to drop out of the equation.

$$\mathbf{C_s = \xi_{O\&M}/W_s}$$

where,
$\mathbf{C_s}$ is the SFH cost of conserved water from dual flush toilets retrofit by normal replacement
$\mathbf{\xi_{O\&M}}$ is the increase in annual costs incurred by Status Quo SFH, minus the monetary benefits of reduced sewer charges for homes that retrofit under normal replacement
$\mathbf{W_s}$ is the estimated average (or levelized) annual water saved (ac-ft/year)
$\mathbf{W_s = L_s/ N_s}$
$\mathbf{L_s}$ is the water savings over the lifetime of the dual flush toilet (ac-ft/year)
$\mathbf{N_s}$ is the typical life of a toilet, which is assumed to be 25 years (CUWCC, 1992) (Gleick *et al.*, 2003).

As stated by Gleick *et al.* (2003, p.123), "when the cost of water from a specific measure ($\mathbf{C_s}$) is less than the cost of water supply displaced by conservation, the customer and the water utility (collectively) will 'make money' via the measure". The above equation was used in this study's spreadsheet model to demonstrate the cost of conserved water from dual flush toilets retrofit by normal replacement. When SFH toilets are replaced with dual flush toilets due to normal replacement – when old toilets fail, SFH are remodeled and toilets are acquired for new construction – the installation costs are unavoidable. However, this cost is separate from the decision of the SFH owner or builder to conserve water by using a HET; thus, toilet installation cost is not included in quantifying the cost of conserved water (Gleick *et al.*, 2003).

For example, looking only at 2007 Albuquerque SFH who (this study estimates) need to retrofit their homes due to normal replacement, and choose to do so with a dual flush toilet acquired from a ABWUD Distribution program, the following data and assumptions were used. Since the discussions in subsequent sections are centered on the inherent benefits of Distribution programs over Rebate programs, then no customer investment is used here. The typical life of a dual flush toilet retrofit in SFH is 25 years (CUWCC, 1992). An estimated population of 11,313 people in Albuquerque SFH is using dual flush toilet units retrofit by normal replacement. Consequently, a total of 35ac-ft is conserved each year from SFH not retrofitting with less

efficient ULFT's and these homes save $12,025 in sewer costs. Additionally, a 5% discount rate was used to discount dollars in 2007 (Blair, 2006).

$$\mathbf{C_s = \xi_{O\&M} / W_s}$$
$$\mathbf{C_s = -(\$11{,}489) / (35ac\text{-}ft\ per\ year / 25\ years)}$$
$$\mathbf{C_s = -\$8{,}120\ per\ acre\text{-}foot\ of\ conserved\ water}$$

The quantified result is negative because monetary benefits of retrofitting and using dual flush toilets cover any cost of or investment in conserved water and saves SFH money (Gleick *et al.*, 2003). Moreover, since the price of water and sewer in Albuquerque is so inexpensive, then the negative results above also suggest that the initial installation investment should not be an issue. Also, as sewer rates increase over time, this argument may become even more apt in ABWUD conservation planning. Considering this equation assumes a Distribution program where SFH investment is zero, likely encouraging a high level of penetration of HET, ABWUD conservation planners should recognize the potential benefits to the utility system (avoided energy costs) of educating customers with regard to the potential savings of dual flush toilets (Gleick *et al.*, 2003).

The above cost of conserved water should highlight the potential value of a Distribution program that enhances the penetration of dual flush toilets in Albuquerque SFH, especially when the alternative of purchasing water rights is considered. That is, the same annual volume of water saved by the normal replacement scenario above, 35ac-ft, would cost ABWUD significantly to purchase. According to Yuhas (2006), water rights were purchased by ABWUD at $7,500/acre-foot October 5, 2005 and have recently sold in New Mexico for $12,000/acre-foot; thus, this is the current going rate. When considering the latter going rate, 35ac-ft of water would cost $420,000 to purchase. Therefore, it is clear that a dual flush toilet Distribution program would

benefit ABWUD and its customers as well as help Albuquerque prepare for drought, climate change and population growth.

5.1.12 Toilet Analyses Data and Assumption Sensitivity

The toilet analyses in the previous sections used many data and assumptions to estimate water and energy demands and costs as well as savings. Moreover, these demands, cost and savings were projected to 2030. In doing so, several parameters were held constant for forecasted period of 24 years. That is, data and assumptions surrounding current toilet water demand, energy demand and monetary costs remained the same through the year 2030.

The results presented in previous sections are likely to change as data and assumptions used may change over time. For example, toilet models are always improving with regard to water use efficiency. The ULFT's models that have been sold and rebated by ABWUD since the mid 1990's, and their respective higher frequency of flushing per capita, certainly will and already are being designed better. Better designs would reduce the frequency of flushing per capita; thus, reducing the total toilet water demand. Toilet water energy demands may also decrease as drinking and wastewater treatment processes increase in efficiency. The costs of electricity and natural gas are certain to change, as are the customer water rates. These cost changes will both increase the annual resource use cost estimates as well as the avoided cost estimates of using dual flush toilets.

5.2 The Shower Water Conservation System

According to this study's findings, SFH shower water use now constitutes a larger demand on city resources than toilet flushing. This is important information that may potentially benefit ABWUD and its customers if integrated into conservation policy design, especially when

considering that an increasing population translates to a greater demand for shower water and shower water energy.

This study's quantified Status Quo SFH shower water use illustrates that ABWUD per capita shower water demand, the energy required to treat and provide shower water, the energy required to heat shower water, and the associated costs to the utility and its customers are likely to increase due to population growth. The Status Quo conditions provide a baseline from which to evaluate the potential savings from newly emerging shower innovations such as the Shower Water Conservation System.

5.2.1 Shower Innovation History

Currently the only technologies widely used in Albuquerque to manage the demand for shower water are low flow showerheads and hot water on demand systems. ABWUD rebate programs exist to help service area customers acquire these two technologies. However, since the rebate programs' inceptions, shower head rebates total 56,784 and hot water recirculator rebates total only 757. Moreover, no electronic record has been kept of the number of these two fixtures' rebates that have been for SFH (Yuhas, 2005).

Low flow showerheads have a maximum flow rating of 2.5gpm and have also been the National standard since the 1992 National Energy Policy Act was implemented in 1994. Hot water recirculating systems have no such standard established to date. The mix/penetration of these water saving devices existing in Albuquerque SFH showers is not determined in this study. Thus, they are not included in model parameters. Instead, showerhead flow rate data (and other data) from Mayer *et al.* (1999) is used in this study's models to quantify the Status Quo shower water use and the savings associated with four SWCS retrofit scenarios.

5.2.2 SWCS and Model Description

The Status Quo shower water demand in Albuquerque SFH and the savings from retrofit scenarios was determined using this study's combined SWCS STELLA 8 simulation model and SWCS Spreadsheet model. STELLA 8 is a modeling framework software used for modeling dynamic systems. This study's STELLA 8 SWCS model was used to simulate SFH showering behavior, hydrologic flow rates, shower water thermodynamics, annual shower water and energy demands and monetary costs. The STELLA 8 model framework constructed for the shower system contains parameters represented by stocks, flows, connectors and converters. The SWCS is not currently available on the U.S. market as this study is part of ongoing research and development of this water saving innovation, designed to modify how individuals use shower water and the energy required to heat it.

The SWCS was designed and its U.S. Utility Patent Application is held exclusively, by this report's author, Andrew Funk[18]. The System is designed to change how people use hot water with each showering event, without requiring a change in showering behavior. One important feature that separates this system from Hot Water on Demand and Hot Water Recalculating Systems is that it functions completely independent of an energy source. It is mounted behind the shower stall between the wall studs and between the faucet and the shower head[19]. Thus, the SWCS operates within the boundary of common household construction and plumbing variables. 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.

[18] U.S. Utility Patent Application Pending
[19] An external model that mounts inside existing shower stalls is under design.

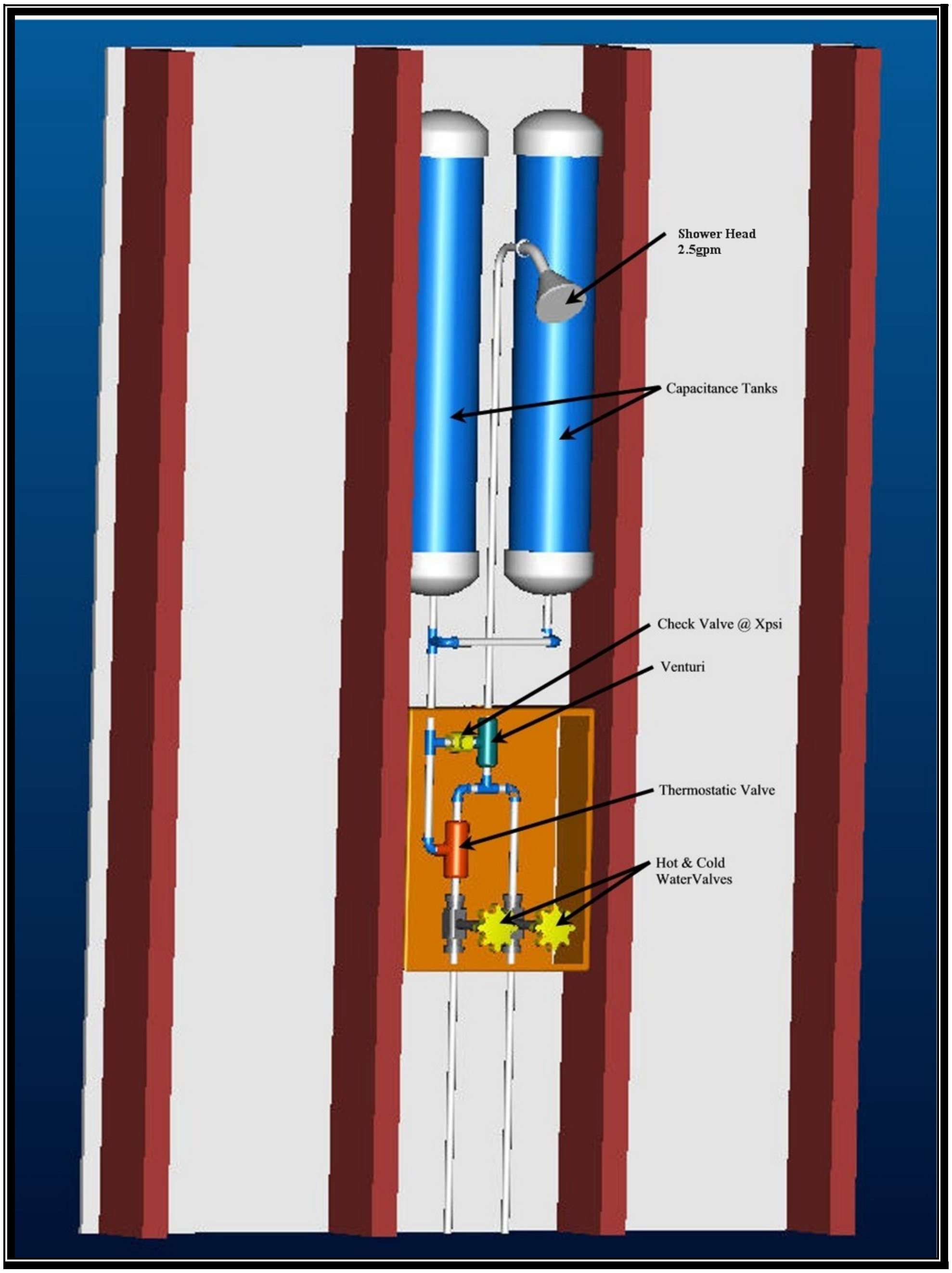

Figure 5.2-1 The Shower Water Conservation System

As the hot water valve is opened the initial water temperature may be anywhere from 60°F to 105°F or higher. The average preferred showering temperature 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. The SWCS eliminates this unnecessary wasting of water and energy resources in the following way.

When cold/lukewarm water flows through the Thermostatic Valve (or thermostat), the valve is open and the water is directed to the two Capacitance Tanks. When the water reaches 105°F the valve 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 Capacitance Tanks 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.

This system's dynamic simulation model was designed to illustrate water, energy and monetary savings from using the SWCS when compared to the Status Quo SFH shower behavior. Here, water savings is defined as the volume of captured water that is no longer lost down the drain while heating to a preferred showering temperature of 105°F. Here, the energy savings is defined by the amount of energy (KwHrs and Therms) no longer consumed for treating and providing water as well as heating water to replace the volume previously lost down the drain and treating wastewater.

The SWCS model data originated from various sources. An engineering firm in Windsor, California, Prime Source, was contracted to assist in conceptually engineering the system. Thus, some of the system's conceptual variables such as mixing temperatures and storage capacity were provided by Prime Source. Other data and assumptions such as preferred shower temperature, average shower time, plumbing flow rates, waiting time for water to get hot, etc. originated from research reports by the Natural Resources Defense Council, Pacific Institute, Rocky Mountain Institute, American Water Works Association and Oakridge National Laboratory (Cohen *et al.*, 2004; Gleick *et al.*, 2003; Heed, 1995; Mayer *et al.*, 1999; Wendt *et al.*, 2004). Data from these sources is discussed in greater detain in following sections.

The variables mentioned above were entered into the SWCS model stocks, flows and converters and the model simulation was run once every day for 365 days. Running the model without the SWCS (or without a policy change) produced the ABWUD Status Quo water, energy and monetary costs associated one SFH annual shower water demand. Modeled Status Quo results reflect both the ABWUD energy use and costs and SFH water and energy use and costs from one home and any number of SFH customers, depending on the year of interest. Once the SWCS (or policy change) was introduced into the model via a series of "binary switches", the water, energy and monetary savings were quantified for the utility and the SFH (See Appendix 12a through 12e for model, data and assumptions).

5.2.3 SWCS Model Causal Relationships

The purpose of developing the SWCS model was to illustrate the potential positive feedback (water, energy and monetary savings) from implementing policy that retrofits SFH with the

system. In an effort to conceptualize the system's cause and effect relationships between SFH water and energy demand, policy change and savings, a causal loop diagram was designed.

Figure 4.2-2 conceptually explains that as drought variability is enhanced by climate change and population expands, the demand on water resources increases. When demand increases, perceptions regarding the available ABWUD water supply decreases. However, when it is perceived that there is adequate supply, there are fewer efforts to design and fund Distribution programs. As funding efforts increase, more SFH are retrofitted with water efficient fixtures. Once there are more retrofits in SFH, gpcd decreases. And finally the causal loop is closed when an increase in SFH gpcd leads to increase demand on water resources. This top feedback loop is balancing because the level of the variable this report is interested in, retrofitting SFH with water saving fixtures, is below what is should be and the loop forces its value to increase (Kirkwood, 1998).

A second causal loop begins at the same variable where the models policy change occurs. This bottom loop is positive and reinforcing because it reinforces the policy change with even more change (Kirkwood, 1998). That is, the rate of retrofitting SFH with the SWCS will increase for the proposed policy change.

Therefore, following the second causal loop, when retrofitting in SFH increases there will follow an increase in homes retrofitted with the SWCS. As homes with the SWCS system increases SFH will save water. The result from SFH water savings is two fold. First, homes will increase their energy efficiency from heating less water. Second, ABWUD water treatment and delivery will decrease. As the utility increases its treatment and provides more shower water its energy savings decreases. An increase in energy savings translates into the water utility avoiding

costs and saving more money. When the utility finds that it has more money in its budget then it increases its efforts to design and fund Distribution programs. And finally the causal loop is completed as the increased funding efforts further increase retrofitting of SFH with water saving fixtures, such as the SWCS.

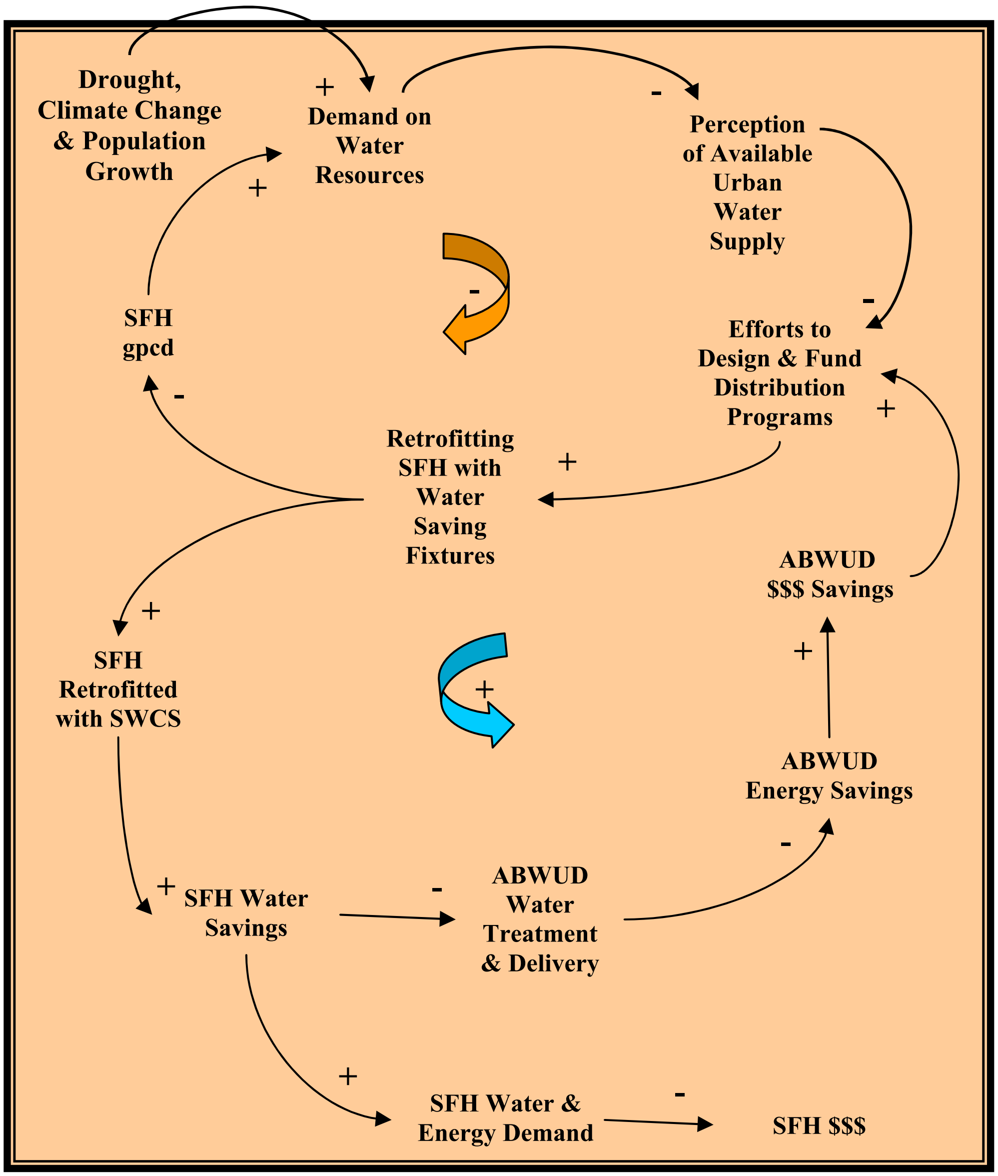

Figure 5.2-2 SWCS Casual Loop Diagram

5.2.4 SWCS Model Sensitivity Analysis

The SWCS model and the parameters used demonstrate that there is a significant water, energy and monetary savings from a policy change that retrofits SFH. However, it is recognized that there is some degree of uncertainty in some of the model's parameters. For example, not all SFH will have three people showering per day.

