MAY 2011

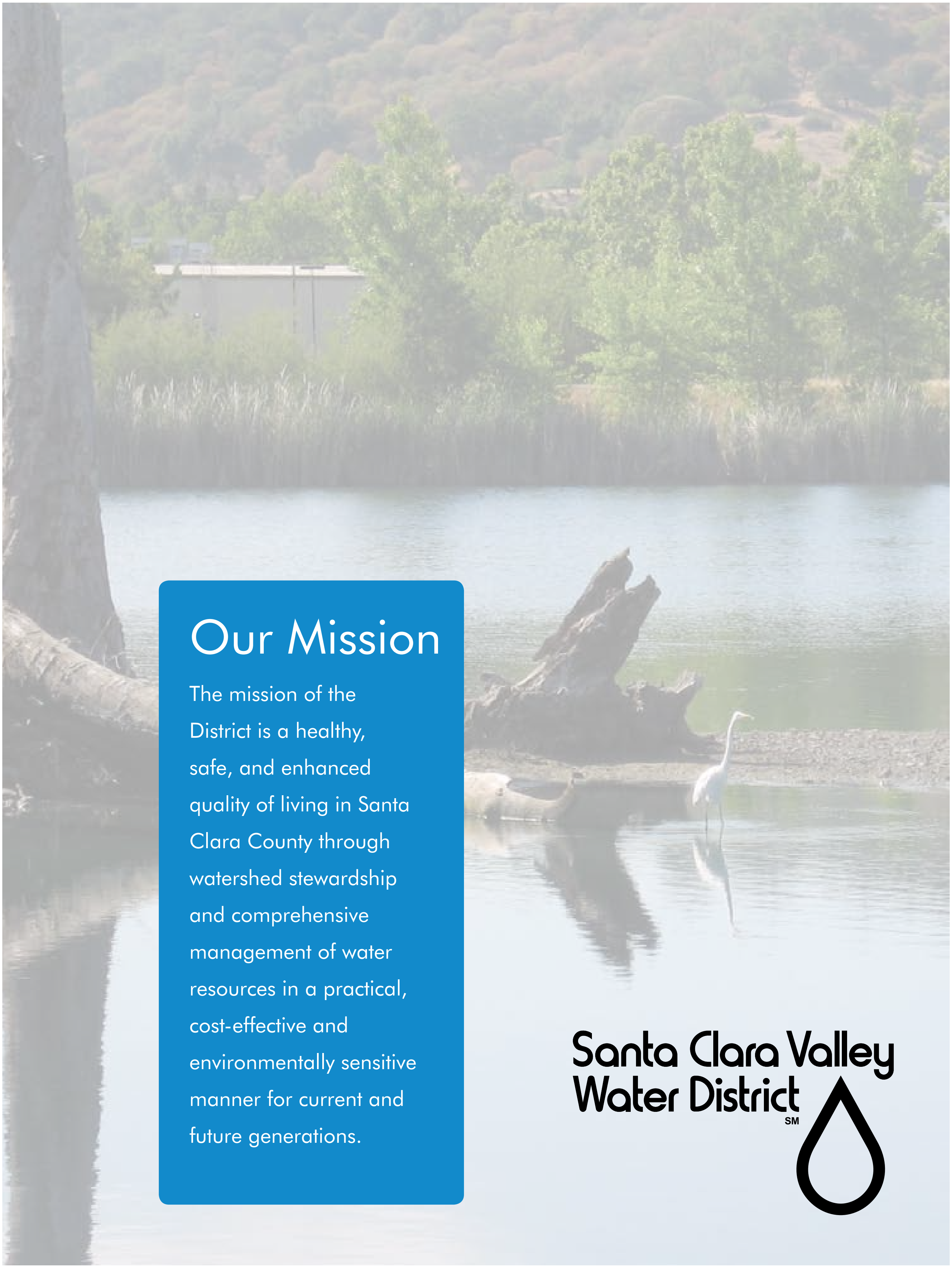
From Watts to Water

Climate Change Response through Saving Water, Saving Energy, and Reducing Air Pollution

Santa Clara Valley Water District

FROM WATTS TO WATER

Water Savings, Energy Savings, and Air Pollutant Emissions Reductions from the Santa Clara Valley Water District's Water Use Efficiency Programs



Our Mission

The mission of the District is a healthy, safe, and enhanced quality of living in Santa Clara County through watershed stewardship and comprehensive management of water resources in a practical, cost-effective and environmentally sensitive manner for current and future generations.

Santa Clara Valley Water District[SM]

Board of Directors

From left to right: Tony Estremera, District 6; Patrick Kwok, District 5; Richard P. Santos, Chair; Don Gage, District 1; Linda LeZotte, Vice Chair; Joe Judge, District 2; Brian Schmidt, District 7

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Letter from The CEO

Water agencies, particularly those in the arid Western United States, view global climate change as one of the most significant long-term threats to water resources management. Climate change may affect California's water supplies in a variety of ways: reduced snowpack, changes in the location, quantity, and timing of precipitation, increased flooding, sea level rise, increased water temperatures, and increased water demand. In 2007 the Santa Clara Valley Water District (District) identified global climate change as a significant challenge, a challenge that will require new or additional initiatives to address the potential impacts to water resources in Santa Clara County. Towards this end, the District's Board passed a Climate Change Resolution in 2008, adopting several policies which mandate that the District address the possible impacts of climate change on the management of the District's water resources.

The District's water conservation and water recycling programs help address climate change through increasing the efficiency with which two limited resources, water and energy, are used; that is, the potable water savings resulting from water conservation and water recycling also lead to significant energy savings and air quality benefits, including reductions of the greenhouse gas carbon dioxide. In 2007 the District released the first "Watts to Water" report, the first of its kind in the state, documenting the energy savings and air pollutant reductions that resulted from water conservation and water recycling. In this current report, the District updated its analysis of the energy savings and reductions in carbon dioxide and other air emissions brought about by its water use efficiency programs. From fiscal year (FY) 92-93 through FY 08-09, the District helped save approximately 2.67 billion kilowatt-hours (kWh) of energy (worth $347 million assuming average residential electricity rates) and eliminated approximately 625 million kilograms (kg) of carbon dioxide, an amount equivalent to removing 115,000 passenger cars from the roads for one year.

In addition to its water use efficiency programs, the District has implemented other programs, projects, and practices that garner energy savings and reduce air emissions, including solar panels at its headquarters campus and hydropower generation from one of its dams. The District was also recently re-certified as a Santa Clara County Green Business. I am proud to say that all of these contribute to the "greening" of the District as summarized in its mission statement: "a healthy, safe, and enhanced quality of living in Santa Clara County through watershed stewardship and comprehensive management of water resources in a practical, cost-effective, and environmentally sensitive manner for current and future generations."

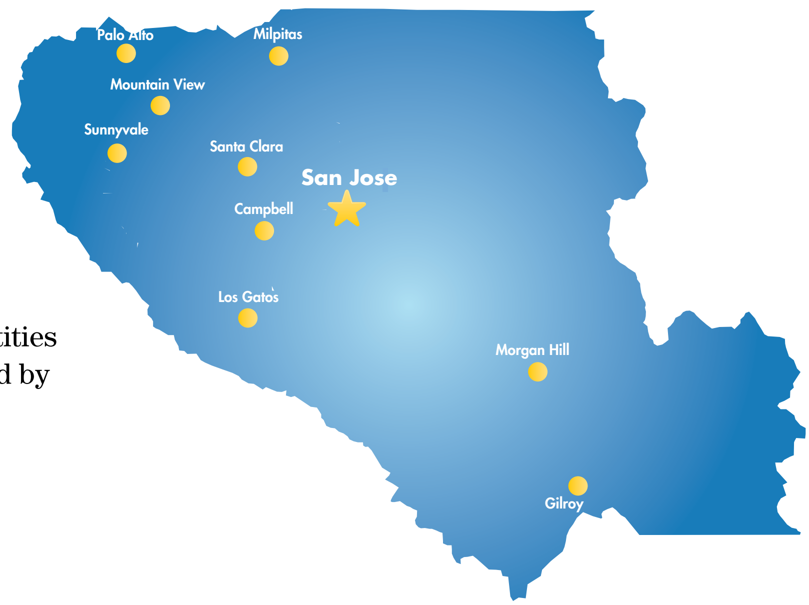
Beau Goldie
Chief Executive Officer
Santa Clara Valley Water District

Executive Summary

The Santa Clara Valley Water District (District), the primary water agency for Santa Clara County, which encompasses the southern part of the San Francisco Bay, provides water supplies for an expanding urban population:

- Containing 1.8 million residents;
- Hosting 200,000 commuters;
- Harboring Silicon Valley, a major economic driver for California.

To help meet increasing water demands in a time of decreasing water supplies, the District has developed a comprehensive suite of water conservation and water recycling programs that have resulted in cumulative savings of 547,000 acre-feet (AF) of new water supplies between fiscal year (FY) 92-93 and FY 08-09. In addition to saving water, water conservation and water recycling programs save energy and reduce air pollutant emissions due to the significant quantities of energy required (and air pollutants generated by energy production) for the water supply chain:



- Water conveyance
- Water treatment
- Distribution
- End use
- Wastewater treatment

Air pollutants generated include (depending on energy source) the following: reactive organic gases, sulfur oxides, nitrogen oxides, carbon monoxide, particulate matter smaller than 10 microns, and carbon dioxide, a greenhouse gas that contributes to global warming.

Climate change and other impacts that occur as a result of global warming present challenges for water agencies. Sea level rise (including saltwater intrusion into the freshwater San Francisco Bay-San Joaquin Delta levee system), a decrease in snow pack, combined with earlier snow melt, in the Sierra Nevada mountain range which supplies water for much of the state, and increased drought are all possible outcomes of global climate change. The District is committed to responding to these challenges through adaptation (preparing for future changes) and mitigation (reducing the District's role in global warming through more efficient use of resources). With regard to the mitigation of global climate change, the District recently completed an update of its analysis of the energy saved by its water conservation and water recycling programs, which have been in operation since FY 92-93. For FY 92-93 through FY 08-09, the District saved approximately 2.67 billion kilowatt-hours (kWh) of energy, representing a financial savings of approximately $347 million and equivalent to the annual electricity required for 412,000 average California households. Through saving energy, the emissions of approximately 625 million kg of carbon dioxide, a greenhouse gas, were eliminated. This is the equivalent of removing 115,000 passenger cars from the roads for one year. Emissions of several other air pollutants were also reduced due to the energy savings from the District's water conservation and water recycling programs (the following numbers are for the FY 92-93 through FY 08-09 time span): reactive organic gases: 39,361 kg; carbon monoxide: 564,349 kg; nitrogen oxides: 275,610 kg; sulfur oxides: 26,259 kg; and particulate matter smaller than 10 microns, or PM10: 48,560 kg.

The District is also engaged in several other energy-efficient practices/projects and received certification as a Green Business in 2004 with recertification in 2008. Since the From Watts to Water report was first published in June 2007, the energy-water analysis and energy/air pollutants savings presented in the report, in combination with the District's alternative energy programs, have resulted in the presentation of several honors to the District: the Breathe California Clean Air Award and the EPA Water Efficiency Leader Award were presented to the District in 2007, the 6th annual Flex Your Power Best Overall Award was presented in 2008.

About the Santa Clara Valley Water District

The Santa Clara Valley Water District (District), located in San Jose, California, is the water wholesaler for Santa Clara County and serves the area's 15 cities, of which San Jose is the largest, with over 1.8 million residents and over 200,000 commuters. The District meets the county's water demands through a combination of local water supplies (groundwater, surface water, recycled water, and water conservation) and imported water supplies (from the San Francisco Bay-Sacramento-San Joaquin River Delta through the Central Valley Project and the State Water Project). The San Francisco Public Utilities Commission also provides water to parts of the county via the Hetch Hetchy Aqueduct from the Sierra Nevada mountain range.

The District acts not only as the country's water wholesaler, but also as its flood protection agency and is the steward for its streams and creeks, underground aquifers and District reservoirs. As the county's water wholesaler, the District ensures there is enough clean, safe water for homes, businesses and agriculture. As the agency responsible for local flood protection, the District works diligently to protect Santa Clara Valley residents and business from the devastating effects of flooding. As the county's watershed steward, stream stewardship responsibilities include creek restoration and wildlife habitat projects, pollution prevention efforts and a commitment to natural flood protection.

The Santa Clara Valley Water District: Saving Water, Saving Energy, and Reducing Air Pollution

In addition to saving energy and reducing air emissions through its water conservation and water recycling programs, the District engages in other practices and activities that save energy and reduce air emissions. Most notably, in 2004 the District received its Green Business Certification (and was re-certified in 2008) as a result of its commitment to water-efficient and energy-efficient practices and procedures as well as to pollution prevention and solid waste reduction.

As part of this green effort, the District completed a $3 million state-of-the-art solar energy project at the District's headquarters campus, installing photovoltaic solar panels on the District's administration building's roof and on the roof of two carports in the parking lot. Through FY 08-09, the solar panel arrays have produced 2.1 million kWh of electricity, providing approximately 20% of the headquarters campus's energy demands and saving approximately 3.4 million pounds of carbon dioxide, 775 pounds of nitrogen oxides, and 62 pounds of sulfur oxides.

An additional source of alternative power generation comes from the District's Anderson Dam Hydroelectric generation facility, located in the southern part of the county. The Anderson Dam Hydroelectric facility has generated over 9.5 million kWh of electricity since its construction in 1988, generating 67,000 kWh of non fossil fuel-based electricity during FY 08-09 alone. The electricity generated from Anderson Hydroelectric facility is sold to PG&E.

The District is also a member of Sustainable Silicon Valley (SSV), "a partnership between businesses, governments, academia, and non-governmental organizations that seeks cooperative solutions to the environmental challenges facing the greater Silicon Valley region."[1] As part of this work with SSV, the District is committed to reducing its carbon dioxide emissions through programs and practices, including replacing its oldest fleet vehicles with hybrid vehicles.

The first "From Watts to Water" report was published in June 2007.In combination with the alternative energy programs presented above, the energy-water analysis and energy/pollutants savings presented in the report have resulted in the presentation of several honors to the District. The Breathe California Clean Air Award was presented to the District in 2007 for achievement in reducing energy and using cleaner energy sources. The District also received the EPA Water Efficiency Leader Award in 2007; this "award recognizes companies, utilities, government organizations, and individuals that display leadership, innovation, and water savings, as well as inspire, motivate, and recognize efforts to improve water efficiency."[2] In 2008, the District received the 6th annual Flex Your Power Best Overall Award for being a "California Leader in Saving Energy."

Water Supply Constraints in Santa Clara County

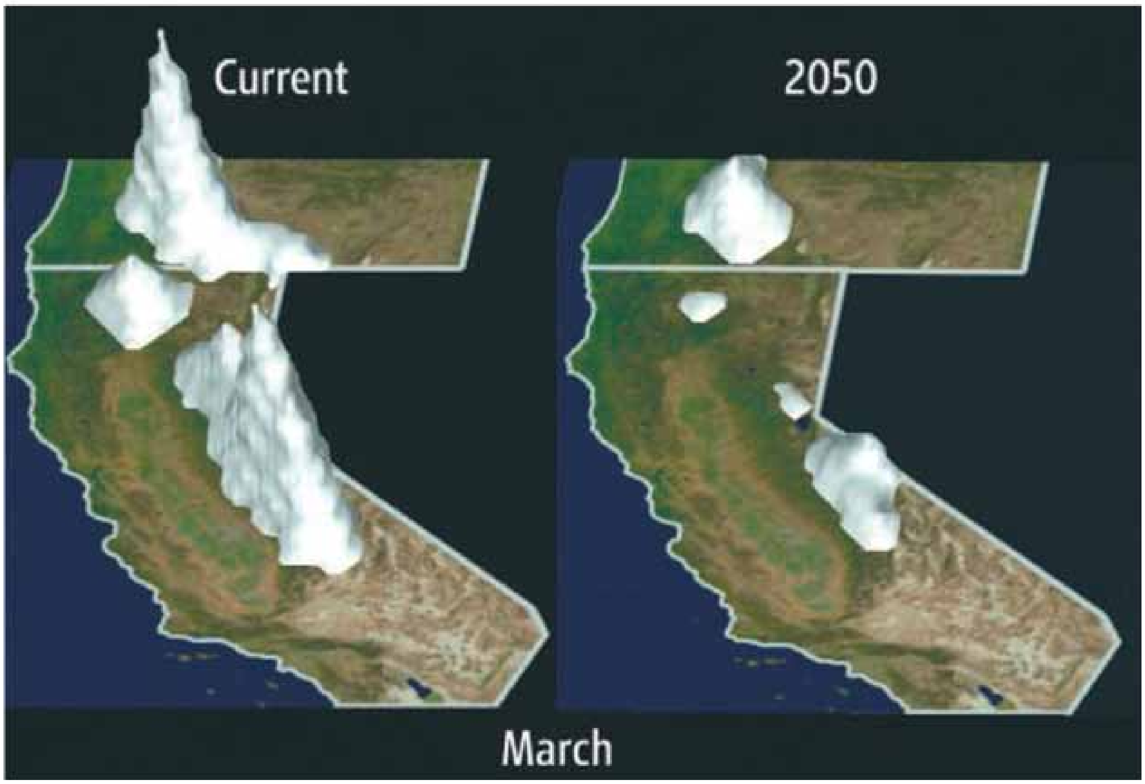
A number of factors are combining to reduce water supplies available to Santa Clara County and strengthen the need for water conservation and for alternative water sources such as recycled water. Climate change effects will enhance drought conditions throughout California, legal and regulatory decisions regarding pumping in the Sacramento/San Joaquin River Delta are decreasing the amount of water available for import into Santa Clara County, and water year 08-09 was the third straight year of less than average rainfall.

