Reducing Greenhouse Gas Emissions Through Improved Water Policy

Most people are surprised to discover that water use in California is extremely energy intense. Today, more than 19% of electricity, 32% of non-power plant natural gas and 100 million gallons of diesel fuel are used to treat, deliver and heat water in California each year.[1] E2 has quantitatively evaluated the connections between energy and water and we believe that by 2020 California can reduce its GHG emissions by up to 7 million metric tons of CO2 equivalents per year (MMTCO2E/yr)[2] by implementing the energy efficiency and water conservation programs summarized below:

Reductions Of Greenhouse Gas Emission through Water Conservation and Management			
	Water Saved (AF/yr)[3]	**Electricity Saved (kWh/yr)**	**Natural Gas Saved (million therms/yr)**
Basic Conservation			
Residences, Indoors[4]	857,000		
Residences, Outdoors[5]	470,000		
Businesses and Institutions, Indoors and Outdoors[6]	980,000		
Meters and Tiered Pricing[7]	330,000		
Established Solutions			
Solar Water Heating[8]	N/A		248
Non-Revenue Water, Urban[9]	140,000		
Centralized Water Recycling[10]	1,000,000		
Biogas to Energy Solutions at Wastewater Facilities[11]	N/A	37,000	
Drip Irrigation for Agriculture[12]	1,300,000		
New Solutions			
Optimization of Processing Plants[13]	N/A	880,000,000	
Smart Water Application Technologies, Urban[14]	51,000		
Emerging Technology			
On-site Water Recycling[15]	92,000		
Total Saved	**5,220,000**	**880,037,000**	**248**

Proven and emerging solutions for water use efficiency can save the state of California approximately 5.2 MAF of water each year -- saving both valuable water and reducing GHG by approximately 5.35 MMTCO2E/yr[16]. In addition, direct annual reductions of approximately 880 MWhr of electricity and 248 million therms (MT) of natural gas will save at least .3 and 1.3 MMTCO2E/yr, respectively, for aggregate water-related energy savings of approximately 7 MMTCO2E/yr. Our conclusions may be understated because: (1) we have assumed that 7 MAF of water is used in the urban environment, whereas the California Department of Water Resources (CDWR) estimates 9 MAF[17], a 22% difference, (2) we use the conversion factors published by the California Climate Action Team (CAT) for estimating the carbon equivalency for natural gas and electricity savings; however, those factors are very conservative, and (3) we have not accounted for any increase in water use due to increased population growth between now and 2020, whereas CDWR assumes significant growth.

1. Basic Conservation

This category addresses the simplest ways to save water-- low-flow and pressure-assisted toilets; low-flow faucets and showerheads; highly efficient residential and commercial washing machines and dishwashers; drip and precision irrigation sprinklers; and recycling water for non-drinking applications, such as toilets, irrigation and certain industrial uses. Saving water saves energy because in California we use a lot of energy to pump, treat, pressurize and heat water.[18]

1.1 Residential-Indoors

The Pacific Institute estimates that 893,000 AF/yr of residential indoor water can be saved with existing technology.[19] This estimate is based on an assumed installed base of toilets that appears to be high[20] and it does not include the impact of new high efficiency toilets (HETs), which require only 1.28 or less gallons per flush (gpf). As a result of recent market developments, a California Urban Water Conservation Council report[21] estimates that by 2020, all existing residential toilets that require more than 1.6 gpf will be replaced with HETs that require an average of 1.25 gpf and that all new residential toilets will be HETs. Based on these assumptions and a 23% reduction in the estimated installed base of residential toilets, the net savings would be 300,000 AF/yr, rather than 420,000 AF/yr savings estimated by Pacific Institute.[22] In addition to deploying water saving fixtures, water agencies need to expand programs that raise awareness of the waste involved in leaving faucets running or in watering lawns without water saving approaches. Through schools, municipalities and other public institutions, we estimate that it is possible to build broad public support for water conservation and to save 84,000 AF/yr by better managing faucet use.[23]