To demonstrate the model's sensitivity to a decrease in the number of showering events per year by one third, a type one sensitivity analysis was performed. Here the outcomes of interest analyzed are those this report is concerned with illustrating, water, energy and monetary savings. When "Shower System Binary 3" is switched off in STELLA's interface mode, the reference mode blue line is the model results assuming three showers per day, the red line demonstrates that SFH and Utility water, energy and monetary savings maintain an increase throughout the year (Ford, 1999) (Appendix 12d).

5.2.5 SWCS Model Validation

The SWCS model is a simplification of what may occur in homes retrofitted with the system. As such, there are numerous assumptions within the stocks, flows and parameter values. Thus, it is important to attempt to validate the model. Face Validity was used to build confidence in the SWCS model (Ford, 1999).

The model's inclusion of changing water flow and temperature according to heating time and preferences emphasizes the importance of system understanding and common sense. Careful attention was given to the models underlying assumptions regarding beginning temperatures and preferences as well as to the models calculated parameter values. These were checked to make

sure they generally make sense. These checks illustrate a level of confidence that should satisfy doubts that may exist regarding the validity of the SWCS model.

5.2.6 SWCS Model Calibration

One of the model's key parameters, "Water Heating Rate Multiplier", was calibrated with existing research data. The time it take water to reach 105°F at the showerhead is highly variable from home to home, depending on plumbing, insulation and distance from the water heater. This converter was calibrated with a 2004 study by the Oak Ridge National Laboratory, "Evaluation of Residential Hot Water Distribution Systems by Numeric Simulation", which determined the typical wait time (within a range) for water at the faucet to reach 105°F.

5.2.7 SWCS Model Policy Input

The policy change of retrofitting SFR homes with the SWCS was input into the model within the existing stocks and flows of a normal shower. The binary variable allows one to switch between showering with and without the system. Placing the policy change into the model this way produced the expected results.

5.2.8 Shower Water Methods and Estimates

Using the STELLA 8 SWCS model simulation results (Appendix 12b) in this study's SWCS spreadsheet model, estimates of the Status Quo and retrofit scenarios' volumes of water demanded for showering each year by ABWUD single family homes from 1994 to 2030 were quantified. Table 5.2-1 summarizes the sources and data used in this study's STELLA 8 and spreadsheet models.

Table 5.2-1 Shower Water Sources and Data		
	Data Source	Data
STELLA 8 Model	Katherine Yuhas, "Water Conservation Officer" Albuquerque Bernalillo County Water Utility Dept. kyuhas@cabq.gov	1.) 3 persons per single family home[1]
	AWWA Research Foundation "Residential End Uses of Water" http://www.awwa.org/bookstore/product.cfm?id=90781	1.) Average flow rate of water through a through 2.5gpm rated showerheads is 2.22gpm[2] 2.) Frequency of showers in single family homes is 0.67 per person per day 3.) Average shower duration is 8.2 minutes per person
	Oak Ridge National Laboratory Buildings Technology Center, "Evaluation of Residential Hot Water Distribution Systems by Numeric Simulation" http://www.ornl.gov/~webworks/cppr/y2001/rpt/122464.pdf	1.) Water heating rate from household plumbing to shower, SEE Appendix 12c for details
	Pacific Institute, "Waste Not, Want Not: The Potential For Urban Water Conservation in California" http://www.pacinst.org/reports/urban_usage/	1.) Preferred temperature an average person seeks when showering is 105°F
Spreadsheet Model	This Study's SWCS STELLA 8 Simulation Model "Status Quo" and "SWCS Retrofit" results	1.) Status Quo demand of 12,817.89 gallons of shower water annually per SFH 2.) SWCS savings of 1,436.12 gallons of shower water annually per SFH
	This Study's Population Projections (section 4.0)	1.) ABWUD service area SFH customer number projections

[1] Katherine Yuhas uses 3.06 persons per household to estimate customer water demand. A 3.00 person home was assumed in this study's STELLA 8 model to simulate annual shower water and energy demands and monetary cost. Thus, this study's estimates are conservative.
[2] This study's STELLA 8 model and spreadsheet models assume all SFH are using 2.5gpm rated showerheads.

This study's SWCS STELLA 8 model used an array of data and assumptions from various sources to simulate the annual water demand of showering events in a typical (Status Quo) three person SFH and the water savings from using the SWCS. These, model parameters and the model framework are explained and displayed in detail in Appendix 12a through 12c.

For example, the ABWUD rebate program has not kept record of the number of SFH that have received low flow shower heads from its rebate program and it is not possible to know how many high flow heads have been replaced due to normal replacement. Therefore, since National Standards required 2.5gpm flow rating on all showerheads after 1994, then Mayer *et al.* (1999) flow trace analysis average results of 2.22gpm was used in the SWCS STELLA 8 model to capture the possible range of showerhead flow rates existing in Albuquerque SFH. Additionally, the model used Mayer *et al.* (1999) determined frequency of showers in single family homes of 0.67 per person per day and average shower duration of 8.2 minutes per person. Finally, the amount of time it takes for water to reach a preferred showering temperature of 105°F was combined with the parameters above to simulate shower water demand (Gleick *et al.*, 2003; Wendt *et al.*, 2004).

Data generated by the SWCS STELLA 8 model was used in this study's spreadsheet model. Model simulation results estimate that under the Status Quo scenario, each SFH uses 12,817.89 gallons of shower water annually. Moreover, when a SFH is retrofit with the SWCS this annual volume of shower water demand is reduced by 1,436.12 gallons. These estimates, along with ABWUD service area SFH customer estimates (from section 4.0), were used to project SFH shower water demands each year till 2030.

5.2.9 Status Quo Shower Water Demand

The estimated shower water demand under the Status Quo conditions tells a story of how Albuquerque SFH shower water use has changed and will continue to change over the next 24 years. Beginning in 1994, the year all showerheads sold in the U.S. were 2.5gpm rated, and until 2002, the number of ABWUD service are SFH customers grew by an average 1.26%. Between

2002 and 2005 SFH customers increased sharply by 2.34%. It is important to recall here that 2003 is the year this study results estimate SFH toilet water demand falls below SFH shower water demand. After 2005 and to 2030 however, thus study's SFH projections predict a fairly steady average annual increase in SFH shower water demand (over that of toilet demand increases) of 0.95% (Appendix 13).

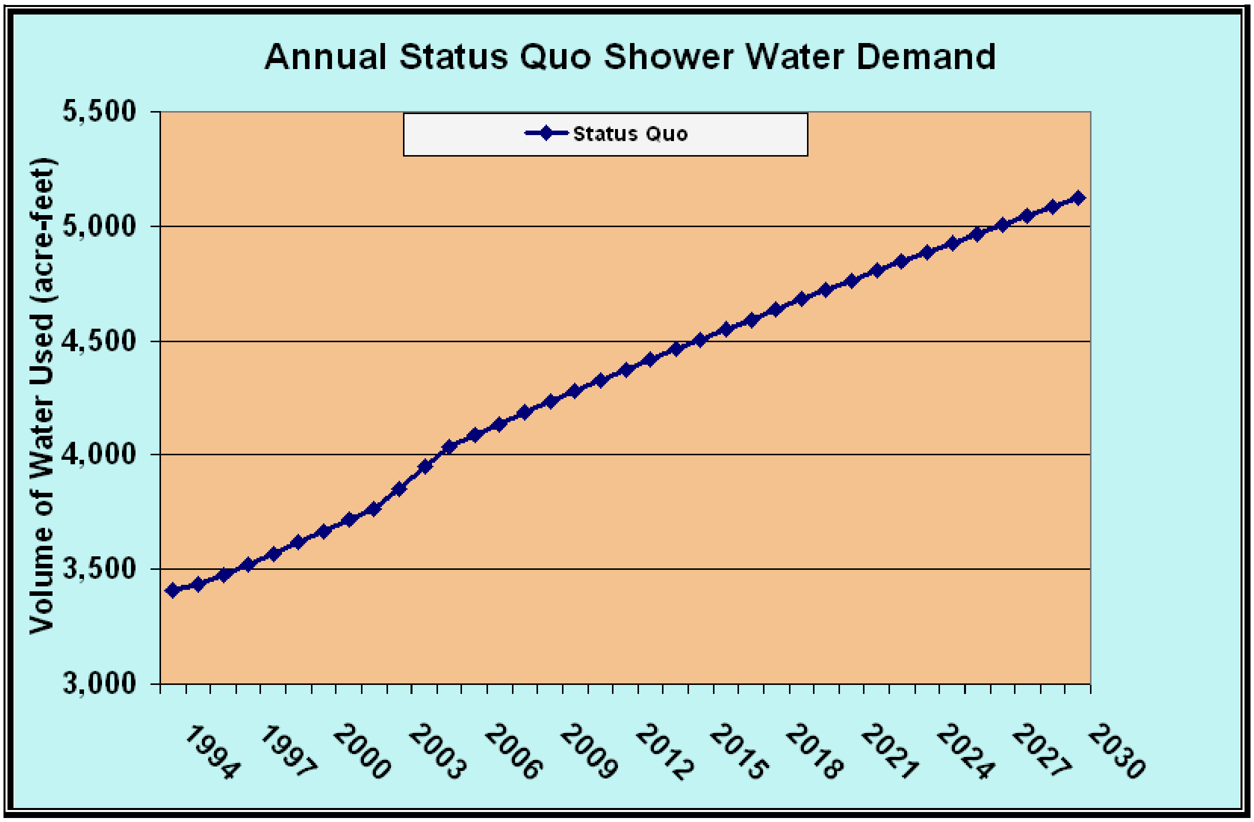

Figure 5.2-3 Estimated and Projected Trend in SFH Shower Water Demand

Looking at the trend in ABWUD single family home shower water demand it is clear that adding to the ABWUD single family home population will increase the showering events and thus, the water and energy resource demand and monetary costs. Since there is no substitute for showering (unless one is more partial to cologne), then it is important to recognize the potential

of newly emerging innovations, such as the Shower water Conservation System that decreases per capita water and energy demand with each shower event.

5.2.10 SWCS Potential Water Savings

Four SWCS retrofit scenarios were considered alongside the above Status Quo projections and it is clear that regardless of the scenario, population growth is unrelenting in its impact on total water usage. It is important then to distinguish between the rates of increase in total shower water demand of the Status Quo and retrofit scenarios. This study estimates that between years 2011 and 2030 the Status Quo and 60% SWCS retrofit scenario total water demand increases at slightly different rates. The plotted slopes of shower water demand then, demonstrate that the difference in total demand is increasingly larger over time. The annual population enhancing water saving potential in 2011, 2020 and 2030 between the Status Quo and 60% SWCS Retrofit Scenario is shown below (Appendix 13a).

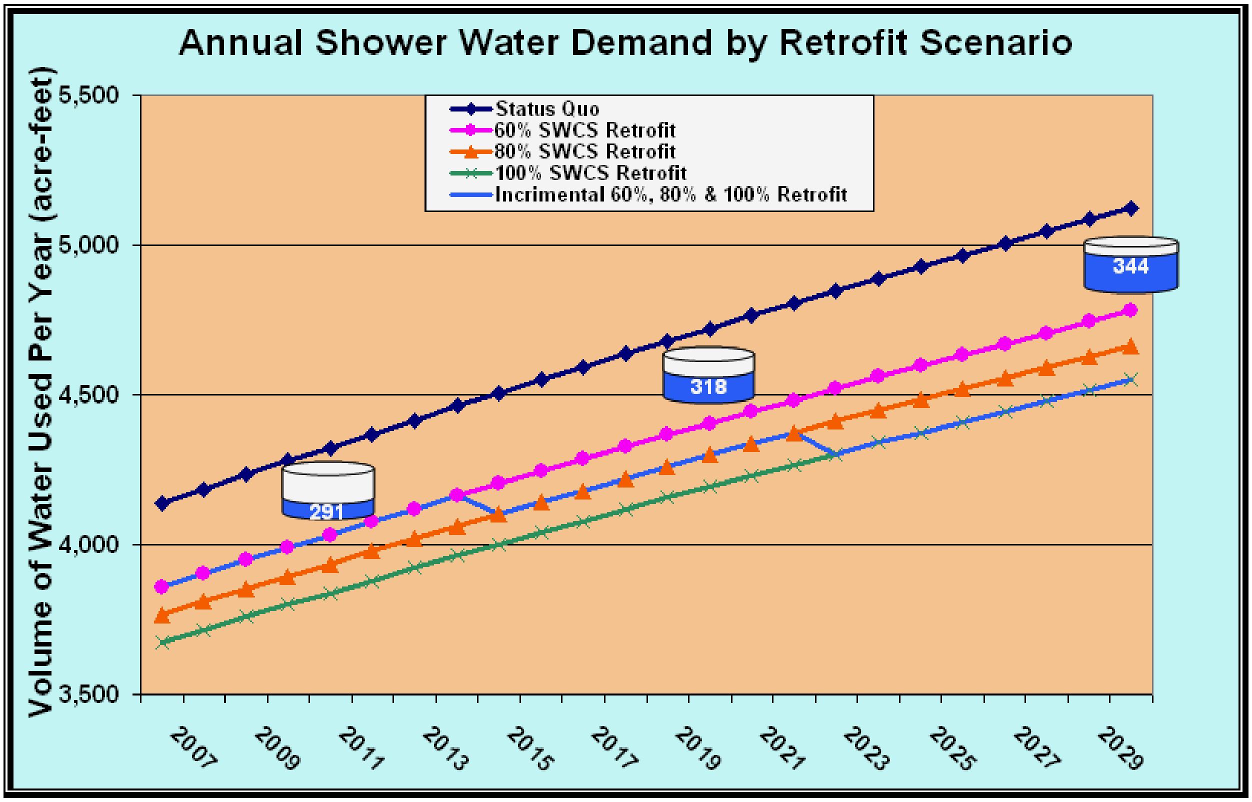

Figure 5.2-4 Projected Trend in SFH Total Shower Water Demand

5.2.11 Shower Water and Energy Nexus

As with the discussion in section 4.1.5 "Toilet Water and Energy Nexus", the energy consumed for each showering event will also increase in time. Here again, energy is consumed at the ABWUD to pump groundwater to city reservoirs, divert San Juan Chama water from the Rio Grande and treat it to potable standards at the new SJCP treatment facility, pump treated water to the Finished Water Pump Station, pump water to city reservoirs to mix with groundwater and treat wastewater at the Southside Reclamation Plant[20]. The key difference between the energy demand of toilets and showers though, is heating.

[20] Here the same data and assumptions for toilet water demand are applied to shower water demand

According to this study's 2008 Status Quo projections, the total Electricity and Natural Gas demand for heating water at Albuquerque SFH is, respectively, 16 and 77 times the Electricity and Natural Gas demand at ABWUD for treating and providing shower water to homes and treating wastewater. This finding supports that of several other studies, which report that the residential sector consumes the most energy for heating water. In California for example, 48% of the total energy (electricity and gas) demand from urban water usage is from the residential sector (CEC, 2005).

5.2.12 Shower Energy Methods and Estimates

While the same estimates and methods discussed in section 5.1.2 "Toilet Energy Methods and Estimates" and in section 5.2.8 "Shower Water Methods and Estimates" are used in this section's analysis, the additive energy requirements for heating water at SFH are also considered. Using the STELLA 8 SWCS model simulation results (Appendix 12b) in this study's SWCS spreadsheet model, estimates of the Status Quo and retrofit scenarios' energy demands for showering each year by ABWUD single family homes from 2006 to 2030 were quantified. Table 5.2-2 summarizes the sources and data used in this study's STELLA 8 and spreadsheet models.