Climate Change Effects

Global warming and the climate changes that may occur as a result of global warming present many challenges for water agencies. It is predicted that Northern California's water supply system will likely change in several ways. First, sea level rise in the San Francisco Bay, brought about by melting of the world's glaciers and polar ice caps, will lead to saltwater intrusion into local groundwater basins and the freshwater San Francisco Bay-San Joaquin Delta levee system.[3] Sea level rise will also lead to increased coastal flooding.[4] Second, as discussed below, snow pack in the Sierra Nevada Mountains will likely decrease significantly (due to increased air temperatures) with the remaining snow pack melting earlier in the season; both of these effects will lead to decreases in and changes in the pattern of springtime runoff (Figure 1).[5] The net effect will be decreases in the volume of water available for export to Santa Clara County and other regions of California. Third, precipitation patterns are expected to change, with more extremes and a shorter, more intense rainy season.[6] These changes in precipitation patterns, combined with an earlier snowmelt, may lead to increased late winter/early springtime flooding and may overwhelm the already fragile (i.e., in need of standard maintenance, repairs, and upgrades) San Francisco Bay-San Joaquin Delta levee system in addition to the District's local supply systems.[7] Finally, increased droughts may occur as well, either seasonally, inter-yearly, or both (see below for information about the current drought).[8]

In California, November through April are traditionally wet months, with May through October hot and dry. Historically, snow melt in the Sierra Mountains and storage reservoirs throughout the state have provided a steady supply of water into the dry summer months. The changing climate is expected to affect this balance in two ways: less precipitation falling as snow and earlier snow melt. At the lower altitudes, even small changes in temperature affect

Figure 1: Predicted California Snowpack in 2050



the balance between precipitation as snow, a natural water storage system, and rain, an immediate source of water.[9] Rising temperatures will also cause the snow to melt earlier and faster, potentially overwhelming streams already swollen with spring rainfall and causing flood conditions throughout the state's watersheds. Over the last 100 years, runoff in April-June has decreased by around 21%, indicating that more snow melt is occurring in earlier months and/or less snow is falling overall.[10] Reservoirs throughout California provide two functions: flood control and storage of water for the dry season. During the rainy season, the reservoirs are kept at lower levels in order to absorb the excess stream flow and protect the areas downstream from devastating floods. Historically, the spring snow melt has then filled the reservoirs for summer water usage. If the snow melt coincides with the floods, there may be no additional water supply to refill the reservoirs and storage tanks for use during the dry summer.[11]

The District is committed to responding to the challenges posed by global climate change through adaptation (preparing for future changes) and mitigation (reducing the District's role in global warming through more efficient use of resources). Water conservation and water recycling play large roles in the District's mitigation efforts. Towards this end the District's Board passed a Climate Change Resolution in 2008 mandating that the District address climate change.[12] Board's Ends Policies were developed from this Climate Change Resolution; among other items, the Board's Ends Policies request that the District's mission apply to "current and future generations", that the District will "strive to minimize its greenhouse gas emissions" (including "achieving carbon neutrality as soon as is practicable"), and "enhance community understanding of climate change and how it challenges the District's mission". The Board's Ends policies also mandate that the District apply its understanding of climate change and climate change impacts as relevant" to its initiatives, programs, projects, and policies.[13] Towards this end, the District is developing a Climate Change Action Plan to provide a framework for analysis, coordination/collaboration, distribution of knowledge, identification of actions/strategies/operations changes, and funding options.

Regulatory and Legal Decisions

The Sacramento-San Joaquin River Delta (Delta) is the primary gateway for the Central Valley Project (CVP) and State Water Project (SWP) to convey water from wetter Northern California to drier Southern California. In 2007, a federal court decision restricted pumping water out of the Delta in order to protect an endangered fish species of smelt, and ordered the National Marine Fisheries Service to create a new plan to adequately protect the smelt. This decision severely restricts pumping from late December through June while the smelt are spawning and are too small to avoid being sucked into the pumps.[14] In 2008, another federal decision was released that restricted water removal from the Delta in order to protect salmon and steelhead populations.[15] The financial cost for the San Francisco Bay area to adapt to reduced imported water availability in an average year is estimated to be $5.4 million per year for the near term, and $1.2 million per year in the long term. Adaptation costs will be even higher in a dry year.[16]

Cumulative Drought Effects

California is in the midst of the third straight year of drought due to La Niña conditions in the Pacific Ocean. Water flow from snowmelt in the Sierra Nevada Mountains was at 57% of normal in 2008 and at 53% of normal in 2007.[17] At the start of May 2009, snowpack water content in California was 60% of normal for that point in the season. While February 2009 was especially wet, conditions had previously been so dry that as of May 1, San Francisco Bay Area annual precipitation to date was at about 90% of normal (statewide at 80%) and local reservoirs were at 90% of capacity.[18] Santa Clara County is fortunate to have significant ground water supplies, which will buffer the county from the worst of the drought impacts; however, much of the agricultural sector in the county relies intensively on surface deliveries from the Delta, which will be greatly impacted by reduced runoff conditions.[19] In normal and wet years, the District utilizes primarily imported water and stores excess water in underground and above-ground storage reservoirs.

In dry years, however, sufficient imports are not available, and the county must utilize groundwater resources extensively, while at the same time cutting back on groundwater recharge programs. Three years of drought plus reduced Delta water availability have created some concern over the condition of groundwater resources,[20] making water conservation and recycling essential to meeting the growing water demands of an expanding population.

The Santa Clara Valley Water District's Water Use Efficiency Programs

The District manages cost-effective innovative programs in water conservation and water recycling and is exploring the feasibility of several desalination initiatives. The District collaborates with its thirteen retailers, local cities, businesses, and the public to implement its water conservation and recycling programs. The District also receives grant funding for its programs. The water supplied through the District's water conservation and water recycling programs has been and continues to be a very important element for meeting the county's water supply demands.

The District offers both agricultural and urban water conservation programs. The latter category includes 1) residential, 2) landscape, and 3) commercial, industrial, and institutional (CII) water conservation programs.

As the County's water manager, the District has partnerships with all four recycled water producers in Santa Clara County. The District also has a partnership with three other Bay Area water agencies to explore the feasibility of a regional desalination facility. This project is studying desalination of brackish water, San Francisco Bay water, and/or ocean water for an optimal regional facility to serve these four agencies and more than 5.4 million people.

Water Use Efficiency Benefits

The District's comprehensive suite of programs helps to reduce the demand on existing water supplies as well as delay or eliminate the need for new water supplies, thereby helping to meet the water demands of an expanding population (Figure 2). Since the District's water conservation programs began in FY 92-93, they have cumulatively saved approximately 429,000 AF of water while the District's water recycling programs, in place since FY 98-99, have cumulatively saved approximately 118,000 AF of water (Figure 3). For FY 08-09 alone, water conservation program savings were approximately 44,000 AF while water recycling program savings were approximately 16,500 AF (Figure 3). The combined water supply/demand management provided by water recycling and water conservation met approximately 15% of FY 08-09 total water use in Santa Clara County.[21]

Besides the water supply management benefits of greater flexibility and increased reliability conferred by the District's water use efficiency programs, these programs provide environmental benefits by helping to protect the South San Francisco Bay salt marsh habitat, local ground water supplies, local surface water supplies, and the associated watersheds. The environmental benefits in turn provide significant aesthetic and human health benefits. The District's water use efficiency programs also help to meet the District's mission of providing "watershed stewardship and comprehensive management of water resources in a practical, cost-effective, and environmentally sensitive manner."[22]

The District's long-term water supply planning combines integrated water resources planning with watershed stewardship. The District's Board's Ends Policies and the District's 2005 Urban Water Management Plan, establish goals for the water conservation programs and water recycling programs to continue to expand, with water conservation supplying 98,500 AF by the year 2030 and water recycling supplying 10% of total water use (i.e., recycled water supply is estimated to be 42,500 AF) by the year 2030 (Figure 3).

Figure 2: Population and Water Use in Santa Clara County by Fiscal Year

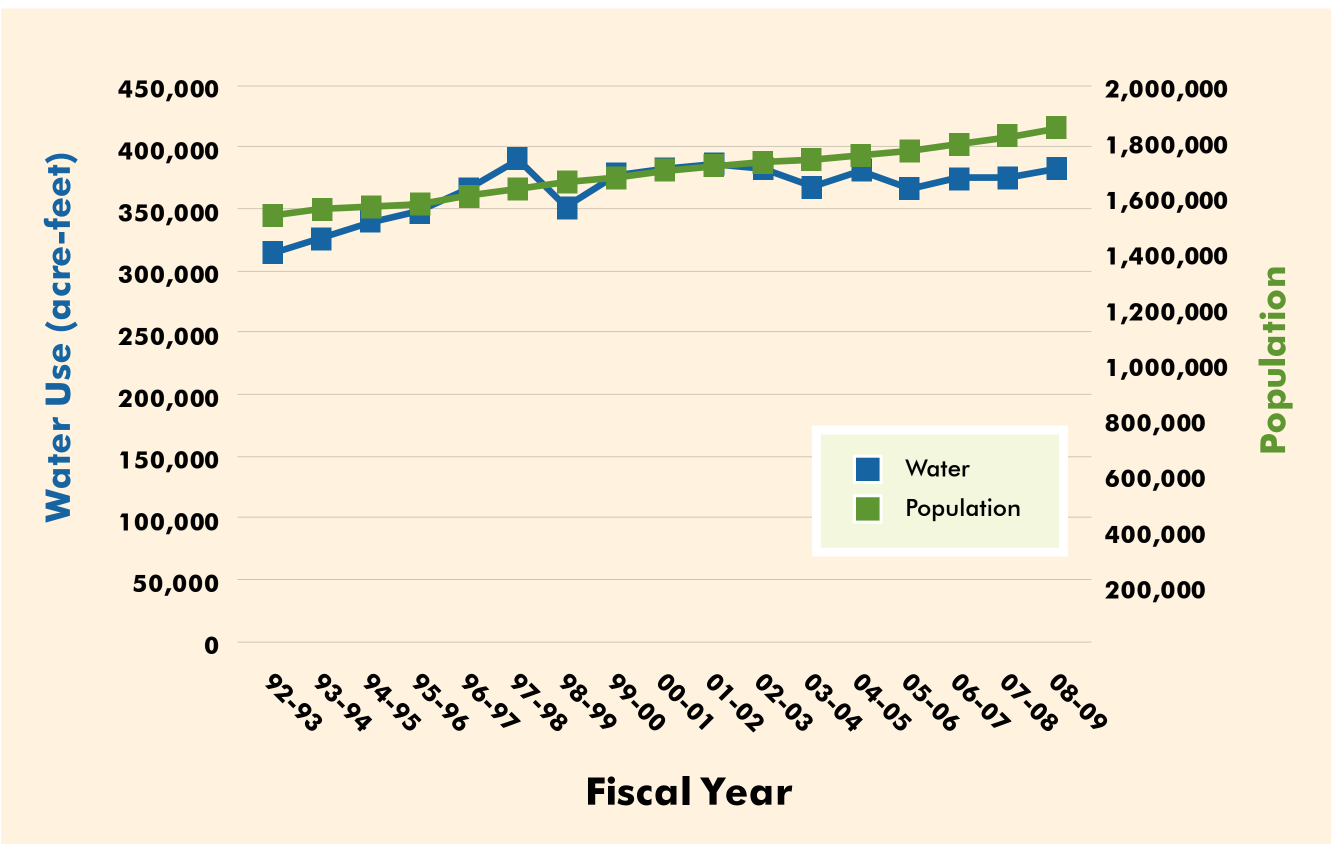
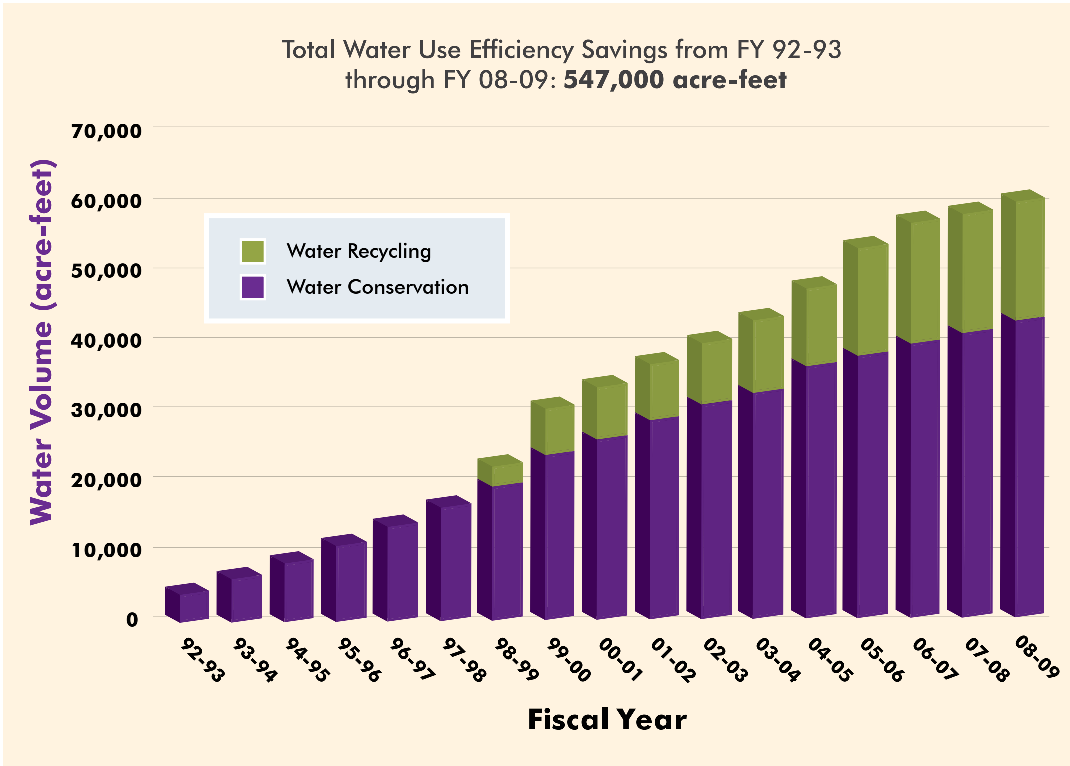


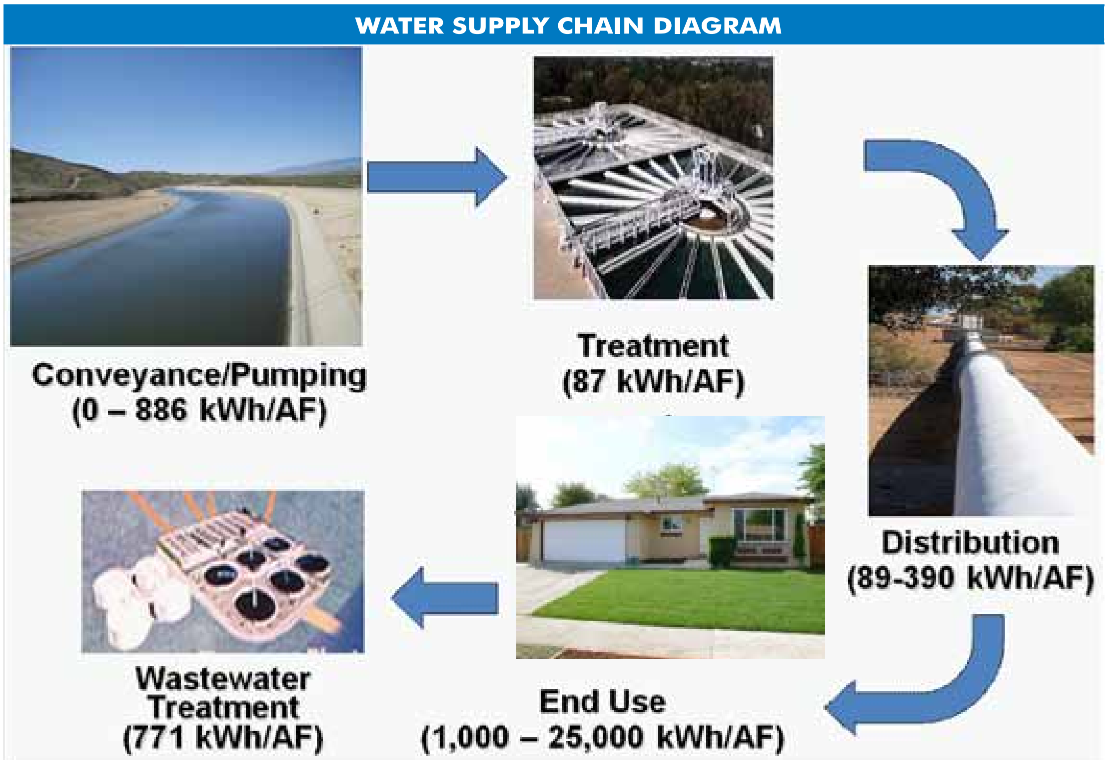
Figure 3: Water Savings from Water Conservation and Water Recycling Programs



