Energy-for-Water Nexus in Cities in San Diego County

Final Report

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ENERGY POLICY INITIATIVES CENTER
UNIVERSITY OF SAN DIEGO SCHOOL OF LAW

About EPIC

The Energy Policy Initiatives Center (EPIC) is a non-profit research center of the USD School of Law that studies energy policy issues affecting California and the San Diego region. EPIC's mission is to increase awareness and understanding of energy- and climate-related policy issues by conducting research and analysis to inform decision makers and educating law students.

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Acknowledgement

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EXECUTIVE SUMMARY

The overall objective of this study was to increase the knowledge and capacity in the San Diego region to analyze water-related energy use[1] and associated greenhouse gas (GHG) emissions and enhance the ability to provide climate-planning services to local governments by providing locally-relevant data. This study focuses only on the water supply and conveyance, treatment, and distribution energy components of the water-use cycle shown in Figure ES 1 . In total, 10 cities were studied and these cities cover 65% of San Diego County's total population.[2]

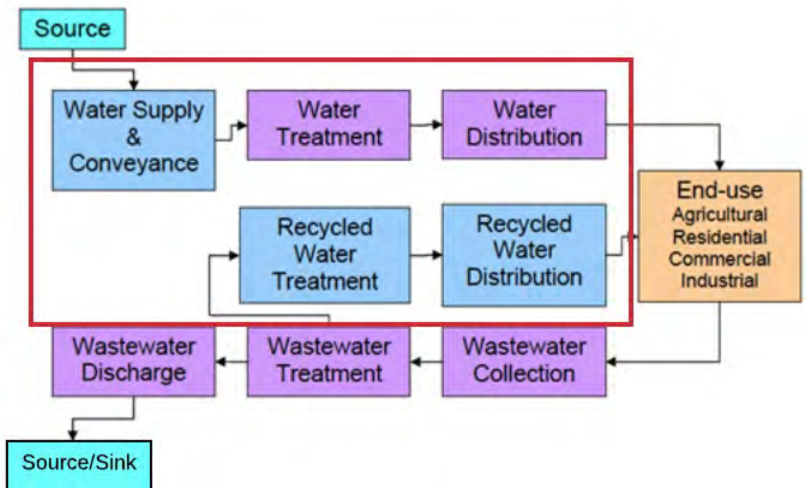


Figure ES 1 Energy-for-Water Nexus and Components Included in this Study (red outline)

KEY FINDINGS

Per Capita Consumption Varies Significantly by City

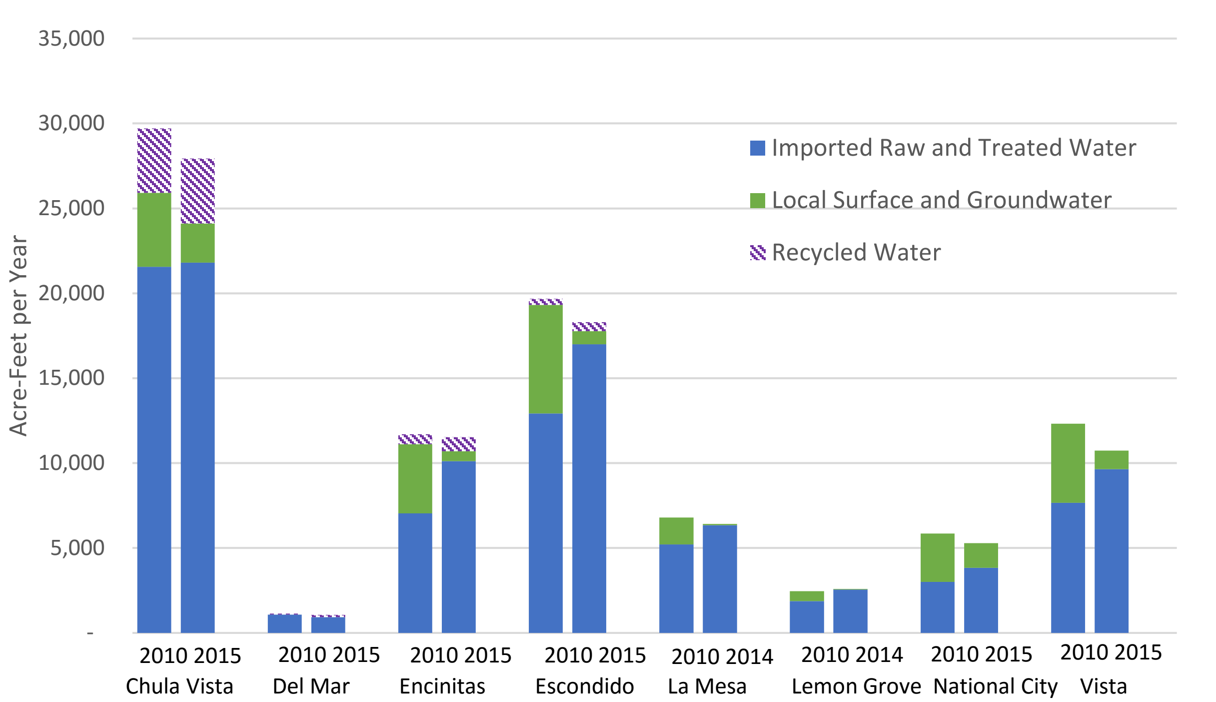
In 2015, the average consumption of water for the ten cities assessed was 124 gallons per capita per day (GPCD). The five cities of Del Mar, Escondido, Solana Beach, Encinitas, and San Diego were above average, while Chula Vista, La Mesa, Lemon Grove, National City, and Vista were below average. There was a large range in consumption, from 73 GPCD[3] to 200 GPCD across the cities.

Imports from the Colorado River and the State Water Project were the Main Water Supply Sources

In the period 2010-2013, an average of 74% was imported and in 2014-2015, on average, 92% of water supplied to the ten cities was imported. These imports came through the San Diego

[1] This study focuses only on the energy-for-water use related to climate action planning, not on the water used for the production and operation of energy generation facilities.
[2] The cities include Chula Vista, Del Mar, Encinitas, Escondido, La Mesa, Lemon Grove, National City, San Diego, Solana Beach, and Vista.
[3] Per capita potable water use does not include recycled water.

County Water Authority (SDCWA) as raw untreated water or treated water, whether directly from the Metropolitan Water District (MWD) or indirectly through contractual arrangements for agriculture-to-urban transfers or from canal lining and conservation projects. During the period of study, there were limited alternative sources, namely, local surface, local groundwater, and local recycled water. The availability of local surface and groundwater varied between 2010 and 2014 or 2015 and may be correlated to precipitation. Year 2010 had the highest total local annual precipitation, and higher local water supplies, and 2011–2014 had considerably lower total annual precipitation with lower local supplies. Six cities had some recycled water supply (Figure ES 2).



The city of San Diego water sources are not shown due to scale. The city of Solana Beach water sources for 2010, 2014 and 2015 were not available. The Carlsbad desalination plant was not yet operation during this period.
Data provided by water agencies for fiscal or calender year, Compiled by Energy Policy Initiaves Center, 2018.

Figure ES 2 Water Supply Mix by City in 2010 and 2015

Imported Water Was the Major Contributor of a City's Water-Energy Use and Water-GHG Emissions

During the period of study, most water was imported. Upstream (non-local) energy use associated with bringing water from the State Water Project (SWP) and Colorado River to San Diego County Water Authority's (SDCWA) operational control formed the largest component of total energy use for a city, outside of end-use energy. Similarly, upstream GHG emissions for water use in a city derived mostly from the upstream component assuming use of California's average grid GHG emission factor. In addition, more water was imported during drought years

2014-2015 than earlier. Therefore, during the years 2014-2015, upstream energy use increased even while total water use decreased.

Imported Upstream Water was the Largest Factor in a City's Energy Intensity and GHG Intensity

Upstream energy and GHG intensity dominated water-energy for any city and cities that relied more on imported water had higher total energy intensities than those that imported less. In general, the more a city imported, the higher the intensities (Figure ES 3, Figure ES 4).

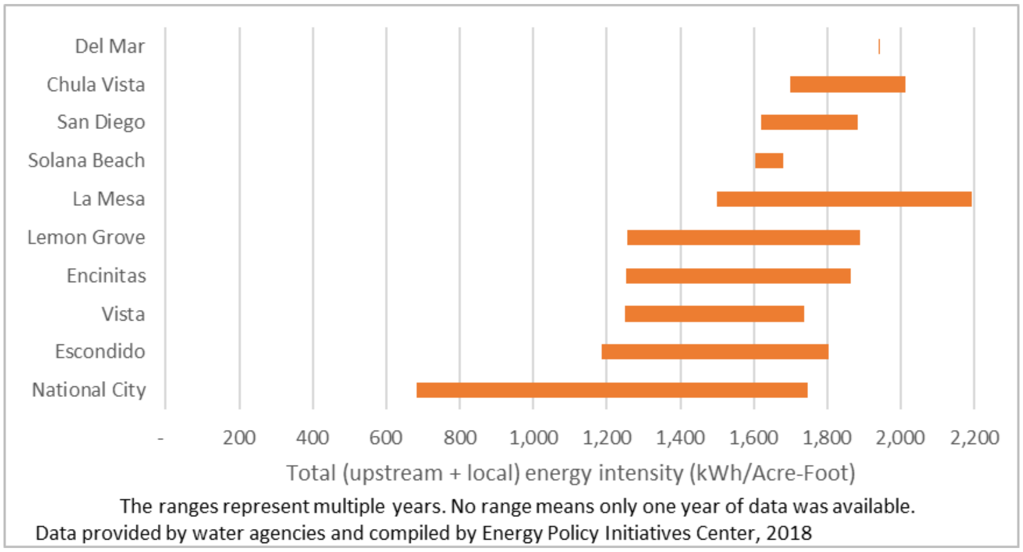


Figure ES 3 Total Energy Intensities -for-Water

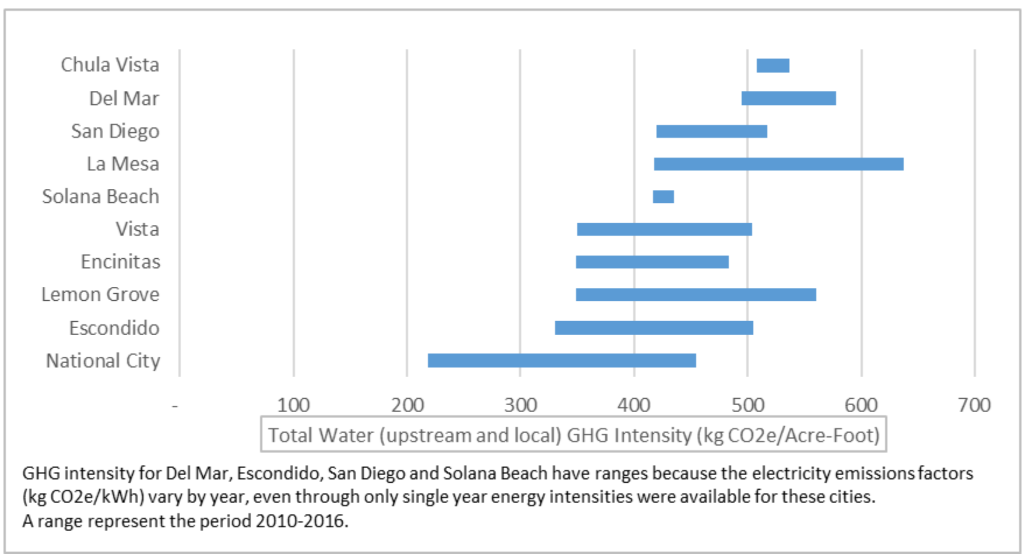
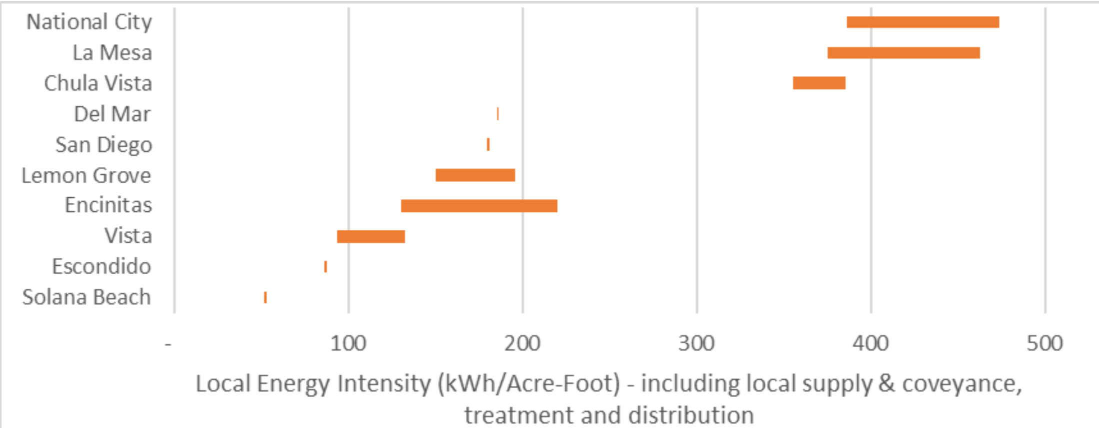


Figure ES 4 Total GHG Intensities of Water

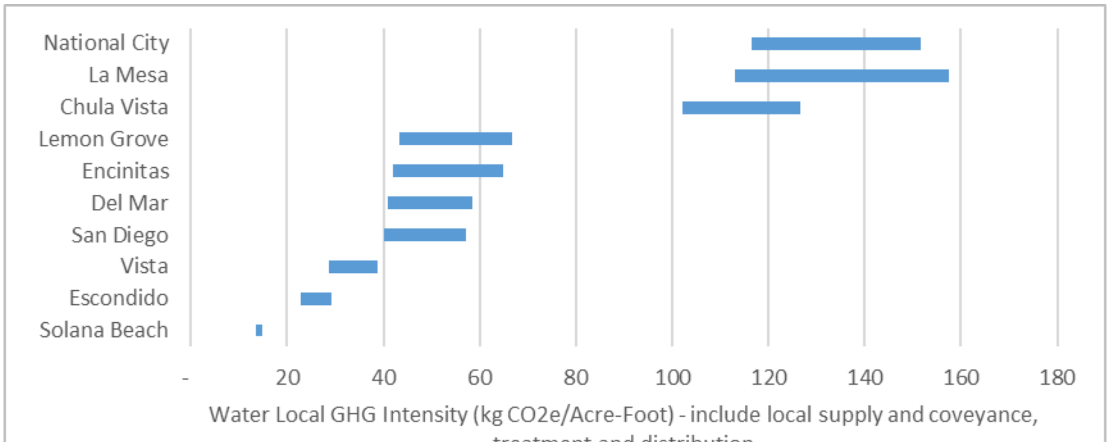
However, removing the effect of upstream energy exposes differences in local-only energy use. City water-energy and water-GHG intensities then fall into two ranges (Figure ES 5, Figure ES

6) — a lower range comprising Solana Beach, Escondido, Vista, Encinitas, Lemon Grove, San Diego and Del Mar, and a higher range comprising National City, La Mesa, and Chula Vista. When local energy intensities are low, this could imply a lower reliance on groundwater, which requires more energy to produce, or that more of the water mix is imported, which is not reflected in the local energy intensity. When local energy intensities are relatively high, this might indicate extraction of more and deeper groundwater supplies or brackish water conversion in the local water mix, as is the case for Chula Vista and National City.



Local energy-for-water intensity for Del Mar, Escondido, San Diego and Solana Beach do not have ranges as only single year data were avaliable from their water supply agencies. For other cities, ranges represent the period 2010-2016.

Figure ES 5 Local-Only Energy-for-Water Intensities for Cities in San Diego County



GHG intensity for Del Mar, Escondido, San Diego and Solana Beach have ranges because the electricity emissions factors (kg CO_2e/kWh) vary by year, even through only single year energy intensities were available for these cities. Ranges represent the period 2010-2016.

Figure ES 6 Local-Only GHG Intensities of Water for Cities in San Diego County

Conserving Water in 2014-2015 May Have Increased Energy- and GHG-Intensity

Water conservation occurred as mandated in 2014-2015 but did not lead to an equivalent reduction in energy use or GHG emissions due to the dependence on imported water in cities in the San Diego region. For purposes of climate action planning, these results suggest that reducing imported water through local conservation and an increasingly renewable electricity supply will lead to some overall energy and GHG emissions reductions. However, as local surface and groundwater supplies are limited, a cleaner upstream grid will be the greater determinant of water-related GHG emissions for cities in the region. With respect to energy and GHG intensities, water conservation appears to have caused an increase in energy intensity and a slight increase in GHG intensity (Figure ES 7). During 2010-2015, it was only in years with greater local supply and treatment that cities had lower water-energy and water-GHG intensities.

