Supporting Information for

Planning for innovative water mixes: Evaluating the electricity intensity of an evolving water supply in California

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California Water System Data

Table S1 lists utilities included in the network model. These 382 utilities submitted Urban Water Management Plans (UWMPs) to the California Department of Water Resources (DWR) in 2010. The represent retail agencies, wholesale agencies, and some that serve both roles (e.g., San Francisco Public Utilities Commission). The UWMPs summarized current and projected water sources at five-year intervals between 2010 and 2030, and optionally through 2035. A summary table available from DWR was used to identify many wholesale transfers between utilities (1). Sales and points of delivery from State Water Project (SWP) were found in (2). If a utility purchased water from multiple points of sale (e.g., Metropolitan Water District buys water from both the East and West Branches), future sales were assumed to be divided proportionally between the same locations. For the Central Valley Project (CVP), data was obtained from (3). To supplement information on future water supplies, proposed water projects that were not included in utility UWMPs but listed the 2013 California Water Plan (4) were also added to the supply sources.

Additional data was obtained from individual UWMPs. Individual UWMPs were consulted to identify and verify water sources for wholesale utilities (as listed in Table S1) and utilities that served the ten largest metropolitan areas. In addition, individual UWMPs were consulted when the original source (i.e., aquifer, surface water bodies, or utility involved in transfers/exchanges) for significant supplies could not be determined another way. Not all supplies were ultimately identified, either because they supplied small volumes or could not be disaggregated as reported.

Table S1: Utility names, types, and utility-specific data sources other than UWMPs included in the analysis