California's Water and Energy Nexus

Supplying Water is Energy Intensive

Figure 4: Water Supply Chain Diagram



While the primary goal of the District's WUE programs is to use water more efficiently, ancillary benefits include energy savings and the resultant air quality benefits. The latter arise because California's water supply chain, or the route water follows as it is pumped and/or conveyed from its source, treated to drinking water standards, distributed, used, and treated to wastewater standards, is energy intensive (Figure 4). More specifically, water-related energy consumption in the state represents approximately 15%-20% of all energy consumed in California.[23] For example, the State Water Project alone, a 444-mile long aqueduct transporting San Francisco Bay-San Joaquin Delta water to Southern California, consumes 2%-3% of all electricity in the state because of the high elevations and long distances over which water must be pumped and conveyed.[24] Thus, a reduction in flow through the water supply chain brought about by an alternative water supply source such as water conservation or water recycling will decrease energy use.[25]

In general, the energy required for water conveyance and for end use consumes the largest proportion of energy when compared to the other steps in the water supply chain (33% and 56%, respectively, based on a case study of San Diego County Water Authority).[26] Among water-related energy demands at the end use step, energy for heating water represents the largest category. Energy is also used at the end use step for cooling, pumping, and purifying water, especially in the CII sector.[27] Therefore, in addition to saving energy by reducing water flow through the water supply chain, water conservation also has the potential to save energy at the end use step by reducing the energy demand for heating, purifying, cooling, and/or pumping water, depending on the end use device; for example, water-efficient clothes washers reduce the energy required for heating water while water-efficient industrial cooling systems reduce the energy required for cooling water.[28]

Supplying Energy is Water Intensive

Producing electricity affects both water quantity and quality. 5 shows an example of the relationship between water and energy. Water is used to extract coal, oil, gas and uranium and to grow materials for biofuels and ethanol. Thermoelectric generating facilities (electricity from fossil fuels, biomass, and nuclear fuel) use large quantities of water for cooling.[29] In fact, 25% of water used in California is used by thermoelectric power facilities.[30] Large hydroelectric facilities lose large quantities of water due to evaporation

Figure 5: "Examples of interrelationship between water and energy"[32]

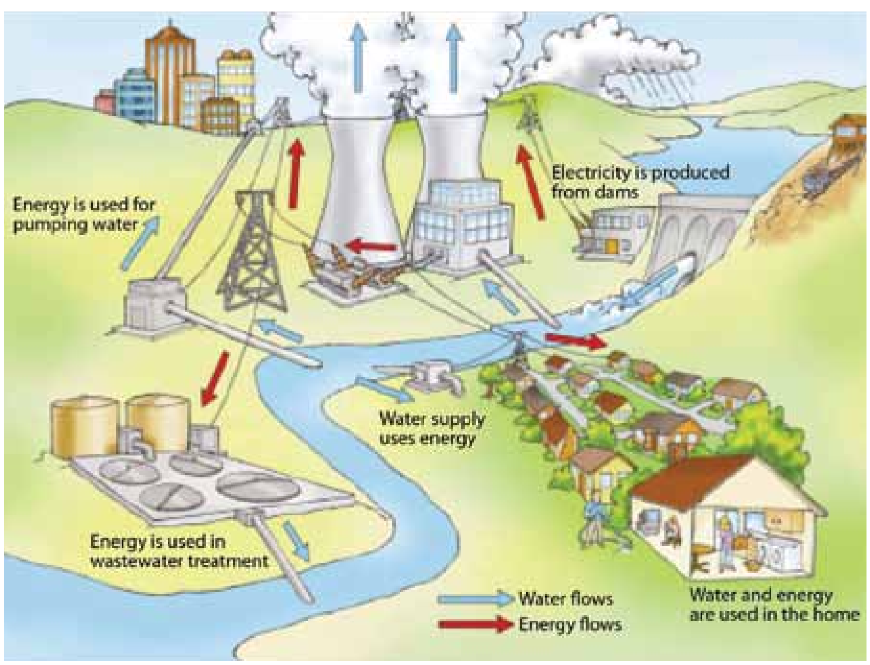


Table 1: Water consumption for different fuels and cooling systems[33]

Fuel Technology		Cooling Technologies - Water Consumption (gal/MWh)	Open-Loop	Closed-Loop Reservoir	Closed-Loop Cooling Tower	Hybrid Cooling	Air-Cooling
Fuel Technology	Thermal	**Coal**	300	385 (± 115)	480	between	60 (± 10)
		Nuclear	400	625 (± 225)	720	between	60 (± 10)
		Natural Gas Combustion Turbine	negligible	negligible	negligible	negligible	negligible
		Natural Gas Combined-Cycle	100	130+ (± 20)	180	between	60+ (± 10)
		Integrated Gastification Combined-Cycle	not used	not used	350+ (± 100)	between	60+ (± 10)
		Concentrated Solar Power	not used	not used	11,271 (± 80)	between	80+ (± 10)
	Non-Thermal	**Wind**	none	none	none	none	none
		Photovoltaic Solar	none	none	none	none	none

* Estimates based on withrawal and consumption ratios.

in the cooling process. Even solar and wind generation, in addition to the water used in device production, uses some water to keep the panels and blades clean and efficient. Additional water is needed to refine the drilled and mined fuels from source-condition to use-condition and to transport fuels to the final use point.[31] In 2005, PG&E-owned thermoelectric facilities consumed approximately 20,000 AF. Table 1 gives approximate values for volume of water consumed by the different cooling systems associated with electricity generation. Every AF and kWh saved through water conservation and water recycling saves additional volumes of water (because of system losses) and the associated supply chain energy; additional water is then saved through avoided electricity production, creating a positive feedback loop, the discussion of which is beyond the scope of this report.

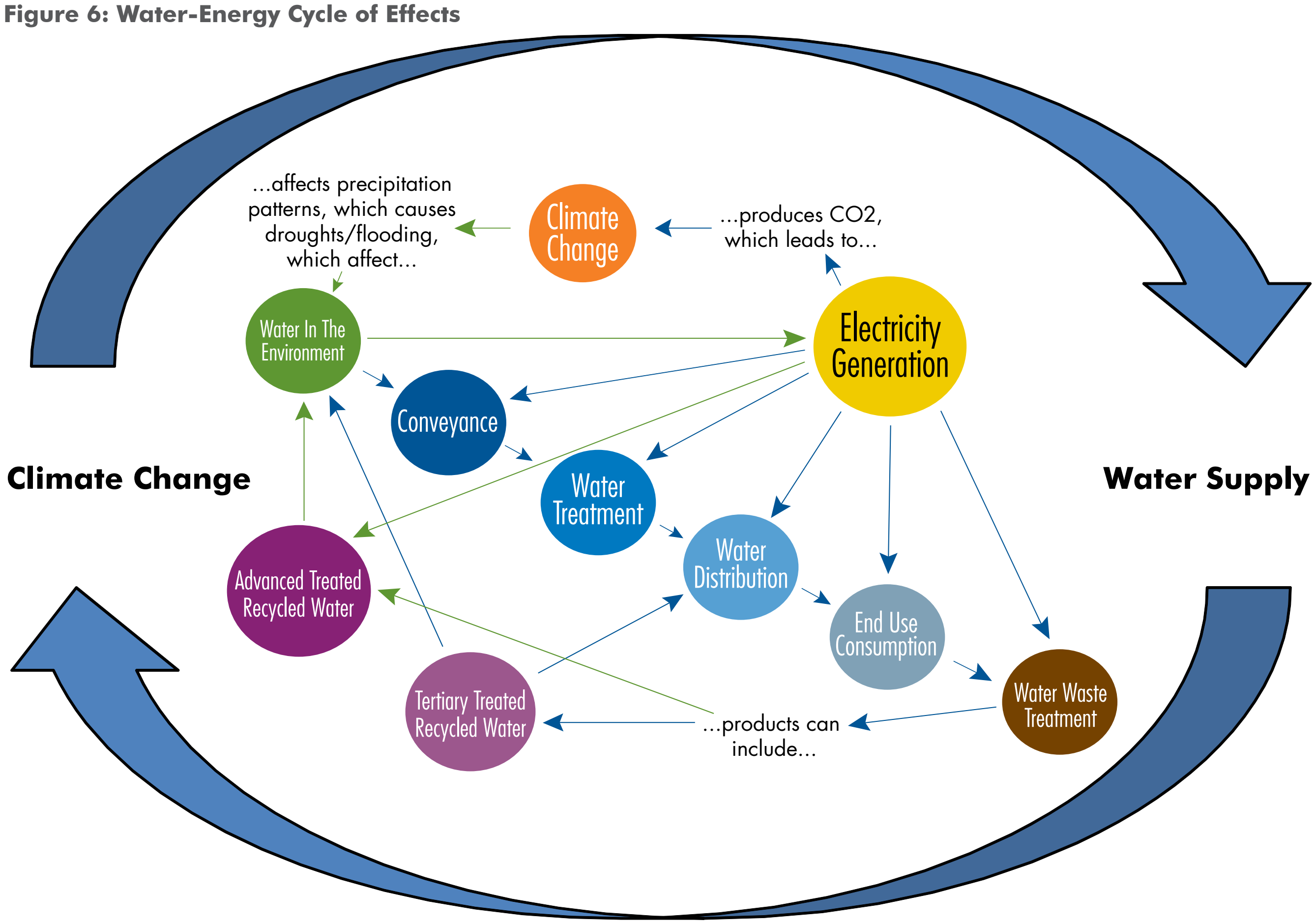
Air Pollution from Energy Production

Electricity production by power plants using non-renewable energy sources such as natural gas and coal generates air pollutants. Thus, a reduction in water-related energy demand due to water conservation and water recycling leads to a reduction in emissions of air pollutants. [34,35] Air pollutants[36] generated by power plants using non-renewable energy sources include reactive organic gases, particulates, carbon dioxide, sulfur oxides, and nitrogen oxides, all of which have adverse impacts on human health and/or the environment.[37] Particulate matter, especially PM10 (particulate matter smaller than ten microns), because of its ability to penetrate into the deepest parts of the lungs, can lead to asthma, bronchitis, other lung diseases, immune system damage, and organ damage.[38] Reactive organic gases and sulfur oxides also have adverse health effects, including organ damage, birth defects, and cancer.[39] Reactive organic gases and nitrogen oxides contribute to smog formation (of which ozone is a major component) while nitrogen oxides and sulfur oxides contribute to acid rain deposition.[40] Carbon dioxide is a greenhouse gas and plays a major role in global climate change. Thus, there is a direct connection between water supply and its ability to impact global climate change.

Cycle of Effects

As implied throughout the previous sections, the issues of water supply, energy production, and climate change are interrelated and cyclical. 6 displays all steps of the water supply chain as described in this report, and makes the connections between each component. The water supply chain is fed by water from the enviroment; environmental water supplies are also used for electricity generation. Electricity is used in every step of the water supply chain, and production of electricity releases climate-affecting air pollutants. These pollutants affect the global climate, which (as described above) affects the availability of environmental water supplies that are necessary for feeding the water supply chain and electricity production. Recycled water programs add an additional layer of complexity to this cycle; a quantity of wastewater is converted into recycled water or advanced treated recycled water which can

Figure 6: Water-Energy Cycle of Effects



then be inserted back into the water supply chain (or may be used to increase environmental water supplies). Tertiary-treated recycled water is energetically free to produce when compared to normal wastewater treatment processes (see Appendices A and B for a more detailed explanation), but advanced treated recycled water production uses additional electricity.

Partnerships Between Water and Energy Professionals

The challenges posed by global climate change have brought together professionals from both the water and energy industries with the goal of understanding the connections between water and energy in California's water supply system. Since 2005, the amount of research and number of publications regarding the water-energy nexus in California and all over the world has exploded. Several California Public Utility Commission (CPUC) directives and the California Water Action Plan have called for increased water use efficiency and decreased energy intensity of the water supply chain.

In December 2007, the CPUC approved several pilot programs in which large investor-owned utilities (including PG&E) and water agencies (including the District) would work together to undertake and evaluate water conservation programs.[41] PG&E and the District are administering a Low-Income Direct Install High-Efficiency Toilet Replacement Program. The CPUC also approved several evaluations and studies between investor-owned utilities and water agencies, including a statewide water-energy relationship study. In November 2008 the CPUC approved additional pilot projects between PG&E and various water retailers to directly install energy-efficient equipment for pumping of water through conveyance and distribution systems.

The draft 2009 California Water Plan Update from the California Department of Water Resources (DWR) includes climate change and energy use in the analysis of sustainable water management. Each water use scenario takes into account varying levels of consumer interest in water and energy conservation, and each potential management strategy is evaluated on the presence of energy benefits.[42]

In 2006, Navigant Consulting published an update to the 2005 California Energy Commission's (CEC) 2005 report, "California's Water-Energy Relationship." The original report investigated the energy requirements of California's water system and made many recommendations regarding additional informational needs, integrated resource planning, and managing demand growth. The update suggested several revisions to the calculations and data, but found that the original values were not unreasonable. Recommendations in the updated report include sub-segmenting the water supply chain steps to allow for more detailed energy efficiency R&D work, focusing on supply and conveyance R&D, and continually updating the energy-water calculations as more research and legislation lead to greater data availability.[43]

In 2006, DWR released a report written by the Climate Change Work Team on the impacts of climate change on state water resources. The report, "Progress on Incorporating Climate Change into Management of California's Water Resources," found that climate change will potentially have the following impacts on California water supplies:[44]

- 10% combined yield reduction for the State Water Project and Central Valley Project
- Changing precipitation patterns with more falling as rain instead of snow and more potential flooding and drought conditions
- Average loss of more than 5 million acre-feet (AF) of water storage in snowpack by 2050 (more than the combined storage of all California reservoirs)
- Sea-level rise impacting coastal land and aquifers through salt water intrusion and possibly damaging the extensive levee system of the San Francisco Bay-Delta

District staff used the theory and calculations behind the Water to Air Models to quantify the energy savings and air pollutant emissions reductions garnered by the district's water conservation and water recycling programs.

The Natural Resources Defense Council (NRDC) released a report, "In Hot Water" in July 2007 as a guide to managing Western water supplies in the context of global warming. The report concludes that global warming will certainly affect future water supplies and that even though some water managers are already incorporating climate change in their analysis, additional immediate and sustained actions are necessary to reduce future impacts. To this end, "In Hot Water" recommends conducting local and regional vulnerability analyses, implementing "no regrets" and "multiple benefit" strategies, especially conservation, investing in inter-agency relationships, restoring aquatic ecosystems for water quality and flood control benefits, and investing only in water management tools that make sense in the context of climate change. [45]

The Models

The initial approach for quantifying the energy embedded[46] in California's water supply system was developed by Bob Wilkinson from the University of California, Santa Barbara (for the California Institute for Energy Efficiency) and was expanded upon by Gary Wolff of the Pacific Institute into the spreadsheet-based "Water to Air Models.[47,48] The model's whole-systems approach for quantifying water-related energy use provides water supply planners with an overview of the energy intensity of different water supply options, allowing for the comparison of water supply scenarios. Users can input agency- (or region-) specific water supply, energy use, and air emissions information or, alternatively, the model has default values that can be used. The District staff used the theory and calculations behind the Water to Air Models to quantify the energy savings and air pollutant emissions reductions garnered by the District's water conservation and water recycling programs.

There are three main differences between the Water to Air Model and the Watts to Water Model:

1. The Watts to Water Model implicitly compares scenarios by calculating incremental changes in water supply and avoided supply chain energy starting with customer water conservation volumes and water recycling volumes instead of starting with total sourced volumes and explicitly comparing two water supply scenarios.
2. From the customer conservation and recycled water volumes, the Watts to Water Model works backwards to determine the avoided volume of sourced water, taking into account system losses throughout the water supply chain (see Appendices A and B).
3. The District calculations develop customer water conservation volumes from known numbers of specific water-savings devices instead of making generic assumptions about customer energy and water usage.

Urban water conservation and water recycling volumes were analyzed for each fiscal year from FY 92-93 through FY 08-09 and for projected FY 30-31 data. Potential savings from agricultural water conservation were also analyzed. The methodology used for this analysis is described further in Appendices A and B; additional information regarding the Pacific Institute's Water to Air Model can be found in the model's user manual.[49]

Water Conservation and Water Recycling Lead to Significant Energy Savings and Air Emissions Reductions in the Urban Sector

Energy Savings

The results of the Model show that the District has achieved significant energy savings since the inception of its water conservation and water recycling programs. Energy savings data are presented in Figures 7 through 9. Table 2 summarizes the results for the FY 92-93 through FY 08-09 time span as well as for projected FY 30-31. Energy savings resulting from the District's water conservation and water recycling programs were estimated to be approximately 2.67 billion kWh for FY 92-93 through FY 08-09, the time span during which the programs have been operational (Figure 7). For comparison, 2.67 billion kWh is equivalent to the electricity required for 412,000 households for one year, representing a savings of $347 million dollars (in 2006 dollars). During FY 08-09 alone, energy savings from the District's

There are three main differences between the Water to Air Model and the Watts to Water Model:

1) The Watts to Water Model implicitly compares scenarios by calculating incremental changes in water supply and avoided supply chain energy starting with customer water conservation volumes and water recycling volumes instead of starting with total sourced volumes and explicitly comparing two water supply scenarios.

2) From the customer conservation and recycled water volumes, the Watts to Water Model works backwards to determine the avoided volume of sourced water, taking into account system losses throughout the water supply chain (see Appendices A and B).