1.2 Residential-Outdoors

While outside water use varies dramatically throughout the state, an average of 39% of residential water is used outdoors. Water agency programs that encourage hand watering, the replacement of sprinklers with drip irrigation, the deployment of weather-sensitive controllers and that offer rebates for turf reduction and water-sensitive plant choices can significantly reduce outdoor water use. The Pacific Institute estimates that 470,000 AF/yr of residential outdoor water use can be conserved with the use of existing technologies.[24]

1.3 Businesses and Institutions

The Pacific Institute provides a detailed analysis to support its estimate that the commercial, industrial and institutional (CII) sector in California can save 974,000 AF/yr, or 39% of total CII water use,[25] before consideration of the newest technologies. The most significant commercial indoor water use is in toilets, and including water use for all manufacturing operations, toilets still account for more than 11%, or 259,200 AF/yr, of total CII water used.[26] HETs and high efficiency urinals (HEUs) represent an important innovation. CII users can save approximately 59,000 AF/yr[27] by replacing all installed low efficiency toilets and urinals with HETs and HEUs and by mandating HETs and HEUs in new construction.

1.4 Universal Deployment of Water Meters and Tiered Pricing

A critical component of any successful conservation effort is measuring water use for each customer, implementing pricing structures that encourage conservation and charging a premium for water use in excess of a base amount. Field experience and research have shown that implementing tiered pricing, with the highest priced tier at 4-8 times the base rate, results in savings of 10-30% in winter and 20-50% in summer.[28] Based on this research and with the universal deployment of water meters and tiered pricing, we estimate that, in addition to the urban conservation savings outlined above, California can achieve at least an additional 12% savings for urban users that do not currently have tiered pricing.[29]

2.0 Established Solutions

This category includes basic technologies have been available for decades and have been used around the world to save water and energy associated with water:

2.1 Solar Water Heating

Solar collectors, usually placed on the roof of a residence or business, absorb the sun's energy to heat water that is then stored in a water tank. In California, solar hot water systems reduce fuel usage for water heating, usually natural gas, by 75% or more in the buildings that employ them. A state solar heating program, as proposed by recently signed AB 1470, would provide state tax credits to compliment federal tax credits and reduce the cost of residential solar collectors to an average $2-3,000 per system, thereby enabling a 10-year return on investment. With this type program, California can save at least 248 million therms, representing 9% of statewide natural gas use for water heating each year.[30]

2.2 Non-Revenue Water

Non-revenue water (NWR) or, unaccounted-for-water, is water that is lost before the water is delivered to a customer. Given the significant dimensions and complexity of California's water distribution system, two kinds of losses are experienced:

- **Apparent losses**--water that is consumed but is not properly measured, accounted or paid for. These losses cost utilities revenue and distort data regarding customer consumption patterns.
- **Real losses--**physical losses of water in the distribution system, including leakage, evaporation and storage overflows. These losses inflate the utility's production costs and stress water resources since they represent water that is extracted and treated, yet never reaches beneficial use.[31]

A detailed water audit and leak detection program of 47 California water utilities found an average loss of 10 percent and a range of from less than 5 to 30 percent of the total water supplied by the utilities. CDWR estimates that up to 700,000 AF/yr of leakage occurs in California urban areas from non-visible leaks alone.[32] South Nevada Water Authority has achieved one of the lowest documented rates of NWR available (6%) for a well-managed system.[33] We estimate that California can lower its NRW from 10% to 8%, for a savings of 2% of California's NRW, or 140,000 AF/yr.

2.3 Centralized Water Recycling

Water recycling offers an opportunity to extend the use of a fixed amount of fresh water by reclaiming a portion of the used water, treating it, and using it for non-potable applications, such as irrigation and some industrial uses. California generates about 5 MAF of municipal wastewater per year and only recycles about 10 percent of that amount.[34] The CDWR has identified 1.5 MAF of additional annual recycling potential by 2030, including 1.0 MAF of potential by 2020, at an average cost of $600 per acre foot and a capital investment of approximately $9-11 billion for additional infrastructure.[35] One impediment to much wider use of centralized recycling is the significant cost of laying separate pipes to transport the recycled water. Onsite water recycling offers CII users significant reclamation without requiring the investment in a separate network of municipal pipes. (See On-Site Water Recycling below).