Table 5.2-2 Shower Energy Sources and Data		
Data Source		Data
STELLA 8 Model	Bagher Dayyani, SCADA Manager, Water Systems Division, City of Albuquerque. BDayyani@cabq.gov	1.) 0.003406 KwHr/gallon & 0.00002589 Therms/gallon pumped form Albuquerque production wells and booster pumps
	John Stomp, Water Resources Director, Albuquerque Bernalillo County Water Utility Authority JStomp@cabq.gov	1.) 0.003234 KwHr/gallon treated at the New San Juan Chama Drinking Water Plant and pumped to reservoirs from the Finished Water Pump Station 2.) SJCP will supply 90% of the ABWUD water and wells 10% after March 2008
	Doug Dailey, Wastewater Utility Manager, Albuquerque Bernalillo County Water Utility Department DDailey@cabq.gov	1.) 0.0008584 KwHr/gallon & 0.00006495 Therms/gallon of wastewater treated at the Southside Water Reclamation Plant
	CONSERV'96 Conference Proceedings, "WATERGY: A Water and Energy Conservation Model for Federal Facilities"	1.) 40% of SFH use electric water heaters & 60% use natural gas water heaters
	Oak Ridge National Laboratory Buildings Technology Center, "Evaluation of Residential Hot Water Distribution Systems by Numeric Simulation" http://www.ornl.gov/~webworks/cppr/y2001/rpt/122464.pdf	1.) Electric water heater efficiency assumed to be 87% 2.) Natural gas water heater efficiency assumed to be 56%
	PNM, "My Home" website http://www.pnm.com/customers/my_home.htm	1.) Water heater temperature is conservatively assumed to be 120°F
	SEISCO, "Tankless Model Selection Criteria" website http://www.seisco.com/pages/model-selection.html#inlet	1.) Temperature of City water entering SFH is 45°F
	Prime Source, "Shower Water Conservation System Report Phase Zero"	1.) Approximately 78% of water saved is from SFH hot water plumbing
Spreadsheet Model	This Study's SWCS STELLA 8 Simulation Model "Status Quo" and "SWCS Retrofit" results	1.) Status Quo demand of 841.44 KwHrs annually per SFH & 52.68 KwHrs annually at ABWUD per SFH 2.) SWCS savings of 94.27 KwHrs annually per SFH & 5.90 KwHrs annually at ABWUD per SFH 3.) Status Quo demand of 66.94 Therms annually per SFH & 0.87 Therms annually at ABWUD per SFH 4.) SWCS savings of 7.50 Therms annually per SFH & 0.10 Therms annually at ABWUD per SFH
	This Study's Population Projections (section 4.0)	1.) ABWUD service area SFH customer number projections

This study's SWCS STELLA 8 model used data and assumptions from several sources as model parameters to simulate the annual shower water energy demands from a SFH. Again, all the same model data and assumptions from section 5.2.8 "Shower Water Methods and Estimates" apply here, now focusing on the energy resource demand associated with using the volumes of shower water estimated earlier. Model simulations were run for both the Status Quo and SWCS retrofit scenario to estimate the energy demands without and with the SWCS respectively. The model parameters and the placement in the model framework is explained and displayed in Appendix 12a through 12c.

As with section 5.1.6 "Toilet Energy Methods and Estimates", the ABWUD infrastructure and facilities shower water energy demands were estimated at Albuquerque's three stages of source water pumping, drinking water treatment and wastewater treatment. Groundwater and booster pumping to City reservoirs requires an estimated 0.003406 KwHr/gallon & 0.00002589 Therms/gallon pumped (Dayyani, 2005). Water treatment at the new San Juan-Chama Drinking Water Project will (beginning in 2008) require an estimated 0.003234 KwHr/gallon treated (Stomp, 2006). The Southside Water Reclamation Plant requires an estimated 0.0008584 KwHr/gallon & 0.00006495 Therms/gallon of wastewater (Dailey, 2006).

The important benefit of the SWCS innovation is that it enables SFH users to use hot water more efficiently with each showering event. So, a mix of data and assumptions were used in the STELLA 8 model to estimate shower energy demand and savings at the household level. The SWCS model simulations used a similar percentage of water heater penetration as exists in the U.S., assuming that 40% of SFH water heaters use electricity and 60% require natural gas

(deMonsabert *et al.*, 1996)[21]. The efficiencies of electric and gas water heaters is likely to vary from house to house, but were assumed to be 87% and 56% respectively (Wendt *et al.*, 2004). Normal water heating temperature was conservatively assumed to be 120°F, although some homes may set their heater thermostats at temperatures up to 140°F (PNM, 2006d). The temperature of City water entering SFH was assumed to be 45°F, which is common (from a range of 40°F -55°F) within the central and Rock Mountain U.S. regions (SEISCO, 2006). Finally it was assumed that 78% of SFH shower water is from the hot water plumbing. The above data and assumptions combined with shower water demands discussed earlier in this report were used in a thermodynamic equation to convert SFH water savings estimates to electricity and natural gas savings estimates.

For example, assuming each three person SFH saves approximately 1,436 gallons annually from showering with the SWCS. 78% of that water came from the hot water plumbing line, which was previously heated at either an electric or natural gas water heater. This example quantifies electricity savings, so 40% of SFH are assumed to be using electric water heaters. The temperature change necessary to heat City water normally entering the home at 45°F to 120°F is the difference between 48.89°C - 7.22°C[22]. The specific heat of water at standard temperature and pressure, or the amount of heat per gram of water required to raise the temperature by one degree Celsius, is 4.184 Joules/gram°C. And finally the electric water heater efficiency is 87%.

[21] 60% of U.S. water heaters use gas, 35% use electricity and 5% are solar, wind, etc. (deMonsabert *et al.*, 1996). So, since data for the latter is not available, then 40% of U.S. water heaters are assumed to be electric in Albuquerque. This assures the energy savings estimates are conservative, since electric water heaters are more efficient than gas. Hot water on demand heaters are assumed to not have a high level of penetration in Albuquerque SFH and not considered in this study.

[22] To convert °F into °C: °C = (5/9)*(°F -32)

Therefore, the annual electricity savings would be:

= ((0.78*1,436gallons/yr)*(0.40)*(0.00378 Cubic meters/gallon)*
(1000 Kilograms/Cubic meter)* (1000 Grams/Kilogram)*(48.89°C - 7.22°C)*
(4.184 Joules/gram°C)*(1Kilowhat Hour/3.6*10^6 Joules)) / (0.87)
= 94 KwHrs/year

The energy demand and savings at ABWUD and SFH from household showering under the Status Quo conditions and from using the SWCS were generated by the STELL 8 model simulation and then used in this study's spreadsheet model. ABWUD service area SFH customer number projections was used with the aforementioned simulation results to determine the electricity and natural gas demand and savings each year till 2030.

5.2.13 SWCS Potential Energy Savings

This study's Status Quo ABWUD and SFH "electricity" demand (combined) was compared to the four retrofit scenarios' demands. Differences between the Status Quo and 60% Retrofit Scenario in 2011, 2020 and 2030 are 6,606, 7,214 and 7,829 MwHrs respectively (Appendix 14a & 14b).

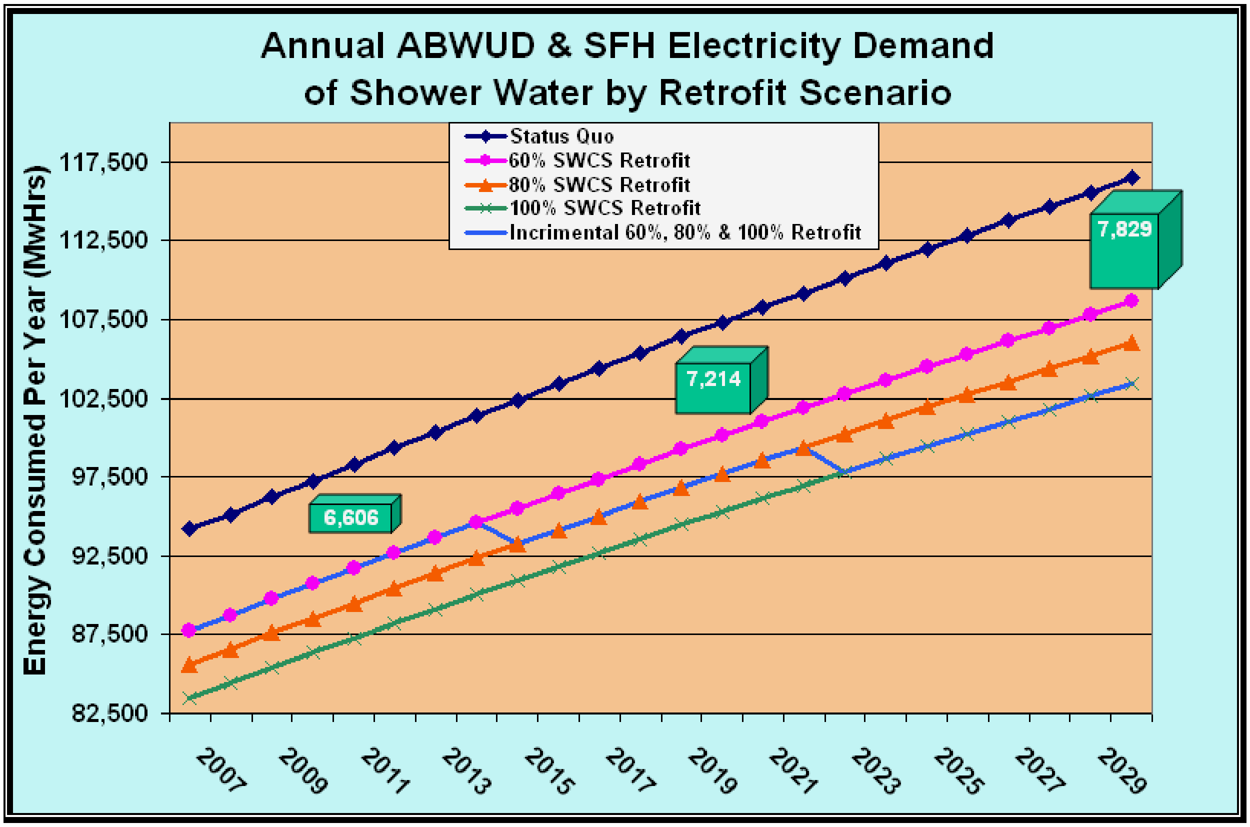

Figure 5.2-5 Projected Trends in ABWUD & SFH Shower Water Electricity Demand

Since 60% of SFH in the utility service area are assumed to use natural gas water heaters, then it is important to also look at the gas demand that is expected. The Status Quo ABWUD and SFH "natural gas" demand combined was compared to this study's four retrofit scenarios. Differences between the Status Quo and 60% Retrofit Scenario in 2011, 2020 and 2030 are 0.50, 0.55 and 0.59 Million Therms respectively (Appendix 15a & 15b).

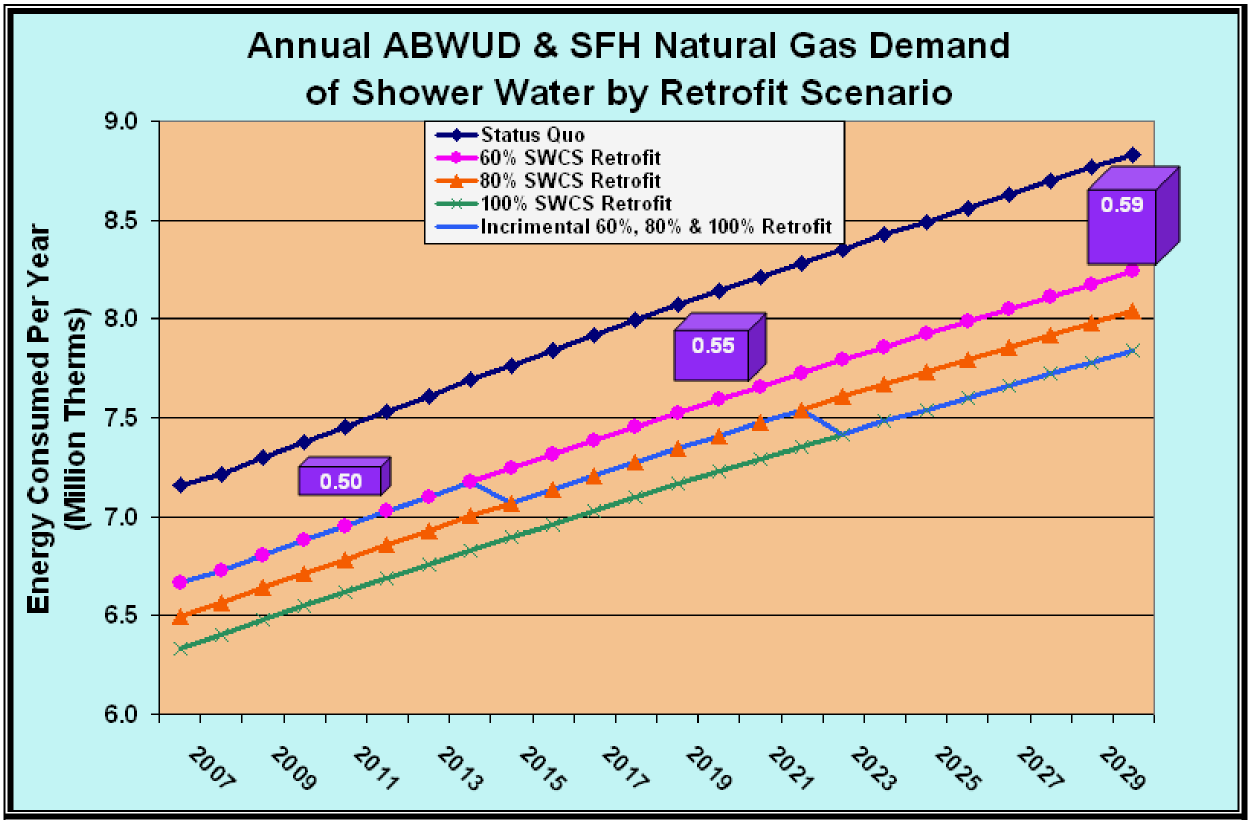

Figure 5.2-6 Projected Trends in ABWUD & SFH Shower Water Natural Gas Demand

5.2.14. Shower Water & Energy Costs

The inextricable connection between water use and energy consumption cannot go unnoticed when considering the costs associated with per capita SFH use of heated water for showering (and other uses). Each showering event not only leads to ABWUD and SFH costs for using water itself, but also adds to the expense at the end user level for heating water. Additionally, due to higher energy prices (than water) the additive SFH expense from heating shower water is considerably larger than for the water and sewerage charges. For example, this study's estimated 2006 Status Quo single family home total cost incurred from showering is 76% for energy usage (electricity and natural gas) and 24% for water and sewerage.

5.2.15 Shower Water and Energy Cost Methods and Estimates

ABWUD and SFH costs associated with shower water and energy demands were collected from various sources. The costs and savings of providing and using shower water, as well as the cost of the energy (both electricity and natural gas) required with each showering event was estimated with the SWCS STELLA 8 model. Simulation results were used in this study's spreadsheet model to estimate the costs and savings to both the ABWUD and its SFH customers. The costs at both the ABWUD and SFH are summarized in table 5.2-3.

Table 5.2-3 Shower Costs Sources and Data

	Data Source	Data
STELLA 8 Model	Bagher Dayyani, SCADA Manager, Water Systems Division, City of Albuquerque. BDayyani@cabq.gov John Stomp, Water Resources Director, Albuquerque Bernalillo County Water Utility Authority JStomp@cabq.gov	1.) ABWUD Monetary Savings & Costs calculated using: Electricity Rate = $0.042/KwHr Natural Gas Rate = $0.67/Therm
	City of Albuquerque, Water Rates website http://www.cabq.gov/customerservices/rates.html	1.) SFH Monetary Savings and Costs calculated using: Water/Commodity Rate = $1.381/unit of water Sewer/Commodity Rate = $0.822/unit of sewerage
	PNM, Electricity & Natural Gas Rates website http://www.pnm.com/regulatory/home.htm	1.) 1.) SFH Monetary Savings and Costs calculated using: Electricity Rate = $0.09/KwHr Natural Gas Rate = $0.6929/Therm
	Jacques Blair, City of Albuquerque Economist	1.) 5% discount rate
Spreadsheet Model	This Study's SWCS STELLA 8 Simulation Model "Status Quo" and "SWCS Retrofit" results	1.) Status Quo costs of $159.87 per SFH & $2.79 annually at ABWUD per SFH 2.) SWCS savings of $17.91 annually per SFH & $0.31annually at ABWUD per SFH
	This Study's Population Projections (section 4.0)	1.) ABWUD service area SFH customer number projections

To estimate the both the water and energy costs associated with SFH showering, the same ABWUD costs of $0.042/KwHr and $0.67/Therm that were discussed in section 5.1.9. “Toilet Water and Energy Cost Methods and Estimates” were used in the SWCS STELLA 8 model. Likewise, SFH charges for potable water, $1.381/Unit, and wastewater treatment, $0.822/Unit are also used in the STELLA 8 model[23]. New to this section however, are the SFH electricity and natural gas costs. Currently, Albuquerque SFH pay $0.09/KwHr of electricity and $0.6929/Therm of natural gas (PNM, 2006c).

The ABWUD costs for providing and treating shower water and the SFH costs for using and heating shower water were used in the STELLA 8 model to simulate the annual costs associated with a years worth of showering events. Simulation results were combined with SFH customer number projections in this study’s SWCS spreadsheet model to estimate ABWUD and its single family home customers’ costs each year till 2030.

Natural gas prices are expected to increase in the near future, so the projected cost estimates provided in this report are conservative (PNM, 2006c). Moreover, water rates are likely to increase as a result of ABWUD service area connection customers using less water so that the utility doesn’t suffer significant revenue losses (Gleick *et al.*, 2003; OSE/HJM86, 2005).

5.2.16 SWCS Potential Avoided Cost

The costs of treating and providing and using per capita shower water itself, as discussed above, along with the cost of electricity and natural gas were included in the SWCS STELLA model. Simulated modeling results were then used in a second spreadsheet model to estimate the costs to both ABWUD and its SFH customers. A ten year period from 2008 through 2017 shows

[23] 1 Unit = 748gallons

total cost reduction to ABWUD of 7%, 9%, 11% and 7% when 60%, 80%, 100% and an Incremental% of SFH respectively, are retrofit with the SWCS. Here, the potential of using smaller volumes of water for per capita showering events is demonstrated by avoided costs (Appendix 15a & 16a). Again a 5% discount rate is used to project using 2006 dollars (Blair, 2006).