3) The District calculations develop customer water conservation volumes from known numbers of specific water-savings devices instead of making generic assumptions about customer energy and water usage.

Table 2: Summary of Energy Savings and Air Pollutant Emissions Reductions from the District's Water Conservation and Water Recycling Programs

	FY 92-93 Through FY 08-09	Projected FY 30-31
Energy Savings (kWh)	2.67 billion	554 million
Carbon Dioxide (kg)	625 million	128 million
Carbon Monoxide (kg)	564,349	116,969
Nitrogen Oxides (kg)	275,610	57,124
Sulfur Oxides (kg)	26,259	5,442
Reactive Organic Gasses (kg)	39,361	8,158
PM10 (kg)	48,560	10,065

Figure 7: Energy Savings from the District's Water Conservation and Water Recycling Programs

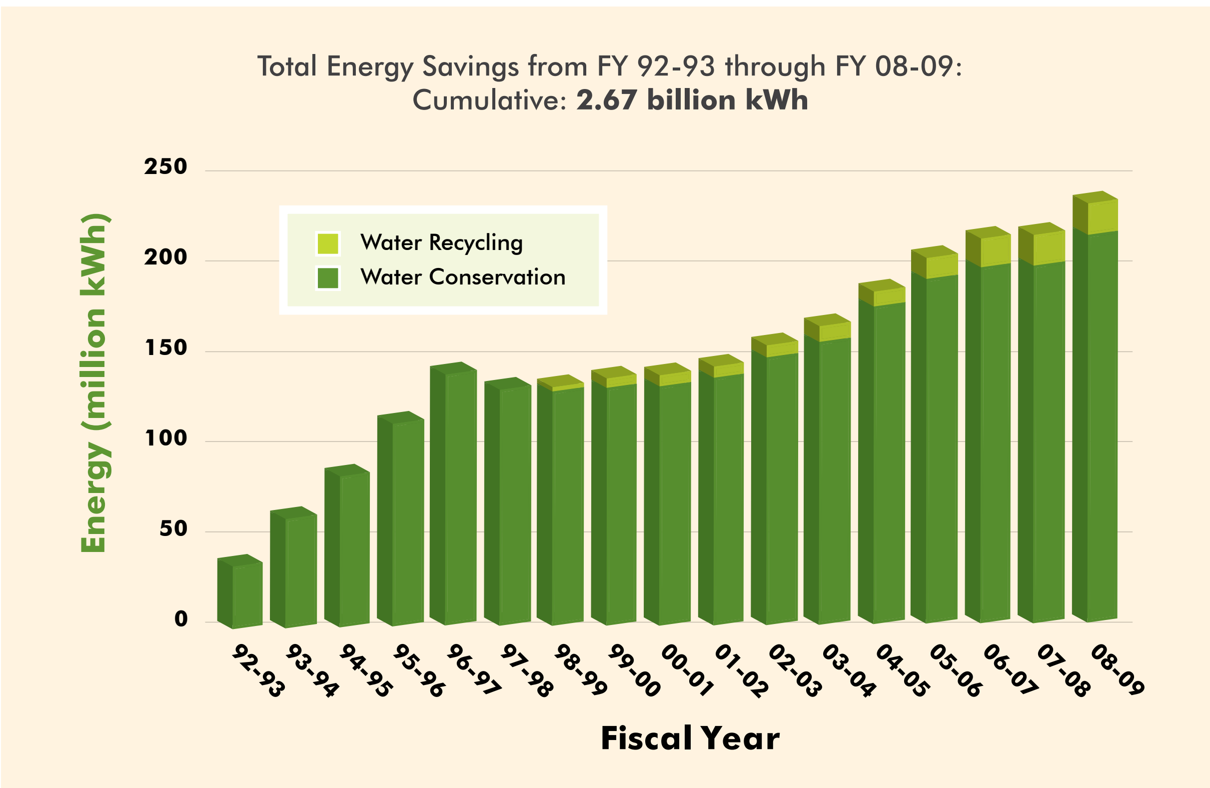


Figure 8: Energy Savings from Water Recycling Programs

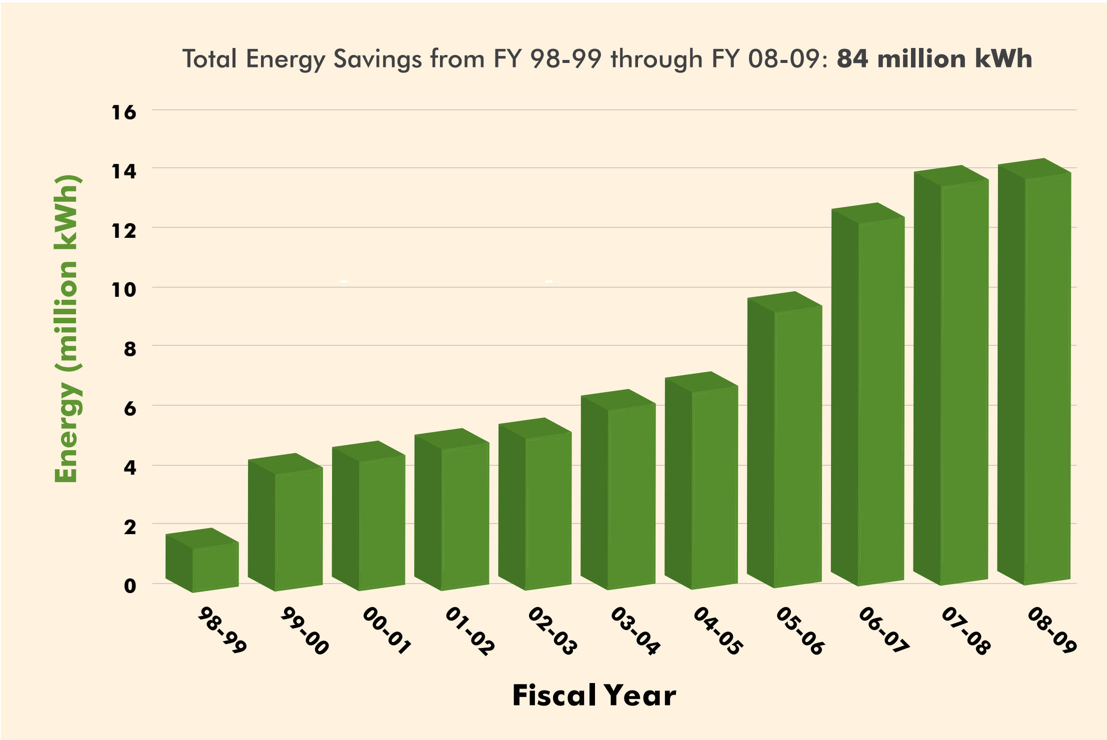
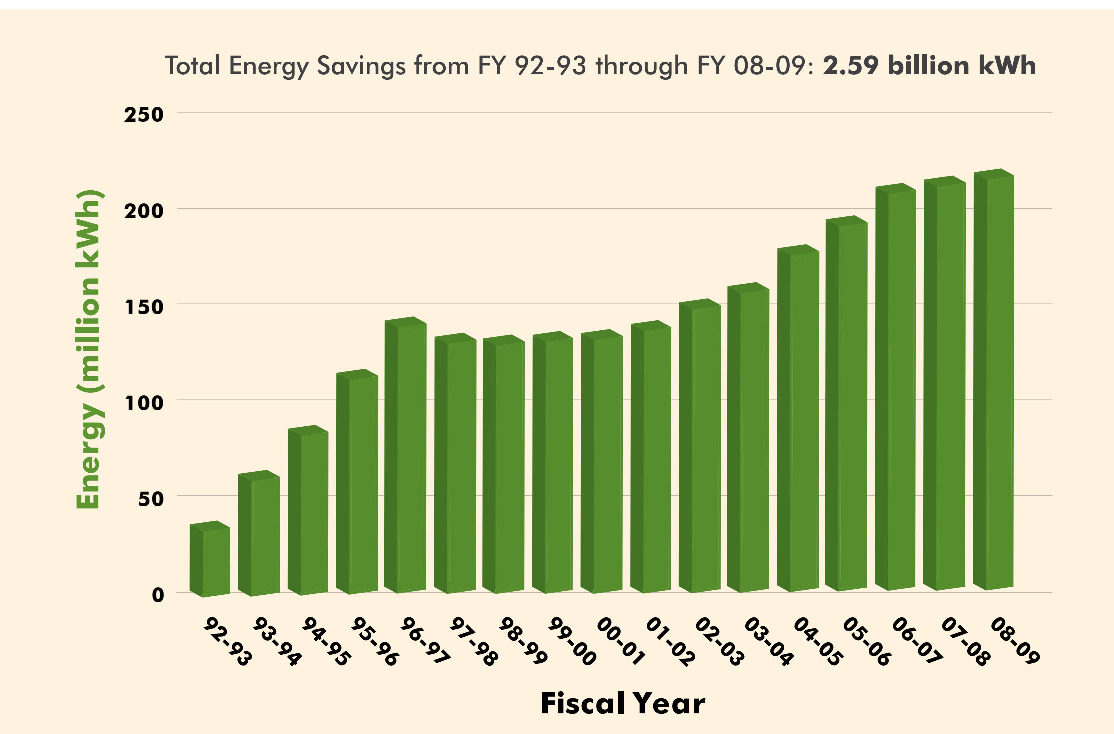


Figure 9: Energy Savings from Water Conservation Programs

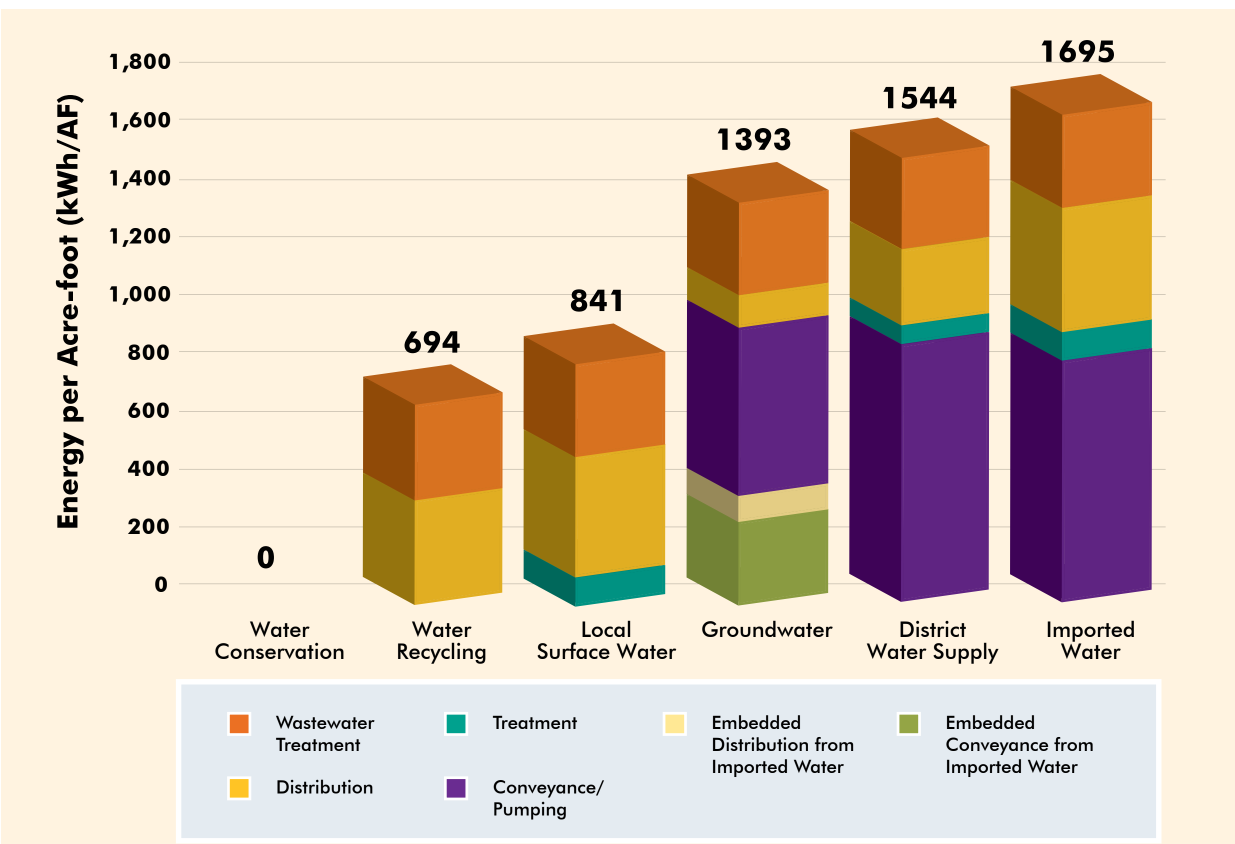


water conservation and water recycling programs were approximately 235 million kWh (Figure 7), representing a savings of approximately $31 million dollars (in 2006 dollars).[50] Projected energy savings for FY 30-31, which are based on projected water conservation savings and water recycling estimates for FY 30-31, will be approximately 554 million kWh (Table 2), representing a savings of $72 million (in 2006 dollars). Of these energy savings numbers, on average approximately 70% of the savings are due to end use energy savings while the remaining 30% of the savings are due to the other four steps in the water supply chain: supply/conveyance, treatment, distribution, and wastewater treatment. For FY 92-93 through FY 07-08, energy savings due to water recycling were approximately 70 million kWh (Figure 7) while energy savings due to water conservation were approximately 2.21 billion kWh (Figure 8).

The Energy Intensity of Water Supply Sources

Figures 7 through 9 demonstrate that water conservation and water recycling save energy when compared to the District Water Supply Mix of half imported and half ground water sources (see Appendices A and B). Another approach to understanding the relative energy intensities of different water supply

Figure 10: Energy Intensity of Water Supply Sources



sources is to use energy factors, which are ratios of energy consumed to volume of water "processed" (conveyed, pumped, and treated to drinking water standards as well as to waste water standards; end use energy not included) and are expressed in kWh/AF (see further discussion of energy factors in Appendices A and B). Energy factors estimate the energy embedded in a unit of water. Excluding energy used for end use, water conservation has the lowest embedded energy with a value of "0" (i.e., water not used does not enter the energy-consuming water supply chain), recycled water has the next lowest value, followed by local surface water, ground water, the District Supply Mix, and imported water (Figure 10).[51] It should be noted that the energy intensity of recycled water will change in the future because the County's largest recycled water producer, South Bay Water Recycling at the San Jose/Santa Clara Water Pollution Control Plant, is in the planning stages to build an advanced recycled water facility. The energy intensity of advanced recycled water is very volume-dependent as it is based on the amount of (incrementally energy-free) tertiary-treated recycled water used to blend with the more energy-intensive advanced treated recycled water. Advanced Treated Recycled Water is discussed further in a section later in this report.

Air Pollutant Emissions Reductions

When compared to energy savings, air pollutant emissions reductions calculated by the Model are similarly significant. Figures 11 through 13 show the emissions reductions of carbon dioxide. For FY 92-93 through FY 08-09, the emissions of approximately 625 million kg of carbon dioxide were avoided as a result of the District's water conservation and water recycling programs (Figure 11). For comparison, 625 million kg of carbon dioxide is equivalent to the removal of 115,000 passenger cars from the roads for one year or to the carbon sequestration by 130,000 acres of conifer forests over the course of one year.[52] For FY 08-09 the emissions of approximately 54 million kg of carbon dioxide were avoided while projected carbon dioxide emissions reductions for FY 30-31 will be approximately 128 million kg (Table 2). The breakdown of carbon dioxide emissions reductions between water recycling and water conservation is shown in Figures 12 and 13.

Thus, in the absence of the District's water conservation and water recycling programs the carbon footprint (i.e., the total output of carbon dioxide) of the District's water supply portfolio would be significantly greater (because ground water and imported water, water supply sources with higher energy intensity and thus higher associated air pollutant emissions, would be supplied in place of water conservation and water recycling programs).