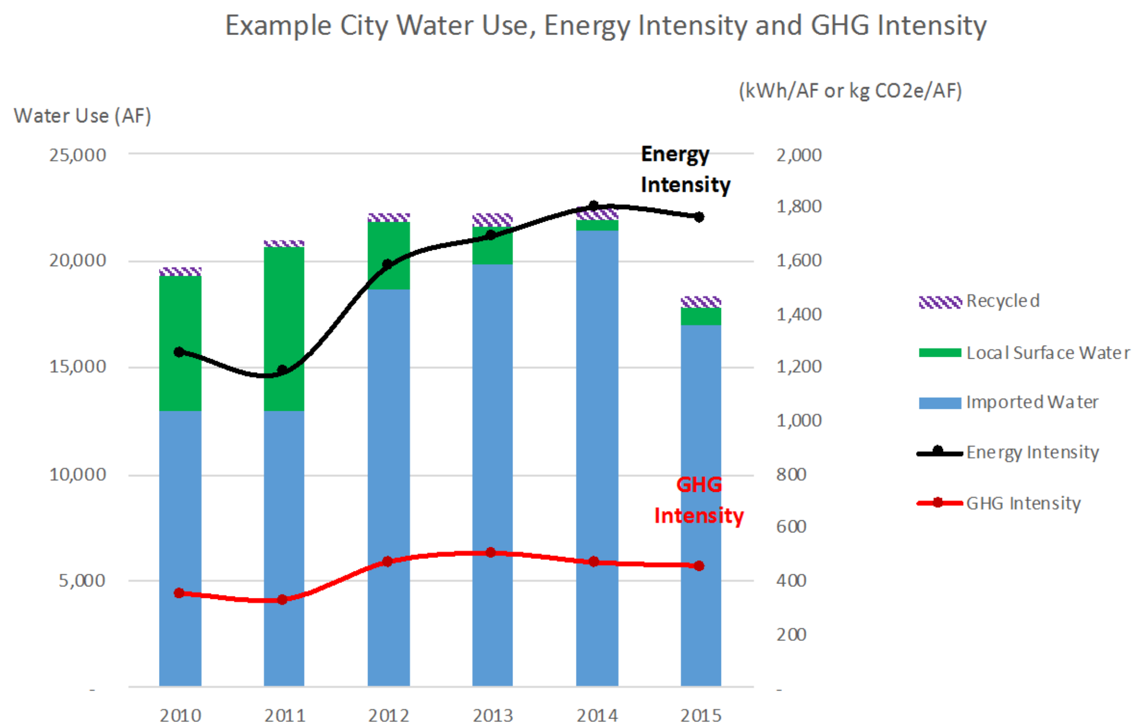


Figure ES 7 Example City Water Use, Energy Intensity and GHG Intensity

RECOMMENDED NEXT STEPS

This study would benefit from an assessment of the GHG intensity of the upstream water supply sources to SDCWA in order to properly develop an upstream GHG intensity factor for the majority of our water sources. While the increased use of local recycled and desalinated water would clearly reduce reliance on both upstream imported water and on weather, specifically precipitation (for local surface and groundwater), the effect of various types of local water (other than recycled, surface and groundwater), on energy intensities, GHG intensities, energy use and GHG emissions by city is not yet known. The effect on city GHG emissions of newer types of local supply such as local desalinated water and wastewater-to-potable water should be assessed.

1 INTRODUCTION

A California Energy Commission (CEC) study published in 2005 has been widely quoted as saying that "water-related energy consumption is large — 19 percent of all electricity used in California" (CEC 2005, p. 8), as shown in Figure 1 below.

Table 1-1: Water-Related Energy Use in California in 2001

	Electricity (GWh)	Natural Gas (Million Therms)	Diesel (Million Gallons)
Water Supply and Treatment			
Urban	7,554	19	?
Agricultural	3,188		
End Uses			
Agricultural	7,372	18	88
Residential			
Commercial	27,887	4,220	?
Industrial			
Wastewater Treatment	2,012	27	?
Total Water Related Energy Use	**48,012**	**4,284**	**88**
Total California Energy Use	**250,494**	**13,571**	?
Percent	**19%**	**32%**	?

Source: California Energy Commission

Figure 1 Water-related Energy Use in California in 2001 (Adapted from CEC 2005, Table 1-1)

The 19% refers to electricity needed for the entire water-use cycle, including for water supply and treatment, water end uses, and wastewater treatment. The study also notes that in addition to the 19% electricity of the state's electricity used for water, 32% of the state's total natural gas is also used for water purposes. Of this electricity and natural gas use, approximately 72% and 98%, respectively, are for end-use, such as heating and cooling and hot water circulation in the residential sector, and chilling and cooling in the commercial and industrial sectors (Figure 2).

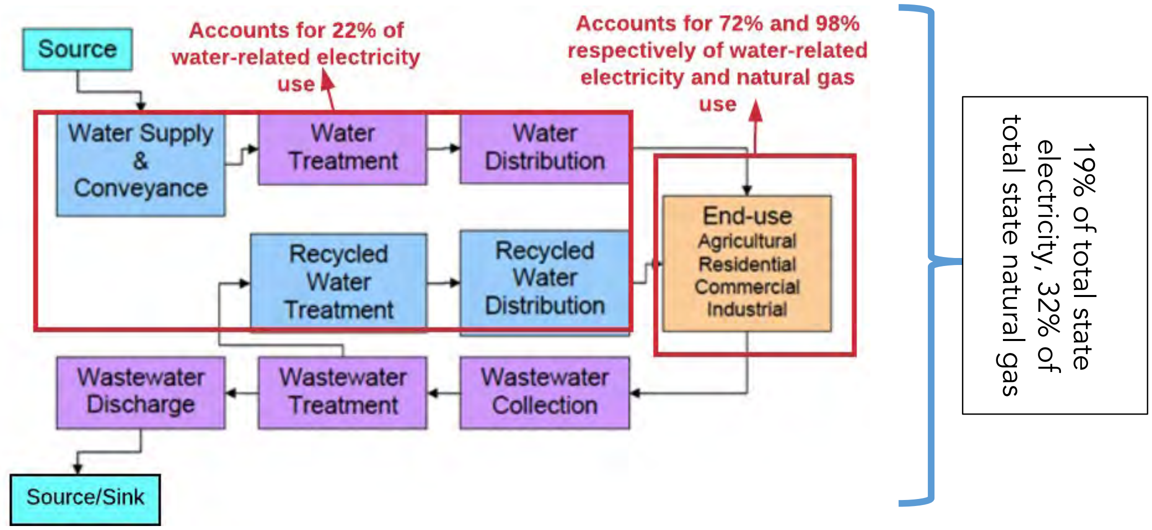


Figure 2 California's Water-use Cycle (Adapted from CEC 2005, Figure 1-1 and Table 1-1)

This study focuses only on the water supply and conveyance, treatment, and distribution energy components of the cycle shown in Figure 2. The main purpose is to assess the energy use for water as it relates to climate planning at the local jurisdiction level. In a jurisdiction's climate action plan, greenhouse gas (GHG) emissions inventories account for the energy consumption associated with only these components of the water cycle. Energy use and GHG emissions from water end-use and wastewater treatment are captured in separate categories in a GHG inventory and do not form part of this study.

1.1 Objective and Goals

The overall objective of this study is to increase the knowledge and capacity in the San Diego region to analyze water-related energy use and GHG emissions and enhance the ability to provide climate planning services to local governments. Specific goals are to:

- Provide an overview of the water supply system in San Diego County and the water mix in selected cities in the County.
- Provide an overview of the water treatment and distribution system in selected retail water agencies and cities.
- Develop metrics that can be used to estimate and track the impacts of water use in the region, including: energy intensity for water (kWh/Acre-Foot or kWh/Million Gallons) and the GHG intensity for water (kg CO_2e/Acre-Foot or kg CO_2e/Million Gallons) for each segment of the water-use cycle for the water delivered to customers in selected retail water agencies and cities.
- Compare results with existing water-energy intensity data from the previous studies. This comparison will help to benchmark data and assess the quality of data in this study.
- Develop an interactive tool to demonstrate multi-year water mix, energy use and GHG emissions associated with water, water energy and GHG intensity by city, by water-use cycle segment, by geographical boundary, so that a user can view and understand the factors that impact water-related energy use and GHG emissions at city level.

- To the extent feasible, present visualizations of the energy-for-water-GHG nexus in San Diego County based on data collected to understand factors contributing to water-related energy use and GHG emissions.

2 BACKGROUND

2.1 Previous Studies

The 2005 CEC study referred to in the introduction provides estimates of the energy intensity for water, the amount of energy consumed in kWh per unit of water (Acre-Feet (AF) or Million Gallons (MG)), for northern and southern California water systems. An updated 2006 study provided refined estimates for these energy intensities. One of the recommendations from the 2006 study was that even though these adjusted energy intensities would be sufficient to inform policy and prioritize research and development, primary data should be collected from water utilities and disaggregated geographically within water-use cycle segments (CEC, 2006).

In 2007, a formal proceeding was initiated by the California Public Utilities Commission (CPUC) to investigate California's water-energy relationship. In particular the proceeding was to assess the impact of the water sector on the energy sector and assess if energy embedded in water could be quantified and used as an energy efficiency resource or if energy efficiency should be pursued through water conservation (CPUC 2010a, 2010b). The resulting studies assessed the energy needed for supply and conveyance at the wholesale level (CPUC Study 1) and the energy needed to treat and distribute water at the retail level and by wastewater systems (CPUC Study 2). In Study 2, energy intensity data were collected from water agencies across California, including from the City of Oceanside and Valley Center Municipal Water District in San Diego County (CPUC, 2010b).

A recent study by the University of California Davis (Spang, 2018, UC Davis) showed that electricity savings from mandated statewide water conservation measures from July –SDCWA September 2015 were almost identical to the first-year electricity savings in the period July 2015-June 2016 from energy efficiency investments by all of the state's Investor-owned Utilities (IOUs). Though this effect was unintended because the purpose of the mandate was to conserve water, it demonstrated the important role that water conservation can play in energy conservation in California.

2.2 Relationship of the Water-Energy Nexus to GHG Inventories and Climate Action Plans

California's Global Warming Solutions Act (AB 32) was adopted in 2006 with statewide GHG reduction targets. The First Scoping Plan for AB 32 and the second Scoping Plan 2017 emphasized the importance of local government action to help achieve these targets (California Air Resources Board, 2008, 2018).

To assist in the achievement of state GHG goals, cities typically assess GHG emissions from five categories — on-road transportation, electricity, natural gas, solid waste and wastewater, and water — and implement local policies to reduce these emissions. The 2013 *U.S Community Protocol for Accounting and Reporting Greenhouse Gas Emissions* (U.S. Community Protocol) developed by ICLEI — Local Governments for Sustainability (referred to as ICLEI) — is the mostly widely-followed protocol in the U.S. for GHG analysis at the city level. This protocol separates water related emissions from wastewater related emissions. Although GHG emissions from the water category are only a small fraction of overall GHG emissions of a city (See Figure 3 City of San Diego's GHG inventory as an example), the water-GHG relationship (GHG intensity of water) is a politically significant part of GHG analysis due to the value of water in California, the need to conserve water and to reduce energy and associated GHG emissions.

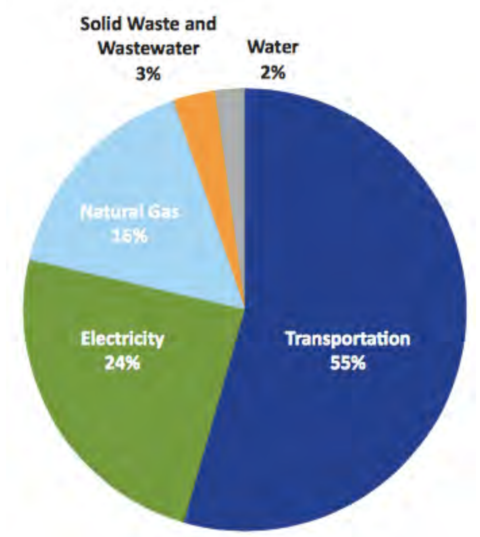


Figure 3 Breakdown of City of San Diego's 2010 Inventory (the Water Category accounts for 2% of total GHG Emissions, City of San Diego Climate Action Plan, Figure 2-1)

2.3 San Diego Region's Water System

An understanding of the region and cities' water needs must be based on an understanding of our water system, including the region's watersheds, water storage capabilities, policy, legal, and regulatory requirements. These are generally described in water agency Urban Water Management Plans (UWMP), Environmental Impact Reports (EIRs). Relevant information is summarized below.

The SDCWA is the primary wholesale water supplier for San Diego County. It has 24 member agencies (retail water agencies), which supply about 95% of the county's population.[4] The 24 agencies consist of:

- Six cities;
- Five water districts;
- Eight municipal districts;
- Three irrigation districts;
- One public utility district; and

[4] The eastern part of the county is not served by SDCWA and is not part of this city-based study.

- One federal military reservation.

SDCWA's main water supplies are the Colorado River and the State Water Project (SWP) from the Sacramento River purchased from the Metropolitan Water District (MWD). SDCWA supplies each retail agency with wholesale raw (untreated) water or treated water. The rest of the water supply is from local sources such as local surface water and groundwater. Some retail agencies also have recycled water supplies. The service area of a retail water agency may cover part of a city, a single city, or parts of several cities in San Diego County.

2.4 Overview of Cities and Their Water Suppliers

The locations of the cities and their water suppliers are shown in Figure 4.

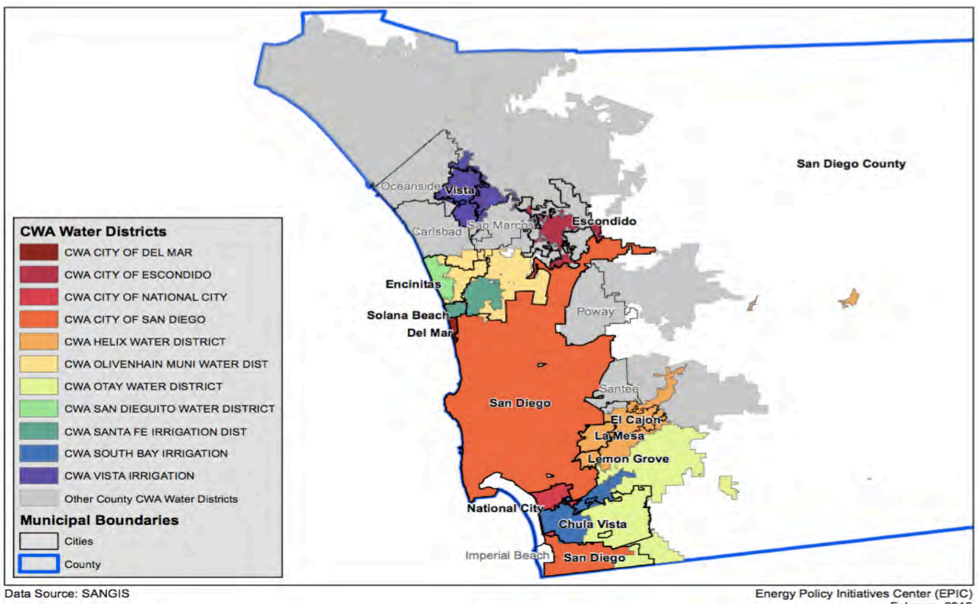


Figure 4 Cities and Water Suppliers Covered in This Study

For a city that is its own water retailer or has only one water retailer, the water service area boundary of the retailer may be different from the city boundary. For example, Vista Irrigation District (VID) is the only water supplier for the City of Vista, but VID's service area (colored in purple in Figure 4) is larger than Vista and covers communities in the unincorporated County of San Diego. For a city with multiple water suppliers, one supplier may cover one part of the city while the other covers another portion. For example, 95% of the City of Solana Beach is covered by Santa Fe Irrigation District (SFID) while 5% is covered by the Olivenhain Municipal Water District (OMWD).

The ten cities in this study cover 65% of the county's total population. The population within each city, their water suppliers and their 2015 per capita water use (gallon per capita per day — GPCD) are provided in Table 1 below.

Table 1 City Population within Water Suppliers' Service Areas and 2015 GPCD

City	Population	Gallons per Capita per Day (GPCD)	Water Supplier		
			Water Supplier Name	City Population within Service Area	Percent of City Population within Service Area
Chula Vista	263,347	86	Otay Water District (Otay WD)	147,215	56%
			South Bay Irrigation District (South Bay ID, under Sweetwater Authority)	116,132	44%
Del Mar	4,248	200	City of Del Mar	4,248	100%
Encinitas	61,473	159	Olivenhain Municipal Water District (OMWD)	24,007	39%
			San Dieguito Water District (SDWD)	37,466	61%
Escondido	101,084	160	City of Escondido	101,084	100%
La Mesa	59,357	93	Helix Water District (Helix WD)	59,357	100%
Lemon Grove	26,446	73	Helix WD	26,446	100%
National City	60,279	80	National City (under Sweetwater Authority)	60,279	100%
San Diego	1,377,893	128	City of San Diego	1,377,893	100%
Solana Beach	13,417	159	Santa Fe Irrigation District (Santa Fe ID)	13,003	97%
			OMWD	414	3%
Vista	97,555	101	Vista Irrigation Districts (VID)	97,555	100%

Service area data from SANDAG based on 2015 estimates, SANDAG 2017; GPCD: Gallons Per Capita per Day is based on the Department of Water Resources (DWR) Urban Water Management Plan (UWMP) definition. GPCD does not include recycled water.