Adelanto, City of [R]
Alameda Co. FC & WCD Zone 7 [W]
Alameda Co. WD [R]
Alhambra, City of [R]
Amador WA [R]
American Canyon, City of [R]
Anaheim, City of [R]
Antelope Valley East Kern WA [W]
Antioch, City of [R]
Apple Valley Ranchos WC [R][1]
Arcadia, City of [R]
Arcata, City of [R]
Arroyo Grande, City of [R]
Azusa, City of [R]
Bakman WC [R]
Banning, City of [R]
Bear Valley CSD [R]
Beaumont-Cherry Valley WD [R]
Bellflower-Somerset MWC [R]
Benicia, City of [R]
Beverly Hills, City of [R]
Big Bear Lake, City of [R]
Blythe, City of [R]
Brawley, City of [R]
Brea, City of [R]
Brentwood, City of [R]
Buena Park, City of [R]
Burbank, City of [R]
Burlingame, City of [R]
Calaveras Co. WD [R]
Calexico, City of [R]
CA Domestic WC [R]
CA WSC Antelope Valley [R][2]
CA WSC Bakersfield [R][1]
CA WSC Bear Gulch [R][3]
CA WSC Chico Dist. [R][2]
CA WSC Dixon, City of [R][2]
CA WSC Dominguez [R][4]
CA WSC East Los Angeles [R][5]
CA WSC Hermosa/Redondo [R][4]
CA WSC Kern River Valley [R][1]
CA WSC King City [R][2]
CA WSC Livermore [R][5]
CA WSC Los Altos/Suburban [R][5]
CA WSC Marysville [R][2]
CA WSC Mid Peninsula [R][3]
CA WSC Oroville [R][1]
CA WSC Palos Verdes [R][3]
CA WSC Redwood Valley [R][1]
CA WSC Salinas Dist. [R][2]
CA WSC Selma [R][2]
CA WSC S. San Francisco [R][1]
CA WSC Stockton [R][5]
CA WSC Visalia [R][2]
CA WSC Westlake [R][6]
CA WSC Willows [R][2]
CA-American WC- LA [R][2]
CA-American WC- Monterey [R][7]
CA-American WC- San Diego [R]
CA-American WC- Ventura [R][8]
Calleguas MWD [W]
Camarillo, City of [R]
Cambria CSD [R]
Camrosa WD [R]
Carlsbad MWD [R]
Carmichael WD [R]
Carpinteria Valley WD [R]
Casitas MWD [W]
Castaic Lake WA [W]
Castaic Lake WA Santa Clarita Wtr Div [R]
Central Basin MWD [W]
Central Coast Wtr Authority [W]
Ceres, City of [R]
Cerritos, City of [R]
Chino, City of [R]
Chino Hills, City of [R]
Citrus Heights WD [R]
Clovis, City of [R]
Coachella, City of [R]
Coachella Valley WD [R][9]
Coastside Co. WD [R]
Colton, City of [R]
Compton, City of [R]
Contra Costa WD [R, W][10]
Corona, City of [R]
Covina Irrigating Company [R]
Crescent City, City of [R]
Crescenta Valley WD [R]
Crestline Village WD [R]
Crestline-Lake Arrowhead WA [R]
Cucamonga Valley WD [R]
Daly City, City of [R]
Davis, City of [R]
Delano, City of [R]
Desert WA [R]
Diablo WD [R]
Dinuba, City of [R]
Downey, City of [R]
Dublin San Ramon SrvD [R]
East Bay MUD [R][11]
East Niles CSD [R]
East Orange Co. WD [R, W]
East Palo Alto, City of [R]
East Valley WD [R]
Eastern MWD [R, W]
El Centro, City of [R]
El Dorado ID [R]
El Monte, City of [R]
El Toro WD [R]
Elk Grove Wtr Service [R]
Elsinore Valley MWD [R]
Escondido, City of [R]
Estero MID [R]
Eureka, City of [R]
Exeter, City of [R]
Fair Oaks WD [R]
Fallbrook Public Utility Dist. [R]
Folsom, City of [R]
Foothill MWD [W]
Fortuna, City of [R]
Fountain Valley, City of [R]
Fresno, City of [R]
Fullerton, City of [R]
Garden Grove, City of [R]
Georgetown Divide PUD [R]
Gilroy, City of [R]
Glendale, City of [R]
Golden Hills CSD [R]
Golden State WC Artesia [R][5]
Golden State WC Barstow [R][5]
Golden State WC Bay Point [R][5]
Golden State WC Bell-Bell Gardens [R][5]
Golden State WC Claremont [R][12]
Golden State WC Cordovan [R][13]
Golden State WC Cowan Heights [R]
Golden State WC Culver City [R]
Golden State WC Florence Graham [R]
Golden State WC Norwalk [R][5]
Golden State WC Ojai [R][12]
Golden State WC Orcutt [R][5]
Golden State WC Placentia [R][12]
Golden State WC S Arcadia [R]
Golden State WC S San Gabriel [R]
Golden State WC San Dimas [R][12]
Golden State WC Simi Valley [R][5]
Golden State WC Southwest [R][5]
Golden State WC West Orange [R][5]
Goleta WD [R]
Groveland CSD [R]
Grover Beach, City of [R]
Hanford, City of [R]
Hawthorne, City of [R]
Hayward, City of [R]