Figure 11: Greenhouse Gas Emissions Reductions from the District's Water Conservation and Water Recycling Programs

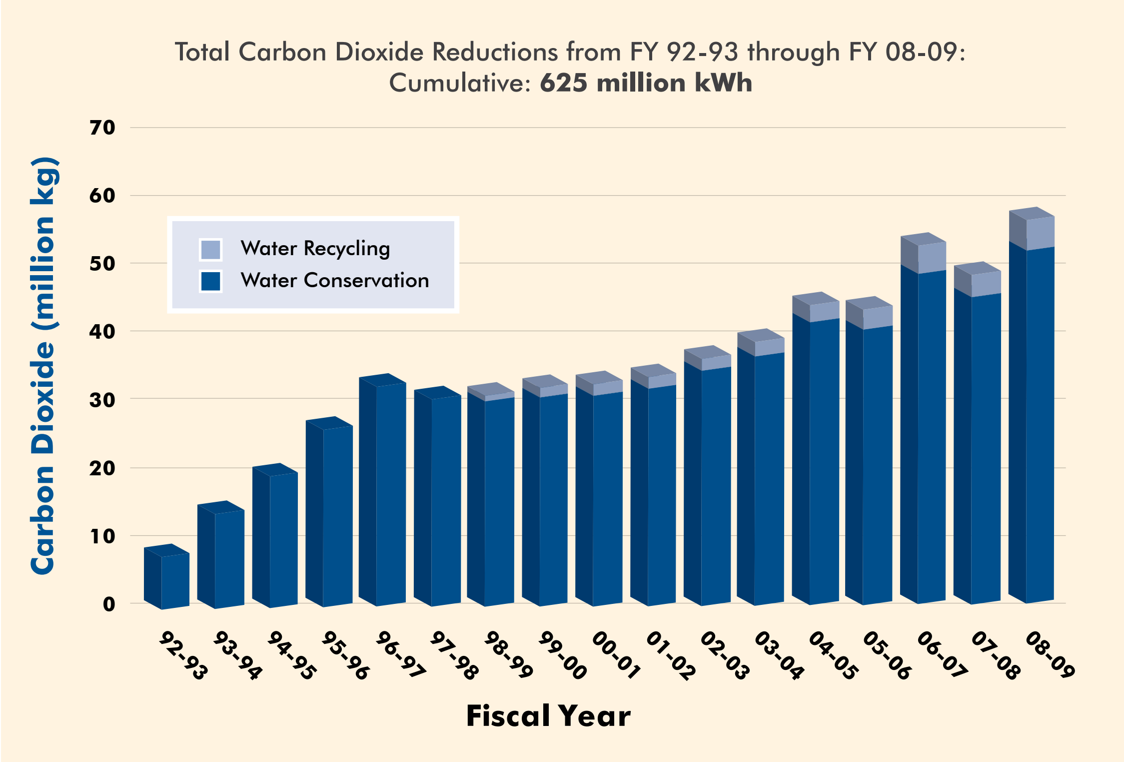


Figure 12: Greenhouse Gas Emissions Reductions from Water Recycling Programs

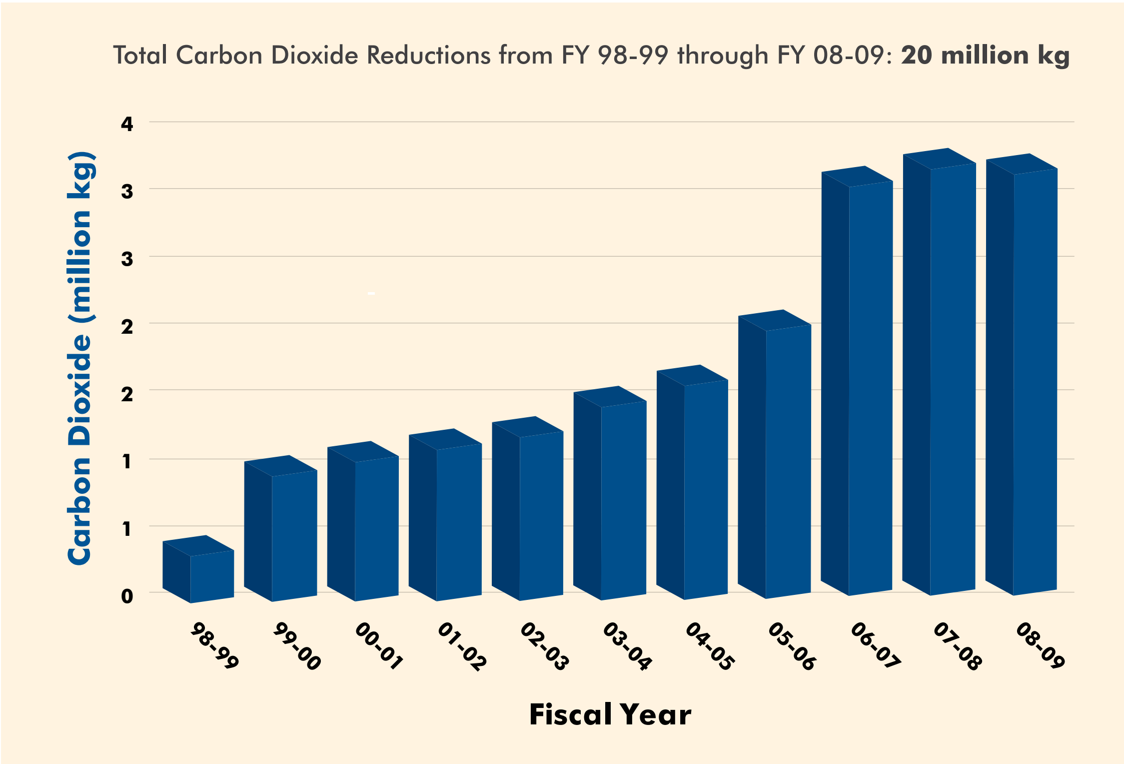
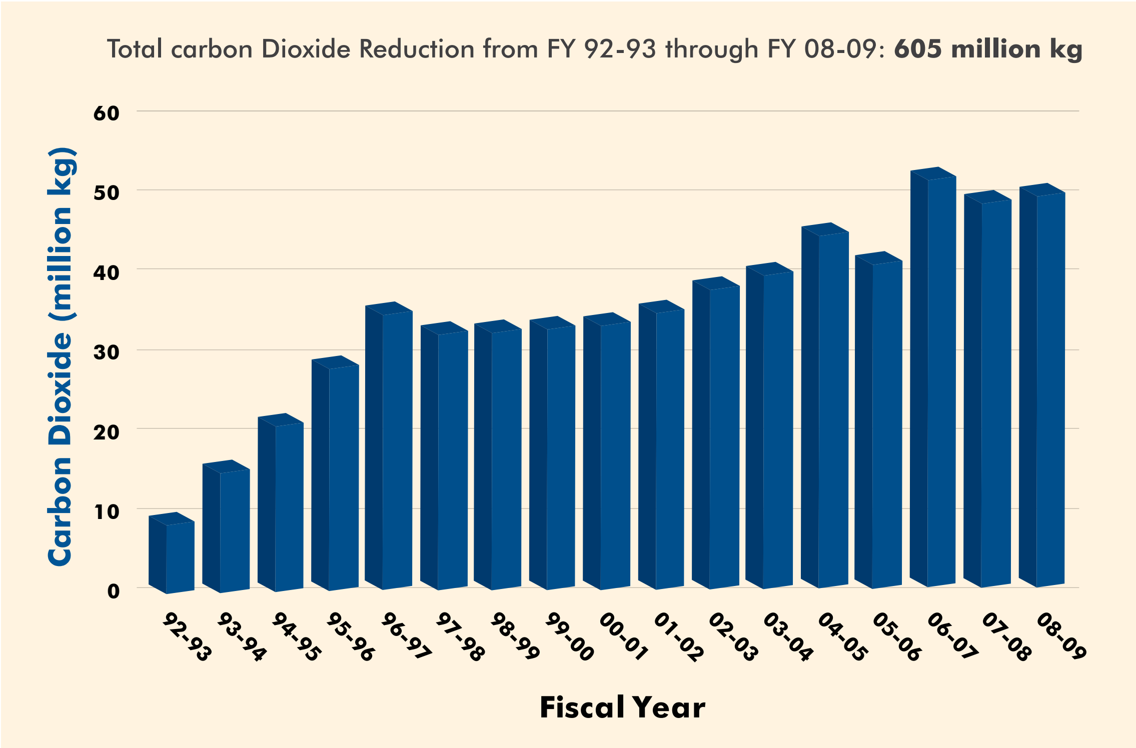


Figure 13: Greenhouse Gas Emissions Reductions from Water Conservation Programs



Figures 14 through 19 show the emissions reductions of five other air pollutants:

- Nitrogen oxides,
- Sulfur oxides,
- PM10,
- Reactive organic gases, and
- Carbon monoxide.

The breakdown between water recycling and water conservation is shown for each air pollutant. As is the case for energy and carbon dioxide, the District's water use efficiency programs resulted in significant reductions in the emissions of these five air pollutants. For a sense of scale, the Bay Area Air Quality Management District imposes fees on annual emissions of nitrogen oxides, carbon monoxide, sulfur oxides, PM10, and organic gases in excess of 50 tons (45,360 kg) while the South Coast Air Quality Management District in Southern California has more stringent requirements: fees are imposed on annual emissions of some air pollutants in excess of 4 tons (3,629 kg).[53,54]

Figure 14: Nitrogen Oxides Saved from Water Conservation and Water Recycling Programs

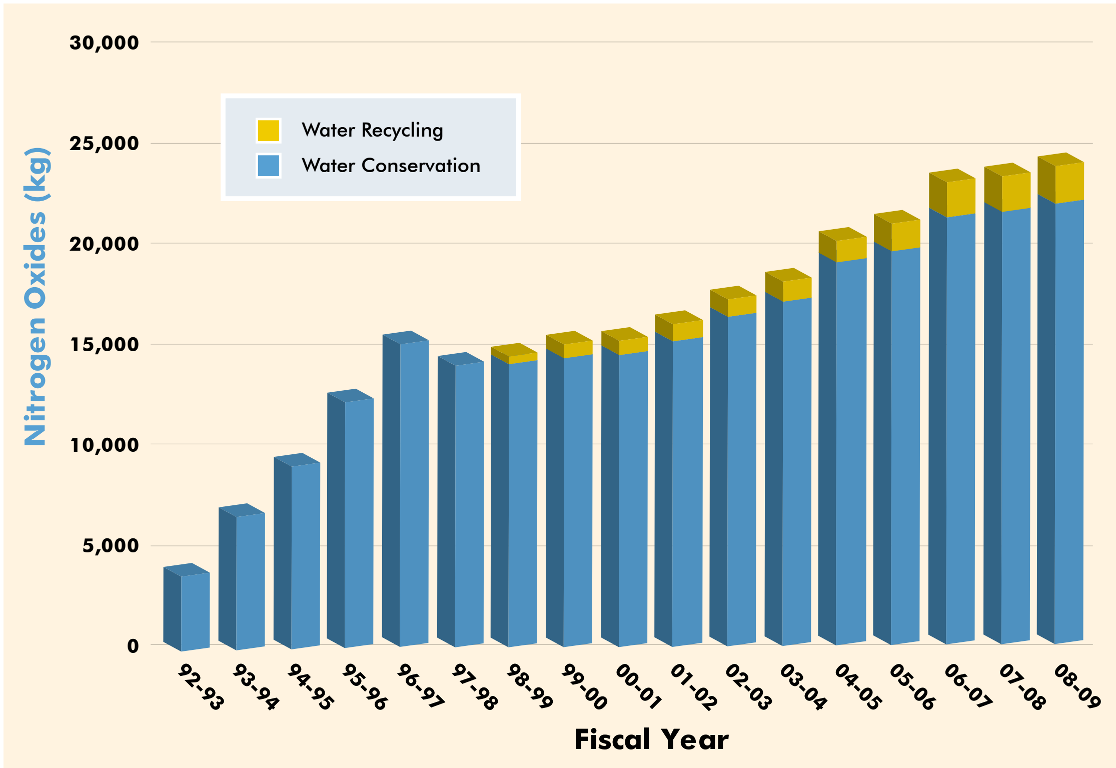


Figure 15: Sulfur Oxides Saved from Water Conservation and Water Recycling Programs

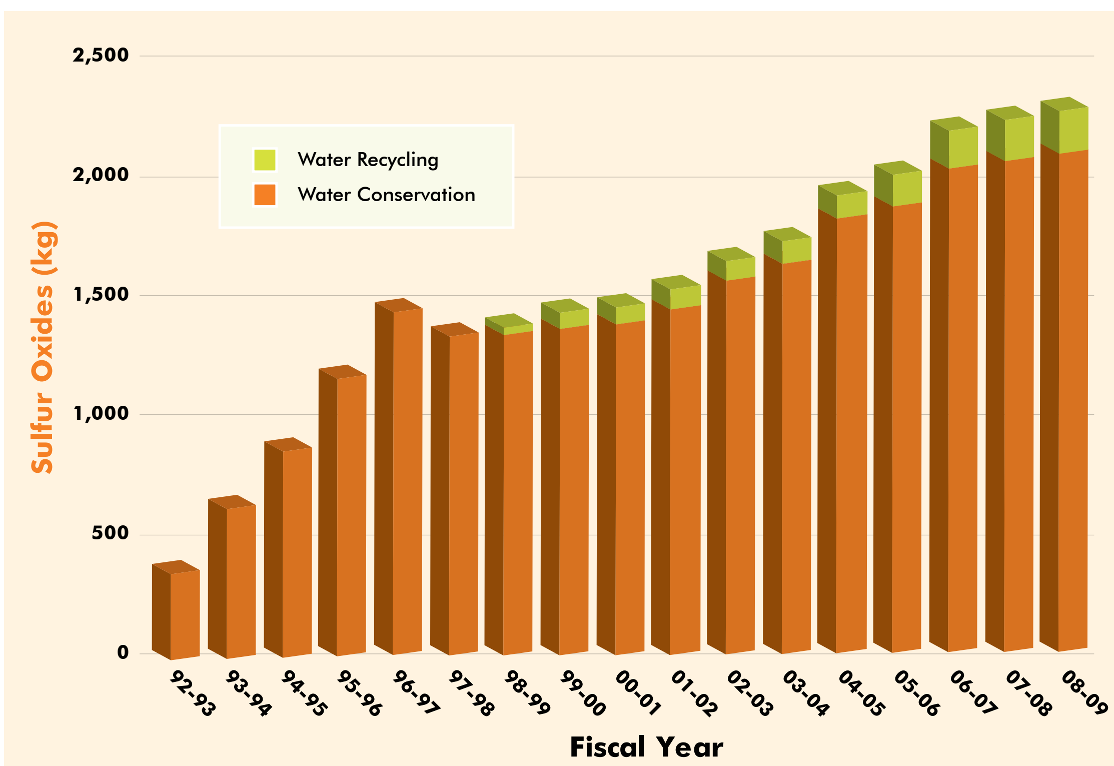


Figure 16: PM10 Saved from Water Conservation and Water Recycling Programs

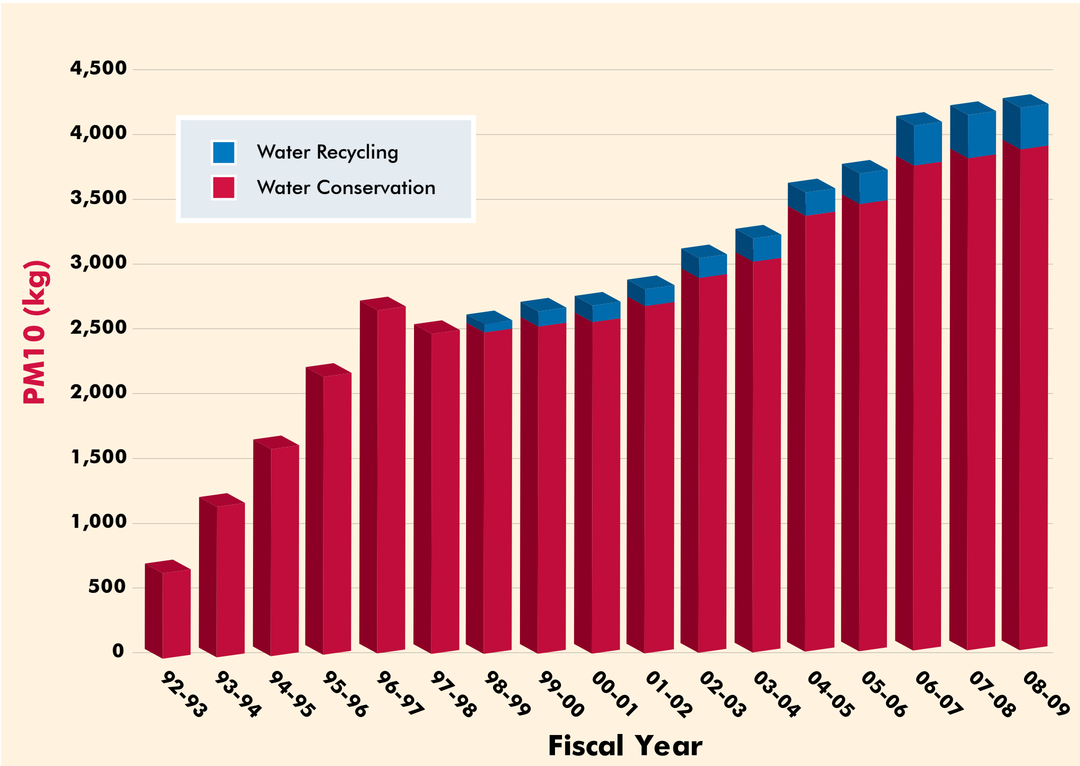


Figure 17: Reactive Organic Gases Saved from Water Conservation and Water Recycling Programs

