Urban Recycled Water Use in California:

A Briefing Paper on Status, Opportunities for Expansion, and the Environmental Health Benefits

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Spring 2015

LOS ANGELES SUSTAINABILITY COLLABORATIVE

About the Los Angeles Sustainability Collaborative

The Los Angeles Sustainability Collaborative (LASC) is dedicated to creating a more sustainable Los Angeles by facilitating collaborative research, providing solutions to emerging environmental challenges and educating stakeholders. LASC seeks to achieve this mission by 1) collaborating with other non-profit organizations and academic institutions to identify research needs on key environmental issues, 2) funding research projects conducted by emerging environmental leaders at the university level and 3) sharing research findings to community, policy and business stakeholders.

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Acknowledgments

The author thanks the Los Angeles Sustainability Collaborative for their generous support for completing this project, specifically Colleen Callahan for her guidance and feedback, and Nora Hakkakzadeh for her help and coordination. Additionally, Jim Crook and Elise Goldman for their advice, expertise and guidance in writing the report.

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1. Executive Summary

California is currently facing its most severe drought of the past 50 years. Reliance on imported water is not sustainable; a more holistic approach is needed to maintain enough water for California's growing population and economy. Water recycling is an important part of the solution and can replace potable water usage and offer resource and financial savings. Water recycling means reusing treated wastewater for beneficial purposes such as landscape irrigation, industrial processes, toilet and urinal flushing, and ground water basin replenishment (referred to as ground water recharge)[1]. Wastewater treatment can be tailored to meet the water quality requirements of a planned reuse.

Implementation of recycled water systems, both for potable and non-potable uses, have been very successful both inside and outside the United States, yet are not as prevalent in California they could be. Historically, recycled water programs have been limited in part due to health-related public perception barriers. However, new financial resources, technological advancements, and improved public awareness and acceptance now underscore California's current opportunity to expand water recycling as part of a comprehensive strategy to ensure greater water supply resiliency and to provide environmental health benefits.

In this policy brief, we evaluate the health impacts of two recycled water methods that could be expanded in response to California's drought: (1) potable reuse and (2) non-potable reuse. The focus is on recycled water for urban applications, which have historically faced some opposition on health-related grounds. This brief will dispel some health-related misconceptions by describing how the expansion of urban recycled water use in California could have a net positive impact on public health.

Overarching recommendation: This report describes the benefits of expanding recycled water use and infrastructure and recommends that state and local agencies prioritize the review proves to update public health restrictions on recycled water use based on newest technologies and research.

2. Introduction: California's Water Supply

California faces an unstable water future. Distributional challenges impede moving the limited water to where it is needed most. During non-drought years, the majority of California's water falls in the Northern parts of the state, yet the majority of the population resides in the Southern portion of the state. Furthermore, the infrastructure used to transport water is aging and, with a major earthquake, has the potential to sever and terminate water flow from Northern California to Southern. These problems are especially significant because California's population is projected to grow from 37 million people currently to 60 million by 2050[2,3]. A conservation method with great potential for expansion is recycled water use, especially in the urban sector.

2.1. Water Sources

California relies on water from two sources: surface water and groundwater. Most of the surface water obtained in Southern California comes from over 200 miles away, either from the Sacramento/San Joaquin Delta (State Water Project/California Aqueduct), the Colorado River (Colorado River Aqueduct), or the Los Angeles Aqueduct. One of the main problems with this imported water is that it originates as mountain snowpack, which due to drought, is shrinking from lack of consistent precipitation. Further, with the onset of climate change, any available snowpack is melting earlier than expected thus eliminating the reliability of the water source.

California relies more heavily on groundwater in drought years, yet as drought progresses, this can become problematic for the water supply. Groundwater storage accounts for roughly 30% of potable water supply, up to 60% in drought years[4]. During drought, reduced mountain snowpack and reduction in rainfall, do not provide enough water to help replenish the groundwater supply. This lack of replenishment causes a major decline in the water quality of the groundwater basins; coastal areas see an increased risk of seawater intrusion.