Reasons for the differences are not part of this study.

In 2015, gallons per capita per day (GPCD) varied greatly across the cities, from 73 GPCD in Lemon Grove to 200 GPCD in Del Mar.

3 TERMS AND DEFINITIONS

Terms and definitions are available from several state agencies and entities involved for different purposes in the water-energy nexus, both in terms of the energy used for water, and the water used for energy production.

From the water conservation perspective, the Department of Water Resources (DWR) is responsible for managing and protecting California's water resources. DWR developed Urban Water Management Plan (UWMP) Guidelines in 1996 for the voluntary reporting of water-energy related metrics in their UWMPs.[5] The Guidelines provide the method for each supplier to report energy use and energy intensity within its operational boundary, which is "to take water from the location where the Urban Water Supplier acquires the water to its point of delivery" (DWR 2016, p. O-2). Under this definition, retail suppliers only need to report the energy use within their operational boundary, not the energy needed for the wholesalers to deliver the water to the retailer's water system. For example, as a retailer, the Vista Irrigation District (VID), need not report water-related energy use upstream of its operational boundary, which would be the energy needed for SDCWA, the wholesaler, to move the water to San Diego County.

Apart from the DWR, the California Energy Commission (CEC) as an energy policy and planning agency, has a focus area on the water-energy nexus due to the effects of water availability on hydroelectric power as well as the energy needs to move the water supplies to where it is needed. In addition, the California Public Utilities Commission (CPUC) regulates privately owned energy and water companies. Both these energy agencies have developed their own definitions for components of the water cycle related to energy.

From the GHG accounting perspective, ICLEI has developed protocols for GHG analysis, including from water use at the local level. ICLEI's U.S Community Protocol method "WW.14 Energy-related Emissions Associated with Water Delivery and Treatment" uses definitions similar to those defined by the CEC and the CPUC. The protocol includes additional clarification that the energy use for activities indirectly related to or that depend on water treatment, such as electricity use at offices in the water treatment facility, are not be accounted for in this segment.

The Climate Registry[6] developed a *Water-Energy GHG Guidance* in 2015, a supplemental document to the Global Reporting Protocol (GRP) water sector, which adopts the definitions from the UWMP guidelines for its GHG intensity metrics reporting.

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[5] Under the California Urban Water Management Planning Act (Water Code sections 10610–10656) urban water suppliers, whether wholesalers or retailer, are required to prepare an UWMP every 5 years starting 2016 if providing municipal water supplied from public water systems to more than 3,000 customers or more than 3,000 acre feet (AF) water annually. They may voluntarily report their energy use.

[6] The Climate Registry created by California in 2001 is now governed by US states and Canadian territories to design protocols and operate voluntary GHG reporting compliance programs globally. Its General Reporting Protocol (GRP) provides a voluntary reporting program and basic framework for its members, mostly organizations and public agencies, to report their GHG emissions.

The next section presents definitions by water segment used by these entities followed by adjusted definitions as used within this report.

	Water Supply and Conveyance			Treatment	Distribution
CEC, CPUC, US Community Protocol	Energy use to collect, extract, store and transport raw water supply			Energy use for water treatment prior to distribution to customers.	Energy use to transport treated water from the treatment plant or wellhead disinfection point to the point of delivery
DWR	**Extract and Divert -** Energy use to remove raw water from a channel, pipeline, stream, or aquifer less any consequential hydropower generation	**Place into storage -** Energy use to place raw water into a storage reservoir or groundwater bank less any consequential hydropower generation	**Conveyance -** Energy use to transport raw water through aqueducts, canals, and pipelines from its source to a water treatment facility or directly to an end use less any consequential hydropower generation	(Energy use to) treat water to potable quality	(Energy use to) transport treated water from the treatment plant or wellhead disinfection point to the point of delivery

3.1 Definitions

Daily per capita water use: "[T]he amount of water used per person per day. Total water use within [a water supplier's] service area, divided by population" (DWR 2016, p. 5-3). The total water use is the gross water use "entering the distribution system of an urban retail water supplier," excluding recycled water, the net volume of water placed into long term storage, conveyance for use by another water supplier or delivered for agricultural use (DWR 2016, p. 5-11).

Gallons per capita per day (GPCD): "Daily per Capita Water Use" measured in gallons. Used when referring to "Daily per Capita Water Use" or GPCD (DWR 2016, p. 5-3).

Energy Use in Segments of the Water Cycle: The CEC, CPUC, DWR and U.S Communities Protocol definitions of segments of the water cycle are shown in Table 2. Supply and conveyance is within a wholesale water supplier's service area. Water distribution is within the retail water supplier's service area. For water treatment, both wholesalers and retailers may have water treatment plants that treat raw water sources.

Table 2 Definitions of Energy Use Segments of the Water Cycle

Types of Water Sources: This refers to the sources as well as the status of treatment of the supply. It has been defined only by the DWR in its UWMP Guidelines as presented in Table 3.

Table 3 Definition of Types of Water Sources (DWR)

Raw Water (untreated)	Potable Water (treated)	Groundwater	Surface water	Recycled Water
Water that is untreated and used in its natural state.	Water intended for human consumption, delivered through a Public Water System, and regulated by a State or local health agency	Water from alluvial groundwater basins, fractured volcanic material and bedrock	Water drawn from streams, lakes and reservoirs	Municipal wastewater that has been treated to a specified quality, enabling it to be reused for a beneficial purpose

Energy Embedded in Water: CPUC Study 1 defines this term, provided in Table 4 (CPUC 2010a, p.12).

Water Energy Intensity: The CPUC Studies and the DWR (UWMP Guidebook) define these terms in the same way as provided in Table 4. This report follows these definitions up to the point where the water reaches the end-users (Figure 2). This is consistent with the characterization of GHG emissions from the water category under the ICLEI – U.S. Community Protocol, used for climate planning purposes.

Table 4 Definitions of Energy Embedded in Water and Water Energy Intensity

<table>
<tr><th>Energy Embedded in Water</th><th>Water Energy Intensity</th></tr>
<tr><td rowspan="3">"Energy that is used to collect, convey, treat and distribute a unit of water to end users, and the amount of energy that is used to collect and transport water for treatment "(CPUC 2010a, p.12).</td><td>"the average amount of energy needed to transport or treat water or wastewater on a per unit basis, expressed in kilowatt hours per acre-foot of water (kWh/acre-foot) or in kilowatt hours per million gallons" (CPUC 2010a p. 15, 2010b p. 4).</td></tr>
<tr><td>The quantity of energy consumed divided by volume of water entering the water management process. A measure of the required amount of energy needed to take a unit volume of water from its starting location through all necessary steps to its point of use (DWR, 2016).</td></tr>
<tr><td>The average amount of energy per volume of water to transport and treat water up to the end user only (This report and consistent with U.S. Community Protocol)</td></tr>
</table>

Wholesale and Retail Water Supplier: Only the UWMP Guidebook defines an urban wholesale water supplier and retail water supplier as provided in Table 5 below (DWR 2016, p. xv).

Table 5 UWMP Guideline Definitions of Wholesale and Retail Water Suppliers

Retailer	Wholesaler
A water supplier, either publicly or privately owned, that directly provides potable municipal water to more than 3,000 end uses or that supplies more than 3,000 acre-feet of potable water annually at retail for municipal purposes.	A water supplier, either publicly or privately owned, that provides more than 3,000 acre-feet of water annually at wholesale for potable municipal purposes

In the San Diego region, SDCWA is a wholesaler for its 24 member agencies, which are retailers. However, the City of San Diego is both a retailer and a wholesaler since it provides wholesale water to a private retailer, the California American Water Company (not a SDCWA member).

3.2 Terms and Definitions Used in This Report

For this report, the focus is to determine the energy use and GHG emissions related to water consumption in each city as is typically done in climate action plans. Therefore, energy and GHG emissions related to supply and conveyance, treatment and distribution of the water are included even if some of the energy use and GHG emissions occurs outside the city's geographical boundary, and even if most cities do not have operational control of the water management process. This is consistent with the activity-based approach used in the ICLEI - U.S. Community Protocol to calculate community-wide GHG emissions inventories where direct and indirect emissions associated with water use are accounted for. Some terms must therefore be different from the definitions described above.

Daily per capita water use: The amount of water used per person per day. Total water use within the city boundary is divided by the city population. City population is obtained from the regional SANDAG population estimates.

Upstream Water Supply and Conveyance (non-local): The portion of supply that is outside San Diego County or upstream of supplier's operational control. For the water delivered to San Diego County, a majority of the water supply and conveyance energy is upstream and occurs before it reaches San Diego County and water retailers and cities in the County. Since most retailers in the County receive water from the SDCWA and its wholesaler Metropolitan Water District (MWD), their upstream water supply and conveyance energy uses are similar.

Local treatment: Energy use for treatment of water used by a city even if outside the city boundary, but within San Diego County.

Local distribution: Energy use to distribute treated water to end use customers in a city, even if some of the distribution lies outside of the city, but within San Diego County

Local Water Supply and Conveyance: SDCWA or retailer's energy use for local production (e.g., local water retailers' energy used to pump groundwater). This may either be outside or inside of a city's geographical boundary or a City's supplier's operational control but within San Diego County.

During the data collection process, some water retailers indicated that the boundaries between supply and conveyance are not clear. Therefore, in this report water supply and conveyance is broken down only to upstream and local, (Table 6) rather than into the three steps ("extract and divert," "place into storage," and "conveyance") indicated in the UWMP Guidelines.

Table 6 Steps in Segments in Water-Use Cycle Definitions in This Report

Segments in Water-Use Cycle (CEC, 2005)	Water Supply Process Approach (DWR, 2016)	This Report	
Water Supply and Conveyance	Extract and Divert	Upstream Water Supply and Conveyance	Local Water Supply and Conveyance
	Place into storage		
	Conveyance		
Water Treatment	Treatment	Local Water Treatment	
Water Distribution	Distribution	Local Water Distribution	

The main difference between the definitions in the UWMP Guideline and this report is the boundary of each segment. Because this study focuses on energy for water related to climate planning, it includes all energy used to bring water to end-use customers in a city, whereas the UWMP Guideline includes only the energy use within the retailer's operational control.

Table 7 shows two facilities as examples of how their energy uses are accounted for under the UWMP Guidebook and in this study.

Table 7 Example of Categorizing Energy Use under UWMP Guideline and This Study

Facility (Operated by)	Segment in Water Use Cycle	Relevant Water Retailer and/or City	Included in Energy Intensity Calculation: This Study	Included in Energy Intensity Calculation: DWR 2015 UWMP Guideline
Lake Miramar Pump Station (City of San Diego)	Local Conveyance - Pumping water from Lake Miramar to Miramar Water Treatment Plant	City of San Diego	✓	✓
		City of Del Mar	✓	x
Badger Filtration Plant (Santa Fe Irrigation District)	Treatment	City of Solana Beach	✓	x
		Santa Fe Irrigation District	✓	✓
		City of Encinitas	✓	x

Facility (Operated by)	Segment in Water Use Cycle	Relevant Water Retailer and/or City	Included in Energy Intensity Calculation	
			This Study	DWR 2015 UWMP Guideline
		San Dieguito Water District	✓	x

The energy use by the Lake Miramar Pump Station is accounted for as local conveyance energy in this report for both the City of San Diego and the City of Del Mar, as Del Mar purchases its water from the City of San Diego. If the City of Del Mar were to report its conveyance energy use using the UWMP Guidebook definitions, Lake Miramar Pump Station would not be included because Del Mar does not operate the station. Similarly, Badger Filtration Plant is co-owned by Santa Fe Irrigation District and San Dieguito Water District, but Santa Fe Irrigation District operates the plant for both districts. Under the UWMP Guidebook, only Santa Fe Irrigation District would report the plant operation energy use as water treatment energy use.

4 PROCESSES AND METHODS OF DATA COLLECTION AND ANALYSIS

EPIC requested water supply and energy use data from eleven cities and obtained responses from the following ten (10) cities and their water agencies: Chula Vista, Del Mar, Encinitas, Escondido, La Mesa, Lemon Grove, National City, San Diego, Solana Beach, and Vista. Oceanside was unable to provide data but as its own water agency, had previously participated in the CPUC Study 2 and those data are provided alongside this study's results.

Most of the data retrieval was through email communication and conference calls. One meeting was held with SDCWA to understand water supply system issues, including long range planning, concerns and issues related to the integration of climate planning into water supply options, data availability and formats etc.

Each city has a unique situation with respect to water supply, distribution and treatment, ranging from ownership and control of the distribution or water treatment system within its geographical boundaries to not owning or operating its own distribution or water treatment system. As a result, though the initial data request was standardized (data request table), communication had to be individualized for each city and their water suppliers.

The following was the initial data request to each city and/or water supplier:

- Name of the agencies that provide potable water and recycled water (if any) to the city;
- Annual amount of potable water and recycled water (if any) delivered from each water agency, 2010-2015;
- Annual amount of water production from each water source (SDCWA raw, SDCWA treated, local surface water and local groundwater) of each water agency, 2010-2015;

- Annual energy consumption (kWh and therms) and amount of water treated (MG or AF), or energy intensity (energy per unit water treated) at the plant, 2010-2015;
- Total energy consumption and amount of water (gallon or acre-foot), or energy intensity (energy per unit water) to convey untreated water to treatment plant and deliver treated water to customers.

Table 8 summarizes the data obtained for this study. Data were not available for all segments for all years. Complete multi-year data were available only for two cities (Lemon Grove and La Mesa) within the years 2010-2015. Most cities had energy use data only for a single year. Some agencies were unable to differentiate supply by city under their current water billing systems and city supply had to be estimated by proxy.

Table 8 Water and Energy Intensity Data Availability

City	Water Delivery/ Sales to City	Water Supplier's Production/Source	Local Water Conveyance Energy Intensity	Local Water Treatment Energy Intensity	Local Water Distribution Energy Intensity
Del Mar		no pre-2012 data			
Solana Beach	no post 2013 data				
Encinitas					
Escondido					
La Mesa					
Lemon Grove					2012-2016
Chula Vista					
National City					
Vista					
San Diego	no pre-2012 data	no pre-2012 data			
Green: multi-year data unless otherwise indicated; Blue: single-year data; Grey: data not available or not applicable					

5 RESULTS AND FINDINGS

5.1 The Water-Energy System in the San Diego Region

Figure 5 summarizes the water supply and distribution system in the region and is consistent with the terminology and definitions described in Section 3.2 above. As shown in figure, the State Water Project and the Colorado River Aqueduct water is first brought into San Diego County through the Metropolitan Water District (MWD) to SDCWA control within the San Diego county boundary. Both raw and treated water are purchased from MWD. According to SDCWA, in 2005 and before, the ratio of treated to raw water purchased was about 60%:40% and strategy changes were undertaken to shift this ratio towards more untreated water. In 2015, treated water imports were expected to be about 25% of total imports.[7]

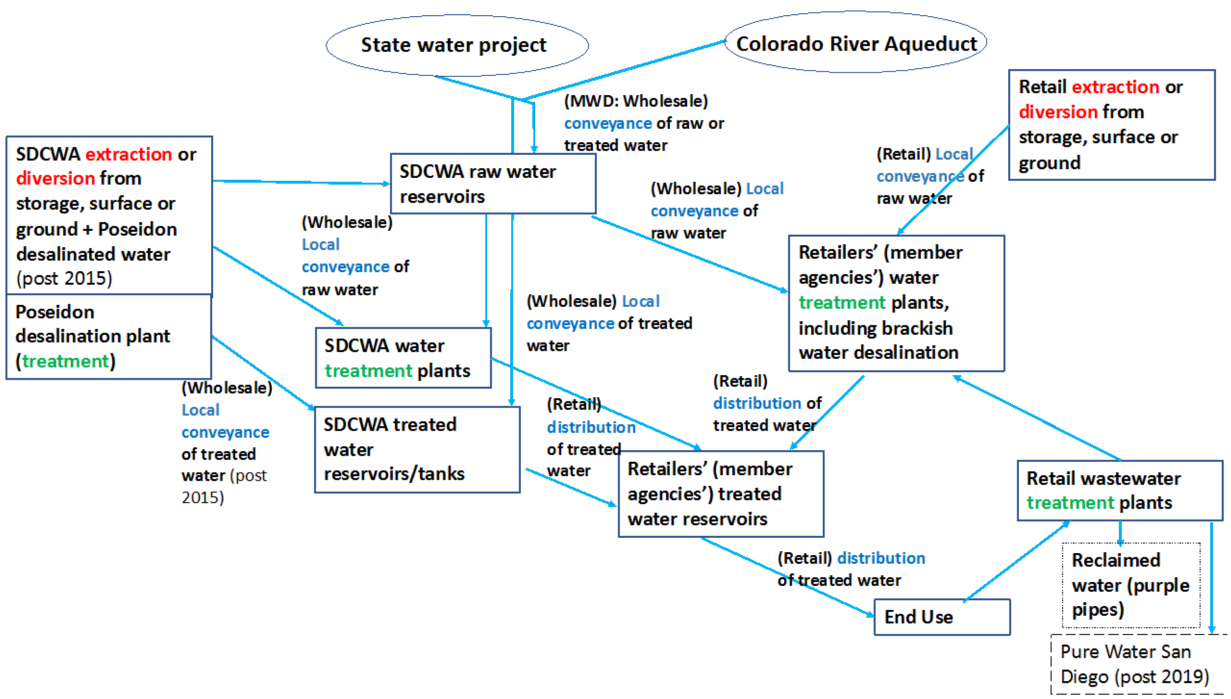


Figure 5 Water Supply and Distribution System in the San Diego County

5.1.1 Annual Precipitation

Annual precipitation can have a significant effect on a city's water source mix. Figure 6 below shows the annual total precipitation measured at the San Diego Airport – Lindbergh Field[8], considered representative for the group of cities in this study. In the period 2010-2016, 2010 has the highest annual total precipitation and 2012-2014 had the lowest annual total

[7] Page 2-8, 2013 Regional Water Facilities Optimization and Master Plan Update, March 2014.
[8] The Western Regional Climate Center records the variation of temperature, precipitation and evapotranspiration from weather stations.

precipitation in recent years. Precipitation determines how much water must be imported, and is a factor in determining the energy and GHG intensity of supply.