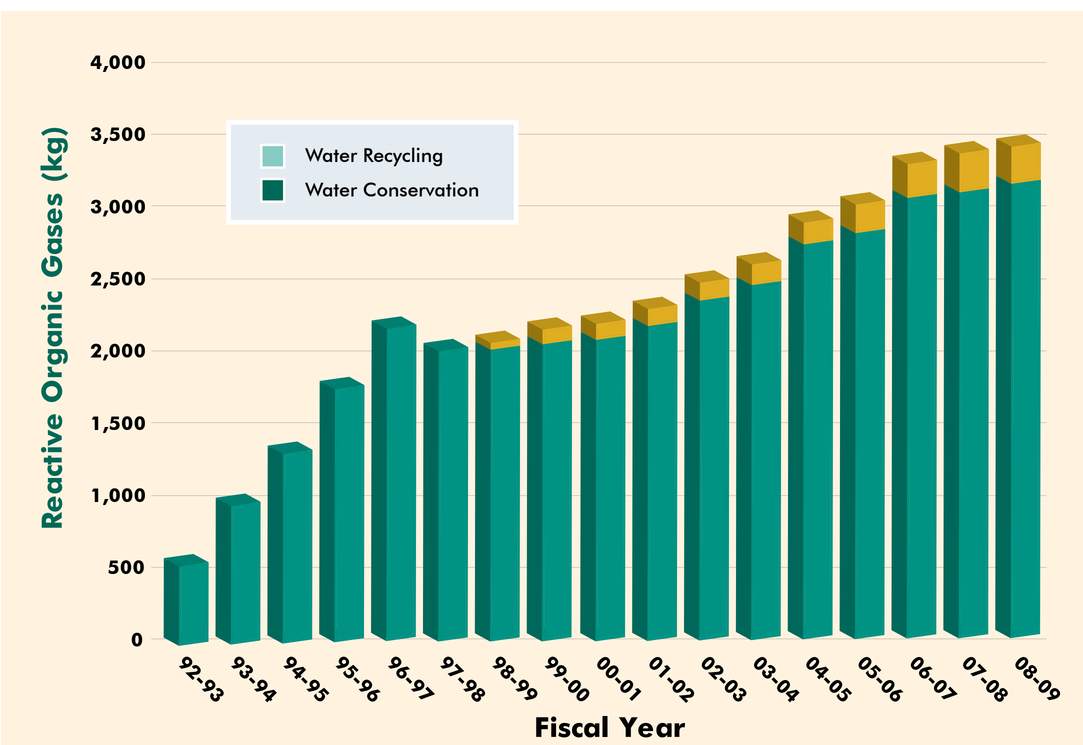
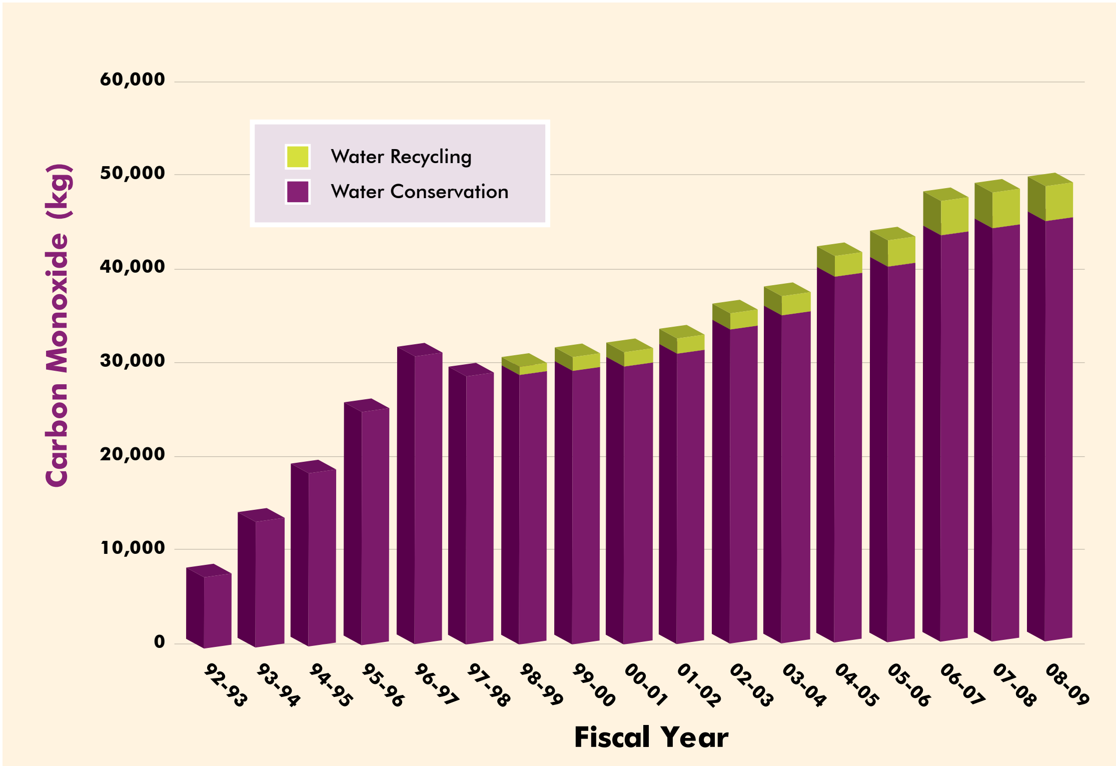


Figure 18: Carbon Monoxide Saved from Water Conservation and Water Recycling Programs



Breakdown of Energy Savings by Water Conservation Program

Energy savings accrue at the end use step of the water supply chain due to reduced demand for hot water (i.e. less energy is needed to heat a smaller volume of water).[55] The District has five water conservation programs that conserve hot water and thus save energy at the end use step.[56] These five water conservation programs, along with all other District water conservation programs, also save energy through reduced flow through the water supply chain. Energy savings that occur at the end use step are referred to as "hot water savings" while energy savings that occur at the other steps of the water supply chain are referred to as "cold water savings". Figure 19 shows how water, energy, and pollutant savings accrue to a hot water-using end use device using a high-efficiency residential washer as an example.

Figures 20 through 23 show the total energy savings and total carbon dioxide emissions reductions brought about by selected residential and commercial, industrial, and institutional (CII) water conservation programs. The bar for each program is broken into cold water savings/emissions reductions (brought about by reduced flow through the water supply chain) and hot water savings/ emissions reductions (brought about by reduced demand for hot water). The greater total energy savings and carbon dioxide emissions reductions of residential water conservation programs relative to CII water conservation

Figure 19: Water, Energy, and Pollution Savings for a Residential Washer

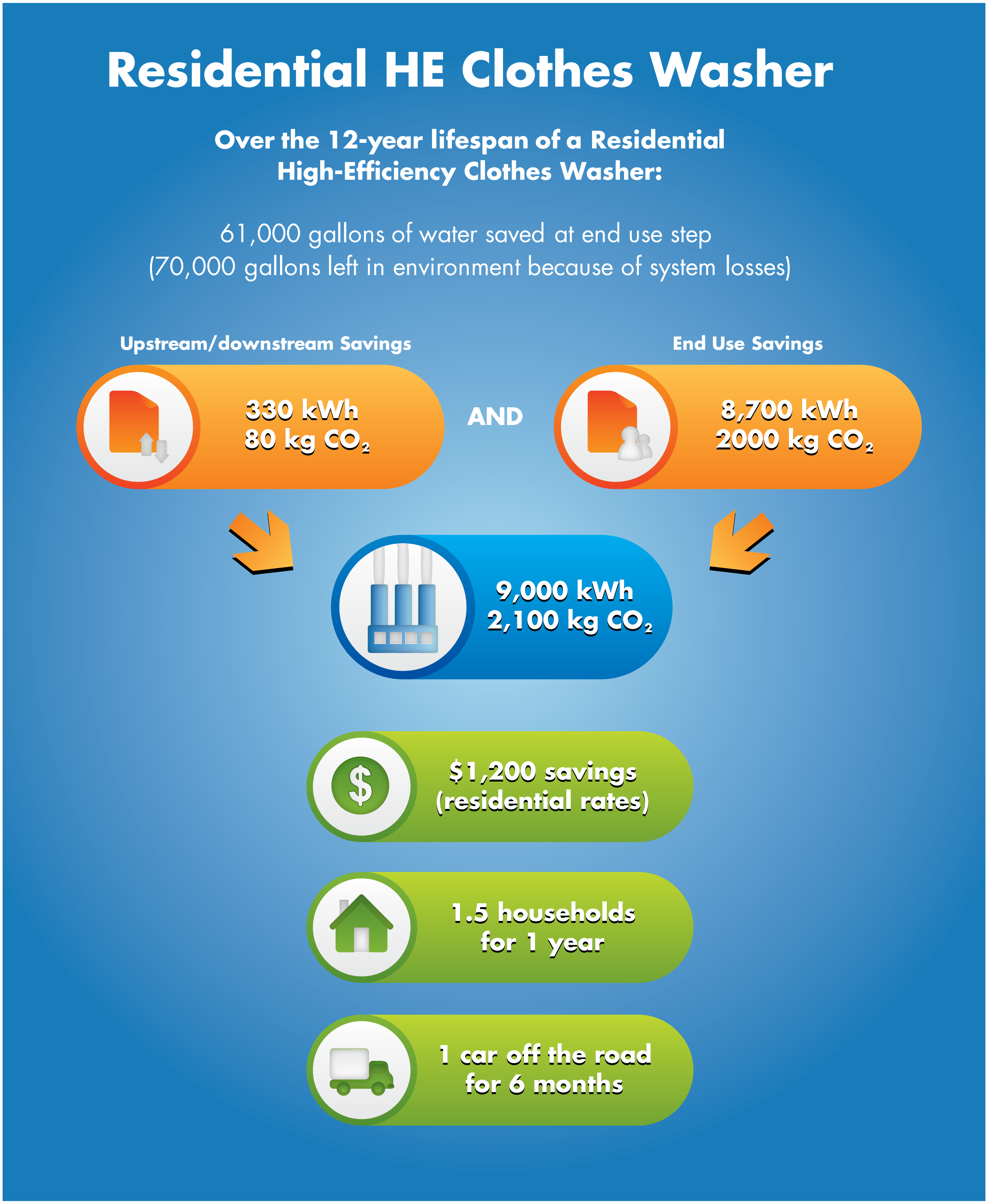


Figure 20: Energy Savings from Selected Residential Water Conservation Programs

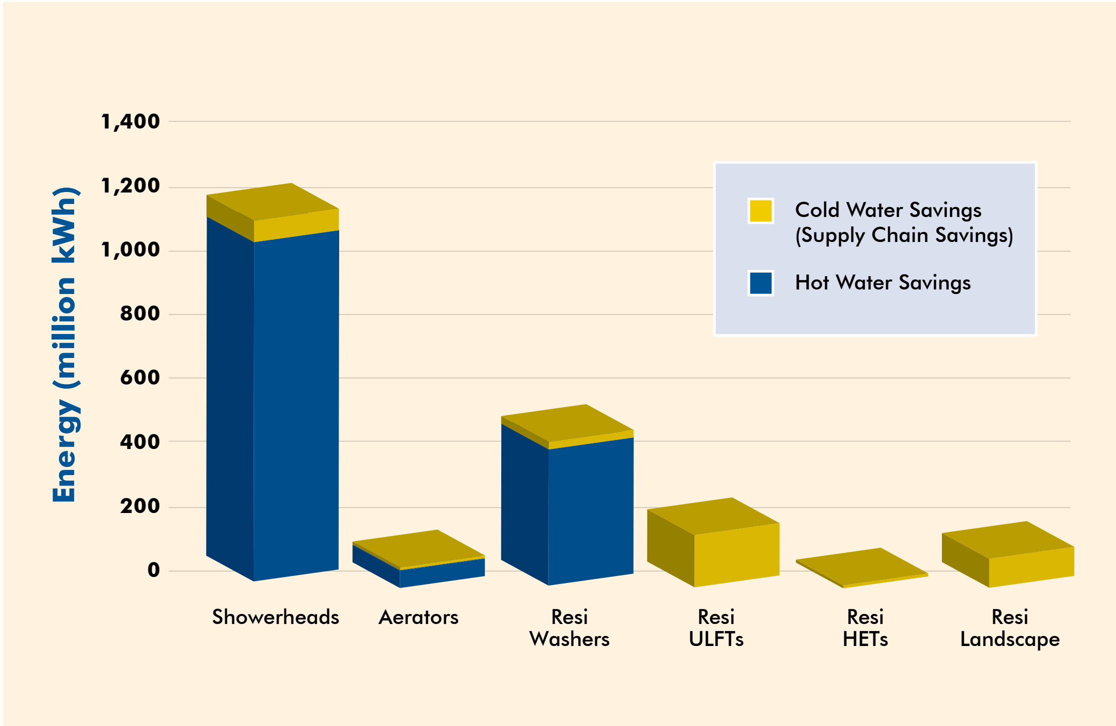


Figure 21: Energy Savings from Selected CII Water Conservation Programs

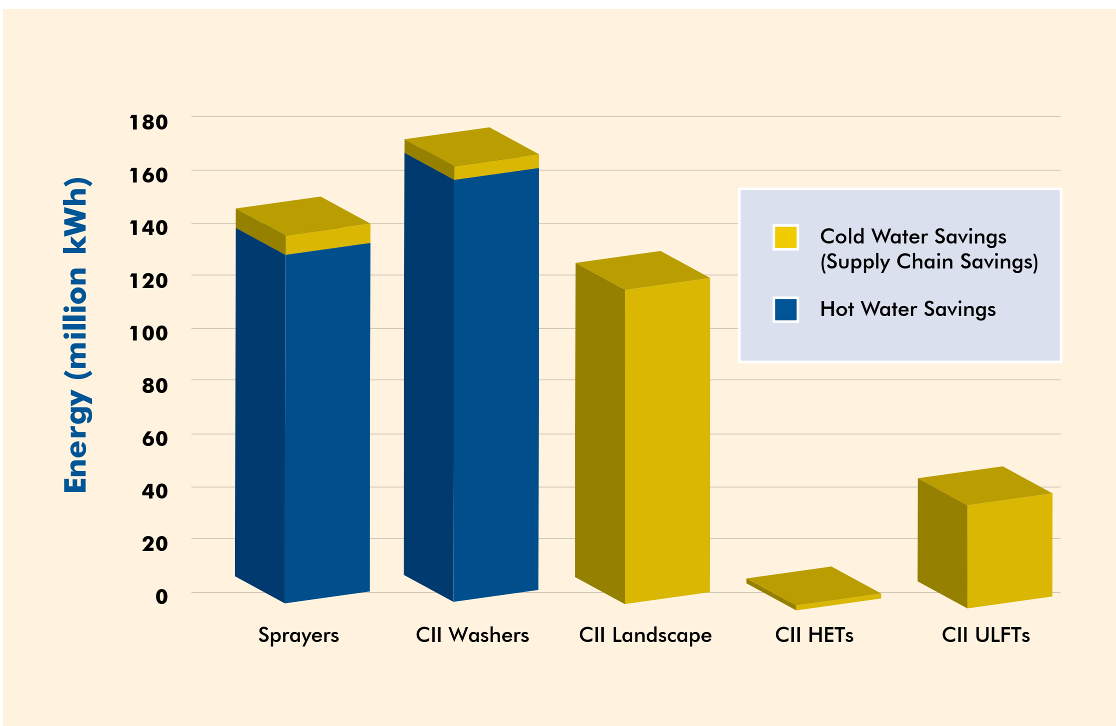


Figure 22: Carbon Dioxide Reductions from Selected Residential Water Conservation Programs

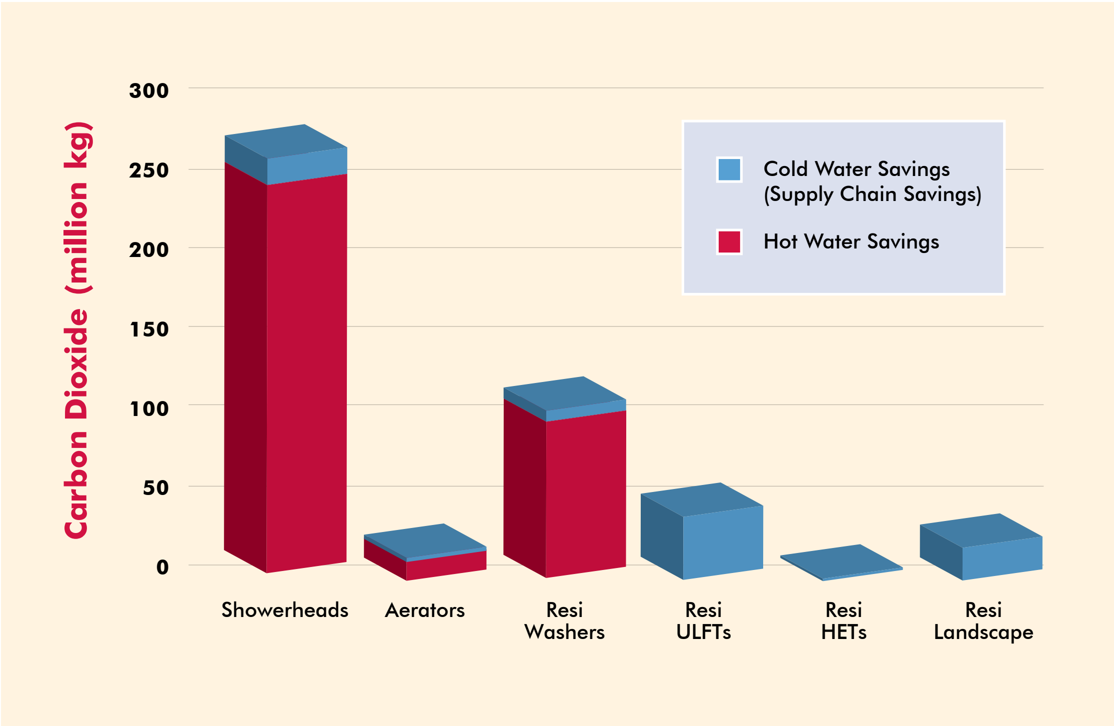
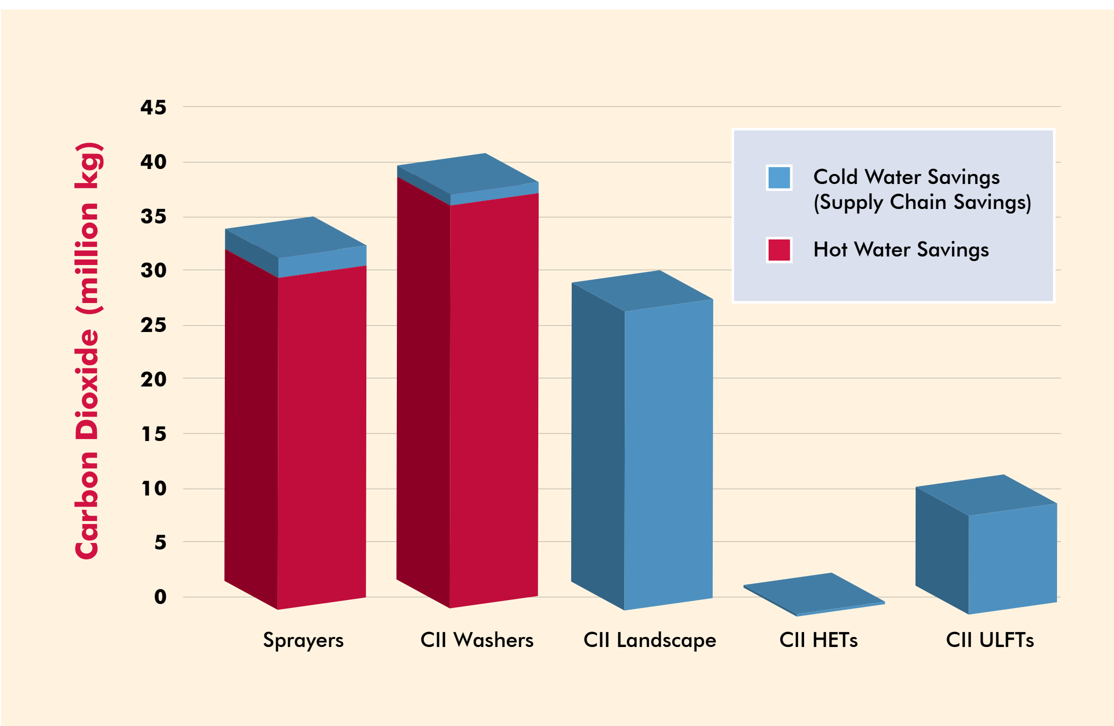