2.2. Health Impacts of Current Water Conditions

Continued reliance on existing water sources exacerbates water scarcity, and also perpetuates an increase of greenhouse gases from energy needed to supply the water distribution system. Greenhouse gas emissions, compounded with rising temperatures from climate change, are more harmful because heat catalyzes the creation of secondary pollutants, leading to poorer air quality and thus increasing potential for respiratory diseases in humans.

The lack of frequent storms to recharge potable groundwater basins will affect groundwater availability during drought. Many existing groundwater basins are contaminated, and the extent of contamination worsens during drought periods. Without natural waters to recharge the basins, contaminants in the groundwater become more concentrated, and exposure to these contaminants can lead to increased rates of gastrointestinal illness and cancers. Excessive groundwater pumping and aquifer depletion can also cause land to sink, known as land subsidence, which can cause permanent loss of groundwater storage and infrastructure damage. Additionally, pumping too much groundwater invites the threat of seawater intrusion, which can severely compromise the water supply in coastal areas.

2.3. New Opportunities: California's Current Water Policies

Since 2009, California's legislature has made several significant advances towards protecting the state's water supply and promoting water conservation. In 2009, California's legislature passed the largest-to-date water legislation package in state history, which included Senate Bill x7-7 (SBx7-7). SBx7-7, a key component of the legislation, mandated a 20% reduction of urban water use in all water districts across the state by the year 2020[5,6]. While there are no mandated water conservation methods required to meet the 20% conservation goals, recycled water programs are encouraged and incentivized within the bill[5,6].

In 2014, to deal with California's prolonged drought, voters approved an even larger water legislation package, Proposition 1. Proposition 1 includes a one billion dollar bond to support California's water needs, including $725 million dollars for recycled water projects[7].

Most recently, in the spring of 2015, California Governor Jerry Brown called upon urban water suppliers to cut water use by 25% from baseline 2013 usage levels[8]. Given these urban conservation mandates and increased funding for recycled water programs, California has a tremendous opportunity to expand urban recycled water programs.

3. Background: Recycled Water

Recycled water, also known as reclaimed water or water reuse, is an umbrella term that refers to treated wastewater that is reused for beneficial purposes traditionally served with fresh, potable water.

Recycled water can be categorized into two types of use: potable reuse and non-potable reuse. Potable reuse applies water towards applications to be consumed by humans, while non-potable reuse applies recycled water towards applications that are not consumed by humans. Recycled water intended for potable reuse is treated to drinking level standards. Recycled water for non-potable reuse is water that has received a minimum secondary or tertiary treatment (as specified in California's Water Recycling Criteria) and is acceptable for many uses. While disinfected tertiary treated water is acceptable for uses that may involve human contact with the water, it does not meet drinking water standards and cannot be used for potable purposes.

There are two types of potable reuse: direct and indirect. Indirect potable reuse (IPR) is the augmentation of a drinking water source (surface water or groundwater) with recycled water followed by an environmental buffer that precedes normal drinking water treatment. Direct potable reuse (DPR) is the introduction of recycled water directly into a potable water supply distribution system downstream of a water treatment plant or into the raw water supply immediately upstream of a water treatment plant.

3.1. Status of Recycled Water in California

Recycled water use in California is quite widespread: 51 of 58 counties have recycled water programs, but their scope of these programs in many counties could be expanded greatly[1]. In 2009, wastewater treatment systems in the South Coast Basin hydrologic region (Los Angeles and surrounding areas) treated 1.5 million acre feet of wastewater[9,10]. Of this, just 176,000 acre-feet (or 11%) were allocated towards recycled water uses and 1.32 million acre feet (or 89%) were discharged into the ocean [9,10]. One acre-foot is 325,851 gallons, or the amount of water necessary to supply two families of four with water for an entire year. It is also the amount of water it would take to cover a football field with to a depth of one foot. Thus, in the South Coast Basin alone over 430 billion gallons of treated water were available for recycled water use programs in 2009 but were instead discharged into the ocean.