2.4 Biogas Energy Solutions at Wastewater Treatment Facilities

Wastewater processing plants can provide a "double benefit" to the environment by limiting the amount of methane gas released into the atmosphere and by using that methane gas to generate electricity and heat for use at the wastewater facilities. There are 242 sewage treatment plants (STPs) in California with average annual flows of at least 1 million gallons per day. Anaerobic digestion is a process that has been used at STPs for many years; however, improved operation of the digestion process has increased gas production by up to 50 percent. Advances in generation and storage systems that can run on digester gas, such as micro turbines, are improving the feasibility of renewable energy generation, particularly at smaller STPs.[36]

The California Energy Commission estimates that approximately 38 MW/yr of electricity could be generated by tapping currently unused biogas at 23 large California STPs, with 5 sites providing more than 2 MW/yr and 18 sites providing less than 2 MW/yr.[37] In addition, livestock biomass can be added to STP digesters to increase electricity production by up to 70 MW/yr. This additional amount is not included in this estimate.

Converting the sewage at these facilities into energy can help offset the purchase of electricity and provide environmental benefits by reducing the discharge of methane and NOX gases and groundwater pollutants. Current regulation discourages the full use of available biogas for either self generation or to offsite loads. Provisions under regulated tariffs enable dairy operations to produce electricity from biogas resources at one location and use it to offset electricity use at multiple locations. This same approach could significantly increase opportunities for biogas generation by wastewater agencies.[38]

2.5 Agricultural Adoption of Drip Irrigation

The agricultural sector currently uses approximately 34.2 MAF of water per year,[39] from both surface and groundwater supplies. Drip irrigation consists of a network of porous or perforated piping, usually installed on the surface or below ground, which delivers water directly to the root zones of crops. Drip irrigation systems reduce water use by an estimated 40% to 60%, compared with gravity systems. Drip irrigation is widely used in some countries. Israel, for instance, uses drip irrigation on at least 50% of its total irrigated area.[40]

Shifting from conventional service irrigation to drip irrigation in India has increased overall water productivity 45-255% for crops as diverse as banana, cotton, sugar cane and sweet potato. [41]

More than 65% of all crops in California are still grown with inefficient flood or sprinkler irrigation systems.[42] Water requirements in California for different crops vary tremendously, depending on crop type, soil and climatic conditions, and irrigation methods. Some crops are very water intensive; others require much less water. These disparities lead to enormous differences in water productivity.[43] The 1987-1992 drought provided an opportunity to see how water cutbacks affected agriculture. Thirty-five percent of farmers in responding districts installed new sprinklers, and 33 percent installed new drip irrigation.[44] Based on the rate of adoption of drip irrigation over the past 20 years, we estimate that an additional group of farmers using approximately 20% of the agricultural water will adopt drip irrigation through 2020 and that they will reduce their water use by an average of 30% (resulting in an overall reduction in agricultural water use by 6%). Case studies of the adoption of drip irrigation have shown that wider and more rapid adoption can be encouraged through state loans for capital equipment related to irrigation. Where initial purchases were supported with government loans, farmers usually made subsequent investment.[45]

3.0 New Solutions

3.1 Optimizing Pumps at Water Purification and Sewage Treatment Plants

Water purification facilities and STPs require significant amounts of electricity to drive their pumps and treat water. Energy costs represent 28% and 34% of wastewater and water costs, respectively.[46] Pumping alone accounts for approximately 5 percent of the state's peak electricity load and 7 percent of total annual electricity usage.[47] California water distribution and wastewater treatment agencies spend more than $500 million annually on energy.[48] Substantial efficiencies can be obtained by employing interim storage to shift processing to off-peak periods and balance processing loads among multiple plants. An audit of the energy savings potential for water and wastewater facilities in California has estimated that more than 880 million kWhs per year could be saved by implementing several measures: load shifting, variable frequency drives, high-efficiency motors and pumps, equipment modifications and process optimization with and without Supervisory Control and Data Acquisition systems.[49]

In addition, it is estimated that infrastructure management systems can save 10% to 30% of the energy required to distribute water through the water management infrastructure.[50] These solutions create an integrated communications infrastructure between all elements of the water delivery system to develop a central “digital dashboard” that provides water agencies with a comprehensive view of real-time activity and movement of water throughout the system, as well as a historic comparison to past performance.

