National Water Research Institute

AN NWRI WHITE PAPER

Direct Potable Reuse: Benefits for Public Water Supplies, Agriculture, the Environment, and Energy Conservation

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About NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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ACRONYMS

DPR	Direct potable reuse
H_2O_2	Hydrogen peroxide
IPR	Indirect potable reuse
MWD	Metropolitan Water District of Southern California
TDS	Total dissolved solids

ABBREVIATIONS FOR UNITS OF MEASURE

ac	Acre; 43,560 ft^2 [(5,280 ft/mi)^2 × (640 ac/mi^2)]
ac-ft	Acre-foot
ft	Foot
gal/capita•d	Gallons per capita per day
gal/lb	Gallons per pound
GWh/yr	Gigawatt hour per year
ha	Hectare; ten thousand square meters (100 m × 100 m)
hm^3	Cubic hectometer; million cubic meters (100 m × 100 m × 100 m)
hm^3/d	Cubic hectometer per day; million cubic meters per day
hm^3/yr	Cubic hectometer per year; million cubic meters per year
kg	Kilogram
km	Kilometer
kWh	Kilowatt
kWh/ac-ft	Kilowatt hour per acre-foot
kWh/m^3	Kilowatt hour per cubic meter
kWh/Mgal	Kilowatt hour per million gallons
L/capita•d	Liter per capita per day
m	Meter
Mac-ft	Million acre-feet
Mac-ft/yr	Million acre-feet per year
mg/L	Milligram per liter
Mgal/d	Million gallons per day
Mgal/yr	Million gallons per year
mi	Mile
Mlb	Million pounds
m^3	Cubic meter
m^3/kg	Cubic meter per kilogram
tonne	Metric tonne (1,000 kg)
TWh/yr	Terawatt-hour per year
µm	Micrometer

1. INTRODUCTION

Direct potable reuse (DPR), in which purified municipal wastewater is introduced into a water treatment plant intake or directly into the water distribution system, is becoming an increasingly attractive alternative to developing new water sources (Tchobanoglous et al., 2011). The rationale for DPR is based on the technical ability to reliably produce purified water that meets all drinking water standards and the need to secure dependable water supplies in areas that have, or are expected to have, limited and/or highly variable sources. To meet the purification level required, wastewater treated by conventional means undergoes additional treatment steps to remove residual suspended and dissolved matter, including trace organics. Questions of public acceptance are answered, in part, by the successful incorporation of DPR in the small resort town of Cloudcroft, New Mexico; by the Colorado River Water District serving a population of 250,000 in Big Spring, Stanton, Midland, and Odessa, Texas; and by the results of a recent public acceptance survey (Macpherson and Snyder, in press).

The focus of this white paper is on the role that DPR will have in the management of water resources in the future. For example, in many parts of the world, DPR will be the most economical and reliable method of meeting future water supply needs. The topics considered in this white paper include:

- An examination of beneficial impacts of DPR.
- A case study to demonstrate the relationship between DPR and urban water supplies, agriculture, the environment, and energy conservation, based on Southern California and the California State Water Project.
- The next steps that should be taken by water agencies to prepare for DPR in the future.

2. BENEFITS OF DIRECT POTABLE REUSE

Direct potable reuse can be implemented to provide a new and stable source of water supply for cities. However, the potential benefits accrued for agriculture, environmental preservation and enhancement, and energy conservation through the application of DPR may be more important.

2.1 Benefits for Public Water Supplies

Alternative solutions to meet urban water supply requirements include the development of inter-basin water transfer systems, desalinization of brackish water and seawater, and DPR. With inter-basin transfer, the availability of water for food production is limited, source area ecosystems are often destroyed, and transmission systems are subject to damage from earthquakes, floods, and other natural and human-made disasters. With desalination, energy requirements are comparatively large and brine disposal is a serious environmental issue. By comparison, DPR will have relatively modest energy requirements and provide a stable local source of water that is less subject to natural disasters. Because the water requirements of cities are greater than wastewater discharges, DPR will not be a stand-alone water supply. However, in many cases, sustainable local sources combined with DPR will be adequate. The application of DPR to create decentralized water resource management systems will allow the use of less pumping and energy consumption – factors that will mitigate increased treatment costs.