In the South Coast Basin, the greatest percentage of urban recycled water is used for groundwater recharge, followed by golf course irrigation, landscape irrigation and commercial and industrial applications[10]. Recycled water in the South Coast Basin also helps to supply water for wetlands and wildlife restoration. There is however significant potential to expand the scope and range of recycled water use in urban settings both in the South Coast Basin and across the state. Additional research and practice in California and other places around the world have shown that a range of urban recycled water uses are viable and can create significant water savings and protect potable, fresh water supplies. These are two examples from Southern California:

- Southern California's West Basin Municipal Water District (WBMWD), where implementation of a recycled water facility now produces over 40 million gallons of recycled water per day, conserving enough water to meet the needs of 80,000 households for a year.
  - WBMWD's recycled water program resulted in savings through replacing potable water use for large-scale turf irrigation (schools, city parks, golf courses) and a series of wells that form an extensive seawater intrusion barriers[11].

- In 2008, Orange County's Groundwater Replenishment System (GWRS) began pumping recycled water into Orange County's groundwater basin for potable use.
  - The GWRS supplies 103,000 acre-feet/year of potable water, enough to supply the water needs of 850,000 people[12].

3.2. Health-Related Barriers to Implementation

Historically, negative public perception has been one of the greatest challenges to implementing potable reuse systems. In California, some proposed potable reuse projects in recent years have not been implemented due to public concerns. Although the technologies used to treat the water for potable reuse produce water that meets or exceeds drinking water standards, the public still has trouble accepting use of recycled water for drinking purposes. The public's primary concern is that the water is unclean or tainted; the "yuck" factor of integrating treated wastewater into the water supply is real. However, studies have shown the public is more likely to accept indirect potable reuse when the treated water is placed in an environmental buffer before being introduced directly into the water supply[13].

In the early 1990s, a developing Southern California recycled water project was dubbed "toilet to tap," which has since pervaded and stymied the public discussion on expanding recycled water across California. For example, the Los Angeles Department of Water and Power planned to build a wastewater treatment plant that would eventually produce enough recycled water to serve 70,000 homes in the East San Fernando Valley and South East Los Angeles in 2000[14]. During the planning process, there was not much public engagement until the end. The lack of communication resulted in public uproar, citing the lack of information regarding the potential health risks, and thus the project was officially terminated in 2001. Conversely, in 2009, the City of San Diego launched a proposal to build an indirect potable reuse plant to provide one million gallons of recycled water for irrigation and industrial purposes. By 2013, San Diego city council unanimously approved the project largely due to the rise in public support. As a result of the city's outreach efforts, San Diegans' approval for recycled water increased from 26% in 2004 to 73% in 2012[14].

3.3. Overcoming Health-Related Barriers to Implementation

The water community, along with public health professionals, can play a critical role in promoting the health benefits of recycled water by working in close collaboration with local water districts to move these efforts forward. For instance, there is clearly a need for local health departments to help develop educational campaigns for the general public promoting appropriate use of recycled water that are both based on the latest science and are culturally sensitive. As the drought progresses, it is imperative that public perception improve as people learn more about new technologies for treating wastewater and understand it is a safe and viable way to supplement the water supply.

The following two sections provide additional details about the two main types of recycled water use – potable and non-potable -- and specific recommendations for how to expand recycled water by overcoming public health misconceptions and other barriers.

4. Findings and Recommendations #1: Direct and Indirect Potable Reuse

Potable reuse is gaining popularity across the world as a promising water conservation method. Characterized by either Indirect Potable Reuse (IPR) or Direct Potable Reuse (DPR), highly treated wastewater is purified by complete advanced treatment (CAT), which includes microfiltration/reverse osmosis plus advanced oxidation with ultraviolet, hydrogen peroxide and chlorine treatments[15]. In the case of IPR, treated water is first injected into an environmental buffer, which is a natural water body (e.g., reservoir or river) before it is reintroduced into the potable water supply. The environmental buffer acts as an additional safeguard, and is beneficial for allaying public opposition. DPR directly injects treated water into the potable water supply via an internal safeguard or engineered buffer system.