3.2 Smart Water Application Technologies

“Smart” irrigation controllers work by using information about site conditions (such as soil moisture, rain, wind, slope and plant type) and applying the right amount of water to the landscape based on those factors, thereby maintaining optimal growing conditions and conserving water. Recent innovations use weather information from the National Oceanic & Atmospheric Administration, electromagnectics to measure soil moisture and integrated circuitry to adjust or shut down watering. By automatically addressing seasonal weather and site factors, these smart controllers can significantly reduce outdoor water use by 20%-50%.[51]

4.0 Emerging Solutions

4.1 On-Site Water Recycling

New small-scale technologies enable cost-effective, on-site waste water processing, as well as the automatic monitoring of water quality in real-time. These technologies use new biological, micro filtration membranes, new electrolysis and electro coagulation processes and advanced oxidation or ultra violet light processes to treat wastewater. Applying water onsite for non-potable uses, such as landscaping, toilets and re-circulating the water used by cooling towers, x-ray machines, and other industrial processes, are potentially one of the most important ways to increase water conservation significantly by the business and commercial sector.

While the use of centralized water recycling has already begun at golf courses, power plant cooling towers and some large CII facilities, it is costly due to the need to lay a separate network of pipes to carry the recycled water to the use location. We estimate that by 2020 large businesses and commercial locations using at least 15% of the 1,227,500 AF/yr that is used indoors in the CII sector (after giving effect to estimated indoor conservation of 672,500 AF/yr)[52] will deploy onsite recycling solutions, and that they will obtain an average of 50% water savings per user, for aggregate savings of at least 92,000 AF/yr.

5.0 Summary

Proven and emerging solutions for water efficiency can save the state of California approximately 5.2 MAF of water each year—saving both valuable water and reducing GHG by approximately 5.35 MMTCO2E per year. In addition, direct reductions of 880,037,000 kWh of electricity and 248 million therms of natural gas per year save approximately 331,000 and 1.3 million MTCO2E per year, respectively, for aggregate water-related energy savings of approximately 7 MMTCO2E per year.

Water Use Assumption Comment

For purposes of this report, we have assumed that approximately 7 MAF of water is used in the urban environment. This amount of water use was determined in Pacific Institute's 2003 comprehensive study *Waste Not, Want Not: The Potential for Urban Water Conservation in California* that included extensive primary research; however, a more recent estimate by the CDWR estimates that approximately 9 MAF is used in the urban environment.[53] If the CDWR water use numbers are used, then it is reasonable to conclude that our estimated water savings should be increased by approximately 22%. In addition, we do not include any provision for increased water use due to growth in population or commercial and industrial activity, whereas CRWR assumes significant increased water use by 2020 due to population growth and increased commercial and industrial activity.

ENDNOTES

[1] Overall energy to distribute, process, heat and treat water is estimated at 48,000 GWh (Giga watt hours), 2,375 MTh (million therms) and 100 million gallons of diesel fuel. See California Energy Commision (CEC), 2005 Integrated Energy Policy Report, CEC-100-2005-007CMF, Sacramento, November 2005, pg. 150, (**hereinafter cited as IEPR-2005**); CEC, *California's Water-Energy Relationship*, Final Staff Report prepared in support of IEPR-2005, CEC-700--2005-011-SF, Sacramento, November 2005 (**hereinafter cited as CEC-2005**); and Wolff, G. and Wilkinson, R., *Statewide Assessment of Water-Related Energy Use*, The Pacific Institute and The Water Policy Program at UCSB, prepared for the CEC PIER Program, draft report dated June 2006, pg. 8 (**hereinafter cited as Wolff-2006**).

[2] The California Climate Action Team created by Governor Scharzenegger and lead by Cal-EPA Secretary estimates that each MWh of electricity is approximately equivalent to .345 MMTCO2E, based on average electricity generation across California. Economics Subgroup Climate Action Team, *Updated Macroeconomics Analysis of Climate Strategies Presented in the March 2006 Climate Action Team Report*. Final Report, October 2007, p.13. (**hereinafter cited as CAT-2007**). When burned, natural gas emits 116.73 lbs of CO2 per MMBTU, resulting in approximately 189 million therms of natural gas for each MMTCO2E.CAT-2007, p.13. Wolff-2006, p.11 estimates that an average of 1.03 MMTCO2E is reduced for each statewide average million acre foot of water that is conserved.