Helix WD [R]
Hemet, City of [R]
Hesperia WD, City of [R]
Hi-Desert WD [R]
Hillsborough Town of [R]
Hollister, City of [R]
Humboldt Bay MWD [W]
Humboldt CSD [R]
Huntington Beach, City of [R]
Huntington Park, City of [R]
Imperial ID [R]
Imperial, City of [R]
Indian Wells Valley WD [R]
Indio, City of [R]
Inglewood, City of [R]
Inland Empire Utilities Agency [W]
Irvine Ranch WD [R]
Joshua Basin WD [R]
Jurupa CSD [R]
Kerman, City of [R]
Kern Co. WA ImpD No 4 [W]
La Habra, City of PW [R]
La Palma, City of [R]
La Verne, City of [R]
Laguna Beach Co. WD [R]
Lake Arrowhead CSD [R]
Lake Hemet MWD [R]
Lakewood, City of [R]
Las Virgenes MWD [R]
Lemoore, City of [R]
Lincoln, City of [R]
Lincoln Avenue WC [R]
Linda Co. WD [R]
Livermore, City of DWR [R]
Lodi, City of PW Dept [R]
Loma Linda, City of [R]
Lomita, City of [R]
Lompoc, City of [R]
Long Beach, City of [R]
LA Co. PWWD 29 [R]
LA Co. PWWD 40 [R]
LA Co. WD #36 [R]
LA Co. WD #37 [R]
LA Dept of Wtr & Power [R][14]
Los Banos, City of [R]
Lynwood, City of [R]
Madera, City of [R]
Mammoth CWD [R]
Manhattan Beach, City of [R]
Marin MWD [R]11
Marina Coast WD [R]
Martinez, City of [R]
McKinleyville CSD [R]
Menlo Park, City of [R]
Merced, City of [R]
Mesa Consolidated WD [R]
Metropolitan WD of Southern CA [W]
Mid-Peninsula WD [R]
Millbrae, City of [R]
Milpitas, City of [R]
Mission Springs WD [R]
Modesto ID [R]
Modesto, City of [R]
Monte Vista WD [R, W]
Montebello land & WC [R]
Morgan Hill, City of [R]
Morro Bay, City of [R]
Moulton Niguel WD [R]
Mountain View, City of [R]
MWD of Orange Co. [W]
Napa, City of [R]
Nevada ID [R]
Newhall Co. WD [R]
Newport Beach, City of [R]
Nipomo CSD [R]
North Marin WD [R]
North of The River MWD [W]
North Tahoe Public Utility Dist. [R]
Norwalk, City of [R]
Oceanside, City of [R][15]
Oildale MWC [R]
Olivenhain MWD [R]
Ontario, City of [R]
Orange, City of [R]
Orange Co. WD [R]
Orange Vale WC [R]
Orchard Dale WD [R]
Otay WD [R]
Oxnard, City of [R]
Palmdale WD [R]
Paradise ID [R]
Paramount, City of [R]
Park WC [R][16]
Pasadena, City of [R]
Paso Robles, City of [R]
Patterson, City of [R]
Petaluma, City of [R]
Phelan Pinon Hills CSD [R]
Pico Rivera, City of [R]
Pico WD [R]
Pismo Beach, City of [R]
Pittsburg, City of [R]
Placer Co. WA [R, W]
Pleasanton, City of [R]
Pomona, City of [R]
Port Hueneme, City of [R]
Port Hueneme WA [W]
Quartz Hill WD [R]
Rainbow MWD [R]
Ramona MWD [R]
Rancho CA WD [R][17]
Redlands, City of [R]
Redwood City, City of [R]
Reedley, City of [R]
Rincon Del Diablo MWD [R]
Rio Linda - Elverta CWD [R]
Rio Vista, City of [R]
Riverside, City of [R]
Rohnert Park, City of [R]
Rosamond CSD [R]
Roseville, City of [R]
Rowland WD [R]
Rubidoux CSD [R]
Rubio Canyon LWA [R]
Sacramento, City of [R, W]
Sacramento Co. WA [R]
Sacramento Suburban WD [R]
San Benito Co. WD [R]
San Bernardino, City of [R]
San Bernardino Valley MWD [R]
San Bruno, City of [R]
San Buenaventura, City of [R]
San Clemente, City of [R]
San Diego, City of [R]
San Diego Co. Wtr Authority [R]
San Dieguito WD [R]
San Francisco PUC [R][10]
San Gabriel Co. WD [R]
San Gabriel Valley Fontana WC [R]
San Gabriel Valley MWD [R]
San Gabriel Valley WC [R][1]
San Gorgonio Pass WA [R]
San Jose, City of [R]
San Jose WC [R]
San Juan Capistrano, City of [R]
San Juan WD [R]
San Luis Obispo, City of [R]
San Luis Obispo Co. FC& WCD Zone 3 [R]
San Marino, City of [R]
Santa Ana, City of [R]
Santa Barbara, City of [R]
Santa Clara, City of [R]
Santa Clara Valley WD [R]
Santa Cruz, City of [R]
Santa Fe ID [R]
Santa Fe Springs, City of [R]