As urban areas grow, pressure on local water supplies, particularly groundwater, will increase. At present, groundwater aquifers used by over half of the world population are being over-drafted (Brown, 2011). The attractiveness of DPR will increase as the world's population becomes increasingly urbanized and concentrated near coastlines where local water supplies are limited and brine disposal is possible (Creel, 2003).

2.2 Benefits for Agriculture

Water exported for urban use decreases its availability for food production. The present world population of 7 billion is expected to reach 9.5 billion by 2050 (U.S. Census Bureau, 2011). A pattern of increased incorporation of animal and dairy products into the diet as people become more affluent and the need to protect aquatic ecosystems provide additional demands on the available water in source regions. The impact of diet on water use is demonstrated by the following statistics (Pimentel and Pimentel, 2003):

- Beef requires 12,000 gallons per pound (gal/lb) [100 cubic meters per kilogram (m^3/kg)] of water.
- Soybeans require 240 gal/lb (2.0 m^3/kg) of water.
- Wheat requires 110 gal/lb (0.90 m^3/kg) of water.

Municipal wastewater generation in the United States averages approximately 75 gallons per capita per day (gal/capita•d) [280 liters per capita per day (L/capita•d)] and is relatively constant throughout the year. Where collection systems are in poor condition, the wastewater generation rate may be considerably higher or lower due to infiltration/inflow or exfiltration, respectively. Thus, the potential municipal water supply offset by DPR for a community of 1-million people will be approximately 75 million gallons per day (Mgal/d) [0.28 million cubic meters per day (hm^3/d)] or 27,400 million gallons per year (Mgal/yr) [104 million cubic meters per year (hm^3/yr)]. Assuming adequate storage is available and evaporation losses are minimal, the water saved in the source region through the application of DPR by a population of 1-million people could result in the annual production of 2.3 million pounds (Mlb) (1,050 tonne) of beef, 114 Mlb (51,800 tonne) of soybeans, or 253 Mlb (115,000 tonne) of wheat. Given losses at various points in the system, the actual available water would most likely be about 50 percent of the potential value, but resulting agricultural production would still be impressive.

2.3 Benefits for the Environment

The elimination or minimization of water importation to cities through inter-basin transfers will reduce environmental impacts resulting from the construction of reservoirs and canals. A classic example of an environmental impact resulting from inter-basin transfers is the purchase of land and water rights in the Owens Valley, which is east of the Sierra Nevada, by the City of Los Angeles in the early twentieth century (Los Angeles Department of Water and Power, 2004). The City constructed reservoirs and the 233 mile (mi) [375 kilometer (km)] Los Angeles Aqueduct that stripped the valley of water for farming and cut off water to Owens Lake. Agriculture in the Owens Valley was decimated. Owens Lake dried up and became a major source of airborne particulate matter. In fact, dust emission from the dry lakebed is the nation’s largest source of particles less than 10 micrometer (μm) in size and accounts for approximately 6 percent of all dust generation in the United States (Gill and Cahill, 1992; U.S. Environmental Protection Agency, 2004). Extension of the aqueduct into the Mono Lake watershed in 1941 resulted in the loss of 31 percent of the lake volume over the following 40 years. Suits by local governments and environmental groups have resulted in decreases in water imports by the City, a significant rise in the water level of Mono Lake, and a plan to manage dust emissions from Owens Lake.

2.4 Reduced Energy for Pumping Water

Inter-basin transfers of water often require large expenditures of energy to pump water over the mountain ranges separating and defining the basins. As a gravity flow system, the Los Angeles Aqueduct is somewhat of an exception to the general rule. However, the much larger Colorado River Aqueduct constructed in the 1930s by the Metropolitan Water District of Southern California (MWD) is an example of the amount of energy often required to import water to urban regions (Wilkinson, 2007). To bring 1.2 million acre-feet per year (Mac-ft/yr) (1,500 hm^3/yr) of water from the Colorado River to Southern California requires lifting water 1,616 feet (ft) [493 meters (m)] and a net power input of 2,400 gigawatt hours per year (GWh/yr) [2,000 kilowatt hours per acre-feet (kWh/ac-ft), 1.6 kilowatt hours per cubic meter (kWh/m^3)], not including the energy and materials required to construct and maintain the 242 mi (387 km) aqueduct consisting of 63 mi (101 km) of canals, 92 mi (147 km) of tunnels, and 84 mi (134 km) of pipes and siphons (Wilkinson, 2007).