[3] Current water use in California is approximately 43 million acre feet (MAF). See California Department of Water Resources (CDWR). Bulletin 160-05. *California Water Plan, Update 2005*. Volume 1, Chapter 3, pg. 3-9 (**hereinafter cited as CDWR-160-05**).
One acre-foot is equal to 435.6 hundred cubic feet (ccf), or 325,851 gallons. Each reference to AF refers to acre feet of water.

[4] This estimate asumes a base level of indoor residential conservation of 893,000 AF/yr, as estmated by Gleick, P., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G., Cushing, K., Mann, A., *"Waste Not Want Not: The Potential for Urban Water Conservation in California", The* Pacific Institute, Oakland, November 2003, p. 40. (**hereinafter cited as WNWN**). This report differs from WNWN in that (1) we assume an installed base of approximately 26.5 million toilets, as described in J. Koeller, Koeller and Associates, *High-Efficiency Plumbing Fixtures, Toilets and Urinals*, Nov. 2005, pp. 6-9 (**hereinafter cited as Koeller-2005**), (as compared to the WNWN estimate of an installed base of 34.4 million toilets), (2) whereas WNWN assumes that 100% of new toilets will be 1.6 gpf toilets, we assume a combination of standard non-efficient toilets (greater than 1.6 gpf), 1.6 gpf toilets, 1.28 gpf HETs, .5-1.0 gpf pressure-assisted models and 0.8-1.6 dual flush models, as described in Koeller-2006 pp12-14, and (3) instead of assuming that no savings are available from faucet-related conservation, we assume conservation programs targeted at reducing faucet waste can achieve 20% savings (84,000 AF/yr) of the 423,000 AF/yr faucet usage estimated in WNWN p. 5.

[5]WNWN, p.7.

[6] For outdoor conservation in the Commericial, Industrial and Institutional (CII) sector, we rely on WNWN, Appendix D, pp. 10-11, table D-17, which estimates that 615,000 AF/yr is used for CII landscape irrigation with a potential savings of 50%, or 307,500 AF/yr. For indoor conservation in the CII sector, we rely on WNWN p. 89, but we differ from WNWN because we assume that all new toilets are HET models with an average 1.0 gpf (rather than 100% 1.6 gpf models), that all new urinals are 0.26 gpf HEU models (rather than 1.0 gpf models) and that by 2020 all existing non-efficent toilets (using more than 1.6 gpf) are replaced by 1.0 gpf HETs, and all existing non-efficient urinals are replaced by 0.26 HEU models. See Koeller-2005, pp.14-17. After giving effect to Koeller's analysis, we estimate approximately 673,000 AF/yr can be conserved indoors in the CII sector, whereas WNWN estimates 668,000 AF/yr of savings.

[7] This estimate assumes 12% savings (in excess of all other urban savings described in this report) for urban users who adopt tiered pricing. See WNWN, pp. 74-75.

[8] This estimate represents the economic potential savings reported by Fred Coito and Mike Rufo, KEMA-Xenergy, Inc. for PG&E, "*California Statewide Residential Sector Energy Efficiency Potential Study*" Section 9.3.2, Table 9.2, April 2003, and "*California Statewide Commercial Sector Energy Efficiency Potential Study*", May 2003.

[9] Actual NRW losses cannot be eliminated entirely; however, they can be significantly reduced, as evidenced in both Singapore and the South Nevada Water Authority (SNWA). See <www.snwa.com> for a detailed example of how to reduce NRW losses in a well-maintained and well-managed system. Each of Singapore and SNWA lowered their NRW to 6%. We assume that California can reduce its urban NRW losses from 10% to 8% of urban water, resulting in an overall savings of 2% of California's urban NRW.