4.1. Status of Potable Reuse in California and Internationally

There are several IPR projects in California. The largest project is in Orange County, where the Orange County Water District's Groundwater Replenishment System (GWRS) treats 100 million gallons of wastewater per day to supply water needs of 850,000 people[12]. While regulated DPR does not occur in California, unplanned/"de facto" potable reuse occurs across the state[15]. For example, effluents from upstream on the Colorado River (Nevada, Utah) ultimately become potable water downstream in California. Other potential inputs to the river include agricultural runoff, urban runoff, storm water and highway runoff.

Integrating potable reuse into the water supply is a feasible method for counteracting consequences of climate change, drought and population rise. Using wastewater as the source for potable reuse allows source water to be in constant supply and thus impervious to the effects of climate change. Wastewater is a local water source and thus lessening the need for costly, energy intensive imported water. In addition to lower cost, potable reuse limits potential system interruptions, such as those from deteriorating conveyance infrastructure within California's primary imported water source, the State Water Project. These two factors render potable reuse a feasible, cost effective solution for supporting California's projected population rise from its current 37 million to 60 million people by 2050[2].

Potable reuse is gaining popularity across the world. Singapore, in particular, has emerged as a leader in the recycled water community, successfully implementing a range of sustainable recycled water use programs and facilities. Similarly to California, the need for recycled water emerged as the result of constraints on the availability of potable water. In Singapore, water scarcity is primarily due to limited ability for water storage. The country built a system that collects and treats 100% of wastewater known as NEWater[16]. Water intended for human consumption is reintegrated into the water supply using IPR, and portions for industrial reuse is reintegrated using DPR. Currently, 10 million gallons per day of advanced treated recycled water are allocated for urban uses and 50 million gallons per day are allocated for industrial and commercial uses[17]. Recycled water programs in Singapore demonstrate that sustainable water management and recycled water use in urban settings are feasible on a large scale. Furthermore, specific recycled water uses in each country could be adopted for use in urban settings in California.

Within the United States, one DPR system currently in use is demonstrating the potential for expansion. The DPR system is operated by Colorado River Municipal Water District (CRMWD) and serves five cities in West Texas. Facing a severe 10-year drought, this area of West Texas found a need to supplement the water supply with potable reuse began operation in 2013[18]. CRMWD's Big Springs Raw Water Facility treats 2.5MGD, of which 5-20% is blended with surface water prior to entering the drinking water treatment plants and distribution throughout their service region.

While IPR is definitively more popular than DPR, DPR is expected to become more prevalent as droughts progress. Additional infrastructure is necessary to operate IPR, and additionally, there will become a saturation point where fewer environmental buffers will be required to distribute the water -- the next step will be to expand DPR.

4.2. Health Benefits of Potable Reuse

Taking a holistic view on health, the following section describes the many health-related impacts of integrating potable reuse (direct and indirect).

Energy and Greenhouse Gas Emissions

Potable reuse (direct much more so than indirect) is less energy intensive than current imported water sources, and much less energy intensive than implementing desalination (See Figure)[19-22]. The lower energy intensity of potable reuse will correspond to a decrease in greenhouse gas emissions and thus help protect and improve air quality.

Water Costs

As water and energy sources become scarcer, future water and energy costs will rise[23]. These higher utility costs will disproportionately affect lower income communities where financial security is a precursor to health outcomes such as increased stress and exacerbation of existing health conditions, such as heart disease[24]. Potable reuse will be a cheaper water source than other options, especially when compared to potential alternative water sources such as desalination, which has much higher operation costs[21].

Water Quality

Allowing for groundwater recharge through IPR will help improve potable water quality. In addition to using recycled water to augment groundwater supplies, it is also used to create seawater intrusion barriers. In some cases, depending n the characteristics of the groundwater basin, some of the injected recycled water used to prevent seawater intrusion flows inland to water supply wells. As result of California's current severe drought, water districts are relying on groundwater to supplement an unprecedented 60% of the potable water supply in the state compared to ~30% in non-drought years[25,26]. This increased reliance on groundwater has had significant implications for human health. Many existing groundwater basins are contaminated, and the extent of contamination is exacerbated during drought periods. Without natural waters to recharge the basins during drought, contaminants in the groundwater become more concentrated; exposure to these contaminants could lead to increased rates of gastrointestinal illness and cancer[27,28].