3. SOUTHERN CALIFORNIA – AN EXAMPLE

Using a portion of the treated wastewater now being discharged to the Pacific Ocean through the application of DPR could stabilize the water supplies for both Southern California and San Joaquin Valley agriculture, significantly decrease the energy required for transporting water, protect and enhance the ecosystems of the Sacramento-San Joaquin Delta, and decrease the pollution of near shore waters and beaches in Southern California.

3.1 Current Southern California Water Supply

Four counties in Southern California (Los Angeles, Orange, Riverside, and San Diego) import the major portion of their water from Northern California through the State Water Project, the Colorado River, and the Owens Valley. With the exception of the portion from the Owens Valley, water importation is managed by MWD. Estimated average daily use in the four counties is 3,110 Mgal/d (3.48 Mac-ft/yr; 4,290 hm^3/yr), as shown in Table 1. The California State Water Project has a projected supply of over 4.0 Mac-ft/yr (4,900 hm^3/yr). A maximum allotment of 2.56 Mac-ft/yr (3,160 hm^3/yr) is contracted to Southern California water agencies, of which 2.01 Mac-ft/yr (2,480 hm^3/yr) is allotted to MWD. Water districts in the San Joaquin Valley have a maximum allotment of 1.20 Mac-ft/yr (1,480 hm^3/yr), with 83 percent allotted to the Kern County Water Agency. Nearly all of the water allotted to districts in the San Joaquin Valley is used for agriculture.

Table 1: Estimated Freshwater Use by Public Systems in Four Southern California Counties in 2005[a]

Item	Los Angeles	Orange	San Diego	Riverside
Population (1,000s)	9,935	2,988	2,933	1,946
Water Use by County (Mgal/d[b])				
Groundwater	331	49	75	86
Surface Water[c]	1,529	335	356	349
Total	1,860	384	431	435

[a] Adapted from U.S. Geological Survey (2005).

[b] 264 Mgal/d = 1 hm^3/d.

[c] Nearly all imported through inter-basin transfers.

"Maximum" is a key word in describing the distribution of State Project water. Since 2000, the allocations have averaged 69 percent of the maximum value, with average values for MWD and the San Joaquin Valley water districts being 1.35 and 0.83 Mac-ft/yr (1,670 and 1,020 hm^3/yr), respectively, as reported in Table 2. Southern California has responded to water supply limitations through water use restrictions, increased emphasis on conservation, and new water recycling projects emphasizing groundwater recharge. Water limitations to the San Joaquin

Valley water districts have been responded to, in part, by improved irrigation management and planting crops that have low water requirements, but the principal response is to reduce cultivated land.

Table 2: State Water Project Allocations to MWD and San Joaquin Valley Water Districts[a]

Year	Total All Contractors (Mac-ft/yr[b])	Percent of Capacity	MWD (Mac-ft/yr[b])	San Joaquin Valley (Mac-ft/yr[b])
Maximum	4.13	100	2.01	1.20
2011	3.34	80	1.53	0.91
2010	1.88	50	0.96	0.57
2009	1.67	40	0.76	0.47
2008	2.46	35	0.67	0.41
2007	2.47	60	1.21	0.72
2006	4.13	100	1.91	1.17
2005	3.71	90	1.72	1.05
2004	2.68	65	1.31	0.77
2003	3.71	90	1.81	1.08
2002	2.89	70	1.41	0.84
2001	1.61	39	0.78	0.47
2000	3.41	83	1.51	1.10
Average	2.93	69	1.35	0.83

[a] Adapted from California Department of Water Resources (2011).

[b] 1 Mac-ft/yr = 1,233 hm^3/yr.

The predicted impacts of climate change on water supplies in California include an overall decrease in annual precipitation, greater year-to-year variability, larger storms, and longer droughts. Thus, the variation in future allocations from the State Water Project is likely to become greater than those experienced since 2000.