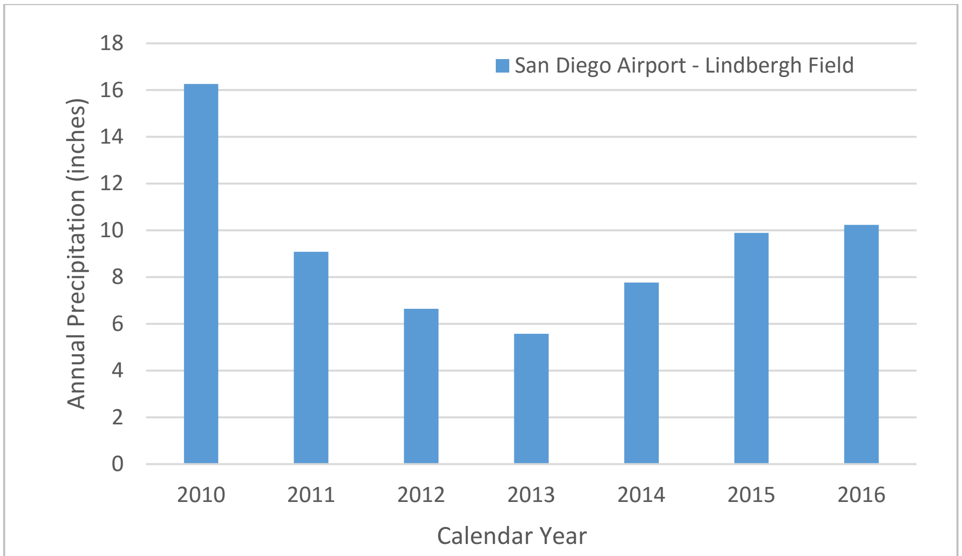


Figure 6 Annual Average Precipitation at Lindbergh Field, San Diego (2010-2016)

5.1.2 Cities and Their Water Sources

Using the definitions described in Section 3.1 and to better categorize the energy intensities associated with each water source, potable water sources are separated into four categories: SDCWA treated, SDCWA untreated, local surface and local groundwater. Currently, recycled water produced is not drinking water quality, and no desalinated water or recycled water for potable use was produced in 2015. On an annual basis, each city procures different amounts from each source, which affects the energy and GHG intensities.

An example (Figure 7) illustrates the variation in sources for the City of Chula Vista from 2010 to 2015. Chula Vista has a mix of SDCWA treated, SDCWA raw, local surface, local ground, and recycled water. Some cities have no recycled water or groundwater. Figure 7 also shows the GPCD for Chula Vista. While total water use dropped in 2015, local supply also decreased significantly in 2014-2015.

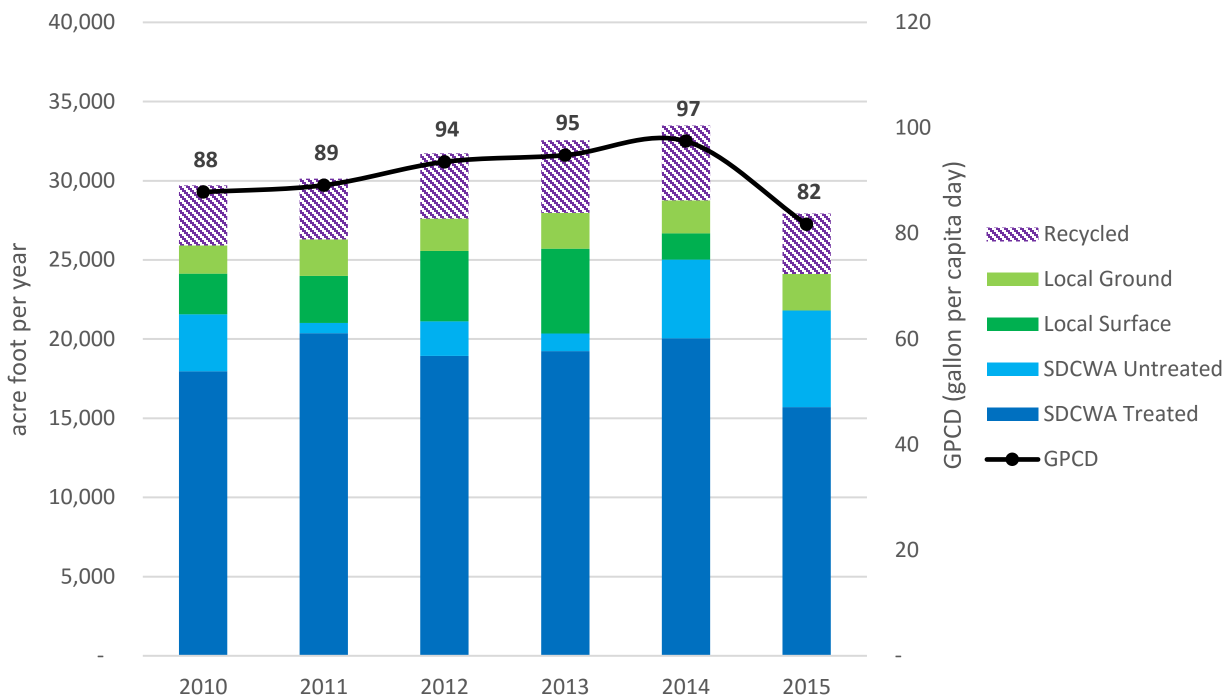


Figure 7 2010-2015 City Water Use by Source (Chula Vista), Gallons per Capita Day (GPCD) Refers to the Average Potable Water Use per Person per day

Figure 8 below compares the source mix (imported and local source) and supply for cities in 2010 and 2015. In 2015, all cities used less potable water in 2015 compared with 2010, mainly due to the mandatory water use restrictions put in place by the State. In addition, the proportion of local water supplies also decreased (green bars in Figure 8) for every city in 2015 compared with 2010.

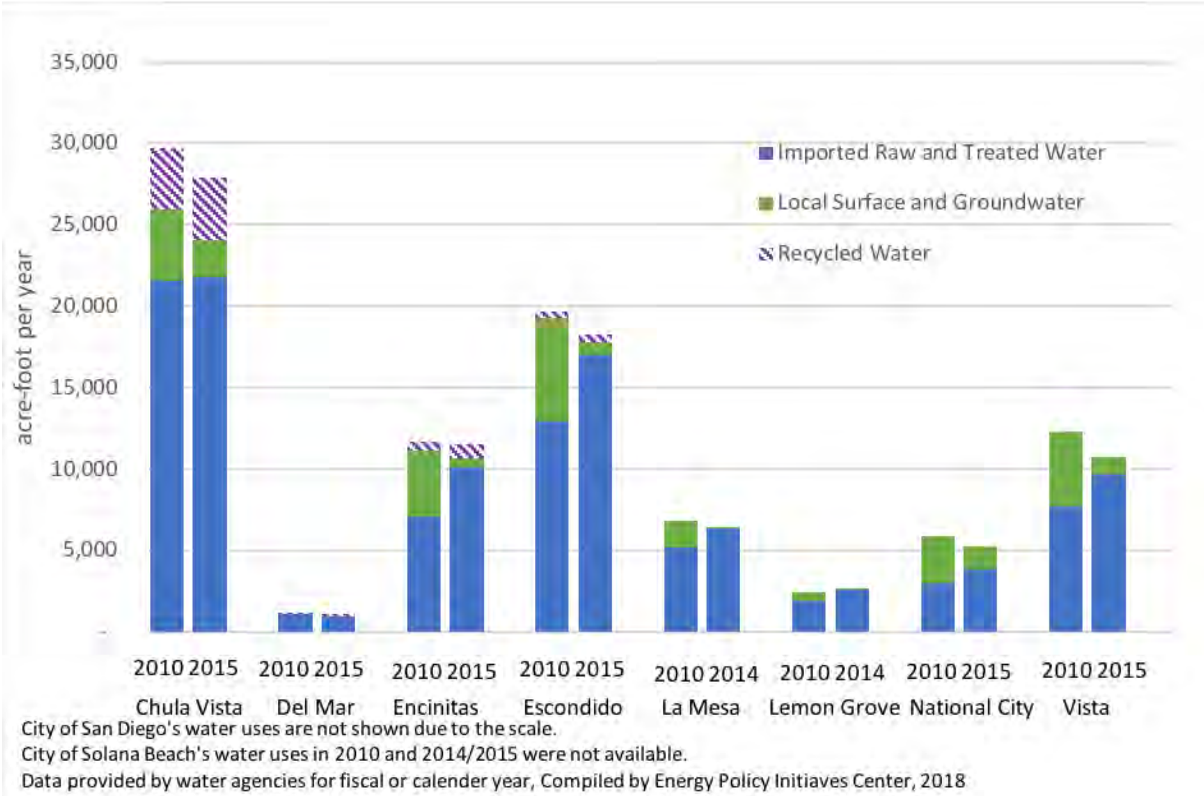


Figure 8 Comparison of Water Mix and Supply in 2010 and 2015 for Cities in San Diego County

As seen in Figure 8, not all cities included in this study have recycled water supplies. Six out of the ten cities in this study, Chula Vista, Del Mar, Encinitas, Escondido, San Diego and Solana Beach — provide recycled water.[9] Because recycled water is generally provided by wastewater agencies rather than water agencies, cities may have recycled water service agencies different from their water suppliers. For example, the City of Del Mar receives potable water service from the City of San Diego, but the recycled water service is provided by San Elijo Joint Powers Authority (JPA), a wastewater and recycled water service agency that serves cities in north San Diego County.

5.2 Energy Intensity by Water-Use Segment

5.2.1 Upstream Water Supply and Conveyance

As defined in Section 3.2 above, the upstream (non-local) supply and conveyance energy boundaries are outside San Diego County or outside the upstream of City water supplier's operational control.

The upstream water supply and conveyance energy intensity depends on the water source, raw or treated water transport distance, and changes in topography along the route (CPUC, 2010a).

[9] City of San Diego's data were not shown in the figure because of the scale and City of Solana Beach's 2015 water use data were not available.

In some cases, treated water is delivered directly to local cities and the upstream supply and conveyance may include the water treatment energy intensity at the wholesaler's treatment plant.

The CEC 2005 study provided upstream supply and conveyance energy intensities separated into Northern and Southern California. The study indicated that in general 50% of Southern California's imported water supply is from the Colorado River and from the SWP. The energy intensity of upstream supply and conveyance for Southern California is significantly greater than for Northern California (CEC 2005, Table 10). The CEC 2006 study refined these estimates for upstream supply and conveyance energy intensity. For Southern California the CEC developed a weighted average intensity of two SWP branches, net of hydro generation on the conveyance system of MWD that includes system losses (CEC, 2006).

The CPUC Study 2 focused on the embedded energy in water for retail water agencies, thus also including the energy intensity of upstream water supply and conveyance of the wholesale water agency and in some cases also included treatment of the water prior to delivery to retail agencies.

For the retail agencies in San Diego County, SDCWA is their wholesale agency providing both treated and raw water. When retail agencies purchase treated water from SDCWA, the associated upstream supply and conveyance energy intensity includes SDCWA's treatment energy intensity.

The energy intensities from the two CEC studies and the CPUC Study 2 are given in Table 9.

Table 9 Upstream (Non-Local) Water Supply and Conveyance Energy Intensity from Previous Studies

Water Supply and Conveyance Energy Intensity	Northern California	Southern California	Northern California	Southern California	SDCWA-Treated	SDCWA-raw
	CEC 2005, (Table 1-3)		CEC 2006, (Table ES-1)		CPUC, 2010b (Study 2, Table 4-5)	
kWh/MG	150	8,900	2,117	9,728	6,912	6,785
kWh/AF	49	2,900	690	3,170	2,252	2,211

In previous GHG inventory analyses for cities in the San Diego region, it was common to use the Southern California water energy intensity from the CEC 2005 study for this component of the water cycle, as recommend by the U.S Community Protocol (ICLEI 2012, Appx. F p. 73). However, the SDCWA-treated and SDCWA-raw water upstream energy intensities reported in CPUC Study 2 are lower than those from the previous statewide studies and would result in fewer GHG emissions from water use than in past inventories.

In their UWMPs, retail water agencies report only the energy intensity within their operational control. Their wholesaler SDCWA, and SDCWA's wholesaler MWD, similarly report the energy intensities within their operational control. For MWD, this includes the energy intensity of conveying water from SWP and Colorado River to MWD's treatment plants or to MWD's distribution system (MWD 2016, Appx. 9). For SDCWA, this includes conveyance of raw water, treatment, and distribution of treated water to member agencies. Therefore, the total non-local upstream energy intensity for cities and their retail agencies would be the sum of the MWD energy intensity (including treatment if raw water) and the SDCWA conveyance and treatment (if raw water) energy. Table 10 shows the overall upstream supply and conveyance energy intensity for retail agencies in San Diego County, calculated by combining the energy intensities from MWD and SDCWA.

Table 10 Upstream Water Supply and Conveyance Energy Intensity of Retail Water Agencies in San Diego County

Segments in Water-Use Cycle	FY 2013 and 2014 Average Energy Intensity (kWh/MG)	FY 2013 and 2014 Average Energy Intensity (kWh/AF)	Data Source
MWD delivered untreated*	5,576	1,817	MWD 2015 UWMP Appendix 9
SDCWA conveyance**	-190	-62	SDCWA 2015 UWMP Appendix K
SDCWA-Raw Subtotal	*5,386*	*1,755*	-
SDCWA treatment	184	60	SDCWA 2015 UWMP Appendix K
SDCWA distribution***	3	1.1	SDCWA 2015 UWMP Appendix K
SDCWA-Treated Total	*5,573*	*1,816*	-

*Includes conveyance from the State Water Project and Colorado River water to MWD's distribution system, and distribution from MWD to MWD's member agencies (e.g., SDCWA)

**Conveyance of raw water supplies to the water treatment plants or to member agency connections (negative value means hydro-electric generation by SDCWA)

*** Distribution of treated water from SDCWA's Twin Oaks Water Treatment Plant to SDCWA's member agencies

"Upstream" refers to moving water from the original source to SDCWA's member agency's service area or first connection point

As shown in Table 10, the upstream energy intensity for SDCWA treated water includes the treatment energy intensity at SDCWA's Twin Oaks Water Treatment Plant (WTP), which also includes the energy intensity to move treated water to a local retail water agency's service area. The energy intensity data from UWMPs are based on an average of FY2013 and FY2014, which are closer to but lower than the SDCWA-treated and SDCWA-raw energy intensity reported in CPUC Study 2.

For upstream (non-local) energy intensity, this report uses the SDCWA-treated and SDCWA-raw energy intensities from Table 10, as they are the best and most recent available data.

Although upstream energy intensities are used as constants, the amount of water delivered through Colorado River and SWP varies year by year, depending on hydrology, weather patterns, etc. As a result of annual changes in water supplies, the energy intensity for upstream supply and conveyance could vary by year (see Section 5.7).

5.2.2 Local Supply and Conveyance (Retail Water Agency)

Local supply and conveyance is within the retail water agency's operational control. For the cities that themselves are retail water agencies, local supply and conveyance is generally within their geographical boundaries. For cities that purchase water from retail agencies, supply and conveyance may either be outside or inside of the city's geographical boundary but is within San Diego County.

Not all water agencies have an energy component for local supply and conveyance. For agencies that receive all their treated water from SDCWA, no energy is attributed to locally moving raw water. The data collection process for this study made clear that in some cases it is difficult to separate local supply and conveyance energy from local water treatment energy. For example, energy use at a lake (reservoir) pump station (considered as local conveyance) and the energy use at the adjacent water treatment plant (considered as local treatment) are often tracked by one electricity meter. In the case of groundwater extraction, treatment (disinfection with chlorine) is applied at groundwater wells, which makes it difficult to separate out the energy uses.