[10] CDWR, Recycled Water Task Force. *Water Recycling 2030: Recommendations of California's Recycled Water Task Force*. Sacramento. June 2003. p.14. (**hereinafter cited as CDWR-2003**). http://www.owue.water.ca.gov/recycle/docs/TaskForceReport.htm.
[11] Simons, G. and Zhang, J., "*Distributed Generation From Biogas in California"* presented at the Interconnecting Distributed Generation Conference. CEC. March 2001, slide 13. (**hereinafter cited as Simons/Zhang-2001**).
[12] This assumes that users of 20% of agricultural water who do not curently use drip irrigation (34.2 MAF less 12 MAF, or 35%) will deploy drip by 2020 and save at least 30% of the water used prior to such deployment, thereby generating 6 percent overall savings on the 22.2 MAF of agricultural water that is not currently subject to drip irrigation.
[13] Electric Power Research Institute, Summary Report for CEC Energy Efficiency Studies, Palo Alto, 2001 (**hereinafter cited as EPRI-2001**). See also CEC-2005, p.32.
[14] This estimate assumes that users of 20% of CII and Residential outdoor water implement one or more Smart Water Application Technologies (SWAT) by 2020 to gain 20% water conservation above other efforts. SWAT solutions include commerically available soil moisture and rain sensors, where water savings with good turfgrass quality range from 11% to 28% and evapotranspiration controllers, where savings range from 36% to 59%. See Shedd, M., Dukes, M. and Miller, G. *Evaluation of Evapotranspiration and Soil Moisture-based Irrigation Control on Turfgrass.* Paper presented at ASCE EWRI World Environmental & Water Resources Congress. Tampa, Florida. May 2007. P.1 (**hereinafter cited as Shedd-SWAT-2007**).
[15]This estimate assumes that users of 15% of the indoor water used in the CII sector (estimated by WNWN to be 1,900,000 AF/yr) less savings of 672,500 AF/yr from indoor conservation) will adopt on-site wastewater recycling and obtain 50% conservation by reusing such recycled water for irrigation, toilet water and selected industrial uses.
[16] Based on an estimated average statewide energy intensity of water of approximately 9,750 kWh and 3,500 kWh per million gallons for average statewide urban and agricultural water use, respectively. Actual energy savings depend on the mix of water use between Northern and Southern California, and between indoor and outdoor use, as illustrated in the Table in the next footnote.
[17] CDWR 160-05, p. 3-9**.**
[18] The following table illustrates the average energy-intensity of water in Northern and Southern California (excluding any heating, pressurization or treatment of water by an end user):

Table ES-1. Recommended revised water-energy proxies

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

Navigant Consulting, Inc. *Refining Estimates of Water Related Energy Use in California*, Prepared for the CEC PIER Program, CEC-500-2006-118, December 2006, p. 3. <http://www.energy.ca.gov/2006 publications/CEC-500-2006-118.pdf> (**hereinafter referred to as Navigant-2006**). Southern California depends heavily on water imports from the Colorado River and Northern California. This water travels hundreds of miles through pipelines and aqueducts and, in some places, must be pumped over mountain ranges before reaching its destination. Conversely, 40 percent of Northern California's population is served largely by gravity-fed systems.
[19] WNWN p. 40. WNWN also concludes that indoor residential water use breaks down as follows: toilets 32%, showers 22%, washing machines 14%, dishwashers 1%, leaks 12% and faucet, 19%. Ibid. p. 26
[20] Koeller-2005, p. 7.
[21] Ibid.
[22] Ibid. p. 14. WNWN p. 40 assumes that 420,000 AF/yr could be saved by replacing installed toilets with 1.6 gpf toilets. A new 1.28 gpf standard has been established in California and both 1.0 gpf pressure-assisted and 0.8-1.6 gpf dual flush models have entered the market. See fn. 4 above for an analysis of how our estimate differs from WNWN with respect to the installed base of toiilets.
[23] WNWN p. 58 acknowledges that technological options, combined with changes in user behavior patterns, have the potential to significantly reduce faucet water use over time; however, WNWN decides not to attribute any potential savings in the area of faucet use. This estimate assumes that it is possible reduce faucet use by 20% (of the 432,000 AF/yr that WNWN p. 38 attributes to faucet use) through well designed public campaigns to reduce faucet waste. The success of trash recycling programs illustrates the potential for educating the public about the energy intensity of water and the ability to conserve it.
[24] Ibid. p. 7 and Wolff, G., Cohen, R., Nelson, B. *Energy Down the Drain: The Hidden Cost of California Water Supply*. The Pacific Institute and National Resources Defense Council. Oakland. August 2004, p.14. (**hereinafter cited as DTD-2004**). Successful models for outdoor water conservation initiatives include those in Las Vegas: <http://www.snwa.com/html/cons_waterfacts_consumptive.html>.
[25] WNWN, p. 89.
[26] Ibid, p. 81.