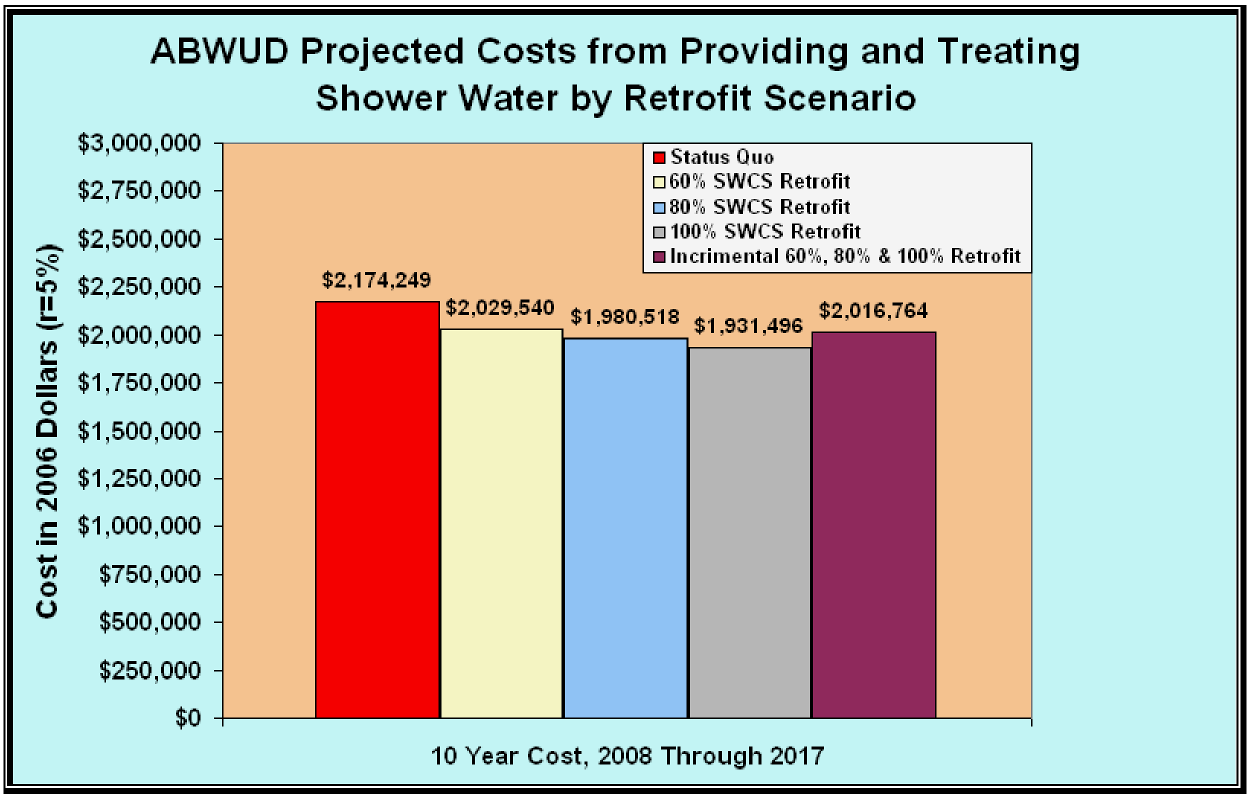

Figure 5.2-7 ABWUD Projected 10 Year Energy Cost

One observation regarding the avoided costs to the water utility from SFH customers using the SWCS is that even though total showering volume demand (in the 10 years projected) is greater than total toilet flushing volume demand, the aforementioned cost reductions are less than those this study finds (on page 40 & 41) when SFH are using dual flush toilets. This distinction is not necessarily due to these two innovations water saving potential per (toilet or

showering) event, but more likely due to the frequency of per capita daily toilet usage over that of showering[24].

SFH also avoid costs when using the SWCS but, as discussed above, are now paying for water, sewerage, electricity and natural gas with each showering event. This total SFH showering cost for water and wastewater service, and energy between 2008 and 2017 are reduced by 7%, 9%, 11% and 7.2% under the 60%, 80%, 100% and Incremental% retrofit scenarios respectively[25] (Appendix 16b, 17b & 18). When focusing on avoided energy costs though, the

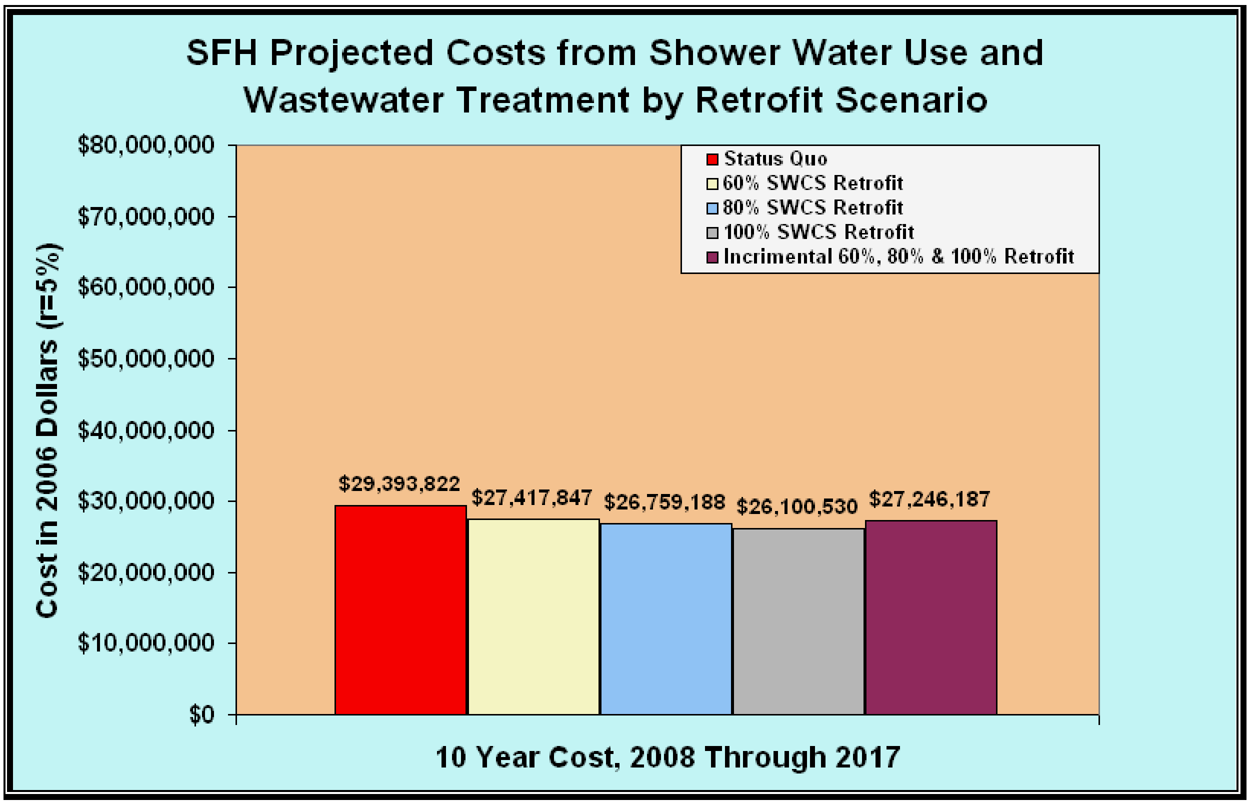

Figure 5.2-8 SFH Projected 10 Year Water & Sewer Costs

[24] According to the report by Mayer *et al*. (1999), each person in a household will flush an average 5.05 times per day and shower an average 0.75 times per day.
[25] The avoided costs resulting from each of these four scenarios are endowed only to the respective percentage of homes using the SWCS.

SFH benefits associated with retrofitting shower stalls with the SWCS are much more significant than when only looking at water and sewer bill savings from using less water.

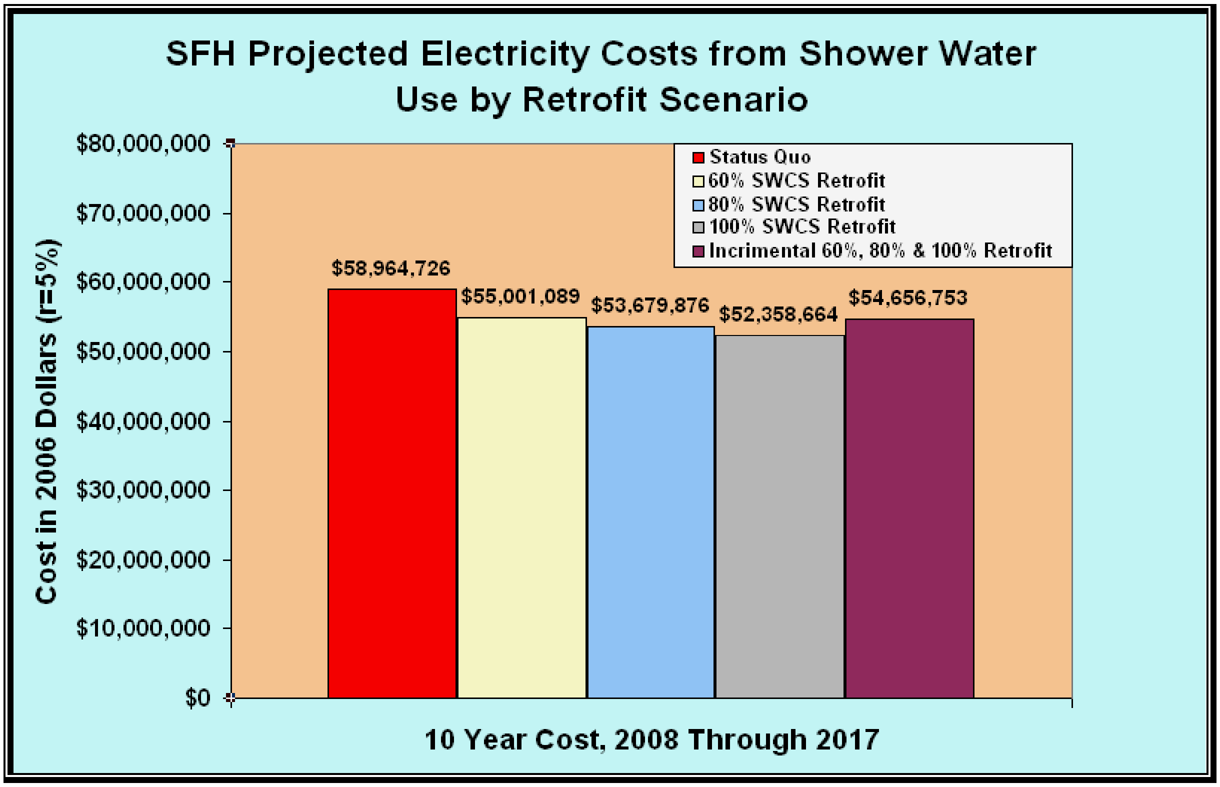

Figure 5.2-9 SFH Projected 10 Year Electricity Cost

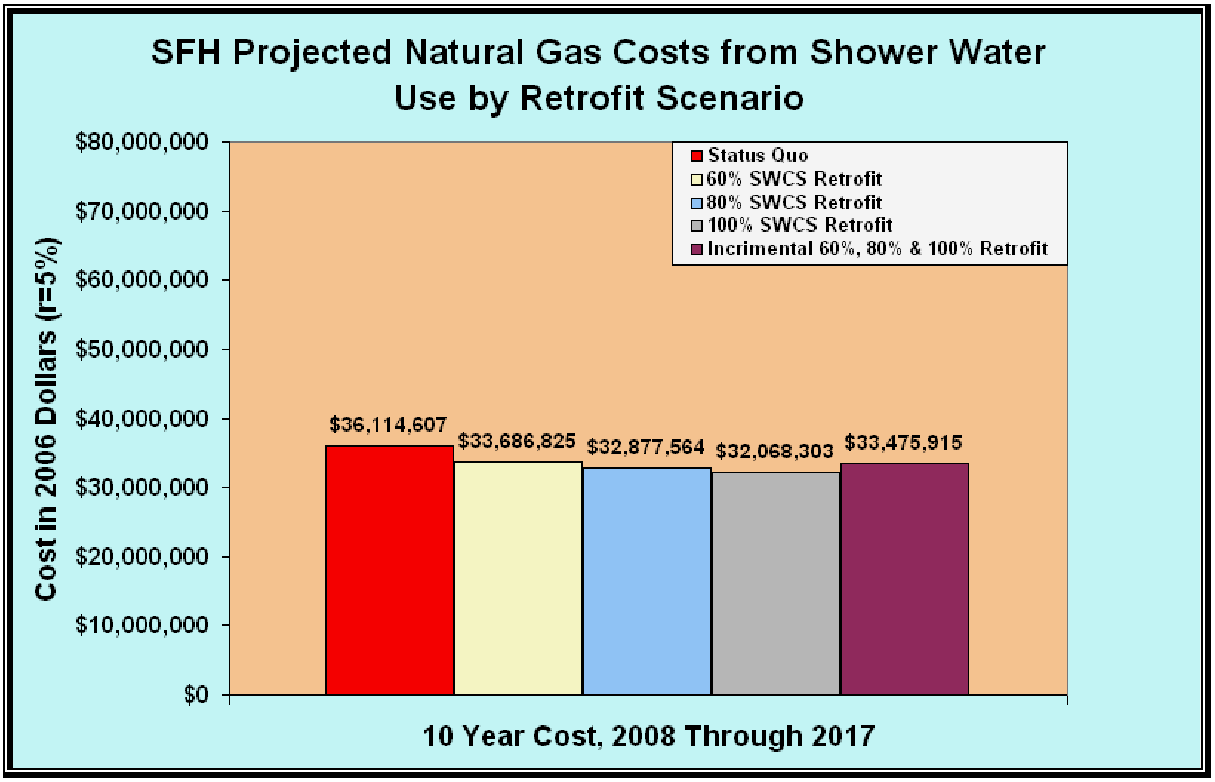

Figure 5.2-10 SFH Projected 10 Year Natural Gas Cost

The ABWUD and SFH avoided costs under each retrofit scenario demonstrate a relatively short period for benefits to be realized. The benefit inherent in retrofitting SFH with the SWCS is that the water and energy demand reductions per capita are permanent (Gleick *et al.*, 2003). Here again it is important for the water utility to understand that adopting newly emerging water saving innovations, especially ones that decrease hot water use, into its rebate or distribution programs is cost effective.

5.2.17 SWCS Cost Effectiveness

This study's SWCS modeling efforts demonstrate the potential water, energy and monetary savings associated with implementing conservation policy alternatives that adopt new technologies designed to alter how SFH use heated water. Alternatives that result in avoided

water and energy costs should be more attractive to both the water utility and its customers since they effectively reduce expenses and tend to be highly cost effective (Gleick *et al.*, 2003).

This sections economic analysis is similar to the one discussed and performed in Section 4.1 for dual flush toilets. However, the SWCS savings include both water and energy used to heat it, so the cost of conserved water decreases significantly. As with the earlier dual flush toilet cost effective analysis, this SWCS cost effective analysis utilizes the same assumptions appropriate with a Distribution program. The cost of conserved water for this newly emerging innovation uses the following equation:

$$\mathbf{C_s = \xi_{O\&M}/W_s}$$

where,

$\mathbf{C_s}$ is the SFH cost of conserved water from SWCS retrofit by normal replacement
$\mathbf{N_s}$ is the typical life of a SWCS, which is assumed to be 25 years[26]
$\mathbf{\xi_{O\&M}}$ is the increase in annual costs incurred by Status Quo SFH, minus the combined monetary benefits of sewer and energy charges for homes that retrofit under normal replacement
$\mathbf{L_s}$ is the water savings over the lifetime of the SWCS (ac-ft/year)
$\mathbf{W_s}$ is the estimated average (or levelized) annual water saved (ac-ft/year)
$\mathbf{W_s = L_s / N_s}$ (Gleick *et al.*, 2003).

Essentially, implementing a distribution program that enhances SFH normal replacement with the SWCS is cost effective if the cost of conserved water is less than the cost of larger scale supply projects or purchasing water rights. Moreover, both ABWUD and its SFH customers will save money (Gleick *et al.*, 2003). The abovementioned equation was used with this study's spreadsheet model to quantify the cost of conserved water from shower stalls retrofit by normal replacement[27].

[26] The SWCS should have at least a 50 years warranty to be marketable. However, at this early stage of research and development it may not be appropriate to assume 50 years. 25 years was selected to provide a more conservative cost effective estimate.
[27] This study's use of Distribution programs forces several terms to drop out of the equation.

For example, if in 2007 ABWUD single family home customers choose to participate in a Distribution program and retrofit their bathrooms with the SWCS due to normal replacement, the following assumptions apply. Since the discussions in Section 6.0 are centered on the inherent benefits of Distribution programs over Rebate programs, then no customer costs are used here. The typical life of a SWCS is assumed to be 25 years. An estimated 3,916 SFH customers are using the SWCS retrofit by normal replacement. Under this scenario, these SFH conserve 17ac-ft of water and save $59,326 in sewer and energy costs. Additionally, a 5% discount rate was used to discount dollars in 2007 (Blair, 2006).

$$\mathbf{C_s = \xi_{O\&M} / W_s}$$
$$\mathbf{C_s = -} \text{ (\$59,326) } \mathbf{/ \text{ (17ac-ft per year / 25 years)}}$$
$$\mathbf{C_s = - \text{ \$85,935 per acre-foot of conserved water}}$$

Here the cost of conserved water is more negative than that of dual flush toilets (-$8,120) because monetary benefits of retrofitting SFH with the SWCS include energy savings. The initial investment however, is much larger than that of a toilet due to the longer labor time involved in working behind a shower stall. It is important to remember here that including installation costs when quantifying cost of conserved water is only necessary for those homes that participate in distribution programs for the sake of conserving water. SFH that participate out of necessity, due to failed shower stall replacement, remodeling and newly built homes with the SWCS system already built into it need not include the installation cost when quantifying the cost of conserved water (Gleick *et al.*, 2003).