Limited energy intensity data were collected for local supply and conveyance, which includes groundwater extraction and surface water storage and conveyance. The results we do have are shown in Figure 9 below. Details on the types and activities of local supply and conveyance for each retail water agency are provided in Appendix A.

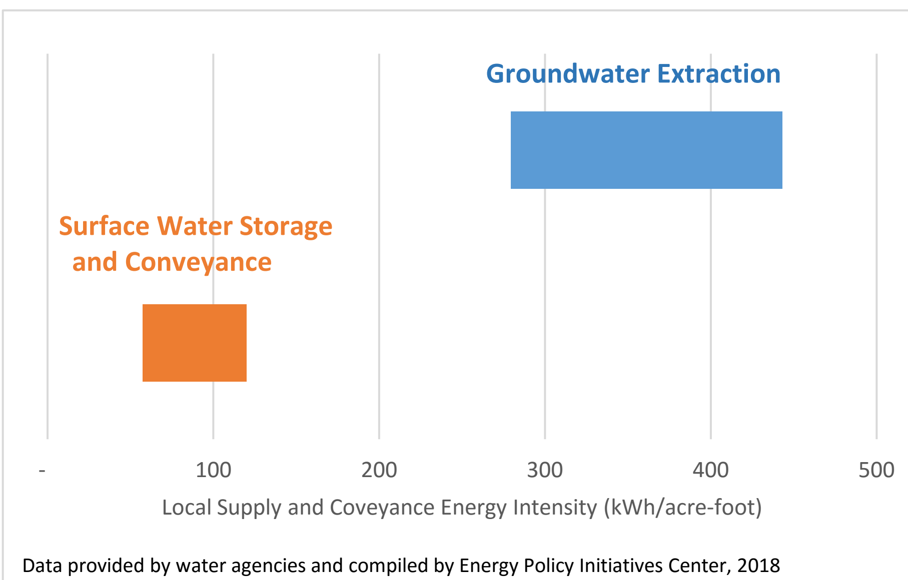


Figure 9 Local Supply and Conveyance Energy Intensity Range (kWh/AF)

5.2.3 Local Water Treatment Energy Intensity (Retail Water Agency)

In addition to the SDCWA's Twin Oaks Valley WTP, ten local retail water agencies own or co-own traditional water treatment plants in the region. These treatment plants have no advanced treatment technology (e.g. reverse osmosis, membrane filtration) and treat mostly raw surface water with low salinity. The surface water is either purchased raw water from SDCWA or local surface water. Treatment energy intensities at eight plants were collected for this study. The water treatment plants and their owners are given in Table 11.

Table 11 San Diego County Retail Water Agency and Their Water Treatment Plants

Retail Water Agency	Water Treatment Plant
Helix Water District	R.M Levy WTP**
Olivenhain Municipal Water District	David C. McCollom WTP**
Santa Fe Irrigation District (Operator) San Dieguito Water District	R.E. Badger Filtration Plant*
Sweetwater Authority	Robert A. Purdue WTP*
City of Escondido (Operator) Vista Irrigation District	Escondido-Vista WTP*
City of Oceanside	Robert A. Weese Filtration Plant
City of Poway	Lester J. Berglund WTP
City of San Diego	Miramar WTP*, Otay WTP*, Alvarado WTP*
**Multi-year treatment energy intensity data collected through this study, *single-year treatment energy intensity data collected through this study	

Figure 10 below shows the water treatment energy intensity (multi-year or single-year, depending on data availability) at the plants.

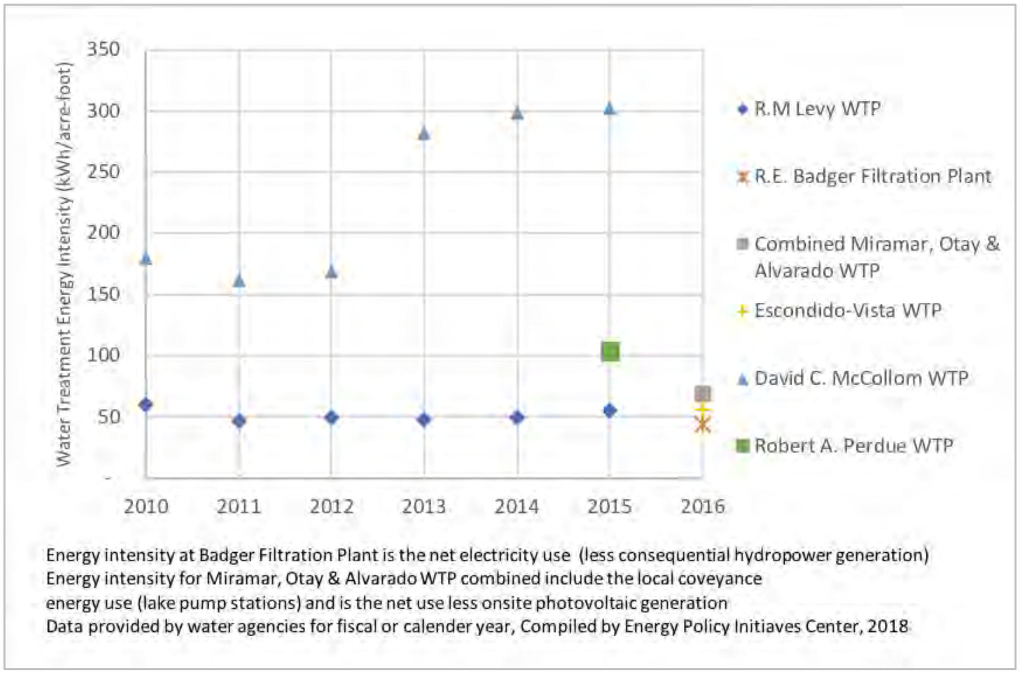


Figure 10 Water Treatment Energy Intensity at Plants in San Diego County 2010-2016

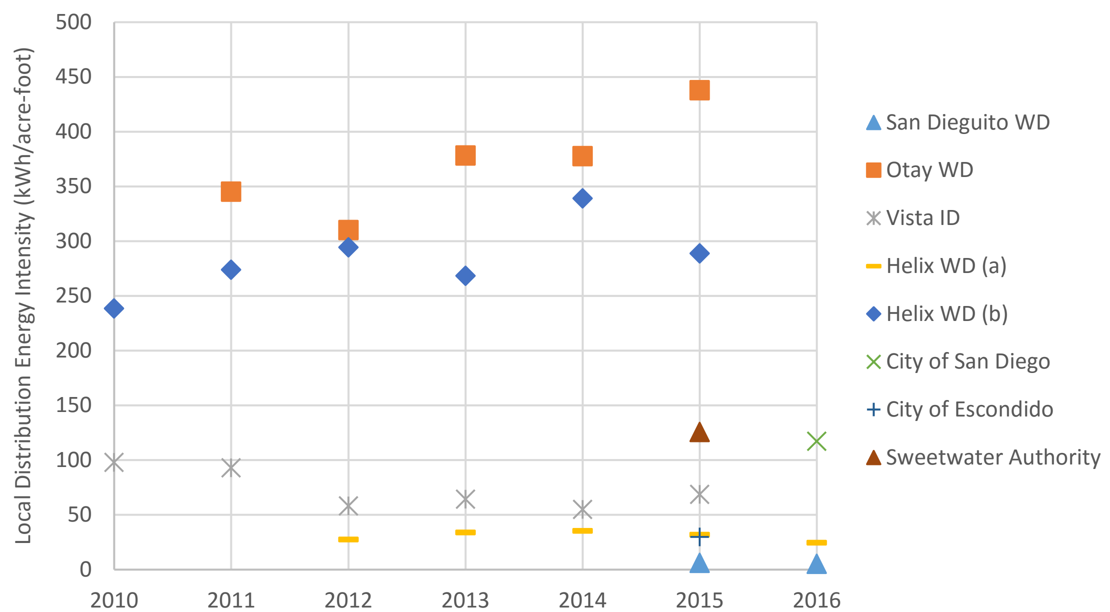
The energy intensity at local WTPs from 2010 to 2016 ranges from 44 to 302 kWh/AF (135 to 927 kWh/MG). Water treatment energy intensity depends on the treatment plant configuration, volume of water treated, treatment technology used, raw water quality, etc. For example, as shown in Figure 10, the increase in energy intensity at the David C. McCollom WTP in 2013 was reported to be due to the addition of new equipment and replacement of previous equipment and pipelines. In the case of the City of San Diego's WTPs (Miramar, Otay and Alvarado), the energy intensity in Figure 10 represents the combined energy intensity of conveyance and treatment. Both Alvarado and Otay WTPs also have on-site photovoltaic (PV) systems. Electricity from these systems are netted out for the energy intensity calculation because only net energy use is provided. The Badger Filtration Plant treats imported raw water during summer months and generates hydropower (known as consequential hydropower generation) for sale back to the electric utility, San Diego Gas & Electric (SDG&E). Since the energy use does not include solar or hydroelectric production, this plant has minimum net energy use for conveyance and treatment.

In addition to the above treatment plants with traditional water treatment, the City of Oceanside's Mission Basin Groundwater Purification Facility (GPF) and Sweetwater Authority's Reynolds Desalination Facility both treat brackish groundwater with energy-intensive reverse osmosis technology. The reported groundwater extraction and treatment energy intensity in the Sweetwater Authority's 2015 UWMP (2016) is 1,109 kWh/AF (3,402 kWh/MG). The reported groundwater treatment energy intensity at Mission Basin GPF in CPUC Study 2 ranges from 364 to 655 kWh/AF (1,117 to 2,009 kWh/MG). Both are higher than the traditional water treatment energy intensity.

The range of treatment energy intensities in this study for plants with traditional treatment but no advanced treatment process — 44 to 302 kWh/AF — is broader than the range in CPUC Study 2, which reported a range of 20 to 150 kWh/AF (50 to 450 kWh/MG) (CPUC 2011, p.89).

5.2.4 Local Water Distribution Energy Intensity (Retail Water Agency)

Each retail water agency in San Diego County maintains its own distribution system, including pipelines, pump stations, pressure reduction stations, storage tanks, etc. Figure 11 shows the water distribution energy intensity (multi-year or single-year, depending on data availability) for seven local retail water agency distribution systems. The water agencies (Santa Fe ID and City of Del Mar) with zero distribution energy intensity within their service areas are not shown in Figure 11.



Helix WD (a) and (b) represents the distribution energy intensities at different parts of the service area.
Energy intensity is within each water agency service area (operation control) only and
varies depends on topography of the area, system configuration, etc.
Santa Fe ID and Cities of Del Mar has zero distribution energy inteisity within theier service areas.
Data provided by water agencies for fiscal or calender year, compiled by Energy Policy Initiaves Center, 2018

Figure 11 Water Distribution Energy Intensity within Local Retail Water Agency's Service Area

The distribution energy intensity within the study ranges from 0 to 438 kWh/AF (0 to 1,344 kWh/MG). The distribution energy intensity depends on the topography of the service area, system configuration, size, etc. The service area can be flat or hilly (on top or at the bottom of a hill). For example, the City of Del Mar and Santa Fe ID distribute water through gravity-fed systems from a higher elevation to lower elevations within their services areas, therefore, the distribution energy intensity is zero. The distribution energy intensity also depends on the system size. Of the cities included in this study, the City of San Diego has the largest service area and maintains 128 main pressure zones and 50 pump stations.

Figure 11 shows two sets of energy intensities for Helix WD's distribution system. This is because Helix WD's service area covers multiple cities, therefore, the energy intensity for each city within the service area were estimated separately by Helix WD based on the percentage of city service in each pressure zone and the energy needs to pump water to each pressure zone.

When calculating the energy intensity for cities, the distribution energy includes all energy needed to move water from WTPs to end-use customers. Even if the retail water agency provides water to a city with a gravity-fed system, the distribution energy intensity for the city may not be zero if the water agency receives pressurized water. The method to categorize energy use in this report is discussed in Section 3.2, which summarizes terms and definitions used in this report.

The distribution energy intensities in this study — 0 to 438 kWh/AF — are lower than the estimates in past studies. The CPUC Study 2 breaks down distribution energy intensities by topography (hilly terrain, moderate terrain, flat terrain and pressure system pumps). It reports a range of 130 to 490 kWh/AF (400 to 1,500 kWh/MG) for hilly areas and a range of 100 to 800 kWh/AF (300 to 2,500 kWh/MG) for areas with pressure-regulating pumps (CPUC 2010b, p. 90).

5.3 Energy Use and GHG Emissions by City

The total energy needed to deliver potable water to a city depends on the water mix, the volume of water from each water source delivered to city, and the energy intensity of each segment in the water-use cycle for the source. Equation 1 below shows the general equation to calculate the energy needed.

Equation 1 General Equation to Calculate Energy Needed to Deliver Potable Water to a City

$$Energy_{water,city} = \sum_{source,segment,agency} (W_{source,agency} * EI_{source,agency,segment})$$

Where,

$Energy_{water,city}$ = total energy needed to deliver potable water to a city (kWh)

$W_{source,agency}$ = annual water from a water source delivered to a city by a retail water agency (acre-foot or MG)

$EI_{source,segment}$ = energy intensity of a water source at a segment of water-use cycle, for a retail water agency (kWh/acre-foot or kWh/MG)

With,

source = [SDCWA treated, SDCWA raw, local surface water, local groundwater]

agency = retail water agencies in San Diego County

segment = [upstream supply and conveyance, local supply and conveyance, local treatment, and local distribution]

Similarly, the total GHG emissions from delivering water to a city can be estimated by multiplying the energy use by the electricity emission factor (Equation 2).

Equation 2 General Equation to Calculate GHG Emissions from Delivering Potable Water to a City

$$GHG\ Emissions_{water,city} = \sum_{source,segment,agency} (Energy_{source,segment,agency} * EF_{source,segment} * 10^{-3}) * 0.000453$$

Where,

$GHG\ Emissions_{water,city}$ = GHG emissions from delivering potable water to a city (MT CO_2e)

$Energy_{source,segment,,agency}$ = total energy needed to deliver potable water to a city, at each segment (kWh)

$EF_{source,segment}$ = electricity emission factor of a water source at a segment of the water system (lbs CO_2e/MWh)

10^{-3} = conversion factor, kWh to MWh

0.000453 = conversion factor, lbs to MT

With,

source = [SDCWA treated, SDCWA raw, local surface water, local groundwater]

agency = retail water agencies in San Diego County

segment = [upstream supply and conveyance, local supply and conveyance, local treatment, and local distribution]

For upstream energy use, a California-wide average emission factor from U.S. Environmental Protection Agency (EPA) Emissions and Generating Resource Integrated Database (eGRID) is applied. For local energy use, some water agencies included in this study use on-site renewable generation, otherwise all are assumed to use grid electricity from SDG&E. EPIC develops SDG&E electricity emission factors annually. These values are used for grid electricity used within the region.[10] The SDG&E electricity emission factors for 2010 to 2016 are given in Table 12.

[10] See EPIC (2016) technical working paper "*Estimating Annual Average Greenhouse Gas Emission Factors for the Electricity Sector: A Method for Inventories" (2016)*. The emission factors depend on the power mix (e.g., wind, solar, natural gas) and the amount of electricity SDG&E procures from each source.

Table 12 SDG&E Electricity Emission Factors (2010-2016)

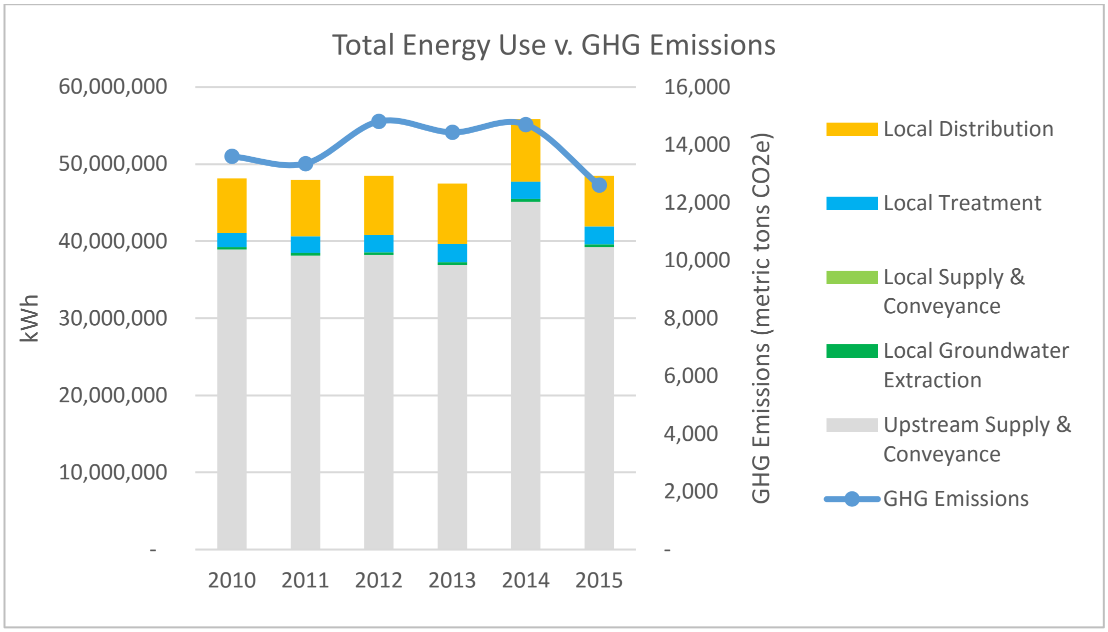
Year	Renewable Content in SDG&E Bundled Electricity (%)	SDG&E Bundled Electricity Emission Factor (lbs CO_2e/MWh)
2010	10%	664
2011	16%	616
2012*	19%	750
2013	24%	729
2014	32%	622
2015	35%	584
2016	43%	525

*The spike in the 2012 emission factor is due to the closure of San Onofre Nuclear Plant and replacement by natural gas-powered electricity.