Green Space & Health

Expanding and integrating IPR and DPR is beneficial for directing recycled water towards green spaces that otherwise cannot be served by existing infrastructure delivering tertiary treated water [29,30]. Green spaces are an important mediator for protecting air quality, eliminating urban hot spots, and promoting physical activity[29,30]. Implementing IPR or DPR into the water system would help local parks maintain green spaces, and may be less costly than implementing non-potable reuse, since investing in mandatory separate recycled water piping systems can be quite costly. Maintenance of green space through potable reuse not only protects the spaces against potential mandatory water restrictions, but also supports health benefits provided by its ecosystem services, such as improving air quality and protecting against urban heat island effect.

Chemicals of Emerging Concern

A 2012 report on water reuse by the National Research Council evaluated the risk of twenty-four chemical contaminants in potable reuse scenarios and determined that risk does not exceed that found in traditional water supplies[31]. Given some uncertainty in their evaluations, their findings dictate the need for diligent monitoring of potable reuse systems to maintain a level of acceptable risk. Today, new technology is in development for direct potable reuse to reduce the need for environmental barriers as a safeguard for the water supply, and innovations for improving water quality of potable reuse will only improve in the future. The improved technology will expedite treated water integration into the potable water supply, thus cutting back on energy and expensive infrastructural modifications.

Thus far, health risks from recycled water contaminants are minimal, while information on long-term effects of newer chemicals is largely unknown, albeit perceived to be very low risk by experts in the field[31]. However, the quality of highly-treated recycled water used for potable reuse through the use of currently available technology exceeds the quality of other major ground and surface water sources; this has led many experts in the field to opine that this benefit outweighs the risks.

Public Perception

Public perception of indirect potable reuse is largely improving, with acceptance of direct potable reuse not too far behind[13]. The health benefits of implementing potable reuse will be beneficial to public health, especially given that the consequences of inaction are much worse.

4.3. Recommendations to Public Health Agencies

- ***Explore incentives for building up infrastructure to support recycled water systems to widen their geographic reach within communities.***
- ***Encourage local water suppliers to apply for funding within California Proposition 1 to expand their recycled water portfolio to include potable reuse projects.***
- ***Foster collaboration between local water suppliers and public health departments to improve public perception of recycled water implementation and expansion.***
  - ***Develop outreach programs and materials to inform public about recycled water programs.***
  - ***Develop uniform terminology when discussing recycled water programs to avoid confusion, which may help gain public acceptance.***

5. Findings and Recommendations #2: Non-Potable Reuse

Non-potable reuse is the use of recycled water for uses that do not involve human consumption of the water, although contact with the recycled water is acceptable for some uses depending on the level of treatment. To prevent misuse of the recycled water and minimize the potential for cross-connections, the water is conveyed through a separate piping system (also known as purple pipe) and is constructed with adequate separation from the potable water system to prevent any mixing with potable water.

Status of Non-Potable Reuse in California

In California, there are currently forty-seven approved uses[32], although no areas use all forty-seven allowable practives. Until recently, the process to apply for permits for non-potable uses was quite cumbersome and required a new permit application for each use. However, a newly implemented permitting system now approves a water district for all forty-seven uses at once, thus expediting the process and helping to promote expansion of non-potable use.

Water treated for non-potable reuse is used for irrigating crops, parks, golf courses, outdoor landscaping, among others[10]. In the Los Angeles region, which has the second highest volume of recycled water use in the state after the Central Valley, groundwater recharge to maintain the area's seawater intrusion barriers is the leading use of recycled water, and accounts for roughly one-quarter of the region's total recycled water use[10].

In 2009, the State Water Resources Control Board adopted the General Waste Discharge Requirements for Landscape Irrigation Uses of Municipal Recycled Water, which allows the use of recycled water for landscape irrigation. Areas qualifying for recycled irrigation include: parks, playgrounds, schoolyards, athletic fields, golf courses, cemeteries, freeway, highway and street landscaping, and commercial and industrial landscaping, minus eating areas.