[27] This estimate assumies that all installed non-efficient toilets and urinals are replaced by 2020 with HET and HEU models, using an average of 1.0 and 0.26 gpf, respectively, and all new installations are these HETs and HEUs, resulting savings of 34,000 AF/yr for toilets and 25,000 AF/yr for urinals. Koeller- 2005, pp.16-17, as compared to WNWN's conclusion of savings of 43,700 AF/yr from toilets and 9,700 AF/yr from urinals, WNWN Appendix D, Table D-9, p. 7.

[28] Olmstead, S., Hanemann, W. and Stavins, R. *Does Price Structure Matter? Household Water Demand Under Increasing-Block and Uniform Price*, Working Paper, New Haven Ct, Yale University. March 2003; Gleick, P., Loh, P., Gomez, S., and Morrison, J. *California Water 2020: A Sustainable Vision*, Web-published May 2005, originally published May 1995, chapters 5-9 (**hereinafter cited as Gleick-2020**); A&N Technical Services, Inc. *Designing, Evaluating, and Implementing Conservation Rate Structures* for California Urban Water Conservation Council (CUWCC). September 1994; Dziegielewski, B., Opitz, E., Hanemann, M., and Mitchell, D. *Setting Urban Water Rates for Efficiency and Conservation*. 1995. <h2opolicycenter.org/pdf_documents/water_workingpapers/2005-002>.; Mitchell, D. and Hanemann, M. *Setting Urban Water Rates for Efficiency and Conservation* for CUWCC. July 1997; and CDWR, 160-2005.

[29] The estimated 12% savings is based on WNWN, pgs 74-75.

[30] This estimate represents the economic potential savings assessed in reports by Coito, F. and Rufo, M., KEMA-Xenergy, Inc. for PG&E, "*California Statewide Residential Sector Energy Efficiency Potential Study*" Section 9.3.2, Table 9.2, April 2003, and "*California Statewide Commercial Sector Energy Efficiency Potential Study*", May 2003.

[31] Lambert, A. "*Best Practice Performance Indicators for Non-Revenue Water and Water Loss Components: A Practical Approach*," IWA Water 21 Journal 2004. (Note: IWA Task Force recommended that use of the term 'Unaccounted for Water' be discontinued.

[32] CDWR Website, *Frequently Asked Questions: Leaks http://www.owue.water.ca.gov/leak/faq/faq.cfm.*

[33] See www.snwa.com.

[34] CDWR-2003, p.12. The midrange of CDWR's estimated potential centralized recycled water use by 2020 is 1.5 MAF/yr, including 500,000 AF/yr that is currently recycled. Ibid, p.14.

[35] Ibid, pp. 5, 14-15. DTD p. 14.

[36]Itron and CH2MHill, *Commerce Energy Biogas/PV Mini-Grid Renewable Resources Program 1.1 Program Planning and Analysis,* PIER Final Report, prepared for the CEC, January 2007, CEC 500-2007-007, p. 3-9. Mean, E., Water and Wastewater Industry Energy Efficiency: A Research Roadmap, published by ECE and AWWA Research Foundation, 2004. P. 35. (**hereinafter cited as Mean-2004**).

[37] Simons/Zhang-2001.

[38] IEPR-2005, page 149.

[39] CDWR, 160-2005, p. 3-9.

[40] Symposium at Johns Hopkins University, *The Coming Water Crisis*. 1999***, (***http://www.infoforhealth.org/pr/m14/m14bib.shtml#139).

[41] Pacific Institute, *Water Management: Soft Water Paths*, Nature Magazine, 25 July 2002 **(hereinafter cited as Pacific Institute-Nature Magazine-2002).** <http://www.pacinst.org/topics/water_and_sustainability/soft_path/nature.html>.