Emission factors updated by EPIC in July 2017 may differ from previous versions due to updates of the source data.

In this study, multi-year water delivery data were available from retail agencies for all ten cities. However, only single year energy data were available for some retail water agencies. To calculate the energy use to deliver water to a city across years and across different water mixes, the single year energy intensity is used as a proxy for all years if multi-year date were not available. For example, only 2016 water treatment energy intensity from City of San Diego's WTPs was available and it was applied to water treated at the WTPs from 2010–2016 to calculate the energy use.

The energy needed to deliver water to a city and the associated GHG emissions by upstream and local, and by each segment at the local level are presented for an example city (Encinitas) in Figure 12.



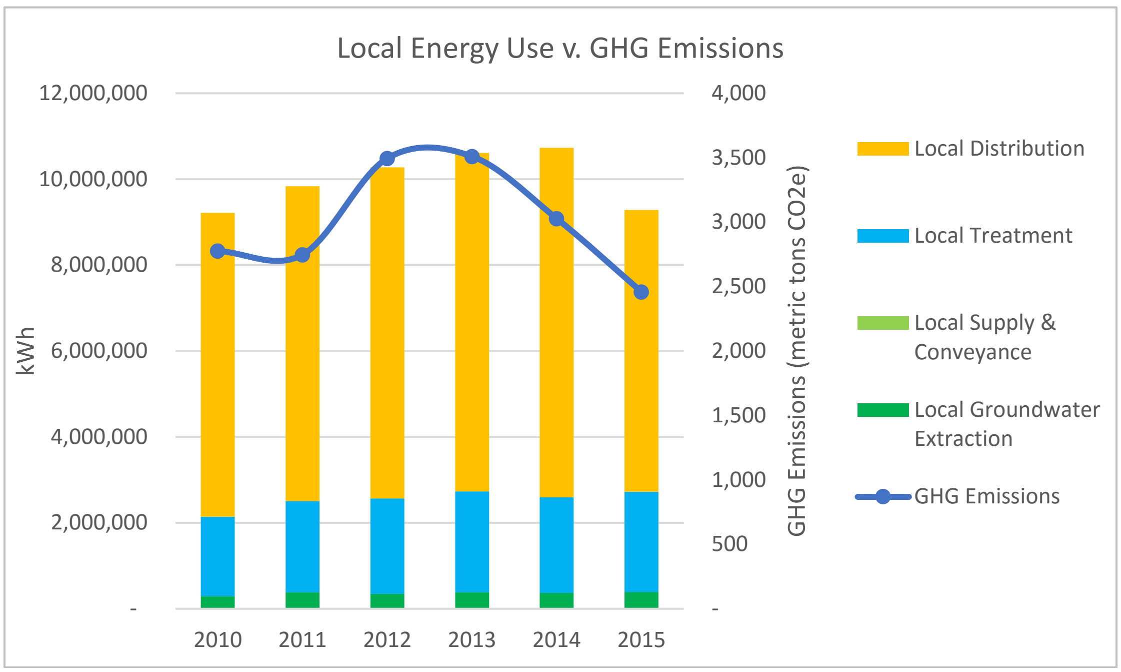


Figure 12 City of Encinitas – Energy Needed to Deliver Potable Water and the Associated GHG Emissions (Upper — Total Energy and Emissions; Lower — Local Energy and Emissions)

As shown in Figure 12 (top), a majority of total energy use is from upstream supply and conveyance (grey bars), approximately 86–90%, and the rest is at the local level (blue and yellow bars). At the local level (Figure 12 bottom), 58%–76% of the energy use is for water treatment. This is because the retail agencies that provide potable water to Encinitas (OMWD and SDWD) obtain the majority of their water sources raw from SDCWA (on average less than 10% treated water was imported from SDCWA per year) and treat this at their own local WTPs.

The GHG emissions (Figure 12, dark blue lines in both charts) follow similar trends as the energy uses across years in both cases. However, as the percentage of renewables in SDG&E's electricity has increased in recent years, the electricity emission factor has decreased. As a result, the rate of decrease of GHG emissions after 2014 was greater than the rate of decrease of energy use. Similarly, during the drought years 2014–2015, cities conserved water which lowered local water-energy uses and water-GHG emissions. Figure 13 below shows an example of city water use by source and the associated local emissions in the City of Escondido. The black line represents the local water related GHG emissions. Because of the high renewable electricity in recent years, the decrease of GHG emissions was faster than the rate of decrease of water use after 2014.

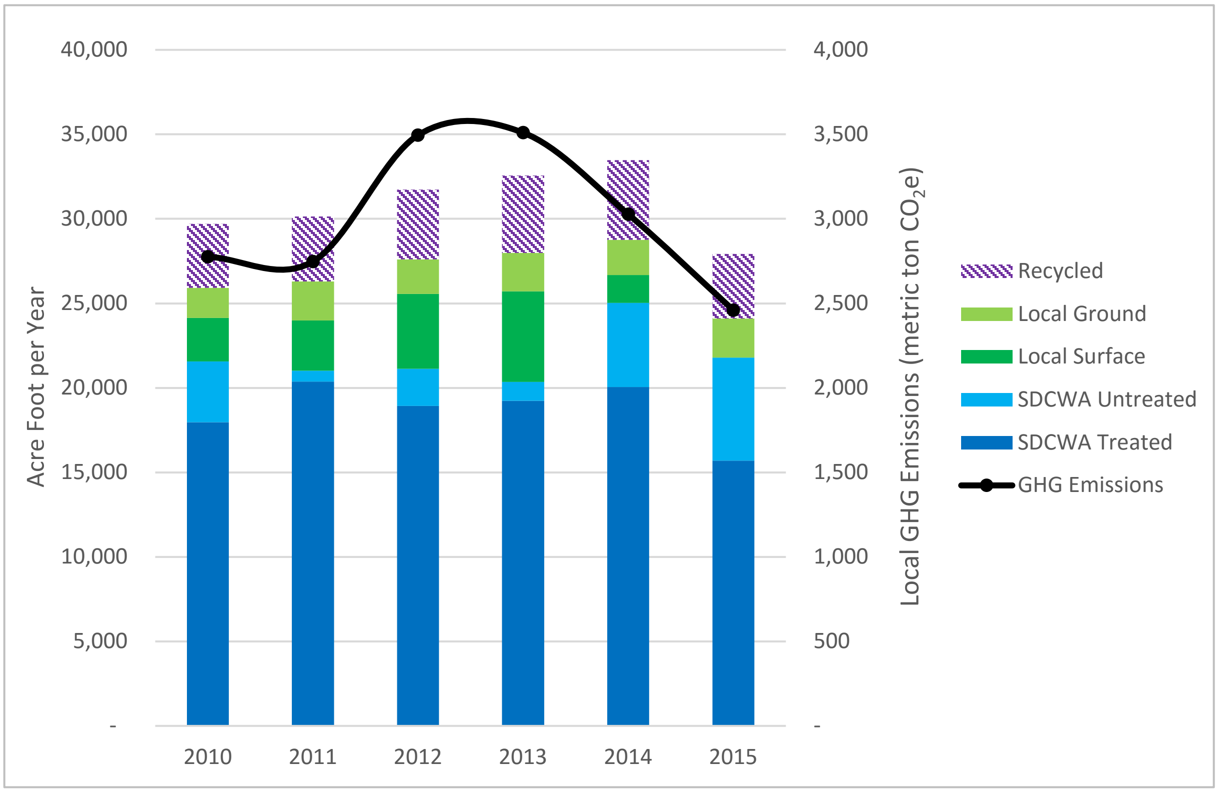


Figure 13 2010-2015 City Water Use by Source (City of Escondido) and Local Water-GHG Emissions

One key finding of the analysis of local energy use is that the greatest difference between city water-energy use is attributed to whether they have their own treatment plants and whether their distribution systems have topographical variations. Due to these factors, GHG emissions from the energy-for-water use by city cannot be directly compared as it depends highly on the structure of the water supply system of the agencies providing the water.

5.4 Energy Intensity for Water by City

Calculating the water energy intensity of a city provides a standard metric to compare the energy needed to deliver water for a city across the years and to understand where and why a city's water-energy intensity is within the range in this region. Equation 3 below shows the general equation to calculate the water energy intensity.

Equation 3 General Equation to Calculate Water Energy Intensity of a City

$$Water\ EI_{city} = \frac{Energy_{water,city}}{\sum_{source,agency}(W_{source,agency})}$$

Where,

$Water\ EI_{city}$	= water energy intensity of a city (kWh/acre-foot or kWh/MG)
$Energy_{water,city}$	= total energy needed to deliver potable water to a city (kWh)
$W_{source,agency}$	= annual water delivered to a city by a water agency (acre-foot or MG)

With,

source	= [SDCWA treated, SDCWA raw, local surface water, local groundwater]
agency	= retail water agencies in San Diego County
segment	= [upstream supply and conveyance, local supply and conveyance, local treatment, and local distribution]

The range of local water energy intensities is provided in Figure 14, not including upstream (non-local) energy intensity. The local energy intensity for Del Mar, Escondido, San Diego, and Solana Beach do not show a range because only single year energy intensity data were available from their water supply agencies. For these cities, the local energy use may differ across years because of the water delivery amounts (discussed in Section 5.3), but the energy intensity was held constant due to limited data availability.

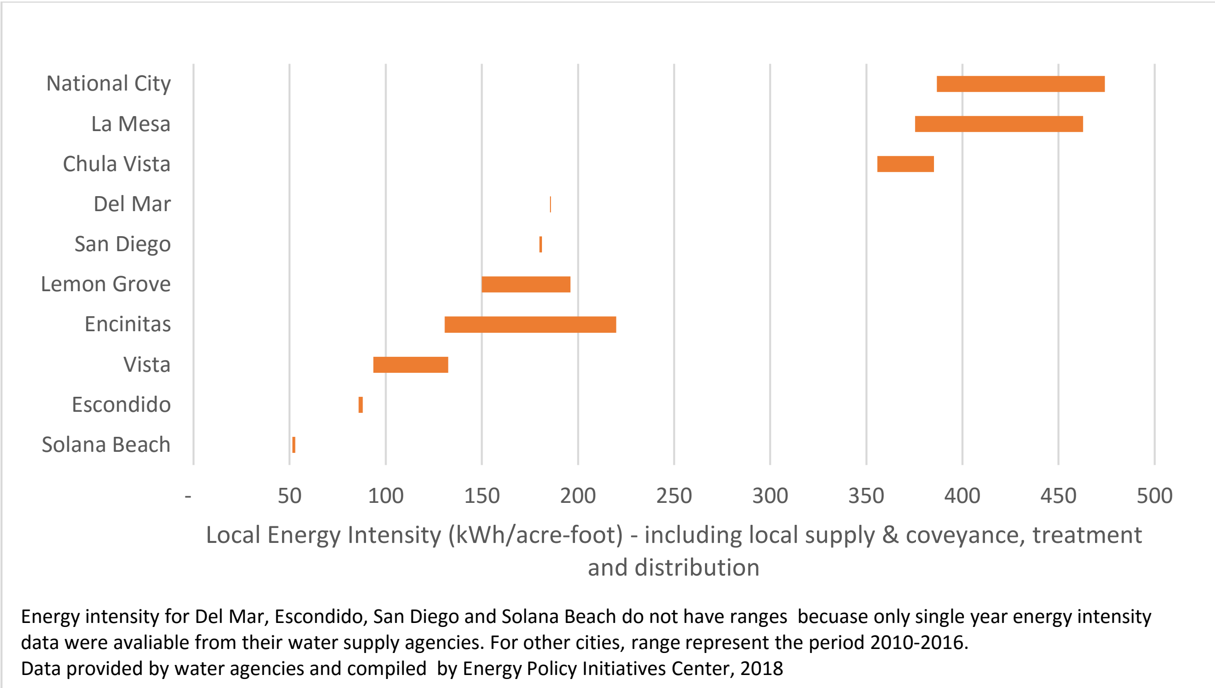


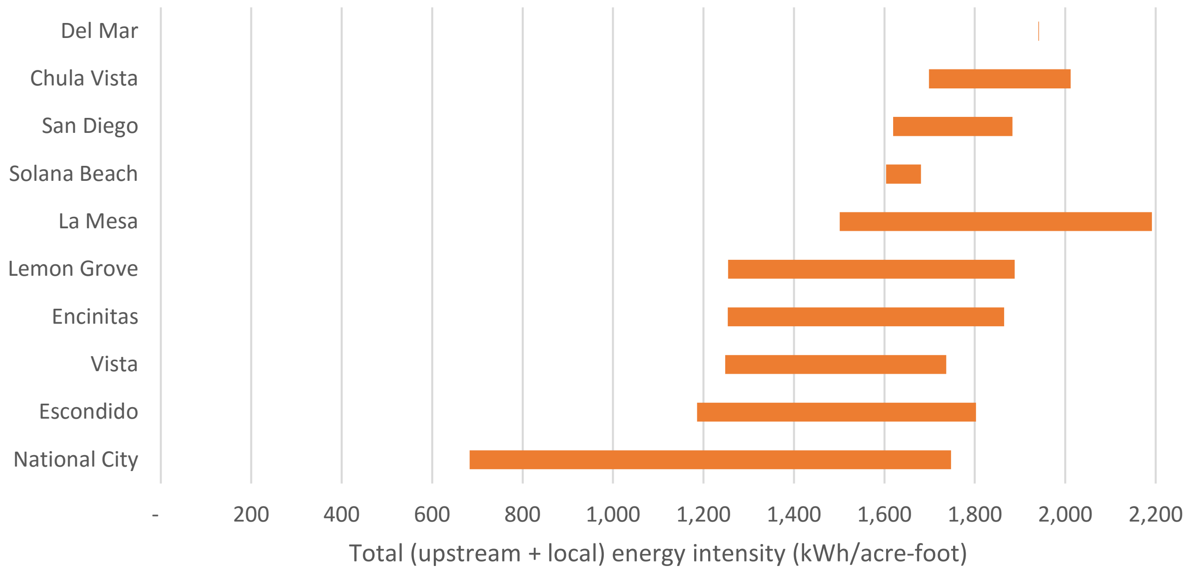
Figure 14 Local Water Energy Intensity for Cities in San Diego County

The lowest local water energy intensity is 51 kWh/AF (158 kWh/MG), and the highest is 474 kWh/AF (1,455 kWh/MG). Solana Beach, Del Mar, San Diego, Lemon Grove, Encinitas and Vista have much lower energy intensities than National City, La Mesa and Chula Vista.

Solana Beach has the lowest local energy intensity because the distribution system of its main water district (Santa Fe ID) is a gravity-fed system with no energy use. As described in Section 5.2.3 (Local Water Treatment Energy Intensity), its Badger Filtration Plant has minimum net energy use because it produces hydropower and sells the electricity back to SDG&E. Encinitas has the biggest range within this lower group reportedly due to facility updates that increased the water treatment energy intensity.

In contrast, National City and La Mesa are cities with high local water energy intensity ranges. For National City and La Mesa this is because their water districts (Sweetwater Authority and Helix WD) purchase mostly raw water from SDCWA that needs local water treatment. In particular, Helix WD does not purchase any treated water, so all water is treated locally. Sweetwater Authority has developed local surface and groundwater sources (on average over 50% water is from local sources with over 80% in 2013), however, groundwater treatment is very energy-intensive.

As explained in Section 5.3 (Energy Use and GHG Emissions by City), many cities receive imported water and a significant amount of energy is used to move water from its upstream source to San Diego County. Therefore, put into this wider context, local water energy intensities represent only a small fraction of the total energy to deliver water to a city. Figure 15 presents the total water energy intensity including upstream for cities in this study.



The ranges represent multi-year ranges.
Data provided by water agencies and compiled by Energy Policy Initiatives Center, 2018

Figure 15 Total (Upstream + Local) Water Energy Intensity for Cities in San Diego County

From this overall context, the lowest total water energy intensity is 683 kWh/AF (2,096 kWh/MG), and the highest is 2,192 kWh/Af (6,727 kWh/MG). The ranking of the cities has also changed and the range of values is now smaller than when evaluating only local energy. In Figure 15, the cities with high total water energy intensities import most of their water. For example, in year 2014 when only 1% of water supplied was local La Mesa's total water energy intensity was the highest of any city in the study. In addition, as discussed previously, La Mesa also has high local water energy intensity with an energy-intensive distribution system that contributes to high total energy intensity. Also, even though Del Mar has the smallest service area among the cities in the study, with a population less than 5,000, the energy intensity is among the highest mainly because all water is imported, treated at City of San Diego's WTP and the distributed through San Diego to Del Mar.