The cost of conserved water for the SWCS above is highly negative. This factor should emphasize the value of a Distribution program that increases the penetration of existing and newly emerging water conservation innovations that enable end users to use hot water more

efficiently. The economic and resource benefits offered by the SWCS are even more attractive when considering the alternative of purchasing water rights to provide the same volume of water saved. At the current rate of $12,000/acre-foot, ABWUD would have to invest $204,000 to gain access to the 17ac-ft of water that is conserved in the scenario above. ABWUD should recognize the potential benefits of educating customers with regard to the potential water energy and monetary savings of newly emerging innovations such as the SWCS (Gleick *et al.*, 2003). ABWUD and its single family home customers would also benefit from savings information and an awareness of what the water and energy savings really mean for Albuquerque.

5.2.18 SWCS Analyses Data and Assumption Sensitivity

The SWCS analyses in the previous sections used many data and assumptions within this study's STELLA 8 and spreadsheet models to estimate water and energy demands and costs as well as savings. Projecting these demands, cost and savings on a 24 year time horizon several parameters were held constant. That is, data and assumptions surrounding current SFH shower water demand, energy demand and monetary costs remained the same through the year 2030.

The results presented in previous sections are likely to change as data and assumptions used may change over time. For example, shower water energy demands may decrease as drinking and wastewater treatment processes become more efficient. The costs of electricity and natural gas are certain to change, as are the customer water rates. These cost changes will both increase the annual resource use cost estimates per showering event as well as the avoided cost estimates of using the SWCS.

5.3 Water Conservation Opportunity

The benefits associated with ABWUD single family home customers using dual flush toilets and the SWCS can be discussed beyond the potential water, energy and monetary savings. Certainly the analysis presented above demonstrates there are significant water and energy resource savings resulting in monetary savings to the utility and its customers. But what do those savings translate into? The answer is opportunity.

In an environment where the ABWUD ability to meet demand 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. As this report demonstrates, there is power in efficient water use innovations beyond mere water conservation. Therefore, it is important to understand and take full advantage of the potential benefits associated with innovations such as the dual flush toilet and SWCS. Motivating the ABWUD and its single family home customers to do so however, may take a little more persuasion. Here, the external opportunities associated with the water energy and monetary savings should be understood.

5.3.1 Water Security

At the beginning of this report the vulnerability of Albuquerque's current water supply solution was discussed with regard to the impending challenges of drought, climate change and population growth. Programs that implement the use of innovations such as the dual flush toilet and SWCS, which force the efficient use of water without imposing restrictions on every day household tasks (such as flushing and showering), contribute significantly to Albuquerque's water security and prepares the city to meet those challenges.

Albuquerque SFH use is approximately 135gpcd, 51% of which (69.3gpcd) is for indoor uses (WRA, 2003). Moreover, the current water usage of all Albuquerque Bernalillo County Water Utility Authority customers is 50.3% residential (Yuhas, 2005). Therefore, there exists a large potential for the ABWUD to secure an alternative source of water supply form SFH efficiency improvements to meet current and future water demand.

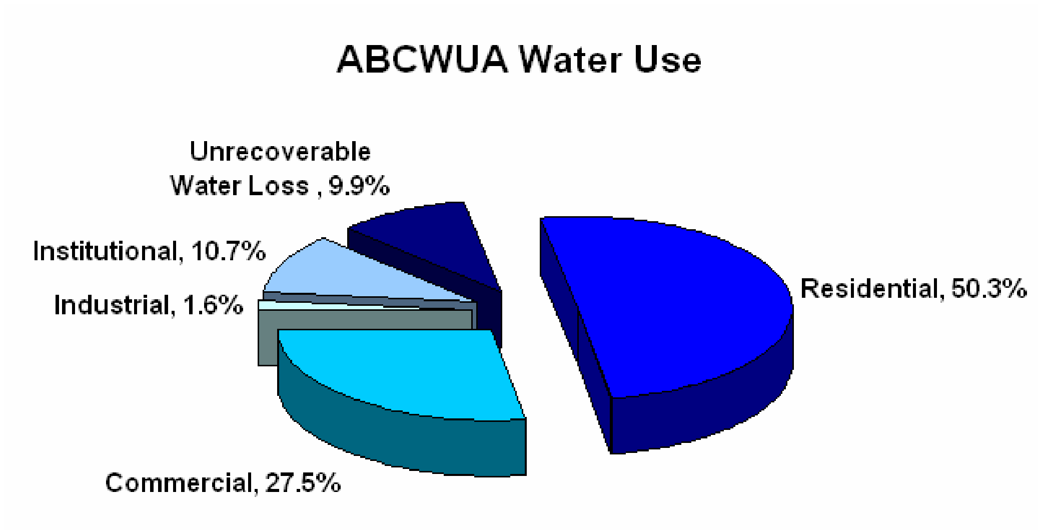

Figure 5.3-1 ABCWUA Water Use Breakdown.
Reproduced from data provided by Yuhas (2006)

The dual flush toilet and SWCS plots and discussions in previous sections illustrated the water savings possible from four different retrofit scenarios. It is important therefore, to understand what these savings mean for ABWUD, its single family home customers and the City of Albuquerque. For example, the water savings revealed in the previous sections represent a volume of water that may be used to meet the demand of a growing population. Focusing on this study's 60% retrofit scenario, a total of 3,013ac-ft may be saved from increasing the efficiency of toilet and shower water use in the three years discussed earlier, 2011, 2020 and 2030. Under current SFH gallon per capita per day demand (135gpcd) the 60% retrofit savings of dual flush

toilets and the SWCS in 2011 combined (920ac-ft) are enough to meet the annual water demand of 1,988 Albuquerque single family homes (Appendix 19 & 20)[28].

Table 5.3-1 "3" Year Potential Water Savings from 60% Retrofit Scenario (acre-feet)				
	2011[1]	2020	2030	Total
Dual Flush Toilet	629	687	745	**2,061**
SWCS	291	317	344	**952**
Total	**920**	**1,004**	**1,089**	**3,013**
[1] Year 2011 was used in Section 4.1 to demonstrate water demand trend				

Looking further into the future at all four scenarios and their projected water savings from 2007 through 2030 the value of saved water is much clearer. This study's results for the 60%, 80%, 100% and Incremental% retrofit scenarios reveal a total of 25,059, 32,968, 40,876 and 33,357ac-ft respectively of water savings from using toilet and shower water more efficiently. Again, and over a 24 year period, the 60% retrofit savings of dual flush toilets and the SWCS combined (25,059ac-ft) are enough to meet the annual water demand of 54,155 Albuquerque single family homes (Appendix 19 & 20)[29]. This number of SFH is 42% of the total number of SFH customers this study projects ABWUD will service in 2030.

Table 5.3-2 "24" Year Potential Water Savings from Retrofit Scenarios (acre-feet)				
	60% Retrofit	80% Retrofit	100% Retrofit	Incremental Retrofit
Dual Flush Toilet	17,561	22,970	28,379	23,236
SWCS	7,498	9,998	12,497	10,121
Total	**25,059**	**32,968**	**40,876**	**33,357**

Looking at these benefits another way, in Fiscal Year 2004 ABWUD pumped a total of 100,046ac-ft from production wells for use in Albuquerque (Dayyani, 2005). So, if we consider a

[28] Assumes 3.06 persons per SFH. This is the number used by ABWUD to estimate residential water demand (Yuhas, 2006).
[29] Assumes 135gpcd total use with 69.3gpcd indoor use in Single Family Homes (WRA, 2003). Also assumes 3.06 persons per residence (Yuhas, 2006)

scenario where 60% of ABWUD single family homes are retrofit with a dual flush toilet and SWCS from 2007 through 2030, then these two every day use fixtures ensure an (25,059ac-ft) alternative water supply that is 25% of the 2004 ground water pumping demand.

Throughout the 24 year period from 2007 through 2030 it is likely that the challenges associated with drought, climate change and population growth will stress ABWUD water supply under the Status Quo scenario conditions. The potential alternative source water described here (as well as from other programs) generates an opportunity to meet those challenges, whether that means enhancing City water tank/reservoir storage or aquifer storage capacity using injection wells, and or meeting increasing water demand associated with an expanding population[30]. These types of projections highlight methods that enable Albuquerque, as well as the greater New Mexico and Southwest, to add to it future water security.

5.3.2 Energy Security

This study also identified the energy savings associated with SFH using dual flush toilets and the SWCS. That is, energy demand is avoided from ABWUD having to treat and provide less water and treat less wastewater, and avoided at SFH from having to heat (or re-heat) less water. Given the inextricable linkages between water use and energy consumption discussed in Section 3.1 (p.22) of this report, it is important to understand what this new and alternative water source from using water more efficiently implies. That is, how does increasing water use efficiency contribute to Albuquerque energy security and aid its meeting the challenges of drought, climate change and population growth?

[30] Although aquifer storage and recovery may be considered a viable alternative for storing water to meet future demand, some issues with this method must first be recognized and considered alongside other alternatives. Planners should recognize/quantify the energy that would be required to treat water to acceptable quality prior to injection and the energy required to inject it and then pump it back out again when needed.

Using water saving innovations that enhance the efficiency of every day per capita end uses effectively eliminates energy demand "upstream" required for pumping and potable treatment and "downstream" for wastewater treatment. Moreover, when innovations add to hot water end use efficiency, an even greater energy demand is eradicated as well (Cohen *et al.*, 2004).

As stated earlier in this report, one third of ABWUD operating budget is spent on pumping water (ECC, 2004). Also, in Albuquerque, SFH use an average of 7.09MwHrs of electricity and (for those that use natural gas) 664Therms per year (PNM, 2006b). Therefore, there is a large opportunity for the water utility and single family home customers to decrease their energy demand and enhance the City's as well as other PNM customers' energy security, while securing an alternative water source with dual flush toilets and the SWCS, and possibly even safeguarding future San Juan Chama project water diversions.

Using water more efficiently and thus, decreasing energy demand, generates positive impacts on the energy production sector. As mentioned earlier in this report, significant volumes of water are required to generate electricity at coal burning power plants. Currently, 46% of Albuquerque electricity comes from coal and the remainder a mix of solar and wind power (PNM, 2006b). Additionally, 58% of the City's thermoelectric power is generated at the San Juan Generating Station, in the San Juan Basin (PNM, 2006e). So, reductions in electricity demand lead to less water used at this and other power plants for cooling processes. PNM's thermoelectric power generating facilities require about 0.74 gallons of water for every Kilowatt-Hour of electricity generated (PNM, 2006a). Any decrease in water demand within the San Juan Basin, especially one as significant as potentially caused by dual flush toilets and the SWCS,

may generate more favorable shortage sharing conditions for the SJCP diversionary right as drought, climate change and population growth affect the basin's ability to meet competing demands. Stated differently, implementing programs in Albuquerque that enhance water use efficiency reduces the demand for San Juan Basin thermoelectric power generation, resulting in greater water (and energy) security for SJCP water users.

So what is the ABWUD single family home potential for supporting the chain of events described above? The energy intensity of toilet and shower water use highlights the avoided energy demand associated with treating, providing, using and heating less water and therefore, reducing the water used to generate electricity[31]. The water demand resulting from providing natural gas mostly only occurs during extraction and is not significant enough to include here (Gleick, 1994).

The energy intensity of water is defined as the amount electricity and natural gas consumed per acre foot of water used (CEC, 2005). This study's Status Quo scenario estimates 1.39MwHrs and 30Therms are currently (in 2006) consumed for every acre foot flushed by ABWUD customers. Similarly, SFH shower water energy usage per acre foot was estimated. Here, due to household water heating, the (2006) estimated energy intensity of shower water is much more significant at 22.78MwHrs and 1,731Therms (Appendix 8-9 & 13-15).

Table 5.3-3 2006 Status Quo Scenario Energy Intensity

	Electricity Intensity (MwHrs/ac-ft)	Natural Gas Intensity (Therms/ac-ft)
Toilet Flushing	1.39	30
Showering	22.78	1,731
Total	**24.17**	**1,761**

[31] There is a larger system of water demand associated with thermoelectric power generation not considered in this study's analysis. U.S. coal mining requires anywhere from 10 to 100 gallons of water per ton of coal (Gleick, 1994).

The above energy intensity includes the electricity and natural gas used to pump groundwater from the City underlying aquifer and booster pumping to storage reservoirs, and treat wastewater at the Southside Water Reclamation Plant. Additionally, the Status Quo energy intensity includes the electricity and natural gas required to heat water. Earlier discussions revealed that in March 2008 the ABWUD new San Juan Chama Drinking Water Plant and Finished Water Pump Station will begin treating and pumping river water, decreasing Albuquerque's groundwater pumping by 90% (Stomp, 2006). This new potable water source is expected to use less electricity and does not use natural gas. Thus, this study forecasts a slight decreased estimate of the energy intensity associated with SFH toilet flushing and showering events. In 2008 toilet water will consume an estimated 1.34MwHrs and 22Therms and shower water will consume an estimated 22.73MwHrs and 1,724Therms (Appendix 8-9 & 13-15).

Table 5.3-4 2008 Status Quo Scenario Energy Intensity		
	Electricity Intensity (MwHrs/ac-ft)	Natural Gas Intensity (Therms/ac-ft)
Toilet Flushing	1.34	22
Showering	22.73	1,724
Total	**24.07**	**1,746**

While the above energy intensity reductions are notable, a good deal more is achievable from using water (including hot water) more efficiently. The energy intensity resulting from SFH toilet water and shower water usage is only likely to change due to alterations in the efficiency of treatment or heating processes. Therefore, the value of dual flush toilets and the SWCS is that they decrease the total amount of water and energy demanded with each flushing and showering event; thus, enhancing current and future energy security in Albuquerque.

Previous sections discussed energy savings plots generated by this study's 60% retrofit scenario. It is important for ABUWD and its single family home customers to understand what these savings mean for the City. Assuming 60% of Albuquerque SFH within the water utility service area are retrofit with dual flush toilets and the SWCS, then a total of 24,409MwHrs and over 1.69 Million Therms no longer need to be consumed in years 2011, 2020 and 2030 combined. Stated another way, managing water demand with these types of efficient innovations effectively manages the demand on the (electricity and natural gas) energy sectors as well.

Table 5.3-5 "3" Year Combined Energy Savings from 60% Retrofit Scenario						
		2011[1]	2020	2030	Total	
Dual Flush Toilet	Electricity (MwHrs)	**842**	**920**	**998**	**2,760**	-
	Natural Gas (Therms)	**13,841**	**15,116**	**16,405**	-	**45,362**
SWCS	Electricity (MwHrs)	**6,606**	**7,214**	**7,829**	**21,649**	-
	Natural Gas (Therms)	**501,190**	**547,330**	**594,021**	-	**1,642,541**
Total		-	-	-	**24,409**	**1,687,903**

[1] Year 2011 was used in Section 4.1 to demonstrate water demand trend

Since Albuquerque SFH use approximately 7.09MwHrs of electricity and 664Therms per year, then the combined savings of dual flush toilets and the SWCS in 2011 alone, are enough to meet the annual electricity demand of 1,051 homes and the annual natural gas demand of 776 homes (PNM, 2006b) (Appendix 21a through 21f).

Clearly, the aforementioned electricity saved from SFH using toilet and shower water more efficiently cannot be stored to meet future demand as is the case with natural gas. Therefore, reducing electricity demand here translates into a reduction of water no longer needed at the San Juan Generating Station, and other PNM facilities for thermoelectric power generation. Since this facility (and other PNM facilities) uses approximately 740 gallons per MwHr and Albuquerque accesses 46% of its electricity from thermoelectric power generation,

then the above 7.09MwHrs of electricity saved in 2011 (7448MwHrs) is enough to decrease the water demand for running thermoelectric power generating by 7.78acre-feet (PNM, 2006a; PNM, 2006b). This study's other three retrofit scenarios' projections highlight even larger decrease in water and energy demand, and therefore a decrease in water demand for generating electricity (Appendix 22a & 22b).

When a 24 year time horizon is considered along side this study's four retrofit scenarios, the potential energy demand reductions and its implications for thermoelectric power generation and the SJCP diversion are clear. The dual flush toilet and SWCS 60%, 80%, 100% and Incremental% retrofit scenarios generate electricity and natural gas savings seen in the following two tables respectively. Under the 60% retrofit scenario alone, the 24 year energy savings are enough to meet the electricity demands of 27,391 single family homes and the natural gas demand of 20,096 single family homes.

Table 5.3-6 "24" Year Potential Electricity Savings from Retrofit Scenarios (MwHrs)

	60% Retrofit	80% Retrofit	100% Retrofit	Incremental Retrofit
Dual Flush Toilet	23,576	30,828	38,081	31,174
SWCS	170,541	227,388	293,235	230,138
Total	**194,117**	**258,216**	**331,316**	**261,312**

Table 5.3-7 "24" Year Potential Natural Gas Savings from Retrofit Scenarios (Therms)

	60% Retrofit	80% Retrofit	100% Retrofit	Incremental Retrofit
Dual Flush Toilet	395,457	516,006	636,554	520,332
SWCS	12,948,224	17,264,299	21,580,373	17,469,891
Total	**13,343,681**	**17,780,305**	**22,216,927**	**17,990,223**

The large volume of energy savings throughout this 24 year period highlights the importance of recognizing the water-energy nexus when designing water conservation policies. Here (under the 60% retrofit scenario) the total "avoided" volume of water required for 24 years

of thermoelectric power generation, 203ac-ft, is offset by retrofitting 60% of Albuquerque SFH with efficient dual flush toilets and the SWCS. Stated differently, a relatively small number of households using dual flush toilets and the SWCS may contribute to enhancing Albuquerque and the greater New Mexico and Southwest energy security by using water (and hot water) more efficiently. Moreover, the resultant electricity demand reductions will result in reduced thermoelectric water demand and may enhance water security in the greater Colorado Basin. It is highly likely that much more energy could be conserved and more water use offset from a comprehensive approach to enhancing water use efficiency in all Albuquerque sectors.