Figure 23: Carbon Dioxide Reductions From Selected CII Water Conservation Programs



programs is due to their earlier inception (and to plumbing code changes); the low-flow showerhead distribution program began in FY 92-93 and both the faucet aerator distribution program and the residential high-efficiency clothes washer rebate program began in FY 95-96 while the CII high-efficiency clothes washer rebate program began in FY 00-01 and the CII pre-rinse sprayer direct installation program ran FY 02-03 through FY 06-07. The residential showerhead program has resulted in the greatest energy savings (and carbon dioxide emissions reductions; Figures 20 and 22). The CII and residential ultra low flush toilet (ULFT) programs have also resulted in significant energy savings (and carbon dioxide emissions reductions) as has the CII pre-rinse sprayer program (Figures 20 through 23). High-efficiency toilets (HETs) are now offered in place of ULFTs.

Potential Energy Savings and Air Pollutant Emissions From Water Conservation

There still remain significant energy savings (and air pollutant emissions reductions) opportunities through water conservation in the CII and residential sectors. For example, the District recently completed a residential baseline study to estimate current saturation rates of water-efficient devices in single-family and multiple-family dwellings as well as to estimate future water savings potential.[57] The baseline study estimated that there were approximately 288,500 high-flow showerheads remaining in Santa Clara County; if all of these showerheads were replaced with low-flow showerheads, the lifetime (i.e. over the life of the device) water savings would be approximately 18,600 AF, the lifetime energy savings would be approximately 385 million kWh, and the lifetime CO2 savings would be approximately 89 million kg.[58] Similarly, the baseline study estimated that there were approximately 307,900 water-inefficient residential clothes washers remaining in Santa Clara County; their replacement with high-efficiency clothes washers would lead to a lifetime water savings of approximately 123,600 AF, a lifetime energy savings of approximately 2.8 billion kWh, and a lifetime CO2 savings of 646 million kg.[59]

As another example, the Water Efficient Technologies program offers rebates for devices that save water (in the CII sector) such as connectionless steamers, which are used for cooking by the food service industry. Connectionless steamers save approximately 224,400 gallons of water per year and approximately 19,000 kWh of electricity per year.[60] There are an estimated 2,974 restaurants, hospitals, and other commercial kitchens in the county that are eligible for replacement with a connectionless steamer, leading to a lifetime water savings of 20,000 AF and lifetime energy savings of 602 million kWh.[61]

Potential Savings in the Agricultural Sector

Water Savings

Historically, water savings in the agricultural sector have been limited due to a number of factors, including subsidized pricing, disincentives to saving water such as loss of water rights (i.e. “use it or lose it”), and high perceived costs of water efficiency technologies. The agriculture sector has been affected by recent drought and reduced Delta pumping, and water conservation will likely become more attractive in the future. Through a combination of irrigation system upgrades to increase distribution uniformities and improved irrigation management, agricultural savings in Santa Clara County could easily reach 6,000 AF per year.

Energy and Air Pollutant Savings

Agricultural pump tests conducted by the District within the county found that the average energy needed to pump ground water and pressurize it for distribution to the crops is 326 kWh/AF. Saving 6,000 AF of agricultural groundwater per year will save approximately 2 million kWh annually. This reduction in energy usage equates to approximately 1,400 kg CO2, and significant reductions in the emissions of other critical air pollutants (Table 3).

Table 3: Annual Potential Agricultural Sector Savings

Annual Potential Agricultural Sector Savings	
Water Savings (AF)	6,000
Energy Savings (kWh)	2 million
Carbon Dioxide (kg)	1,400
Carbon Monoxide (g)	1,300
Nitrogen Oxides (g)	620
Sulfur Oxides (g)	60
Reactive Organic Gasses (g)	88
PM10 (g)	100

Energy Intensity of Proposed Water Sources

Advanced Treated Recycled Water

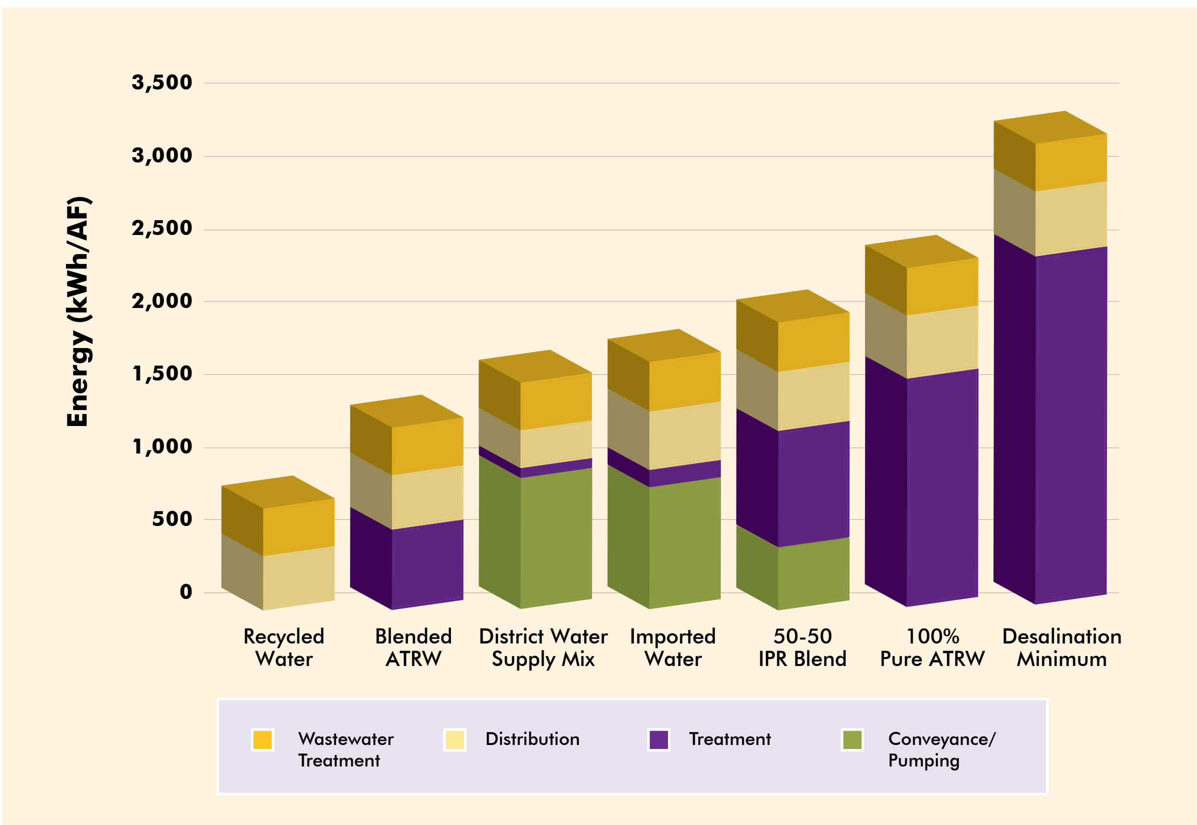
As part of the commitment to mitigating and adapting to the effects of global climate change, the District is actively investigating ways to decrease the need for new water supplies. To meet this end, the Board has set ambitious goals for the future supply of recycled water; the projected recycled water supply for FY 30-31 is 42,500 AF. Demand for recycled water must increase significantly to reach the projected supply level. Growth is limited in part because recycled water is non-potable and therefore is limited to applications such as irrigation, industrial processes (e.g. cooling systems) and fire fighting. Also limiting growth of recycled water demand is its salinity content, which exceeds limits for many sensitive industry applications. Advanced recycled water treatment facilities are under consideration to produce a higher quality product that increases the range of applications and contributes to increased demand for recycled water. Additionally, advanced treated recycled water can be used for groundwater recharge instead of importing water for that purpose.

The advanced recycled water treatment facility currently under consideration for installation at the San Jose/Santa Clara Water Pollution Control Plant is a microfiltration (MF)/reverse osmosis (RO) system. In this type of system, tertiary-treated wastewater is fed into the MF section where submerged filters remove any remaining suspended matter. The MF water is next forced through the RO membranes, where electric currents force salts and organic materials out of the product water. The MF/RO treated water is then exposed to ultraviolet (UV) lamps to kill any remaining bacteria, and finally blended with tertiary treated wastewater to bring the salinity of the recycled water to an appropriate level before distributing it to the customer.

Energy and Air Pollutant Costs of Advanced Treated Recycled Water

The advanced recycled water treatment facility under consideration would require approximately 1600 kWh to create an AF of 100% pure advanced treated recycled water (ATRW). However, 100% pure ATRW would not be delivered to customers; customers would receive a blend of 100% pure ATRW and tertiary-treated recycled water. A 1/3 100% ATRW and 2/3 tertiary-treated recycled water blend lowers the energy used in production to around 550 kWh per AF. Even after accounting for energy used in the other steps of the supply chain, delivering blended ATRW uses less energy than delivering the District Water Supply Mix (Figure 24). For comparison, an estimated minimum energy factor for desalinated water is included.[62]

Figure 24: Energy Factors for Advanced Treated Recycled Water



Also currently under consideration is a 50-50 blend of 100% pure ATRW and imported water to use in groundwater recharge instead of pure imported water (noted as “50-50 IPR Blend” in Figure 24). While this mix for groundwater recharge will not save energy under current conditions, imported water may become less available due to regulatory decisions, drought conditions, and/or climate change. Producing advanced treated recycled water may also become less energetically costly as treatment equipment becomes more efficient.

Even though the advanced recycled water treatment facility may have overall higher energy consumption (relative the current tertiary treatment facility), the resulting air pollutant emissions, especially carbon dioxide, may not be as high as would be expected if the facility was using energy supplied through the California power grid. Many of the wastewater and recycled water treatment facilities, including the San Jose/Santa Clara Water Pollution Control Plant, run digesters to convert waste materials into methane and generators to convert the methane into energy for use on site or sale back to the grid. This digester gas is considered carbon neutral (eligible renewable) and to have a much smaller greenhouse gas effect than burning fossil fuels (coal or natural gas) to produce much of the grid electricity. With the advanced recycled water treatment facility so close to the digesters, energy could easily be supplied by clean burning digester gas, thus potentially maintaining or decreasing the overall level of emissions.

Findings and Recommendations

The District will continue to improve the energy efficiency of its operations, buildings, and practices as it has a strong commitment to the efficient use of two valuable resources, water and energy.

In this report the District has shown the significant energy savings and air emissions reductions achieved by the District's projects and programs, particularly by urban water conservation. The District Board's Ends Policies and the District's Urban Water Management Plan both emphasize the importance of water conservation and water recycling for meeting future water supply goals. In the future, the District will continue to expand its successful water conservation and water recycling programs through the following activities:

- Integrate energy savings and air quality benefits into cost-benefit analyses. The results of these analyses will be factored into programmatic decisions so as to maximize multiple benefits.
- Expand cost-sharing partnerships with the District's retailers. Cost-sharing on programs makes the most efficient use of limited resources.
- Expand regional programs co-offered with other Bay Area water agencies. Offering regional programs is more cost-effective and leads to shared knowledge, thus providing financial and intellectual leverage.
- Seek increased grant funding. Grant funding provides funds for additional programs, some of which may not be locally cost-effective (but are regionally cost-effective). In the future, additional sources of funding may be available through the energy sector.
- Continue developing Water Agency-Energy Utility partnerships. The District has begun working with the local energy utility in a partnership to administer water conservation programs.

At the research level, the District supports further investigation and quantification of the water-energy-air emissions connection. For example, more research is needed regarding water-related end use energy use in the CII sector as well as regarding the energy used for distribution and advanced treatment of recycled water.

At the policy level, the District supports the integration of energy considerations into water policy decision-making because increased coordination among state resource management agencies (i.e., California Department of Water Resources, California Energy Commission, California Public Utilities Commission) will lead to more effective water and energy policies. Towards this end, the District recommends that the California Department of Water Resources expand an energy intensity analysis and continue to recommend strategies for reducing water-related energy use in the California Water Plan. Additionally, the District recommends that the California Urban Water Conservation Council incorporate energy costs and benefits into its standard cost-benefit methodology and encourage water agencies to consider energy implications of water conservation programs.

The District also supported the passage of AB 32, the Global Warming Solutions Act, which requires California to cut its greenhouse gas emissions by about 25 percent by 2020. Finally, the District recommends increased financial support (at the state and federal level) for water use efficiency, particularly water conservation, given the significant energy savings, air quality benefits, and role in global climate change mitigation.

Appendix A: Methodology for Estimating Energy Savings and Air Emissions Reductions

Water Supply

Staff obtained recycled water supply values and end use water conservation values for FY 92- 93 through FY 08-09 from the District's Final Water Utility Enterprise Reports and from the District's Urban Water Management Plan reports. Water supply and conservation projections for FY 30-31 were obtained from the District Board's Ends Policies and the District's Integrated Water Resources Planning Study 2003. The District Supply Mix, imported water, groundwater, and surface water were the four water supply sources against which recycled water and conservation water supplies were compared in this analysis. Various blends of advanced treated recycled water were compared to the District Supply Mix, imported water, groundwater, and tertiary treated recycled water; desalination was not considered because it is not currently a water supply source and facility construction plans are still in the feasibility stage. Recycled water supply values and end-use water conservation values were entered into the District Model to analyze the savings (this was done for each fiscal year from FY 92-93 through FY 08-09 and for projected FY 30-31).

Energy Sources and Factors

Prior to the estimation of the energy savings due to water conservation and water recycling, energy factors were calculated for each step of the water supply chain. Energy factors are the ratio of energy consumed (kWh/yr) to water consumed (AF/yr) and allow for comparisons of energy use on a per water unit basis (kWh/AF). The model uses energy factors as a multiplier for water supply values to determine energy embedded in each step of the water supply chain. District-specific energy factors were used; Table 4 lists energy factors used for this analysis and their source (see Appendix B for additional calculation details).

Table 4: Energy Factors

Energy-Consuming Step	Energy Factor (kWh/AF)
Source and Conveyance (0 - 4,500 kWh/AF)[a]	
Ground Water	558 (905)[b]
Surface Water	0[c]
Recycled Water	370[d]
Imported Water	717[e]
Water Treatment (33 kWh /AF)[a]	87[f]
Water Distribution (390 kWh/AF)[a]	89 and 390[g]
Wastewater Treatment (360 - 670 kWh/AF)[a]	771[h]

a Numbers in parentheses are averages for generic California water agencies and are from CEC update (2006).

b Calculated based on data from and personal communication with staff of several in-county ground water retailers. The first value is the energy needed to pump ground water to the surface, while the value in parentheses also takes into account the embedded energy from using imported water as ground water recharge.

c Default value for model; assumes gravity-fed system.

d Calculated based on data from and personal communication with staff of all four wastewater/recycled water treatment facilities. The number is a weighted average of all four facilities. The energy factor reflects the pumping energy required for the recycled water distribution system but does not include tertiary treatment (as this is required prior to discharge and is not an incremental cost associated with recycled water production).

e Calculated based on operations data from SWP and CVP; energy factor is derived from 2001-2006 data. These values do not account for hydropower generation by the SWP or CVP because energy production by these projects occurs independently of energy consumption.

f Calculated based on data from and personal communication with District staff. The energy factor is a weighted average of the energy factors for the three District treatment plants. Assumes energy consumption by the treatment plants for non treatment-related purposes (lighting, etc.) is negligible.

g Calculated based on data from and personal communication with District staff and with retailer staff. The first value is the energy factor for ground water distribution and is calculated based only on retailer operations data. The second value is the energy factor for imported water distribution and includes data from the District's in-county pumping system plus data from retailers' operations.

h Calculated based on data from and personal communication with staff at all four wastewater treatment facilities. Assumes all energy consumption is volume-dependent.