National City has the largest range and the lowest total energy intensity because of the significant change of its water mix across the years. In 2013, 87% of its water was from local sources which led to low upstream energy use and low total energy intensity. In 2015, only 27% of the water was from local sources, which led to the higher end of the energy intensity range. However, the lower end of its total water energy intensity is the smallest among all cities in the study because when precipitation is normal, Sweetwater Authority does not need to import a high percentage of water from SDCWA, which lowers the contribution of upstream energy intensity.

In general, the high end of each city's total water energy intensity range represents the years 2014-2016, when California experienced drought conditions. The water agencies supplying the cities had to import more upstream water that led to an increase in water-energy intensity at the same time cities were limiting water use in response to the drought. A comparison of potable water use and energy intensity from 2010 to 2015 for the City of Chula Vista is shown in Figure 16 below.

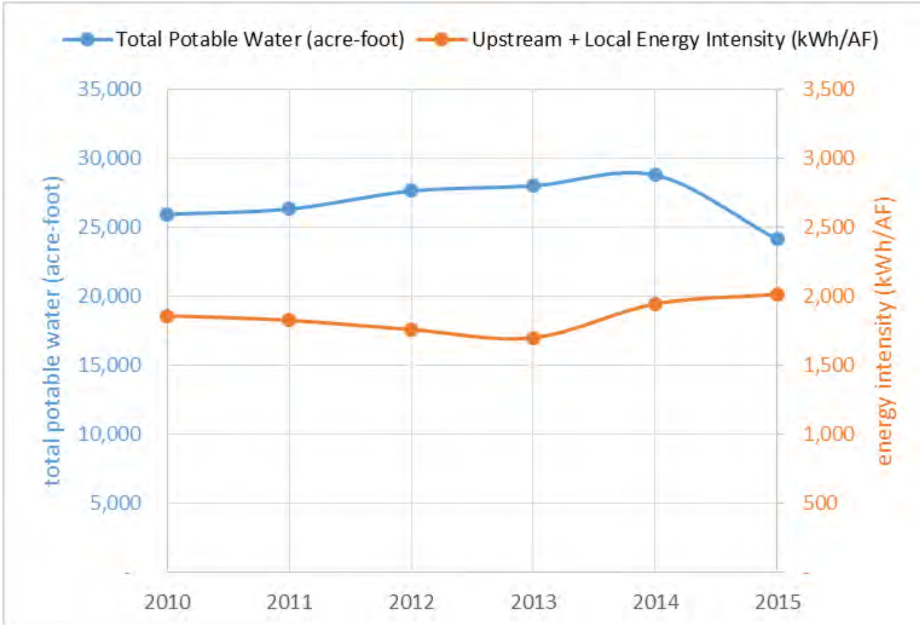


Figure 16 Comparison of Potable Water Use and Total (Upstream + Local) Energy Intensity in City of Chula Vista (2010–2015)

As shown in Figure 16, the City of Chula Vista had the lowest potable water use and highest total water energy intensity in 2015, because the City imported more upstream water, which led to an increase in the water-energy intensity.

Geospatial visualizations of the same energy intensity data can also help understand some of these differences. When only local energy intensities are considered, some cities still have *relatively* high energy intensities as seen in Figure 17 for the cities of Chula Vista and National City in comparison with other cities in the region. This is due partly to the use of brackish and groundwater in these two cities. When total energy intensities are considered through the geospatial lens, imported water energy intensities dominates the total energy-for-water intensities, and cities that rely on imported water have *relatively* higher total energy intensities.

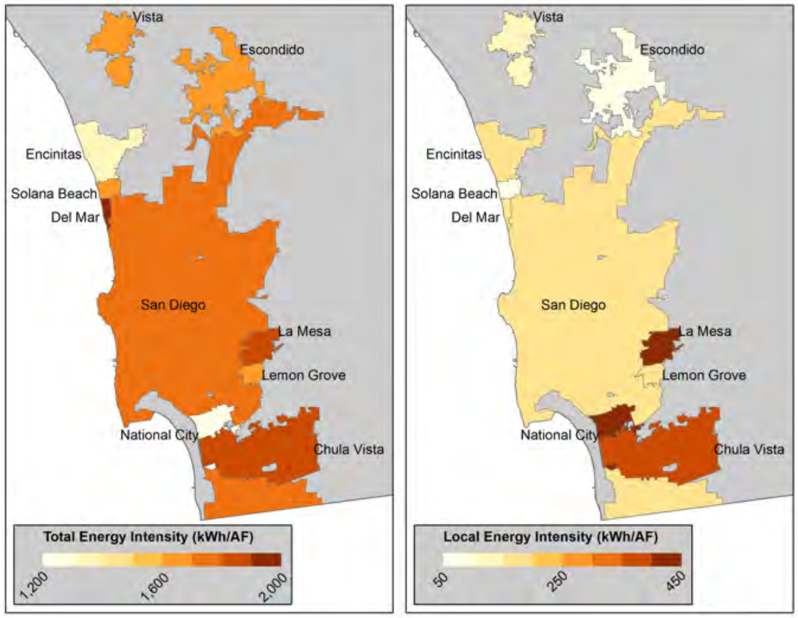


Figure 17 Energy Intensities by City Including Upstream (left-hand side) and Excluding Upstream (right-hand side)

5.5 GHG Intensity for Water by City

Similar to the water-energy intensity for a city, water-GHG intensity, the GHG emissions associated with water use in a city, provides a standard metric to compare the GHG emissions from supplying water to a city across the years and to understand where and why a city's water-GHG intensity is within the range in this region.

Equation 4 below shows the general equation to calculate the water-GHG intensity.

Equation 4 General Equation to Calculate Water GHG Intensity of a City

$$Water\ GHG\ Intensity_{city} = \frac{GHG\ Emissions_{water,city}}{\sum_{source,agency}(W_{source,agency})}$$

Where,

$Water\ GHG\ Intensity_{city}$ = water GHG intensity of a city (kg CO_2e/acre-foot or kg CO_2e/MG)

$GHG\ Emissions_{water,city}$ = GHG emissions from delivering potable water to a city (MT CO_2e)

$W_{source,agency}$ = annual water delivered to a city by a water agency (acre-foot or MG)

With,

source	= [SDCWA treated, SDCWA raw, local surface water, local groundwater]
agency	= retail water agencies in San Diego County
segment	= [upstream supply and conveyance, local supply and conveyance, local treatment, and local distribution]

This study estimates both local only and total water-GHG intensities for cities. The range of local water GHG intensities is provided in (Figure 18).

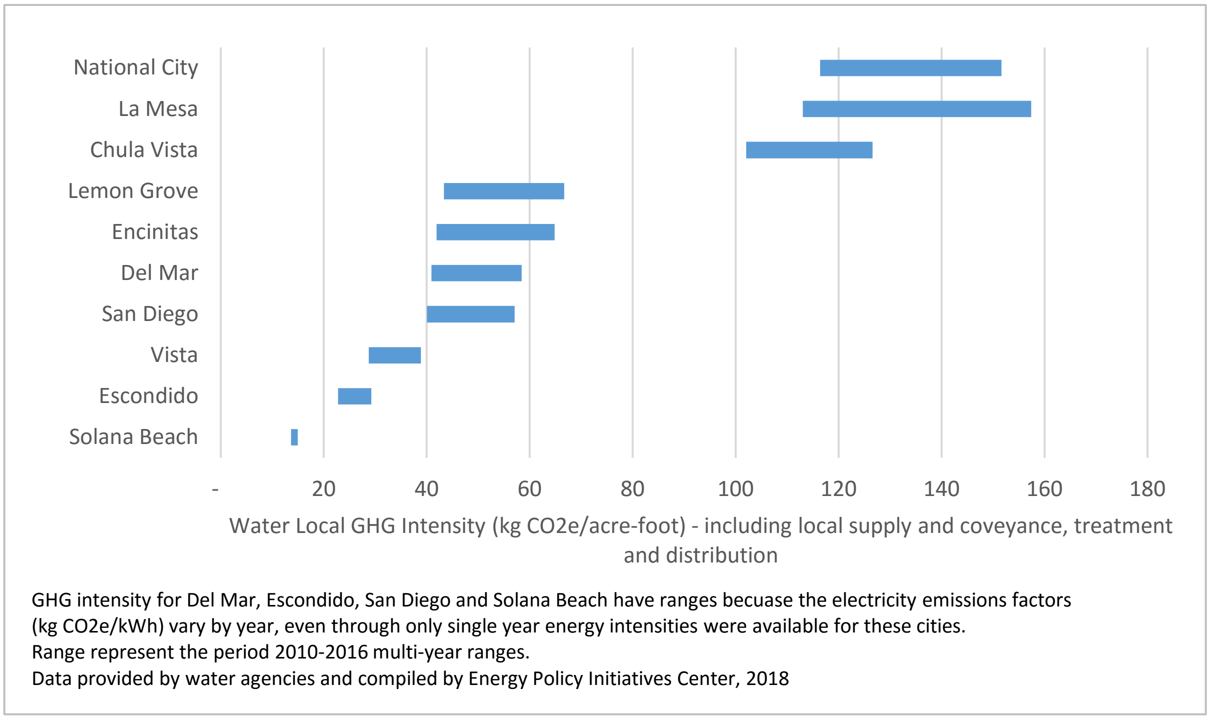


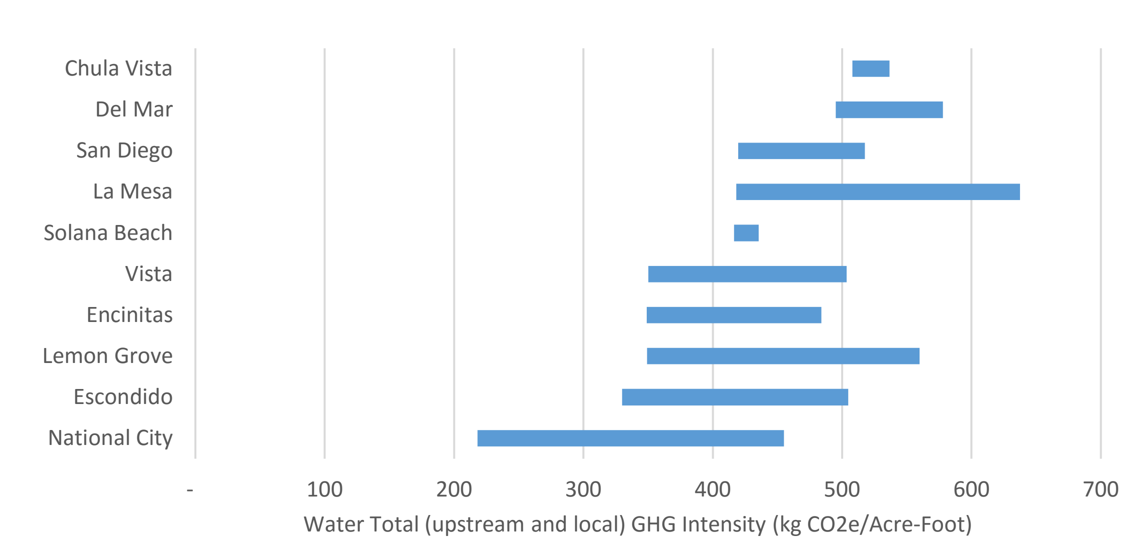
Figure 18 Local Water GHG Intensity for Cities in San Diego County

In Figure 18, all local water-GHG intensities have ranges even though for some cities only single year energy intensity data were available (discussed in Section 5.4). This is because the power mix of the electricity used for water delivery changed across years, which leads to different water GHG intensities. The lowest local water-GHG intensity is 14 kg CO_2e/AF (42 kg CO_2e/MG) in this study, and the highest is 157 kg CO_2e/AF (483 kg CO_2e/MG).

Similar to the water-energy intensities there is a grouping of cities within a lower range and a grouping of cities in the higher range. National City and La Mesa have two of the highest local water GHG intensities while Solana Beach and Escondido have two of the lowest. The city of San Diego's local water GHG intensities are at the low end of the full ranges for all cities, while their energy intensities on the high end, mainly because they have on-site solar generation with zero emission at WTPs, which provides on average 20% of the facilities (WTPs + lake pump stations) electricity use.

The high end of each city's local water-GHG intensity range in general represents year 2012-2013, when SDG&E had high electricity emission factors.[11] Since then SDG&E has increased its mandated renewable electricity purchases that has led to a decrease of the electricity emission factor to less than the 2012 value.

Similar to the total water energy intensity shown previously the water-GHG intensity by city looks very different when put into the context of the total (upstream and local). The total water-GHG intensity (Figure 19) includes the GHG emissions from upstream. As a result, Del Mar has one of the highest total water GHG intensities, while National City and Escondido have the two lowest.



GHG intensity for Del Mar, Escondido, San Diego and Solana Beach have ranges becuase the electricity emissions factors (kg CO2e/kWh) vary by year, even through only single year energy intensities were available for these cities.
Range represent the period 2010-2016 multi-year ranges.

Figure 19 Water Total (Upstream and Local) GHG Intensity for Cities in San Diego County

5.6 Relationship of GHG Emissions, Local Water Supply and Precipitation

During the period of study (2010–2015), precipitation decreased substantially (Figure 6). This led to a decrease in local surface and groundwater supplies for all cities in this study. Total water consumption also decreased due to mandates[12] but the relative amount of imported water increased in the water portfolios of all cities in this study (Table 13). Those cities that

[11] The high electricity emission factor and high local water GHG intensity were mainly due to the closure of San Onfore Nuclear Generating Station (SONGS) in 2012. Before 2012, on average 15–20% of SDG&E's annual power purchase was from SONGS, which was a zero emission source. In 2012, only 1% of power purchases was from SONGS and none in the following years due to its closure. This power was replaced by natural gas-powered electricity following 2012 which led to the increase of the electricity emission factor and therefore of the associated water-GHG intensity.

[12] Executive Order B-29-15 of April 1, 2015, called for a mandatory 25% reduction in potable water through February 2016 compared with the amount used in 2013.

could have more local supplies in a wetter year (National City, Vista) appear to have relied more on imported water over this period.

Table 13 Water Source Portfolios for Cities in San Diego County

City	Water Source	2010	2011	2012	2013	2014	2015
Chula Vista	Imported	83%	80%	77%	73%	87%	90%
	Local	83%	80%	77%	73%	87%	90%
Del Mar	Imported	100%	100%	100%	100%	100%	100%
Encinitas	Imported	63%	63%	70%	66%	91%	95%
	Local	37%	37%	30%	34%	9%	5%
Escondido	Imported	67%	63%	85%	92%	98%	96%
	Local	33%	37%	15%	8%	2%	4%
La Mesa	Imported	77%	62%	80%	98%	99%	n/a
	Local	23%	38%	20%	2%	1%	n/a
Lemon Grove	Imported	77%	62%	80%	98%	99%	n/a
	Local	23%	38%	20%	2%	1%	n/a
National City	Imported	51%	38%	27%	13%	58%	73%
	Local	49%	62%	73%	87%	42%	27%
San Diego	Imported	n/a	n/a	85%	89%	82%	97%
	Local	n/a	n/a	15%	11%	18%	3%
Solana Beach	Imported	n/a	n/a	n/a	n/a	88%	93%
	Local	n/a	n/a	n/a	n/a	12%	7%
Vista	Imported	62%	64%	83%	89%	93%	90%
	Local	38%	36%	17%	11%	7%	10%

n/a: Water source breakdowns in 2015 La Mesa, 2015 Lemon Grove, 2010-2011 San Diego and 2010-2013 Solana Beach are not available.

Figure 20 shows the effect of changes in the portfolio on energy and GHG intensities for one city from 2010–2015. The energy intensity increased during the period of study with a slight dip between 2014 and 2015 but the GHG intensity remained approximately the same.