The natural gas demand identified in this study should not go unnoticed by Albuquerque water resource planners. While the future of natural gas is not discussed in this report, it has been forecasted that coal bed methane production will increase over the next 24 years within the San Juan Basin to meet with a growing national demand. Since large volumes of produced water from methane extraction wells are typically saline and not suitable for potable purposes, then there may be both positive and negative implications for thermoelectric power generation and water quality respectively (EIA, 2006). Therefore, any decrease in natural gas demand from using and heating water more efficiently is a positive step towards increased energy security.

The impending challenges of drought, climate change and population growth and the potential for mitigating the impacts to Albuquerque's municipal water supply with water efficient technologies has been the reoccurring theme of this report. This section exposed the larger system of energy resource use connected to SFH water demand to highlight the benefits of thinking outside the water conservation box. The implicit opportunity expressed in this report is the increased understanding of the connections between water and energy demand. The value of

such an understanding lies in the design of conservation policy that takes full advantage of the nexus and the inherent benefits associated with using water efficiently.

As Albuquerque advances into the 21st Century and is faced with greater water scarcity, ABWUD (and other water resource managers) should take full advantage of every opportunity obtainable from technologies that enable end users to use water and energy resources more efficiently. Moreover, the quantifiable opportunities should be used to justify much more progressive conservation programs than currently implemented, as well as increased coordination between water and energy purveyors. Doing so would likely assist the City and its residents in improving future water and energy security; thus, better equipping Albuquerque to manage future drought, climate change and population growth.

6.0 WATER CAPTURE POTENTIAL

Modern water capture technologies offer ABWUD and its service area customers a large potential for augmenting its current and future water supply and are recommended by this study to enable Albuquerque to begin to prepare for the challenges of drought, climate change and population growth. Currently, rainwater harvesting is utilized on an almost negligible scale with rain barrels collecting water for irrigation purposes. The annual volume of water that runs off of Albuquerque SFH rooftops is far greater than can be captured in barrels and may be used to meet current and future water demands and aid in relieving the pressures of a declining aquifer and an uncertain San Juan Chama Project water supply. Therefore, this study examines rainwater harvesting as a means of augmenting ABWUD municipal water supply.

As with the previous examination of the dual flush toilet and shower water conservation system, this study used the rooftops of SFH existing within the ABWUD service area as the

analysis extent. The objective of this section is to reveal this study's estimates of the significant volume of alternative water supply that may be harvested from SFH rooftops. Contained within the ABWUD service area boundary, SFH zoned areas constitute 22% of the developed land use area; thus, this study's four retrofit scenarios, 60%, 80%, 100% and Incremental% were used to demonstrate the significant water harvesting potential.

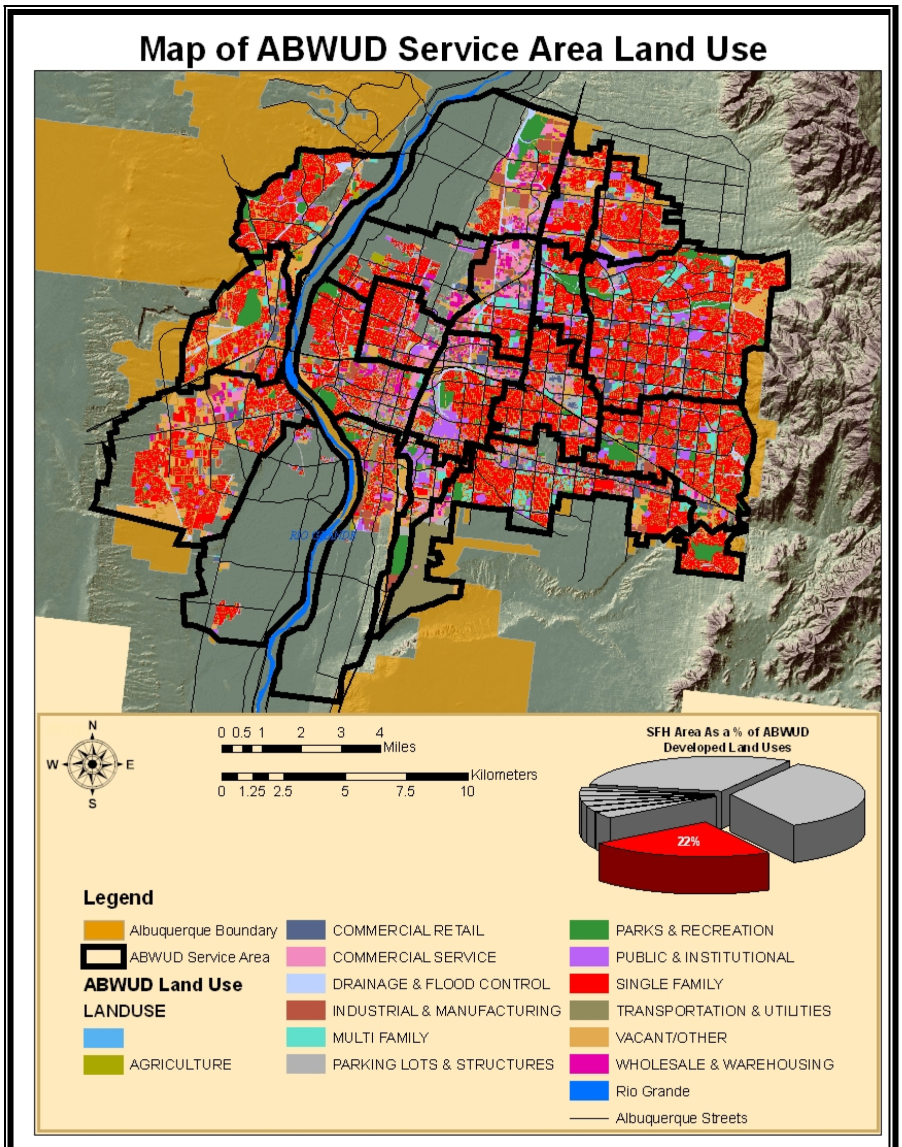

Figure 6.0-1 ABWUD Land Use[32]

[32] Other SFH zoned areas within the City of Albuquerque are serviced by NM Utility.

6.1 Water Capture Methods and Estimates

Several data sources were used to execute the GIS analysis of SFH rooftops. This study used Arc View 9.1 software to analyze spatial data representing natural and anthropogenic features existing within the boundary of the ABWUD service area. The data employed in this analysis came from various sources, the breadth of which may be viewed in Table 6.1-1.

Table 6.1-1 Data Sources, Types and Projections

Data Source	Data Type	Original Projection
City of Albuquerque http://www.cabq.gov/gis	1.) Albuquerque Boundary *.shp 2.) Bernalillo County Land Use *.shp 3.) Major Streets *.shp	NAD 1983 HARN State Plane New Mexico Central FIPS 3002 Feet
City of Albuquerque by special permission from Pauline Ramos[1] PRamos@cabq.gov	1.) ABWUD Service Area Boundary *.shp 2.) ABWUD Pressure Trunk Zones *.shp	NAD 1983 HARN State Plane New Mexico Central FIPS 3002 Feet
RGIS http://rgis.unm.edu	1.) 10m 7.5minute Quad DEMs a. Albuquerque West b. Hubbel Spring c. Isleta d. La Mesita Negra e. Los Griegos f. The Volcanoes g. Sandia Crest h. Tijeras i. Albuquerque East j. Alameda 2.) 7.5minute Quad for New Mexico *.shp	GCS Assumed Geographic 1 Not Projected
USGS Seamless Data Distribution http://seamless.usgs.gov	1.) 1m Resolution Orthoimages *.tif	GCS Assumed Geographic 1 Not Projected
NRCS http://www.wcc.nrcs.usda.gov/images/precip.html	1.) 1971 to 2000 New Mexico Average Annual Precipitation *.shp	GCS Assumed Geographic 1 Not Projected

[1] For security reasons a disclosure statement was required to receive this data. Thus, this data is for use in this study only and is only available by permission from the City of Albuquerque.

Most of the GIS files originated from The City of Albuquerque GIS website. These included Albuquerque Boundary shapefile, Bernalillo Land Use shapefile, Major Streets shapefile, ABWUD Service Area Boundary shapefile, and ABWUD Pressure Trunk Zones shapefile. The latter two shapefile are “Public Works Infrastructure” specific and were acquired by special permission from Pauline Ramos, from Albuquerque Geographic Information System (City of Albuquerque, 2006a). Next, ten 10meter digital elevation models (DEM) and a 7.5minute Quad shapefile for New Mexico were downloaded from The New Mexico Resource Geographic Information System Program (RGIS, 2006). Key data elements to this report’s analysis, six orthoimages (TIFF) of six different neighborhoods within the ABWUD service area, were acquired from the USGS Seamless Data Distribution website (USGS, 2006). Finally, the average annual precipitation shapefile for New Mexico (years 1971 to 2000) was downloaded from the Natural Resources Conservation Service (NRCS, 2000). The original projections of the data used in this report varied as they were from different sources.

Since all the data were distributed from their source as either defined and projected or undefined and not projected, then all the data were defined and or projected using the Arc Toolbox extension tools for features and raster. This study focused on surface area for quantifying rainwater harvesting potential and thus, used a NAD 1983 Geographic Coordinate System and a USA Contiguous Albers Equal Area Conic projection, which effectively preserved the area of rooftops. Viewing the data projected between two standard parallels successfully minimized the distortion of both the continuous and discrete features and allowed for more accurate calculations of surface area (Lo *et al.*, 2002).

To transform the ArcMap viewed data into a more presentable cartographic design which displayed elements of this study's rainwater harvesting analysis such as, precipitation, ABWUD service area, SFH neighborhoods and topography, various tools were used in the ArcMap environment. Spatial Analyst was used to perform surface analyses with the ten DEM raster data files, generating hill shade and slope. More data analysis was performed using select by location, extraction/clip, overlay and editing tools to manipulate shapefiles so that the attribute tables contained the fields of calculated rooftop and neighborhood surface areas necessary for export and further analysis in this study's rainwater harvesting spreadsheet model. Detailed GIS methodology is listed in Appendix 23.

An essential component of this study's GIS analysis was digitizing the rooftop surface area of six randomly selected subdivisions' orthophoto/TIFF images, geographically located within the ABWUD service area. Four precipitation zones exist with the service area, a large 9 inches per year zone, a smaller 11 inches per year zone, 13 inches per year zone and 15inches per year zone. Since the 9 and 11 inch per year zones contain a large percentage of ABWUD total SFH customer land use area, 70.46% and 23.39% respectively, then two subdivisions were selected in each to quantify a more representative rooftop area density. One subdivision was selected within the 13 and 15 inch zones each, which constitute 5.14% and 1.02% respectively, of the total SFH customer land use area (Appendix 23).

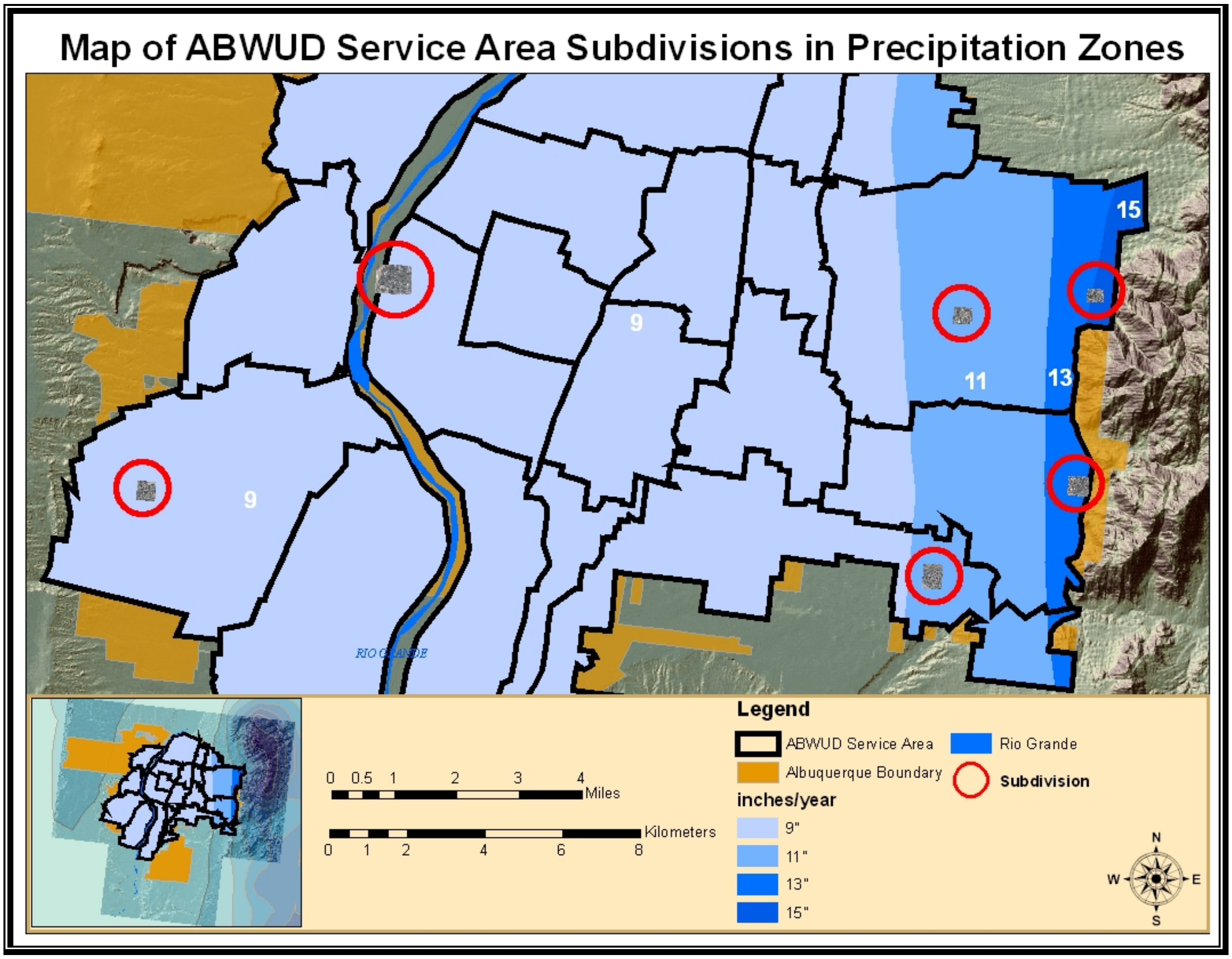

Figure 6.1-1 Geographic Location of Subdivisions &
Average Annual Precipitation Zones (1971-2000)

To arrive at a total SFH rooftop surface area, representative of the total SFH zoned residential area inside each precipitation zone, a couple assumptions were made. First, it was assumed that the randomly chosen subdivisions and their quantified rooftop areas are representative samples of other subdivision rooftop areas existing within their respective precipitation zones. That is, the percentage of rooftop area per subdivision area (from the viewpoint of the orthophoto image) is assumed consistent within each precipitation zone. Second, since it was not possible to visually count the number of SFH existing within each

precipitation zone, then each zone's respective percentage of ABWUD total SFH customer land use area was used with this study's SFH customer projections to estimate the total number of homes in each zone.

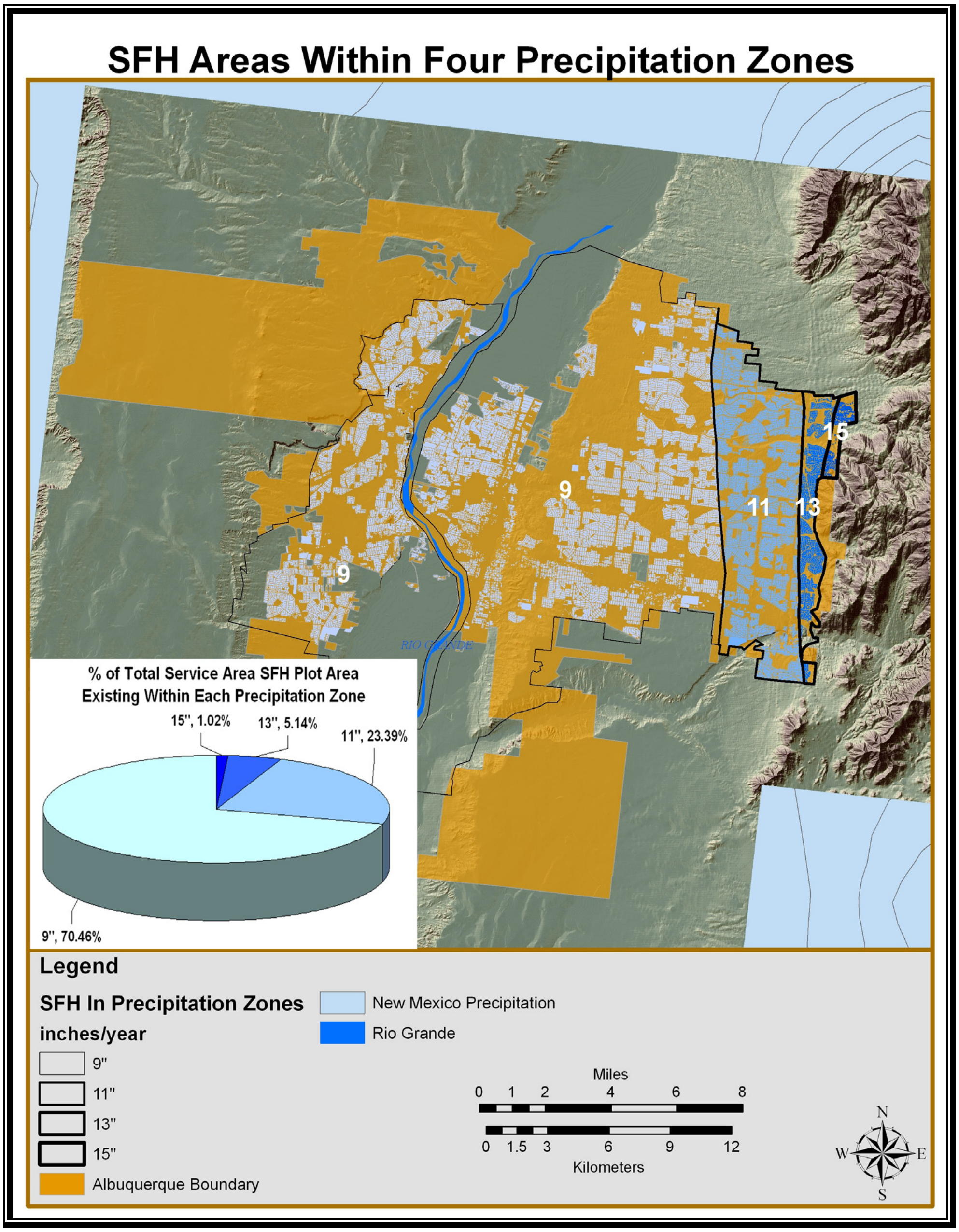

Figure 6.1-2 Location and Percentage of SFH Zoned Area within Precipitation Zones

Rooftop digitizing was done with the Arc View 9.1 Editing Tool. Essentially, the rooftop outline was traced to create a polygon, within which surface area could be calculated.