End Use Energy Estimation

While the heating of water is the major end use energy demand in the urban sector, energy is also consumed for other end uses such as cooling water, pumping water, and purifying water, particularly in the CII sector. Water-related energy use data on the latter three processes for the CII sector are limited as they are generally embedded into broader categories and/or are organized according to type of production or process (e.g., energy required for a manufacturing plant to produce one unit of an item);[63] therefore, energy required for pumping, cooling or purifying water at the urban end use step was not considered for this analysis. Thus, only the five water conservation programs that save hot water were assumed to contribute to urban water conservation end use energy savings (table 3): low-flow showerheads, faucet aerators, residential high-efficiency clothes washers, CII high-efficiency clothes washers, and pre-rinse sprayers.[64] However, it is likely that there are energy savings at the end use step (due to cooling, pumping, or purifying water) from some of the District's other water conservation programs but is outside the scope of this analysis. The annual kWh savings per device, the annual number of rebates (or direct installations or free distributions), the device lifespan, and the number of years the program has been operational were used to determine annual end use energy savings as well as total end use energy savings (through FY 07-08) due to the District's five hot-water saving conservation programs (Table 5). For FY 30-31, staff assumed that a similar suite and proportion of hot water-saving programs would be in place as those offered in FY 08-09, leading to an annual end use energy savings breakdown profile similar to the annual end use energy savings for FY 08-09.

Table 5: Energy Savings from the District's Hot Water Conservation Programs

Hot water using end use device	Average annual energy savings per device (kWh/year/device)	Device lifespan (years)	Number of devices rebated, distributed, or installed since program's inception
Low-Flow Showerheads	256[a]	5	815,448
Faucet Aerators	32[a]	2	873,907
Residential High-Efficiency Clothes Washer	730[a]	12	78,640
CII High-Efficiency Clothes Washer	1,930[b]	12	11,271
Low Flow Pre-Rinse Sprayers	7,630[c]	5	4,295

a From "Energy Down the Drain" (www.pacinst.org) and CUWCC's "Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices."
b From Consortium for Energy Efficiency fact sheet (www.cee1.org).
c From "Rinse and Save Phase One Final Report."

Air Emissions Reductions

Air emissions reductions were calculated using air emissions factors, a ratio of air emissions generated (grams/hour) to energy produced (kWh/hour). Air emissions factors for the California Grid (the energy source assumed for this analysis), were obtained from the California Air Resources Board and the California Energy Commission.[65] As mentioned in more detail below, the carbon dioxide emissions factors were adjusted to reflect the air emissions factors per PG&E energy production data.[66] Table 6 lists the air emissions factors used for this analysis.

Table 6: Air Emissions Factors

Air Pollutant	Air Emissions Factor (grams/kWh)
Carbon Dioxide	231 [a]
Reactive Organic Gases	0.015 [b]
Carbon Monoxide	0.211 [b]
PM10	0.018 [b]
Sulfur Oxides	0.010 [b]
Nitrogen Oxides	0.103 [b]

a From PG&E Climate Registry report. Value is for average PG&E energy portfolio from 2005-2007.
b Default value for Water to Air Model; average for California Energy Grid obtained from California Air Resources Board.

Appendix B: Assumptions and Energy Factor Calculations

Source of Conserved Water / Recycled Water:

In general, half of the water supplied by the District to the county is imported and half is sourced locally through ground water. Approximately one-third of the ground water was originally imported water (and entered the groundwater basin through groundwater recharge), while the other two-thirds came from natural recharge processes and from local water sources (e.g. local reservoirs).[67] This is the most accurate way to estimate the savings from water conservation/water recycling in the past. As the water supplies change in the future, the ratios (and possibly sources) will need to be updated (for example, desalinated water may need to be considered).

The imported water energy factor represents the weighted average of the sum of energy factors (calculated on an annual basis) at each pumping station along the State Water Project (SWP) and the Central Valley Project (CVP) between the Sacramento/San Joaquin Delta and Santa Clara County. The energy factor is calculated by dividing the total energy used at a pumping station by the total amount of water passing through that station. It should be noted that a significant portion of the energy required for conveyance of water through the SWP or the CVP comes from the projects' hydroelectric power plants located in Northern California (e.g., Lake Oroville-Hyatt Thermalito Complex) and at hydroelectric generators located at pumping stations along the projects' length (e.g., Devil's Canyon pumping station of the SWP, located in Southern California). For example, for FY 05-06 approximately 45% of the energy required for the operation of the SWP was obtained from SWP hydroelectric power, with the remainder coming from a partially SWP-owned coal fired power plant in Nevada and from the California electric grid. While hydroelectric power does not have air pollutant emissions associated with it as does fossil fuel-based energy sources, an assumption was made that hydroelectric power saved through the District's water conservation and water recycling programs can be used to offset fossil fuel-based energy use elsewhere. Thus, the District has chosen to take credit for the air pollutant emissions using the air emissions factors for the PG&E grid as mentioned earlier. A corollary of this assumption is that it is also assumed that SWP and CVP operations, including hydroelectric power generation, did not and will not change in response to the District's water conservation and water recycling savings; that is, it is assumed that hydroelectric energy saved through the District's water conservation and water recycling programs is still available for use by the projects or for sale to the California electric grid. Finally, the terms "energy savings" and "air pollutant emissions reductions" refer to benefits that accrue to the District.

The Hetch Hetchy system represents another source of imported water supplied to a portion of Santa Clara County, representing about 15% of total water used in the county. The Hetch Hetchy system is a gravity-fed system located in Yosemite National Park which transports Sierra Nevada snowmelt from the Hetch Hetchy reservoir on the Tuolomne river. This system is owned and operated by the San Francisco Public Utilities Commission. Because the Hetch Hetchy system is neither owned nor operated by the District and because the system is gravity-fed, Hetch Hetchy water was not considered in the estimation of imported water energy factors used for this analysis.

There is no energy associated with the natural recharge or moving water from the reservoir to the ground water; however, there is energy associated with importing water to use as ground water recharge. 347 kWh/AF is needed to import the third of total ground water that was imported for ground water recharge, including accounting for import system losses. The remaining 558 kWh/AF of the ground water energy factor is due to pumping the ground water and is estimated by the weighted (by delivery) average energy factor for pumps utilized by the five retailers that represent 74% of all the groundwater pumped in Santa Clara County. Thus, the average energy intensity of groundwater pumping is 905 kWh/AF.

Tertiary treated recycled water itself is assumed to have no incremental source energy because the same level of treatment is required before wastewater water can be released into the San Francisco Bay. The recycled water energy factor (kWh/AF) used in the model is a weighted average (by output) of the distribution energy required by the four recycled water producers in the county to pump the recycled water throughout their respective service areas. These four facilities represent 100% of the total recycled water supplied in Santa Clara County.

Water Treatment and Distribution

It is assumed that no groundwater passes through a treatment plant. Therefore, only half of the water conservation/ water recycling savings save treatment energy. All water passes through the distribution system. Energy factors are estimated by dividing the total energy used by a treatment plant by the total amount of water passing through that treatment plant, using the total water and energy for the three Water Treatment Plants for the treatment energy factor (87 kWh/AF). The same methodology was used to calculate the distribution energy factor, for in-county pumping plus estimated retailer pumping for the imported water distribution energy factor (390 kWh/AF). The ground water distribution energy factor (89 kWh/AF) consists of only retailer distribution pumping energy. Retailer distribution energies are calculated from the weighted (by total water supplied) average of booster pump energy used by the five retailers that represent about 74% of all ground water distributed in the county.

Agricultural Water

This model treats all water conservation /water recycling as if it were from urban uses. Agricultural water savings presented in this report are estimates based on possible future actions taken by agricultural water users. Such actions include improving existing irrigation system efficiency and better water use management. It is assumed that all agricultural water savings will result in avoided ground water pumping and pressurization, therefore, the energy factor (326 kWh/AF) used to calculate potential energy savings due to agriculture is the average energy used by on-farm pumps and pressurization equipment in Santa Clara County.[68]

End Use Estimations

The energy factors (kWh/year/device) for each hot-water savings device were calculated from a variety of sources (Table 5). For showerheads and aerators, the annual water savings per device were estimated, and then, using assumptions about the temperature of the water, the energy savings were calculated. For example, using the assumption that all water in the county is delivered at 60°F, and that people shower at 106°F, the energy required to heat each gallon of water 46 degrees can be calculated. There is not a good estimate of the proportion of electric to gas water heaters in the county, so all calculations were made assuming electric water heaters. No assumptions were made about efficiency decay, and all installed devices are assumed to remain in service their entire suggested lifespan.

As discussed earlier, water recycling saves energy by reducing flow through the water supply chain (as does water conservation) but does not specifically save energy at the end use step as is the case for water conservation. Accordingly, the above end use energy calculations for the water conservation savings were not done for the water recycling savings because water recycling end uses are assumed to be the same as if the customer were using potable water (i.e., the volume of total water supplied does not change, only the source: recycled water versus the District Supply Mix). In other words, it is assumed that the ratio of consumptive to non-consumptive water use (54%:46%, see "Supply Chain Water Loss" section below) is the same for potable District Supply Mix water as for non-potable recycled water. In reality, it is likely that the end uses (and thus, end use energy) of recycled water differ somewhat from those of other water supply options (imported, groundwater, etc.) because recycled water is a non-potable water supply source; however, a detailed analysis of the difference in end uses between water supply sources is outside the scope of this study.

Wastewater Treatment

As with end use, recycled water is assumed to have no impact on the amount of energy or water consumed in the wastewater treatment step of the process. The energy factor for the wastewater treatment step is calculated in the same way as tertiary treated recycled water distribution, using energy and water volume data from all four waste water treatment facilities.

Supply Chain Water Loss

As water flows through the import track of the water supply chain, a water loss of 5% during conveyance, 7% during treatment, and 7% during distribution is assumed; through the groundwater track, only a 7% distribution loss is assumed. Water losses occur due to evaporation, seepage, and system leakage. For example, the California State Water Project and the California Central Valley Project both estimate conveyance losses of 5%.[69] Consumptive use of water during the end use step was assumed to be 54%, a default value used in the Water to Air model (based on case studies of urban areas in California) but one that appears consistent with water use patterns in the District's service area.[70] Thus, 46% of the water from the end use step enters wastewater treatment plants and becomes treated wastewater. An additional 4% loss is assumed during conveyance between the end use step and the wastewater treatment plant.

Energy Supply and Air Pollutant Emissions Factors

The California electricity grid, which represents average electricity purchased by (or produced from) the average electric utility in California from a mix of energy sources (coal, natural gas, hydropower, etc.), was assumed to be the energy source for each energy-consuming step in the water supply chain; however, when possible, the air emissions factors for the California grid were adjusted to reflect the air emissions factors for the delivered mix of energy sources used by Pacific Gas and Electric (PG&E), the utility provider for much of Northern California and the Bay Area (PG&E was assumed to be the energy provider for all steps in the water supply chain).[71]

For calendar year 2008, the most recent year for which data are available, the mix of PG&E energy sources used to generate electricity were as follows: 14% eligible renewable (2% wind, 4% small hydropower, <1% solar, 5% geothermal, and 4% biomass and waste), 16% large hydropower, 22% nuclear, 39% natural gas, 8% coal, and 1% other (see further discussion of this above in the air emissions reductions section).[72] Total energy, electrical energy plus thermal energy (the source of energy for some end use devices), converted into kWh is reported in the model outputs as equivalent energy (or kWh) and is the parameter used throughout this report (but is simply referred to as "energy" or "energy savings"). Electricity costs represent average 2005 PG&E rates for businesses and residences located in Northern California ($0.13/kWh).[73]

It is worth noting that the air emissions reduction data presented in Figures 6 through 17 assume that water neither conserved nor recycled but instead supplied by the District Supply Mix (an assumption of all scenarios; see appendix A) would be subject to the same energy portfolio (i.e., mix of energy sources) as the volume of local ground water and imported water currently supplied.

Notes

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[21] While water conservation is technically a demand management measure and not a "new" water supply source, water conservation provides a "supply" of water that would need to be supplied by an alternative water supply source were water conservation programs not in place. Thus, water conservation will be referred to as a water supply source throughout this paper.

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[35] PG&E staff, personal communication. The quantities of air pollutants emitted by a power plant depend on the source used for energy production. For example, natural gas is a "cleaner" (i.e., leads to less air pollution) energy source than coal.

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[37] Bay Area Air Quality Management District (http://www.baaqmd.gov/).

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[46] The term "embedded energy" refers to the energy required for all steps of the water supply chain: supply/conveyance, treatment, distribution, end use, and wastewater treatment.
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[49] Ibid.
[50] The average California household uses 6,750 kWh of electricity per year. California Energy Consumption by Sector. Retrieved July 3, 2009 from http://energy.ca.gov/electricity/consumption_by_sector.html.
[51] These numbers include energy factors for the following steps in the water supply chain (see Figure 3 for diagram of chain): 1) source and conveyance, 2) treatment, 3) distribution, and 4) wastewater treatment. They do not include the end use energy factor. Water losses through the supply chain are accounted for.
[52] EPA provides a website for converting masses of greenhouse gases into quantities that are more easily related to, such as "number of cars removed from the roads for one year" or "number of barrels of oil. Retrieved July 13, 2009 from http://www.epa.gov/cleanenergy/energy-resources/refs.html
[53] Bay Area Air Quality Management District staff, personal communication.
[54] South Coast Air Quality Management District website. Retrieved July 3, 2009 from: http://www.aqmd.gov/.
[55] Pumping cooling, and filtering also consume energy but we assume those uses are negligible
[56] The five water conservation programs that conserve hot water are 1) the high-efficiency residential clothes washer rebate program, 2) the CII high-efficiency clothes washer rebate program, 3) the low-flow showerhead distribution program, 4) the faucet aerator distribution program, and 5) the low-flow pre-rinse sprayer distribution program.
[57] Santa Clara Valley Water District (with M.Cubed, Farrand Research, Inc., Western Wats, Inc. and Conservision Consulting, LLC.), Santa Clara County Residential Water Use Baseline Study (San Jose: 2004).
[58] Formula for end use energy savings: 288,500 showerheads X 256 kWh savings/year/showerhead X 5 year lifespan for each showerhead = 369,280,000 kWh. The The District model was used to estimate additional energy savings from the other four steps of the water supply chain. Formula for water savings: 288,500 showerheads X 1971 gal savings/year/showerhead X 5 year lifespan for each showerhead X 1 AF/325,852 gal = 8727 AF. The The District model was used to estimate additional water savings from the other four steps of the water supply chain.
[59] Formula for end use energy savings: 307,910 clothes washers X 730 kWh/year/clothes washer X 12 year lifespan for each clothes washer = 2,697,204,000 kWh. The The District model was used to estimate additional energy savings from the other four steps of the water supply chain. Formula for water savings: 307,910 clothes washers X 5,110 water savings/year/clothes washer X 12 year lifespan for each clothes washer X 1AF/325,852 gal = 57,942 AF. The The District model was used to estimate additional water savings from the other four steps of the water supply chain.
[60] Fisher-Nickel Food Service Technology Center and Koeller and Company, Evaluating the Water Savings Potential of Commercial "Connectionless" Food Steamers, prepared for Metropolitan Water District and East Bay Municipal Utility District (2005). Retrieved July 13, 2009 from http://www.cuwcc.org/uploads/product/Steamer-Field-Study-Final-Report.pdf
[61] Formula for end use energy savings: 2,974 restaurants and CII kitchens X 1 steamer/restaurant X 19,000 kWh savings/year/steamer X 10 year lifespan for each connectionless steamer = 565,060,000 kWh. The District model was used to estimate energy savings from the other four steps of the water supply chain. Formula for water savings: 2,974 restaurants and CII kitchens

X 1 steamer/restaurant X 224,400 gal water savings/year/steamer X 10 year lifespan for each connectionless steamer X 1 AF/ 325,852 gal = 20,480 AF

[62] District staff, personal communication.

[63] Wolff, Cohen, and Nelson, Energy Down the Drain (New York: Natural Resources Defense Council, 2004).

[64] End use energy savings due to passive water conservation were included. Energy savings due to the other four steps of the water supply chain for passive water conservation were also accounted for in this analysis. This is a change from the original analysis.

[65] Wolff, Water to Air Models. (Oakland: 2004). Available at: http://www.pacinst.org/resources/water_to_air_models/index.htm.

[66] PG&E staff, personal communication.

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[69] Wolff, Cohen, and Nelson, Energy Down the Drain (New York: Natural Resources Defense Council, 2004).

[70] Pacific Institute staff, personal communication. Santa Clara The District District staff, personal communication.

[71] PG&E staff, personal communication.

[72] Coal-produced electricity was purchased by PG&E at a higher than usual rate in 2008 due to drought-induced reduced hydroelectric generation. PG&E. Energy Resources PG&E Actual Power Mix. April 2009 Bill Inserts. Retrieved May 8, 2009, from http://www.pge.com/mybusiness/myaccount/explanationofbill/billinserts/previous/2009/apr.shtml.

[73] Ibid.

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