[42] Testimony of H. Cooley, before the House Subcommittee on Water and Power: "*Extinction is not a Sustainable Water Policy: The Bay-Delta Crisis and the Implications for California Water Management,*" July 2007. p.2. <http://www.pacinst.org/publications/testimony/Cooley_DeltaHearing_7_2_07.pdf>.

[43] Pacific Institute-Nature Magazine-2002.

[44] See Fidell, M., Gleick, P., and Wong, A. "*Converting to efficient drip irrigation: Underwood Ranches and High Rise Farms*."1999. cited in Gleick, P.,Owens-Vian, L., and Wong, A., (eds). *Sustainable Use of Water: California Success Stories*. Pacific Institute. Oakland. Jan. 1999 (**hereinafter cited as Gleick-1999**).<http://www.pacinst.org/reports/sustainable_california/ca_water_success _stories.pdf>.

[45]By the mid-1990s, approximately 13 percent of California farmland was irrigated with drip systems, up from five percent in the mid-1980s. Much of this conversion occured on land planted with vine and orchard crops, and with high-valued fruit and vegetable crops. Since then, however, innovative efforts have shown that row crops not previously irrigated with drip systems can be successfully and economically converted as well, reducing applied water needs and increasing crop yield and quality. These examples show that drip technology has far greater potential for agriculture than has been realized. See Gleick-1999, p20.

[46] Mean-2004. p. 20. In 2001, the Inland Empire Utilities Agency (IEUA) upgraded the pumping systems at its Ontario, California regional wastewater treatment plant. The plant implemented a system-level project that removed eddy current clutches from many pumps and retrofitted most of the plant's pumps with high efficiency motors. This increased the efficiency of the plant's major pumping system, resulting in projected annual energy savings of 475,000 kWh, which represented 10% of the electricity used. Overall, IEUA reduced grid energy demands by up to 90 percent during peak hours and saved 2,991,980 kWh during 120 days in the summer of 2001. Whitman, E., "*Water/Wastewater Case Study: Inland Empire Utilities Agency" Flex Your Power Final Report*, December 2002. < http://www.fypower.org/pdf/RES171203_Inland_Pump_Case.>

[47] Association of California Water Agencies "*California's Energy Crisis: What it Means for Water Agencies*," December 2002. <www.acwanet.com/products/acwausa/energycrisis/whatitmeans.asp>. Mean-2004. p. 2.

[48]CEC, "*The Water-Energy Connection*." 2002 <www.energy.ca.gov/process/water/water_index.html>.

[49] EPRI-2001. See also CEC-2005, p. 32.

[50]Mean-2004. pp. 28, 35. In August 2004, East Bay Municipal Utilities District (EBMUD) installed optimization technology at its wastewater processing plants and reduced its electricity costs by 12% in its first year of operation by moving distribution pumping to lower cost tariff periods and by operating a single pump or a series of pumps at or close to their optimal efficiency points on the pump curve. Wastewater optimization technology achieves energy savings in three ways: by varying operating setpoints to accommodate the different seasonal demands; deep cycling of reservoirs with low water turnover, and using synchronized pumping in cascade systems (where fresh water is sent to terminal tanks by bypassing intermediate tanks). Kurland, A., "*Pump-Scheduling Software Helps the East Bay Municipal Utility District Lower Costs Without Compromising Water Pressure*," Water Efficiency Magazine, March/April 2007. Forester Communications. <http://www.forester.net/we_0703_delicate.html>. See also <http://www.derceto.com/cms/lib/46pdf>. Other solutions offer additional oversight and infrastructure management throughout the water delivery system. See <www.ipnp.co.il>.

[51] Shedd-SWAT-2007. See also Cardenas-Lailhacar, B. *Sensor-Based Automation of Irrigation of Bermuda Grass*, University of Florida, 2006. Pp. 9-10.

[52]Total water used in the CII sector was estimated by WNWN, p. 3, to be 2,515,000 AF/yr, including 615,000 AF/yr for use outdoors and 1,900,000 AF/yr for use indoors. After giving effect to the estimated CII indoor conservation of 672,500 AF/yr, CII indoor use would be 1,227,500 AF/yr . This estimate assumes 15% of this amount will be subject to onsite recycling by 2020.

[53] CDWR 160-05, p. 3-9**.**