3.2 Value of Agriculture in the San Joaquin Valley

The San Joaquin Valley of California is the most productive agricultural region in the world, but depends almost completely on irrigation because of limited annual precipitation extending from May through October. The value of agriculture in the valley will increase as global population increases and crops suitable for energy production are grown. The principal crops include a wide range of vegetables, grapes, melons, nuts, and stone fruits, many of which are grown almost exclusively in the valley, as shown in Table 3. Although a small portion of the total U.S. cotton crop, 90 percent of the nation's long fiber Pima cotton is grown in the valley (Starrs and Goin, 2010). Similarly, hay production is a small portion of the national crop, but is used locally for the large dairy herds in the valley that make California the leading producer of milk and cheese in the U.S. Although not usually recognized as a wine producing region, approximately 380,000 acres (ac) (150,000 hectares [ha]) of the State's 535,000 ac (217,000 ha) of wine grapes are grown in the Central Valley.

Table 3: Data for Selected California Crops Produced Principally in the Central Valley in 2008[a]

Crop	Percentage of U.S. Commercial Crop	Area Planted (ac[b])	Dollar Value	Approximate Annual Water Requirement (ft[b])
Almonds	99	680,000	2,400,000,000	4.3
Walnuts	99	218,000	750,000,000	3.3
Pistachios	96	150,000	600,000,000	3.5
Peaches	70	55,000	498,000,000	3.5
Nectarines	98	31,000	284,000,000	2.8
Pears	29	14,000	106,000,000	2.8
Apricots	95	24,100	35,000000	2.9
Plums	99	102,000	218,000,000	2.9
Oranges	30	184,000	1,100,000,000	3.9
Mandarins[c]	37	16,000	77,152,000	3.9
Grapes	91	590,000[d]	4,000,000,000	3.0
Cantaloupe	55	46,000	150,000,000	2.5
Tomatoes-processing[e]	95	276,000	812,000,000	2.1
Hay	6	570,000	1,400,000,000	4.0
Cotton	8	268,000	326,000,000	2.4

[a] Adapted from Starrs and Goin (2010).
[b] 2.47 ac = 1 ha; 3.28 ft = 1 m.
[c] California Fruit and Nut Review (2008).
[d] Central Valley only.
[e] California Processing Tomato Report (2008).

3.3 Potential for DPR in Southern California

Treated wastewater in the four Southern California counties is recycled for urban applications, used to recharge groundwater, or discharged to the Pacific Ocean. The greatest fraction of municipal wastewater is conveyed to treatment plants near the coast and discharged into the

Pacific Ocean through long ocean outfalls. Ocean discharge, comprising the most available source water for DPR, averages 1,259 Mgal/d [1.410 Mac-ft/yr (1,739 hm^3/yr)], as reported in Table 4. Purified water used for groundwater recharge is primarily from the upper reaches of the drainage basins and must be treated at least to the tertiary level. A significant portion of the wastewater is not used for recharge because of high salt concentrations.

Table 4: Quantities of Municipal Wastewater Discharged to the Pacific Ocean and Recycled in Southern California[a]

Drainage Basin	Quantity (Mgal/d[b])	
	Ocean	**Recycled**
Los Angeles	696	206
Santa Ana	246	44
San Diego	317	37
Total	1,259	287

[a] Adapted from Heal The Ocean (2010).
[b] 264 Mgal/d = 1 hm^3/d.

A model for potable reuse has been provided by the Orange County Water District, which operates a 70 Mgal/d (0.26 hm^3/d) advanced treatment facility purifying wastewater to drinking water standards and beyond (Orange County Water District, 2011). About half of the water is used for indirect potable reuse (IPR) through surface infiltration to the aquifer with an approximate residence time of 6 months, and the other half is used for injection wells to prevent seawater intrusion into coastal aquifers. It should be noted that the quality of purified water is reduced when it is blended into groundwater aquifers due to the presence of groundwater constituents.

Water Quantity: Treating a significant fraction of the wastewater now being discharged to the ocean to drinking water standards and introducing DPR will stabilize the water supply in Southern California. For example, using one-half the volume now discharged to the ocean [0.70 Mac-ft/yr (860 hm^3/yr)], would make up the difference between the average water allotment since the year 2000 and maximum State Water Project. Further, in the event that the delivery of State Water Project water to Southern California was interrupted due to an unforeseen event, such as a natural or human-made disaster, a substantial local water supply would still be available.