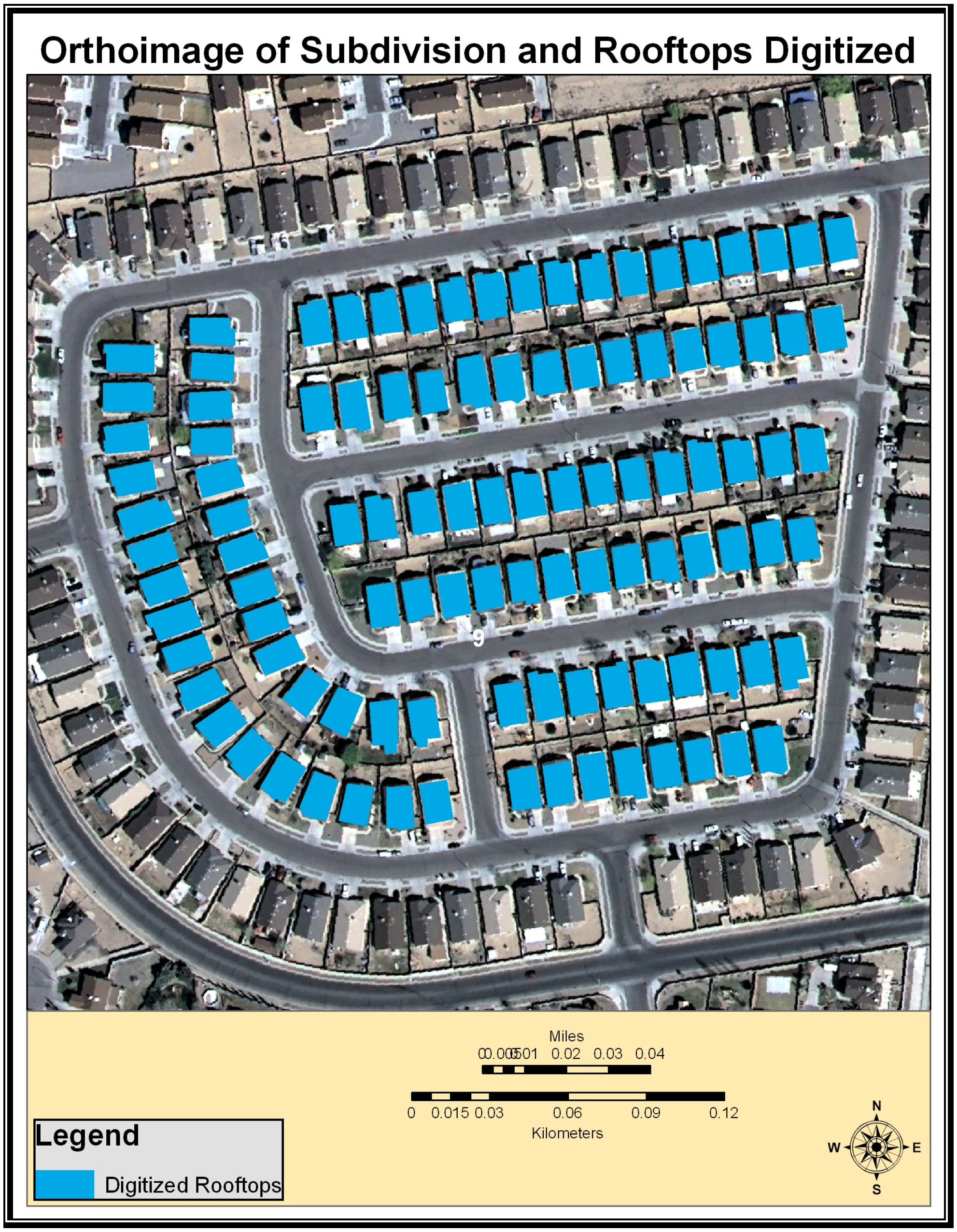

Figure 6.1-3 Digitized SFH Rooftops

The rooftop area and the annual rainfall intensity for the six SFH subdivisions were multiplied together and then by a runoff coefficient of 0.95, which is the standard for rooftops of metal, asphalt, gravel and shingles (City of Albuquerque, 2003). The resultant volume of rooftop runoff from subdivisions in each of the precipitation zones represents the amount of rain fall that could potentially be collected from rooftops in one year. This study's rainwater harvesting spreadsheet model projected the harvesting potential to 2030 in each of the four retrofit scenarios.

6.2 Water Capture Potential

The important distinction between the scenario trend lines below is that the total alternative water supply is increasingly larger over time. That is, as the number of ABWUD single family home customers increases annually, the volume of accessible alternative source water increases. Between 2011 and 2030 the 60% and 80% SFH Rainwater Harvesting scenarios water capture potential increases by 18.51% and 18.50% respectively. Therefore, since at each year the percentage of SFH harvesting rainfall is assumed consistent (for each scenario), then differences between the 60% and 80% retrofit scenario plots demonstrate the potential for a significant increase in alternative water supply over time; so, there is a large incentive to capture rainfall from as many SFH rooftops as possible. Moreover, this water supply may help offset the amount of groundwater ABWUD needs to pump annually, enhancing aquifer storage recovery. The figure below shows the water capture potential under the four retrofit scenarios as well as the increasing alternative water supply at 2011, 2020 and 2030 between the 60% and 80% scenarios. The Rainwater Harvesting estimates and projections can be found in Appendix 23.

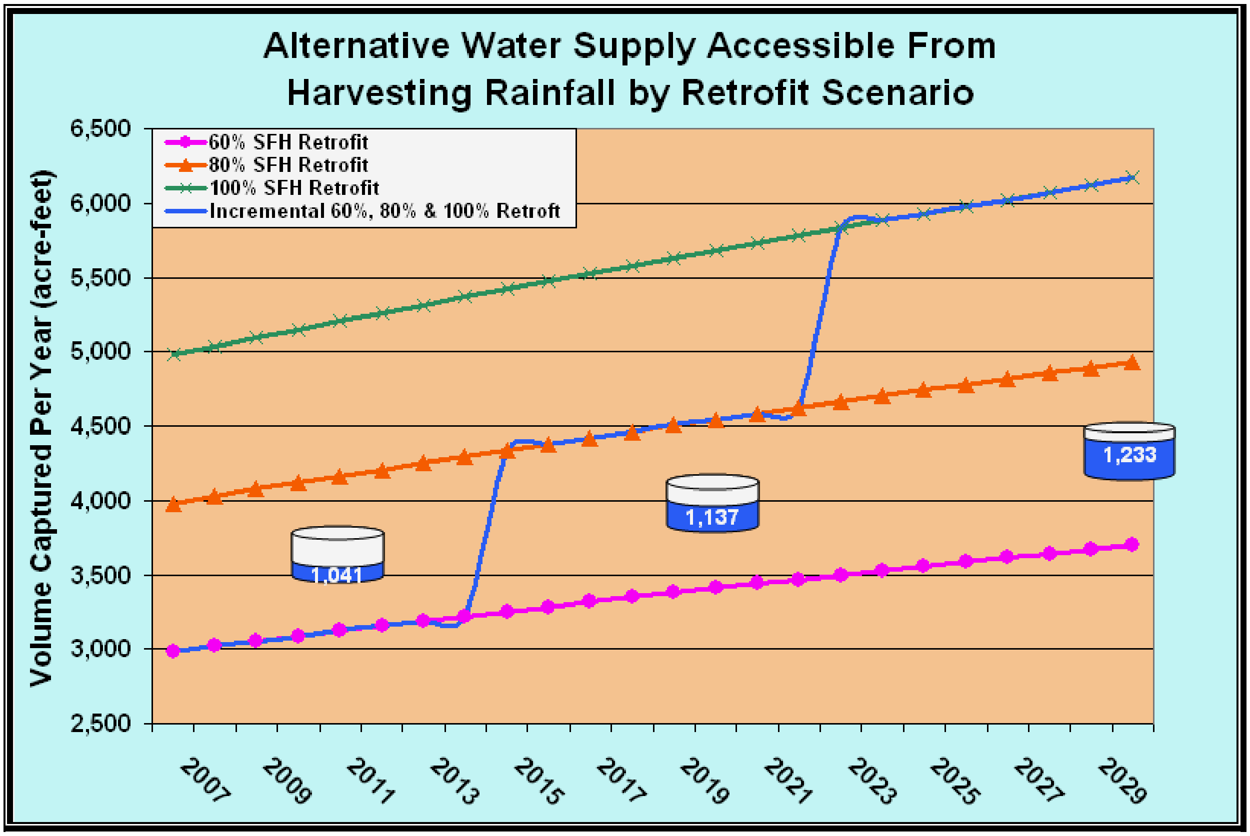

Figure 6.2-1 Potential Annual Alternative Water Supply

6.3 Water Capture Analyses Data and Assumption Sensitivity

The rainwater harvesting analyses in the previous sections used many data and assumptions to estimate the potential alternative water supply accessible from Albuquerque SFH rooftops. Projecting the supply estimates available each year over a 24 year time horizon several parameters were held constant.

The alternative water supply estimates in the previous section are likely to change as data and assumptions used may change over time. For example, this study used annual average precipitation data from years 1971 to 2000. It is likely that under the drought and climate change conditions described in this report, precipitation patterns in the 21st Century will not reflect that

of the data used. That is, the expected increased intensity, but possibly less frequent rainfall events, as well as higher than average temperatures, forecasted by climate models, may enhance the localized SFH rooftop rainwater capturing potential.

6.4 Water Capture Opportunity

The benefits associated with ABWUD single family home customers harvesting rainfall are noteworthy and should be considered when assessing alternatives to other more expensive water source projects. As with water that is conserved from SFH using innovations that allow them to use water more efficiently, harvested water presents Albuquerque with opportunity.

Since it is likely that the pressures of drought, climate change and population growth will force ABWUD to meet a growing water demand, then it is important to recognize rainwater harvesting as a method of acquiring an alternative water supply. The Albuquerque Bernalillo County Water Utility Authority understands the need to find new water sources to meet future customer demand. Their own Drought Management Strategy forecasts that Albuquerque will need "New Sources" in about fifty years (Stomp, 2006)[33]. Rainwater harvesting can provide ABWUD and its single family home customers with the opportunity to fill in the "New Sources" gap.

[33] As stated throughout this report, Albuquerque's water supply is at risk to drought, climate change and population growth. Therefore, a fifty year time horizon before the City needs "New Sources" may be too optimistic.

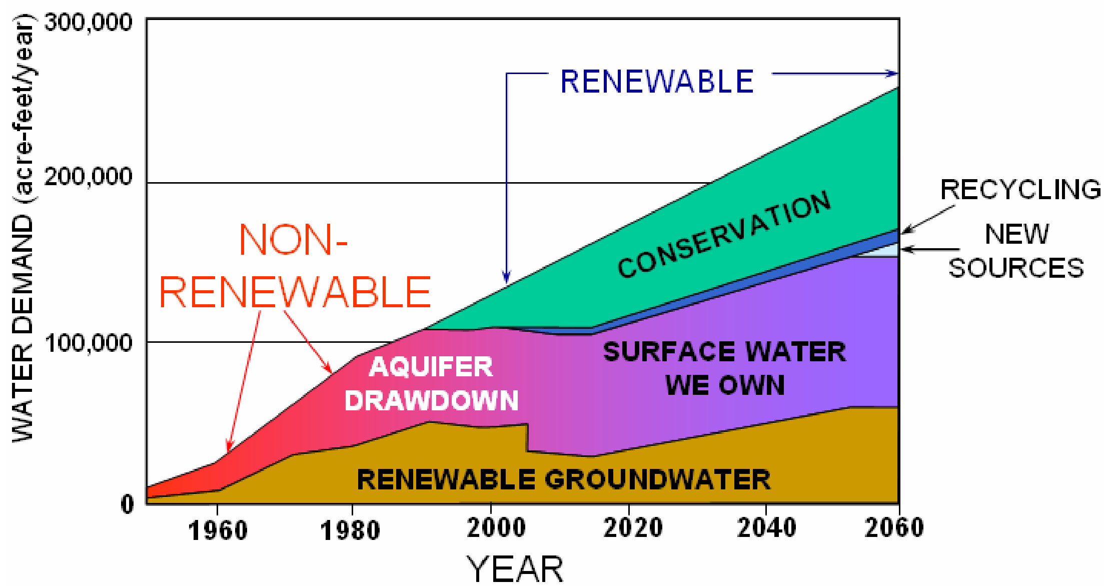

Figure 6.4-1 ABCWUA Water Resource Strategy Implementation, Image source (Roth, 2006)

Understanding the potential energy resource and monetary benefits associated with water capturing technology at SFH requires knowledge of status quo water surface and groundwater supply costs, as well as rainwater harvesting and treatment costs. This study does not attempt to quantify the latter and thus, the difference in potable treatment and pumping costs are not discussed[34]. Instead this report provides an estimate of the annual amount of alternative source water available from rainwater capture at SFH.

The volume of rainfall that may be captured at ABWUD single family homes is noteworthy and should be considered as an alternative to other more expensive water source projects. This study highlights the potential water supply harvested from rooftops and the external opportunities generated to enhance understanding of its importance for coping with drought, climate change and population growth.

[34] Rainwater harvested from rooftops must be treated for pathogens (TWDB, 2005). Moreover, since rainwater is much cleaner, relative to surface water flows of the Rio Grande/San Juan Chama, then the benefits of using less energy and fewer chemicals are likely to be significant.

6.4.1 Water Security

This report has highlighted the vulnerability of Albuquerque's current water supply. Programs that implement the retrofit of existing SFH and mandates or building codes that require all new homes be built with rainwater harvesting technologies can contribute significantly to Albuquerque's water security and prepare the city for a changing climate and growing water demand.

Albuquerque SFH residential areas constitute 22% of all the developed land area within the ABWUD service area. Therefore, there exists a large potential for the ABWUD to secure an alternative source of water supply form SFH rooftops to meet current and future water demand. Moreover, and if indeed climate modeling efforts are accurately predicting more annual precipitation as rainfall (less as snow pack), with more intensive rainfall events, then the benefits of this alternative water source may be considered permanent (Gleick *et al.*, 2003; Saunders *et al.*, 2005).

The four retrofit scenarios plotted earlier estimate the volumes of water that are available for capture. A clear picture of the potential alternative water supply highlights the opportunity to use this additive supply to meet current and future water demands. Focusing attention again on the 60% Retrofit Scenario, the total projected volume of water that may be captured in years 2011, 2020 and 2030 combined is 10,231ac-ft. This potentially harvested volume equals 10% of the 100,046ac-ft of groundwater volume pumped by the ABWUD in 2004 (Dayyani, 2005). Additionally, this three year alternative water supply estimate is enough (combined) to meet the annual water demand of 22,109 single family homes (Appendix 24).

Table 6.4-1 "3" Year Potential from 60% Retrofit Scenario (acre-feet)					
Rain Water		2011	2020	2030	Total
	Captured	**3,122**	**3,409**	**3,700**	**10,231**
	Annual SFH Demand Met	**6,746**	**7,367**	**7,996**	**22,109**

Looking at the opportunity accessible by harvesting water from SFH rooftops over a 24 year time horizon (2007 through 2030) and under this study's four retrofit scenarios, water capture looks more attractive. Here, the 60%, 80%, 100% and Incremental% retrofit scenarios demonstrate alternative water supply volumes that are enough (under current SFH water demand estimates) to meet the annual demand of 174,043, 232,057, 290,071 and 234,908 homes respectively. Considering that there are currently about 103,926 SFH within the ABWUD service area, then the opportunity presented in the long term is significant. Moreover, the harvestable volumes below equal 81%, 107%, 134% and 109% respectively, of the 2004 ABWUD groundwater pumped from City production wells (Dayyani, 2005).

Table 6.4-2 "24" Year Potential from Retrofit Scenarios (acre-feet)					
Rain Water		60%	80%	100%	Incremental%
	Captured	**80,538**	**107,384**	**134,230**	**108,703**
	Annual SFH Demand Met	**174,043**	**232,057**	**290,071**	**234,908**

As discussed early in this report, Albuquerque's water supply challenges associated drought, climate change and population growth are likely to be more acute as we advance into the 21st Century. The considerable volumes of alternative water supply discussed above, and in previous sections, will enable the City and its residents to enhance water security by using both new and old innovations, saving energy resources and money along the way.

6.4.2 Energy Security

It is important to mention that even though this study has not attempted to quantify the energy demand of treating and providing captured rain water, it is likely that the treatment costs would prove less energy intensive and less costly. Anyone who has seen the surface water flows of the Rio Grande can imagine that purifying it to drinking water standards may require more energy and chemicals than what would be required for rooftop rainwater runoff. However, rooftop runoff (like the Rio Grande) can contain pathogenic contaminants such as E. coli, Cryptosporidium, Giardia lamblia, legionella, fecal coliforms, and viruses (Lye, 2002). Therefore, appropriate treatment processes using a combination of ultraviolet radiation, ozonation, nanofiltration, reverse osmosis and chemical treatment (chlorine, iodine and fluoride) as well as pumping to storage reservoirs would certainly place a demand on energy resources (TWDB, 2005).