5.1. Health Impacts of Non-potable Reuse

As uses and technologies for urban recycled water are expanded within California, it is important to investigate how these applications may affect human health. Overall, expansion of non-potable uses will have a positive impact on public health. Health benefits of non-potable uses stem from protection against water scarcity, decreased used of energy and greenhouse gas emissions, positive impact on air quality, and potential to decrease the urban heat island effect.

Landscape Irrigation & Health

While irrigating landscapes with recycled water is generally considered safe, there are some public health concerns. Recycled water intended for irrigating outdoor landscapes undergoes treatment processes (secondary or tertiary treatment depending on use), yet it is still below potable water standards. As such, landscape irrigated with recycled water can have concentrations of microbial organisms higher than landscape irrigated with potable water. These slightly elevated microbial levels do not present unreasonable health risks, and are significantly reduced after the water evaporates[33]. Thus, irrigation using recycled water should occur in the early morning or late evening to avoid human contact, and to allay public concerns.

Among the most prominent non-potable uses, large-scale landscape irrigation has the potential for the most significant impact on water use and holds the most benefit for human health. With water use regulations and mandatory irrigation cutbacks becoming more prevalent in response to drought, implementation of recycled water will also help irrigate and maintain green spaces. Green space is beneficial for preventing urban hot spots and urban heat island effect, which is especially significant given predictions for warmer temperatures and extreme heat events in the future; prevention of urban hot spots and urban heat islands also have a positive impact on air quality and respiratory disease[29,34,35]. Availability of green space also has positive impacts on promoting physical activity and related health outcomes such as obesity, heart disease, elderly health, and mental health[30,36,37].

Water Costs

Reaching new areas to irrigate with recycled water comes with it the cost of building new infrastructure. The cost of installing a new pipeline or high-level treatment facilities may be prohibitively expensive when compared to the marginal costs of using more water from existing sources. Constructing recycled water treatment facilities today will be beneficial to the consumers of tomorrow, especially when the cost for saltwater desalination or the rising costs of imported water sources are compared to recycled water as supply. Expanding recycled water treatment facilities is more feasible today thanks to government grants and loans made available through California’s recent water legislation, Proposition 1. Reduced water costs will not only positively affect current users (especially low-income households), but investing in recycled water systems now will help prevent more extreme costs, to water suppliers and consumers, in the future.

Impacts on household income are correlated to increased stress and exacerbation of illnesses, which disproportionately affect lower income and minority communities[24].

Energy Use, Greenhouse Gas Emissions & Health

Expansion of recycled water through non-potable reuse lessens the need for imported water thus reducing the energy needed and resultant greenhouse gas emissions released from water transport. The decreased need for imported water will have positive implications for air quality and respiratory disease. Although urban water use constitutes only 15% of the state's total water use, it accounts for a majority of the energy associated with water supply and treatment. This energy is largely generated from combustion of fossil fuels, produces emissions affecting local and regional air quality and greenhouse gas levels, which exacerbate respiratory conditions throughout California. With less reliance on imported, potable water sources, increased urban recycled water use could decrease statewide energy and greenhouse gas emissions to improve health. The decreased need for imported water will have positive implications for air quality, and respiratory disease. Energy demands to treat water for non-potable reuse generally are significantly less than for potable reuse alternatives, and most importantly, may not have an increased energy demand for transport where the water source is local.