Water Quality: Improvement in Southern California water quality is an added benefit of DPR. State Project and Colorado River water have total dissolved solids (TDS) concentrations of approximately 300 and 650 milligrams per liter (mg/L), respectively, and contain trace organic compounds from agricultural runoff and upstream cities, most notably Las Vegas, Sacramento, and Stockton (Metropolitan Water District of Southern California, 2010, 2011a). Water leaving the DPR treatment facilities will have a TDS concentration of about 50 mg/L after mineral addition to provide chemical stabilization.

Cost of DPR: The Orange County Water District obtains treated wastewater from the Orange County Sanitation District (Orange County Water District, 2011). The treatment steps include microfiltration, reverse osmosis, and advanced oxidation with ultraviolet light and hydrogen peroxide (H_2O_2), and combined chlorine disinfection. The total capital and operating costs of treatment for the 2009-2010 fiscal year was \$747/acre-foot (ac-ft) [\$0.61/cubic meter (m^3)]. For comparison, MWD sells treated potable water for \$742/ac-ft (\$0.60/m^3) and untreated water for \$527/ac-ft (\$0.43/m^3), with increases to 794 and \$560/ac-ft (0.64 and \$0.45/m^3), respectively, starting in January 1, 2012 (Metropolitan Water District of Southern California, 2011b).

The Value of Water: In addition to the above considerations, the value of the purified water relative to other water sources must also be considered in assessing the potential of DPR. Such an assessment is of importance in light of recent court decisions regarding the allocation of water from Northern California and from the Colorado River to Southern California. Based on an analysis by the California Department of Water Resources, the cost of developing additional water supply in Southern California ranges from about 1,000 to \$10,000/ac-ft (0.81 to \$8.10/m^3) for alternatives such as desalination, water storage, and water conservation; municipal water reuse projects were identified as the least-cost, highest-gain option for long-term water supply reliability (Legislative Analyst's Office, 2008). A marginal cost analysis would be needed to assess the potential value of DPR as a water source.

3.4 Stabilization of the San Joaquin Valley Water Districts' Supply

The production of 0.70 Mac-ft/yr (860 hm^3/yr) of potable water through DPR in Southern California would make the same volume available to San Joaquin Valley water districts on a reliable basis. In low precipitation years, such as 2008, when allotments were 35 percent of the maximum, the districts could receive close to a full allotment [0.40 + 0.70 Mac-ft (490 + 860 hm^3)]. In years with more precipitation, the excess water could be used for other purposes, such as increasing farmed acreage, enhancement of the Sacramento-San Joaquin Delta, increasing storage volume, or groundwater recharge in the Central Valley. Water made available in the San Joaquin Valley through DPR in Southern California does not need to be treated before use in irrigation.

The decision of how the water made available would be allocated will be difficult because of the number of stakeholders involved. Farmers, environmentalists, and water districts in the San Francisco Bay area and originating areas north of Sacramento, as well as Southern California water districts, will become involved.

3.5 Environmental Enhancement

Instituting DPR in Southern California could greatly decrease environmental stress on the Sacramento-San Joaquin Delta. The State Water Project was highly controversial because of the environmental impacts foreseen and because water originating north of Sacramento was being transferred to the San Joaquin Valley and, more significantly, to Southern California. The initial phase of the California State Water Project, comprising 34 reservoirs and dams and 700 mi (1,120 km) of canals and pipelines, was completed in 1973. Since 1973, some additional phases have been completed, such as the 100 mi (160 km) coastal branch conveying water to San Luis

Obispo and Santa Barbara Counties. However, what remains unresolved is how best to convey water through or around the Sacramento-San Joaquin Delta.

The protection of endangered species, notably Delta smelt and winter-run salmon, and preventing salinity intrusion that impacts both the Delta ecosystems and water quality of communities in the East Bay and of water entering the California Aqueduct at the south end of the Delta, have resulted in a political stalemate for nearly 40 years. Numerous studies have been conducted and solutions proposed that address the environmental issues of the Delta. Each proposed solution has been attacked by one or more of the stakeholders – Delta environmental groups, Delta and East Bay water districts, MWD, and the San Joaquin Valley water districts receiving State Project water. A reliable source of 0.70 Mac-ft/yr (860 hm^3/yr) produced by application of DPR (which is 17 percent of the maximum annual yield of the State Water Project) could address most of the concerns, if political agreement can be reached.