A clear understanding of the energy intensity of rainwater harvesting would facilitate analysis of the energy and monetary benefits beyond the already established significant volume of alternative source water. Stated differently, the more information the ABWUD and its customers have regarding the water energy and monetary benefits of water capture, the more they are empowered to design and implement harvesting policies that decrease Albuquerque water supply energy demand; therefore, enhancing the City's future energy security.

7.0 WATER CONSERVATION & CAPTURE EXTERNAL BENEFITS

The previous sections focused on the benefits of innovations that facilitate using water more efficiently and capturing rainfall from rooftops. The vulnerability of Albuquerque's current water supply was also discussed. The important thing to consider when designing policies that

implement the use of conservation and or capture innovations is that individually, neither will solve the City's water scarcity challenges. It is likely that only a comprehensive approach will aid ABWUD in meeting current and future demand under the pressures of drought, climate change and population growth.

When considering a scenario where 60% of all ABWUD single family homes are using dual flush toilets, the Shower Water Conservation System and harvesting rainfall, then the opportunities presented by conservation and capture are much more interesting. The total volume of alternative source water accessible here in years 2011, 2020 and 2030 combined equals 13,244ac-ft, enough to meet the annual water demand of 28,620 single family homes. Energy resource savings are likely to be even more attractive than reported in previous sections because rainwater harvesting is expected to be less energy intensive than current surface and groundwater sources which require more potable treatment and pumping. Additionally, monetary savings to both ABWUD and their single family home customers are likely to be even larger than presented in this report, as both electricity and natural gas prices are expected to increase within the next ten years (EIA, 2006; PNM, 2006c).

The external benefits of these three innovations are that they may enhance Albuquerque's future water and energy security. As the effects of drought and climate change impact the San Juan Chama Project water source (and its competing uses), snow pack in the San Juan Basin, alternative water supply is likely to be necessary to meet the demand of a growing population.

The availability of alternative source water also offers the benefit of offsetting the need to build larger and more energy intensive water supply and wastewater treatment projects or the need to purchase expensive water rights (Gleick *et al.*, 2003). Albuquerque's Southside Water

Reclamation Plant treatment capacity is 68 million gallons per day, but currently 59 million gallons are treated each day (ABWUA, 2006a). Water saving innovations may delay the need to construct/expand treatment facilities to meet increased wastewater treatment demand due to population growth. According to Yuhas (2006) water rights were recently purchased for $12,000 per acre-foot in New Mexico. Clearly, purchasing water rights should not be considered as an alternative before the three innovations discussed in this report or other conservation strategies.

Meeting the Albuquerque peak summer time water demand may become more difficult due to climate change altering the timing of snow pack runoff, forcing early and larger reservoir releases upstream (Saunders *et al.*, 2005). Thus, any increases in alternative water supply due to conservation and capture technologies (and other policies) may aid ABWUD cope with seasonal (peak) scarcity challenges, especially if the City's reservoir storage capacity is sufficient to collect rainfall during the monsoon season.

The chemical cost of drinking water treatment was not quantified in this report. Currently Chlorine and Fluoride are injected into Albuquerque groundwater prior to delivery (Dailey, 2006). When the San Juan-Chama Drinking Water Project comes on line in 2008, more chemicals will be used to treat surface water of the Rio Grande to potable standards; thus, a larger chemical cost. Conservation and capture technologies can help decrease these costs by reducing the demand for Rio Grande water diversions.

An important factor to consider when looking at large scale rainwater harvesting is the reduced urban runoff resulting from less water making its way to city streets and storm drains. The excess contribution to urban runoff from SFH would otherwise add to the nutrient loading of arroyos and eventually the Rio Grande. The constituents of runoff from SFH areas are typically

cadmium, lead, zinc, petroleum hydrocarbons, phosphates and pesticides (Brooks *et al.*, 2003). Depending of the assimilative capacity of aquatic and wetland vegetation in and along the Rio Grande, many of these contaminants would contribute to polluting the river. Additionally, quick and high discharge from the arroyos into the river can contribute to bank erosion and increased sediment flux downstream. Harvesting rain water from SFH rooftops will reduce these impacts.

Another dynamic this study recommends that ABWUD and other State agencies consider as they collaborate with other States on actions that mitigate the impacts of climate change, is the air quality benefits associated with reducing urban water demand. Governor Bill Richardson and Arizona Governor Janet Napolitano signed in February 2006 the Southwest Climate Change Initiative. The Initiative established the framework necessary for New Mexico and Arizona to tackle climate change and reduce greenhouse gasses in the Southwest. As established in this report, using water and hot water more efficiently, as well as reducing energy demands from treating less energy intensive rainwater, results in less a demand on thermoelectric power generation. Thus, less power plant greenhouse gasses are emitted. The two State Initiative calls for actions such as “identifying options for reducing greenhouse gas emissions, and promoting … energy efficient technologies” (Goldstein, 2006). The water conservation and capture benefits identified in this study may aid these pursuits. ABWUD should consider quantifying the potential greenhouse gas reductions using the Pacific Institute Water to Air Model, which empowers water purveyors to understand the air quality benefits of their conservation programs (Wolf *et al.*, 2004).

Finally, it deserves reinforcing that while the costs of new surface water projects increase over time the cost of conserved water remains constant throughout the useful life of the water

saving innovation. That is, using water (and energy) more efficiently with technologies offers a "cost of service reliability benefit" (Gleick *et al*., 2003, p.122).

The potential of water saving and water capturing innovations should now be clear. The challenge is then, how to ensure the ABWUD and its single family home customers take full advantage of the benefits associated with using water more efficiently and harvesting it from the sky.

8.0 RECOMMENDATIONS

This study finds that water conservation and capture results in significant water energy and monetary benefits, making it potentially one of the most effective water management tools; thus, offer a strong support for a new paradigm in policy regarding ABWUD (and other U.S. cities) water supply. The innovations discussed in this report (and many others not discussed) can produce the largest, most cost effective and environmentally sound source of water required to meet future needs (Gleick, 2004). Therefore, it may be prudent for these types of innovative adaptation strategies to be used within a more comprehensive planning effort to empower the State's water purveyors and their customers to adequately prepare for 21st Century water scarcity challenges.

8.1 State Role

Currently, the State of New Mexico does not have a comprehensive foreword looking strategy for coping with the scarcity inherent in drought and climate change and the inefficient demands of a growing population. According to the Intergovernmental Panel on Climate Change, "water demand management and institutional adaptation are the primary components for increasing system flexibility to meet uncertainties of climate change" (IPCC, 1996). Without a

comprehensive State wide urban (and agricultural) conservation plan that effectively increases efficiency, decreases end usage and implements the use and retrofit of alternative source water providing innovations, the State's competing demands for water will likely become more contentious as climate changes impact both the available supply and deeply rooted inefficient water use norms.

The challenge the State faces in designing a water conservation plan is that throughout the State (and the greater U.S.) there exists a culture of waste, which is supported by many existing beliefs, industry and even existing policies and statutes. Currently water is being delivered and used inefficiently in every urban sector and the energy consumed for pumping, conveyance, treatment, delivery, end usage, waste treatment and discharge is needlessly lost (Cohen *et al.*, 2004; Gleick *et al.*, 2003).

It is important to recognize the State role in aiding water systems such as the ABWUD in meeting the water scarcity challenges of drought, climate change and population growth. There are many barriers to realizing the maximum water savings and water capture potential. This report identified the potential savings and alternative water supply associated with using water more efficiently and capturing water. However, there are many institutional, statutory, technical, technology, economic and social barriers in the State that interfere with these types of improvements being implemented (Gleick *et al.*, 2003). Therefore, it is vital that the State take the leading role in drafting statutory language that clearly defines and or creates a State Office of Water Conservation (Watkins, 2005). The ability of the New Mexico Office of the State Engineer (OSE) Water Conservation Bureau to aid ABWUD (and other State water systems) prepare for 21st Century water scarcity challenges is limited at best.

In New Mexico there is no clear institutional designation of responsibilities with regard to efficiency and conservation programs. The State Water Plan makes the policy statement that “the State shall engage in a coordinated and concerted effort to promote conservation and efficient use of water in all water use sectors as one of the cornerstones of New Mexico’s efforts to meet the State’s present and future water needs” (OSE/ISC, 2003). Here (in Section C5), it is implied that the OSE lead the work to promote efficiency and conservation programs. However, since the main responsibility of the OSE is regulatory, then it has no real authority to empower cities like Albuquerque and the ABWUD get to the level of efficiency and water and energy supply security needed to cope with drought, climate change and population growth.

ABWUD would best serve its water customer interests if it were properly equipped with the State mandates necessary requiring that not only water use efficiency and rainwater harvesting innovations (and other innovation) use is mandatory in Albuquerque, but also aiding in designing and funding programs that ensure a high level of water saving and water capturing technology use in all sectors. One way the State can ensure that water utilities like ABWUD are able to achieve a high level of efficiency and water and energy security is to enter into bulk purchasing contracts with manufacturers of water efficient and water capturing appliances and fixtures. Additionally, the state should offer low or no interest loans to municipalities and water utilities to participate in bulk purchasing programs; thus, gaining access to appliances and fixtures at a very low cost per unit (Ash, 2005).

As highlighted in this study, dual flush toilets, or HET, offer the potential to enhance water and energy security because they use a lot less water and demand less energy resources than ULFT currently used in ABWUD rebate programs and sold at all Albuquerque plumbing

suppliers. Moreover, the less efficient models tend to be less expensive, generating a disincentive for SFH to invest in more efficient models. To eradicate this problem and begin aiding ABWUD customers in making more informed decisions, this study looked into the possibility of the State entering into a bulk purchasing contract with Caroma, the manufacturer of the Caroma Royal 305 dual flush toilet (Ash, 2005). This toilet is an HET because it exceeds performance standard testing (Gauley *et al.*, 2005). A quote was prepared by a Caroma sales representative for 2000 units. The normal retail cost is $362 per toilet, but the bulk purchase rate quoted was $154 per toilet (Appendix 25).

This price ($154 per toilet) is $21 "LESS THAN" the ABWUD current rebate offer for dual flush toilets. Beginning on July 1, 2006, ABWUD began offering $50 more on top of the current toilet rebate of $125 for customers that switch out their current toilet with a dual flush toilet or HET (ABWUD, 2006b). If the State were to enter into a bulk purchasing contract with Caroma or any other dual flush toilet manufacturer, and offer low or zero interest loans to Water Purveyors to participate in the Bulk Purchasing Program, then the ABWUD would be empowered to Distribute toilets directly to its customer free of charge (Ash, 2006). The only cost to the customer then, would be for installation. If we assume that $55 per hour is the going rate for labor then approximately $105 would be the total installation cost (Gleick *et al.*, 2003). New toilets cannot be purchased and installed in Albuquerque at this price. Therefore, it is likely that a State led bulk purchasing program would enable ABWUD and its customers to realize the potential water, energy and monetary savings associated with using toilet water more efficiently.

The aforementioned strategy should be adopted for all types of water saving and water capturing innovations. Furthermore, it is likely that larger bulk purchase agreements directly

from the manufacturers of such innovations will lower the cost per unit. Therefore, Distribution programs, rather than the current rebate programs, would be more effective, ensure a high level of customer participation, enhance the City's water and energy security, eliminate unnecessary costs for water and energy demand and possibly even help encourage a conservation ethic (as people do tend to appreciate free stuff) (Ash, 2005).

As noted earlier, the IPCC (1996) points out that "institutional adaptation" is necessary to cope with the inherent water resource challenges of climate change. Current New Mexico Office of the State Engineer Rainwater/Snowmelt Harvesting Policy states the following: "The New Mexico Office of the State Engineer supports the wise and efficient use of the state's water resources; and, therefore, encourages the harvesting, collection and use of rainwater from residential and commercial roof surfaces for on-site landscape irrigation and other on-site domestic uses" (OSE/ISC, 2004). This designates harvested water only to be used on site and does not authorize its full potential as an alternative source of water for municipal use.

Given the significant volumes of alternative source water accessible from rainwater harvesting quantified in this report, it is recommended that the OSE revise its policy to empower ABWUD and other state water purveyors to utilize this untapped resource to meet current and future demand, while reducing their systems' energy demands.

This study has highlighted the potential energy savings associated with using water and hot water more efficiently throughout the ABWUD water cycle. The benefits discussed generate substantial opportunity for reducing demands on Albuquerque's energy purveyor, PNM; thus another "institutional adaptation" is introduced here. While PNM can and has invested in programs that encourage energy efficiency, it may not currently recognize or have the authority

to invest in water conservation and capture programs that enhance their ability to reach energy efficiency goals (CEC, 2005; LANL, 2006). For example, PNM is currently engaged with the ZeroNet Initiative, a cooperative effort between Los Alamos National Laboratory, the Electric Power Research Institute, and PNM to enhance water use efficiency at PNM energy producing facilities (LANL, 2006). Here the focus and funding is centered on water used for energy production and not end user water use efficiency.

The State would benefit from encouraging and or creating incentives for PNM to invest in research and coordinate with water purveyors to enhance end water use efficiency in an effort to reduce energy demand. Moreover, and as this study has demonstrated, the State would also benefit form requiring and authorizing coordination between its water and energy sectors to enable more aggressive efficiency goal setting and to enhance its water and energy security.

8.2 ABWUD Role

ABWUD programs would benefit from a clearer understanding of who is using what types of innovations in their service area. As highlighted by this report, rebates that have been offered since 1996 have not been entered into any database for analysis. That is, the water utility does not currently know how many toilet, washing machine, dishwashers, showerheads, etc. have been rebated in each urban sector. Moreover, rebate forms for toilets do not require information regarding the type of (or gallon per flush) toilet being replaced[35]. Therefore, ABWUD is working with incomplete information and cannot target specific end use sectors and cannot accurately quantify (no more than this report) how much water and energy demand there is from various uses.

[35] ABWUD rebate forms used for the new dual flush toilet or HET rebate, effective July 1, 2006, should also record this information.

The Albuquerque Bernalillo County Water Utility Authority Resolution Establishing Five-Year Goals and One-Year Objectives states the following:

"Section 1. That the Authority adopts the following five-year goals and one-year objectives.

GOAL 1. WATER SUPPLY AND OPERATIONS: Provide a reliable, safe, affordable, and sustainable water supply by transitioning to renewable supplies and minimizing long term environmental impacts on the community and natural resources while ensuring the ability of the community to grow in a responsible manner.

Objective 4. Review conservation program including conservation goal and examine per capita versus per account methodology for measuring conservation progress and make recommendations to the Authority by the end of FY06" (ABWUA, 2006b).

To achieve this objective it would be prudent for the ABWUD to consider the methodologies presented in this report. Albuquerque will only "grow in a responsible manner" if the ABWUD and its customers take full advantage of the types of benefits estimated in this study. Designing conservation and capture policy around per capita water and energy demand and harvesting potential measurement methods offers the water utility, its customers and the entire City of Albuquerque the opportunity to meet current and future demand in a water scarce environment of drought and climate change and an increasing demand of a growing population.

9.0 FUTURE RESEARCH

There are many more water saving innovations that should be analyzed using a per capita end user methodology. The ABWUD and its customers would benefit from a comprehensive innovative approach to increasing water and energy security.

The potential for an alternative water supply from rainwater harvesting is significant in Albuquerque. Future research needs to focus on the engineering and social factors involved in retrofitting homes with water capture technologies as well as the institutional barriers that

impede using this alternative water source. Moreover, estimates of the differences in energy costs between the Status Quo and that of treating rainwater need to be understood to increase support for such a large alternative water supply program.

Given the competing demands within the San Juan Basin and the impending precipitation regime changes likely to occur due to drought and climactic change, all San Juan Chama Project water reliant parties should try to understand what shortage sharing may mean for them and their future. New Mexico water is fully appropriated and ABWUD and its Albuquerque customers are depending on Chama water to aid in returning to a sustainable groundwater pumping regime (City of Albuquerque, 2005a). Further research should form a collaborative modeling effort, involving stakeholders, policy makers and water resource professionals to understand the likelihood and severity of shortages, and come to a consensus on adaptive strategies needed to cope with shortages (Lorie *et al.*, 2006).

10.0 CONCLUSIONS

Water saving and water capturing innovations offer ABWUD and its customers the opportunity to cost effectively maintain an alternative water supply to meet current and future demand as well as adapt to cope with the challenges of drought, climate change and population growth. Albuquerque's current water supply is likely to face shortages in the future due to climactic changes and a growing demand. However, the types of innovative solutions examined in this report demonstrate a large potential for mitigating adverse impacts to supply.

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 resources that may be use meet current and future demand. Moreover, both ABWUD and its SFH customers save money.

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.

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 SFH rooftops will allow ABWUD to meet customer water demands now and into the 21st Century.

The State of New Mexico (and the entire U.S.) can no longer manage water and energy resources separately. This study recommends that water and energy efficiency planners are encouraged to recognize the benefits of crafting policy that takes full advantage of the intimate relationship exposed in this report. Comprehending the breadth of these benefits is likely to propagate a conservation ethic as well as investment in conservation and capture technologies, as consumers and investors respond to incentives.

The water, energy and monetary savings associated with using water more efficiently and harvesting rainfall are important to understand. If ABWUD and the customers it serves choose to take full advantage of the benefits they have to offer, then these types of innovations are likely to enable Albuquerque to further enhance water and energy security and decrease its reliance on groundwater, better equipping it to manage future drought, climate change and population

growth. Aldo Leopold said, "Conservation is a positive exercise of skill and insight, not merely a negative exercise of abstinence or caution" (Leopold, 1949). The benefits linked to recognizing the inextricable connection between water use and energy consumption must be fully understood in the 21st Century. Skillfully designing and implementing conservation and capture policies and programs that reflect these insights will empower Albuquerque to adapt to meet the challenges drought, climate change and population growth for years to come.

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