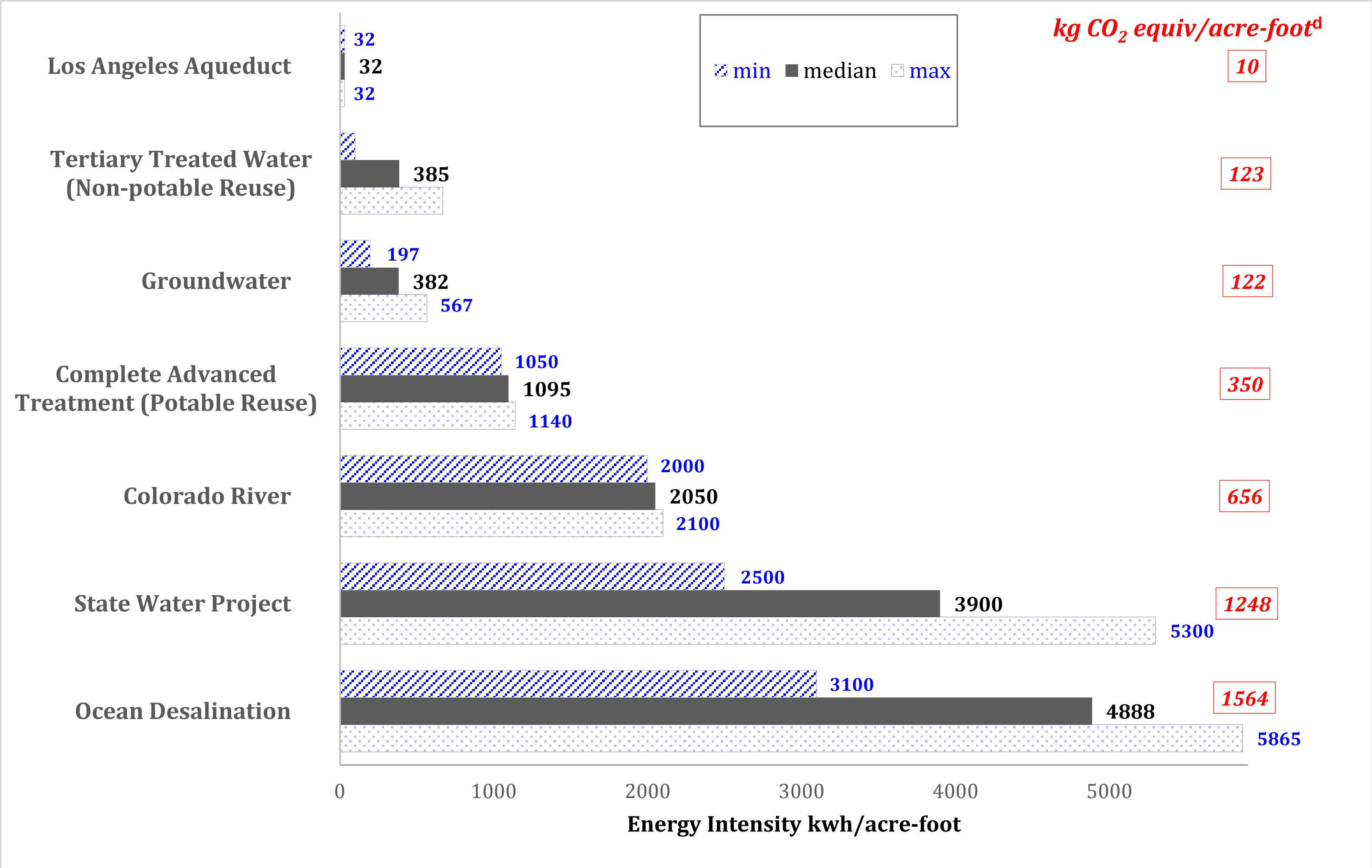
5.2. Recommendations

- ***Incentivize and promote rebates for water reuse in landscape irrigation, both in public and residential spaces.***
    - ***Promote expansion of recycled water systems for irrigation, thus maintaining green space for physical activity, and reducing potential for urban heat island effect.***
- ***Encourage water districts to collaborate with neighboring districts to expand reach of recycled water when connections are nearby service area borders.***

6. Conclusion

Continued integration and expansion of recycled water into California's water portfolio is necessary for meeting future water demands and supporting California's growing population and economy. State legislation mandates increased water conservation measures into the future, and with $725 million allocated towards recycled water project from the 2014 Proposition 1 water bond, it is important to understand the health impacts of recycled water applications. Public perception has been an impediment towards recycled water in potable and non-potable uses, and the awareness that integrating recycled water will benefit, not harm, public health is extremely important. Incentives from local water suppliers to expand recycled water uses and applications, along with increased public involvement, education and outreach programs emphasizing the health benefits of recycled water – and especially the potential harms of not implementing recycled water – may be key factors for widespread acceptance of its use throughout California.

Figure 1: Energy Intensity of California's Current and Potential Water Sources[19-22].



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