3.6 Energy Conservation

At present, 19 percent of the electric power consumption in California is used to transport water (California Energy Commission, 2005). Consumption for urban water use, including wastewater treatment, is approximately 3,800 kilowatt hours per million gallons (kWh/Mgal) [1,200 kWh/ac-ft (1.0 kWh/m^3)], excluding conveyance. Importing water to Southern California requires an additional 8,750 kWh/Mgal [2,850 kWh/ac-ft (2.31 kWh/m^3)], as reported in Table 5.

Table 5: Electric Power Consumption in Typical Urban Water Systems[a]

Use	**Power Consumption (kWh/Mgal**[b]**)**	
	Northern California	**Southern California**
Supply and Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700

[a] Adapted from California Energy Commission (2005).
[b] 3785 kWh/Mgal = 1 kWh/m^3.

The energy required for the production of purified water will vary from 3,800 to 5,700 kWh/Mgal [1,200 to 1,900 kWh/ac-ft (1.0 to 1.5 kWh/m^3)] beyond secondary treatment, depending on the wastewater total dissolved solids (i.e., about 500 to 1,000 mg/L). For comparison, desalination of seawater requires 13,000 to 15,000 kWh/Mgal [4,200 to 4,900 kWh/ac-ft (3.4 to 4.0 kWh/m^3)]. The potential net energy savings in Southern California of developing 0.70 Mac-ft/yr (860 hm^3/yr) of purified water by DPR can be computed as the energy savings for supply/conveyance [estimated to be 8,750 kWh/Mgal (2.31 kWh/m^3)] reduced by the energy input required for the purification process [estimated to range from 3,800 to 5,700 kWh/Mgal (1.0 to 1.5 kWh/m^3)]. Thus, the estimated net energy savings ranges from 3,000 to 5,000 kWh/Mgal (0.8 to 1.3 kWh/m^3), or 0.7 to 1 terawatt-hours per year (TWh/yr). At \$0.075/kWh, the savings would be 50 to \$87 million per year.

4. IMPLICATIONS OF FINDINGS AND NEXT STEPS

DPR is a technically feasible method of stabilizing water supplies for municipalities and agriculture; preventing, minimizing, or correcting environmental damage resulting from inter-basin water transfers; and conserving energy. However, the application of DPR on a large scale, such as in Southern California, will raise significant political issues related to the ownership of water that will need to be resolved.

Given appropriate terminology and context, there is strong support for DPR based on the findings from a recently completed study of public attitudes (Macpherson and Synder, in press). Based on this finding, it is clear that the water and wastewater industry should undertake an initiative to develop a planning process to examine the potential of DPR and impediments to its implementation.

One of the major steps that should be taken by the water and wastewater industry is to develop closer ties with respect to the management of available water resources. As water distribution system modifications and replacements are planned and implemented, attention should be focused on appropriate locations within an existing system where engineered storage buffers or water purification plants can be located (e.g., near existing water treatment plants or other suitable locations within the service area). Studies should be undertaken to assess what blending ratios would be acceptable with the existing water supply to protect public health, maintain water quality, and control corrosion.

For example, conventional wastewater treatment systems will need to be designed or modified to optimize overall performance and enhance the reliability of the DPR water purification system. Measures that can be undertaken to enhance the reliability of a DPR system include: enhanced (targeted) source control programs, enhanced physical screening, upstream flow equalization, elimination of untreated return flows, modifying the mode of operation of biological treatment processes, improved performance monitoring systems, and the use of pilot test facilities for the ongoing evaluation of new technologies and process modifications (Tchobanoglous et al., 2011).

5. SUMMARY

As a result of worldwide population growth, urbanization, and climate change, public water supplies are becoming stressed and tapping new water supplies for metropolitan areas is becoming more difficult, if not impossible. In the future, it is anticipated that DPR will become an imperative (Leverenz et al., 2011). When compared with other options, water reuse is the most cost-effective approach to long-term water supply sustainability. The case study of Southern California illustrates the potential impact of DPR: stabilization of water supplies for a large urban population and a major agricultural region and energy savings ranging from 0.7 to 1 TWh/yr, roughly a savings of $50 to $87 million per year. Thus, the steps that will be necessary to make DPR a reality and the elements of an implementation plan should be identified. Starting the planning process now will allow for early identification of the changes required to both the water and wastewater infrastructure to accommodate DPR. These findings are applicable not only in California, but also worldwide.

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