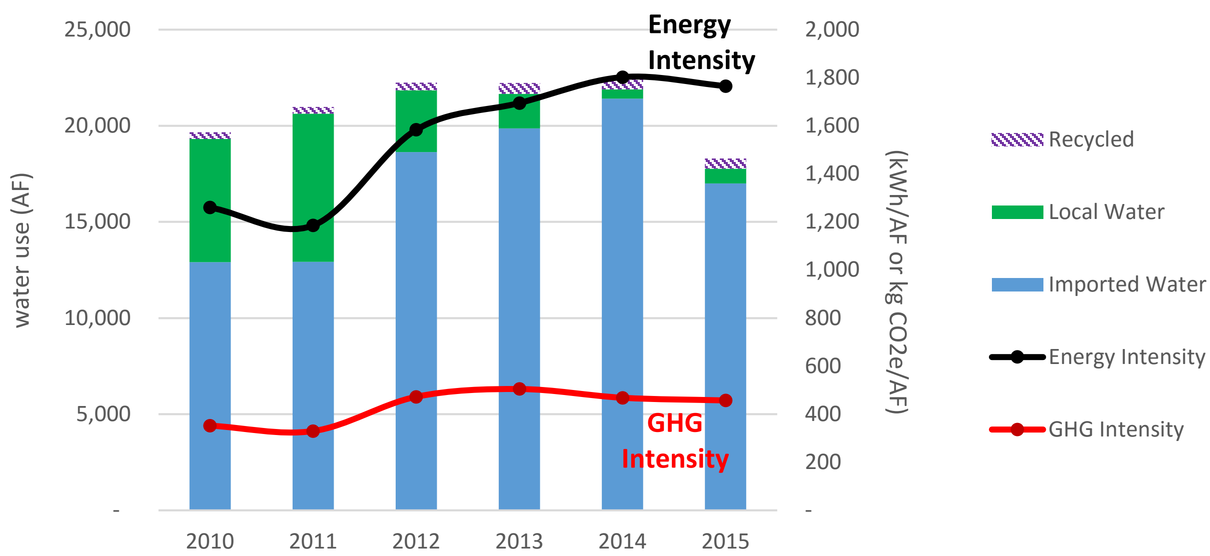


Figure 20 Relationship Water Supply, Energy and GHG Intensity

With increasing water imports, energy intensities increased from 2010–2015. The example city shown in Figure 20 shows the observed typical change in imported water supply and energy intensity. Figure 20 also shows that, unlike energy intensities, the GHG emissions intensity did not increase as much as the energy intensity in the earlier years. The mandated approximately 20% decrease in water use from 2014–2015 was not accompanied by a similar decrease in energy and GHG intensity likely due to the relatively greater imported water. However, the decrease in GHG intensity during 2014-2015 was greater than the decrease in energy intensity.

During 2010–2011, on average years with increased precipitation, local surface and groundwater supplies were maximized and GHG emissions related to water use in all ten cities were lower. As the local grid approaches 50% renewables, any year with average or higher precipitation would be expected to lead to even lower GHG intensities than in 2010–2011. In contrast, during drought years, or years of mandatory restrictions on water use, there may be greater dependence on imported water leading to greater upstream energy use and a higher total energy intensity for cities. Similarly, the GHG intensity will be determined by that of the imported water.

These results suggest that the drivers of water related GHG emissions for cities today are primarily related to the amount of imported water use and the grid GHG emission factor of upstream water. The proportion of local water (mainly local surface and recycled water) will help to reduce GHG emissions as long as the upstream grid emission factor is larger than the local SDG&E grid emission factor. However, in order to significantly reduce GHG emissions related to city water use, the amount of imported water would have to decrease, the amount of local surface and recycled water increased. The effect of local groundwater supplies on *energy intensity* would depend on the depth of extraction. The effect of local groundwater on *GHG intensity* would depend on the grid GHG emission factor. Similarly, if desalinated water is part of the mix, desalinated water may have a high energy intensity but lower GHG emissions depending on the GHG emission factor of its electricity supply.

Because local surface and groundwater supplies are limited in the San Diego region, a cleaner electricity supply upstream is currently the greater determinant of water-related GHG emissions in our cities and region.

6 LIMITATIONS OF ENERGY AND GHG INTENSITY RESULTS

Factors other than a jurisdiction's water demand and hydrology can affect the actual supply of water by a retail agency. Water rights and contractual obligations can affect the amount water deliveries to and from an agency in any year, and water storage can affect the energy intensity of local supply and conveyance. The following sections discuss additional limitations affecting the results of this study.

6.1 Changes in the Water Mix of Wholesale Water

As discussed in Section 5.2.1 (Upstream Water Supply and Conveyance), the energy intensity for SDCWA's upstream water supply and conveyance is an average based on the latest available data from FY 2013 and FY 2014 included in its 2015 UWMP. However, the average of 2013 and 2014 energy intensities may not be representative for other years. The upstream energy intensity depends on the water source mix (the percentage of water production from each source), which varies widely depending on weather and climate conditions. Figure 21 shows SDCWA's water mix in 2017, compared with a past year and projected for future years.

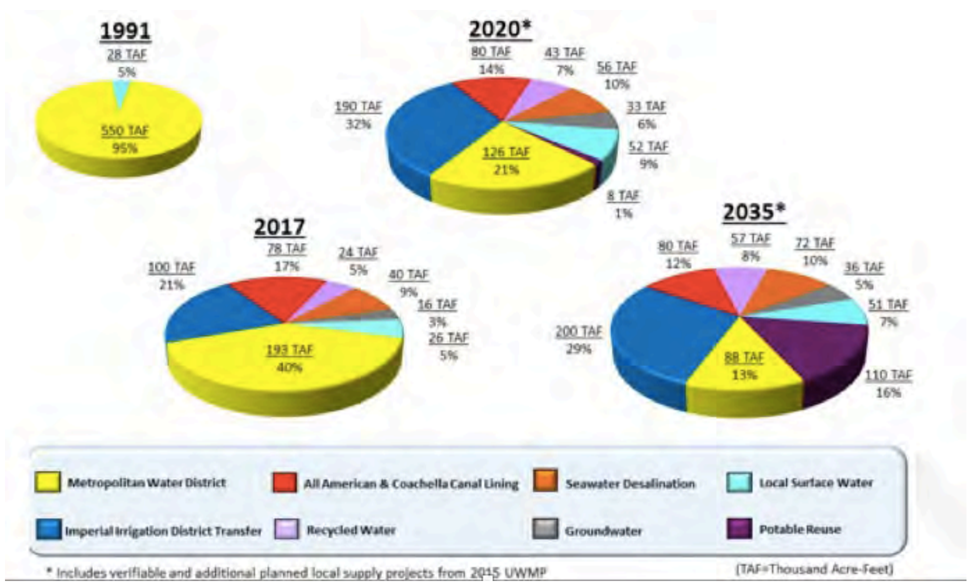


Figure 21 San Diego County's Existing and Projected Water Mix (SDCWA)

The percentage of water from SWP and Colorado River varies year by year. SDCWA is investing heavily in diversification. One example of the new supply is the Carlsbad Desalination Plant, which has been providing treated water as part of SDCWA's treated water supply since December 2015. Desalination is an energy-intensive water treatment process and not included in the upstream energy intensities used in this study, since the data were based on 2013–2015 sources.[13] However, as shown in Figure 21, the Carlsbad Desalination plant contributed 9% of the water supply in 2017 and is projected to supply 10% of total in 2020. This may result in higher water energy intensity and GHG intensity for SDCWA water from 2016 and beyond.

6.2 Separation of Energy Intensities between Local Supply and Conveyance and Treatment

It can be difficult to separate out local supply and conveyance energy from local water treatment energy use. For example, energy use at a lake (reservoir) pump station and the energy use at the adjacent water treatment plant are often tracked together. When groundwater is extracted, treatment (disinfection with chlorine) may be applied at the wellhead. In this study, local supply and conveyance energy may include some treatment. As a result, local supply and conveyance energy may be overestimated, or treatment energy may be underestimated. An alternative approach may be to include local treatment with local supply and conveyance with clear separation only from distribution.

7 CONCLUSIONS

This study has increased capacity in the San Diego region to analyze water-related energy use and GHG emissions and enhances the region's ability to provide climate-planning services to local governments here. In particular, this study:

- Provides an overview of the water supply system in San Diego County and water supply mix in ten cities;
- Provides an overview of the water treatment and distribution system in the associated wholesale and retail water agencies;
- Provides metrics that can be used to estimate and track the impacts of water use in the region, including: energy intensity (kWh/AF or kWh/MG) and GHG intensity (kg CO_2e/AF or kg CO_2e/MG) for each segment of the water-use cycle up to water delivered to customers;
- Compares results with existing energy intensity data from previous studies;
- Develops a user-friendly interactive tool to produce charts and demonstrate multi-year water mix, energy use and GHG emissions and intensities by city and by water-use cycle segment; and
- Presents visualizations of energy-for-water-GHG nexus in San Diego County.

The ten cities assessed comprise 65% of the region's population. These 10 cities are served by 11 water agencies all drawing most of their water supply from SDCWA. In 2015, GPCD ranged from 80 (National City) to 200 (Del Mar). SDCWA as well as each city has diversified their supply mix away from only imports in the period 2010–2015. However, the extent to which local water supplies can help diversify the mix is limited and affected by periods of low precipitation. In the recent drought years 2014–2015, on average 92% of water supplied to the 10 cities was imported from outside the region. In 2010–2013, an average of 74% was

[13] The energy intensity for seawater desalination with reverse osmosis is approximately 13,800 kWh/MG (4,500 kWh/acre-foot) as reported in the CPUC Study 2 (CPUC 2010b, Table 4-6).

imported. By 2015, six (6) of the ten (10) cities were using recycled water but the Carlsbad desalination plant was not yet on-line and did not yet contribute to SDCWA or any other water sources in the region.

The largest component of total energy use and GHG emissions for a city comes from upstream (non-local) to bring the water from the SWP and Colorado River to SDCWA's operational control. Therefore, during the years 2014–2015 when more water was imported by all cities in this study, the upstream energy use component increased. When this happened, even while water use decreased, energy use and energy intensity did not decrease at the rate water use decreased. Therefore, in our region, water conservation can lead to most energy conservation if the water conserved is the imported water.

The GHG emissions from water supply by city also depends on the power mix of the electricity used to treat and distribute. The greater the renewables in the power mix, the more GHGs are avoided when water is conserved. Considering only **local** water-energy intensities (kWh/AF) and water-GHG intensities (kg CO_2e/AF), Solana Beach, Escondido, Vista and Encinitas lie on the lower range and National City, La Mesa and Chula Vista lie on the higher range of the 10 cities in this study. However, considering **total** water-energy intensities and water-GHG intensities including upstream, National City, Escondido and Vista lie in the lower range and Del Mar, Chula Vista and San Diego lie in the higher range of the 10 cities in this study.

Finally, during "normal" precipitation years, cities with more local supply and treatment have lower water-energy and water-GHG intensities leading to lower GHG emissions. The lower GHG emissions are also due to the cleaner grid power in the San Diego region than the average California grid power.

8 RECOMMENDED NEXT STEPS

This study would benefit from an assessment of the GHG intensity of the upstream water supply sources to SDCWA in order to properly develop an upstream GHG intensity factor for the majority of our water sources. While the increased use of local recycled and desalinated water would clearly reduce reliance on both upstream imported water and on weather, specifically precipitation (for local surface and groundwater), the effect of various types of local water (other than recycled, surface and groundwater), on energy intensities, GHG intensities, energy use and GHG emissions by city is not yet known. The effect on city GHG emissions of newer types of local supply such as local desalinated water and wastewater-to-potable water should be assessed.

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Appendix A Activities within Each Segment in Water-use Cycle for Each City

City	Segment in Water Cycle	Detail	Electricity Provider
Chula Vista	Local Groundwater Extraction	Within Sweetwater Service Area: National City Wells produce potable groundwater and brackish groundwater from deep San Diego Formation wells is treated at Reynolds Desalination Facility	SDG&E
	Local Supply & Conveyance	Within Otay WD service area, no local water; Within Sweetwater Authority service area, surface runoff from Sweetwater River watershed (Sweetwater Reservoir) and Loveland Reservoir. Water from Loveland Reservoir is either released or naturally spilled to Sweetwater River Channel for conveyance.	
	Local Treatment	Within Otay WD service area, no local water but portion of SDCWA imported water is treated at Helix's R.M. Levy Water Treatment Plant. Within Sweetwater service area, Reynolds Desalination Facility for brackish groundwater treatment and Purdue Water Treatment Plant (next to Sweetwater Reservoir) for surface water treatment including local surface water and SDCWA imported.	
	Local Distribution	Sweetwater service area: 23 pumping stations for the entire service area	
Del Mar	Local Supply & Conveyance	Purchased SDCWA untreated water is treated at City of San Diego's Miramar Water Treatment Plant, so energy intensity same as City of San Diego's	SDG&E + On-site PV
	Local Treatment		
	Local Distribution	No within City boundary distribution energy use (gravity flow no pumping), assuming the distribution energy intensity to deliver water from City of San Diego to Del Mar is the same as the distribution EI in San Diego	SDG&E
Encinitas	Local Supply & Conveyance	Within SDWD service area, transfer from Lake Hodges (Cielo pump station) and San Dieguito Reservoir to Badgers Filtration Plant. Double Cielo Pump Station energy use is roughly the local conveyance energy use. Within OMWD service area, no local surface water and the treatment plant is at the bottom of the Olivenhain Reservoir.	SDG&E (treat imported water in summer month to generation hydro power

City	Segment in Water Cycle	Detail	Electricity Provider
	Local Treatment	R.E. Badgers Filtration Plant (SDWD — shared with SFID) David C. McCollom Water Treatment Plant (OMWD)	and sell back to SDG&E)
	Local Distribution	Only included distribution energy for SDWD. OMWD's distribution energy intensity is not available.	SDG&E
Escondido	Local Supply & Conveyance	Surface water at Lake Henshaw, Lake Wohlford (via open canal from Lake Henshaw) and Lake Dixon reservoirs. Energy use not available but small hydroelectric plant when water is conveyed from Lake Wohlford.	SDG&E
	Local Treatment	Escondido-Vista Treatment Plant (shared with VID)	
	Local Distribution	Five major pump stations within the city boundary	
La Mesa	Local Supply & Conveyance	El Capitan Reservoir, include Well 101 in El Monte Valley, small volumes of local runoff at Lake Jennings (the Lake itself is a SDCWA imported water storage)	SDG&E (Helix Operation center has PV system – 290 kW)
	Local Treatment	R.M. Levy Water Treatment Plant (Helix — the plant is also treating imported SDCWA water for other nearby agencies)	
	Local Distribution	Estimated based on the percent of city service in each pressure zone and energy used to pump to each pressure	
Lemon Grove	Local Supply & Conveyance	El Capitan Reservoir, include Well 101 in El Monte Valley, small volumes of local runoff at Lake Jennings (the Lake itself is a SDCWA imported water storage)	SDG&E (Helix Operation center has PV system – 290 kW)
	Local Treatment	R.M. Levy Water Treatment Plant (Helix—the plant is also treating imported SDCWA water for other nearby agencies)	
	Local Distribution	Estimated based on the ratio of the Lemon Grove gravity system energy to Treatment Plant's Los Coches Pump Station energy use	
National City	Local Groundwater Extraction	National City Wells produce potable groundwater and brackish groundwater from deep San Diego Formation wells is treated at Reynolds Desalination Facility	SDG&E?

City	Segment in Water Cycle	Detail	Electricity Provider
	Local Supply & Conveyance	Surface runoff from Sweetwater River watershed (Sweetwater Reservoir) and Loveland Reservoir. Water from Loveland Reservoir is either released or naturally spilled to Sweetwater River Channel for conveyance.	
	Local Treatment	Reynolds Desalination Facility for brackish groundwater treatment and Purdue Water Treatment Plant (next to Sweetwater Reservoir) for surface water treatment including local surface water and SDCWA imported.	
	Local Distribution	Sweetwater service area: 23 pumping stations for the entire service area	
San Diego	Local Groundwater Extraction	Santee/El Monte Basin via San Vicente Production Well	SDG&E
	Local Supply & Conveyance	Surface water: SDCWA imported water is stored at City's reservoirs, pumped by raw water pump stations from reservoirs to nearby treatment plants Groundwater: conveyed to San Vicente Reservoir	SDG&E and On-site PV (PV only supplies to Pump Station)
	Local Treatment	Alvarado Water Treatment Plant: next to Lake Murray, treats water from San Vicente, El Capitan and Sutherland Reservoirs via El Monte Pipeline and SDCWA imported water. San Vicente Reservoir water also includes groundwater. Miramar Water Treatment Plant: next to Lake Miramar, treats water from local runoff and SDCWA imported. Otay Water Treatment Plant: next to Lower Otay Lake, treats water from local runoff, Morena and Barrett Reservoirs and SDCWA imported.	SDG&E
	Local Distribution	128 main pressure zones and 50 water pump stations in the City and maintained by City's Public Utilities Department	SDG&E
Solana Beach	Local Supply & Conveyance	Within SFID service area, transfer from Lake Hodges (Cielo pump station) and San Dieguito Reservoir to Badgers Filtration Plant. Double Cielo Pump Station energy use is roughly the local conveyance energy use.	SDG&E (treat imported water in summer month to

City	Segment in Water Cycle	Detail	Electricity Provider
		Within OMWD service area, no local surface water and the treatment plant is at the bottom of the Olivenhain Reservoir.	generation hydro power and sell back to SDG&E)
	Local Treatment	R.E. Badgers Filtration Plant (SFID — shared with SDWD) David C. McCollom Water Treatment Plant (OMWD)	
	Local Distribution	Gravity flow within SFID service area. OMWD's distribution energy intensity is not available.	SDG&E
Vista	Local Supply & Conveyance	Natural water runoff at Lake Henshaw. In low-run-off year, groundwater pumped from the Warner Basin that is held as surface water in Lake Henshaw — energy intensity not available	SDG&E
	Local Treatment	Escondido-Vista Water Treatment Plant (shared with Escondido)	
	Local Distribution	energy intensity for the entire VID service area as proxy	