Santa Margarita WD [R]
Santa Maria, City of [R]
Santa Monica, City of [R]
Santa Rosa, City of [R]
Scotts Valley WD [R]
Seal Beach, City of [R]
Serrano WD [R]
Shafter, City of [R]
Sierra Madre, City of [R]
Solano Co. WA [R]
Soledad, City of [R]
Sonoma, City of [R]
Sonoma Co. WA [R][18]
Soquel Creek WD [R]
South Coast WD [R]
South Gate, City of [R]
South Pasadena, City of [R]
South Tahoe PUD [R]
Stallion Springs CSD [R]
Stockton, City of [R]
Stockton East WD [R]
Suburban WS San Jose Hills [R][19]
Suburban WS Whittier/La Mirada [R][5]
Suisun-Solano Wtr Authority [R]
Sunnyslope Co. WD [R]
Sunnyvale, City of [R]
SweetWater Springs WD [R]
Tahoe City PUD [R]
Tehachapi, City of [R]
Tehachapi-Cummings Co. WD [R][14]
Thousand Oaks, City of [R]
Three Valleys MWD [R]
Torrance, City of [R]
Trabuco Canyon WD [R]
Tracy, City of [R]
Triunfo/Oak Park Wtr Service [R]
Truckee-Donner PUD [R]
Tulare, City of [R]
Tuolumne Utilities Dist. [R]
Turlock, City of [R]
Tustin, City of [R]
Twentynine Palms WD [R]
Ukiah, City of [R]
United WCD [R]
Upland, City of [R]
Upper San Gabriel Valley MWD [R]
Vacaville, City of [R]
Valencia WC [R]
Vallecitos WD [R]
Valley Center MWD [R]
Valley of the Moon WD [R]
Valley WC [R]
Vaughn WC [R]
Ventura Co. WWD No 1 [R]
Ventura Co. WWD No. 8 [R]
Vernon, City of [R]
Victorville WD [R]
Vista ID [R]
Walnut Valley WD [R]
Wasco, City of [R]
Watsonville, City of [R]
West Basin MWD [R]
West Kern WD [R]
West Valley WD [R]
Westborough WD [R]
Western MWD of Riverside [R]
Westminster, City of [R]
Whittier, City of [R]
Windsor, Town of [R]
Woodland, City of [R]
Yorba Linda WD [R]
Yuba City, City of [R]
Yucaipa Valley WD [R]

ACRONYMS IN TABLE S1

BDSLT	Brackish water desalination
BGWS	Brackish groundwater supply
CA	California
Co.	County
CSD	Community Service(s) District
CWD	Community Water District
Dept	Department
Dist	District
DIST	Distribution
Div	Division
FC	Flood Control
GWR	Groundwater recharge
GWS	Groundwater supply
GWT	Groundwater treatment
ID	Irrigation district
ImpD	Improvement District
IMPWS	Imported water supply (local or interbasin)
LA	Los Angeles
LWA	Land and Water Association
LOCALWS	Local water supply mix
MID	Municipal Improvement District
MUD	Municipal Utilities District
MWC	Mutual Water Company
MWD	Municipal Water District
ODSLT	Ocean desalination
PUC	Public Utilities Commission
PUD	Public Utilities District
PW	Publics Works
PWWD	Public Works Waterworks District
RWS	Recycled water supply
RWT	Recycled water treatment
SanD	Sanitation District
SrvD	Services District
STW	Stormwater collection and reuse
SWS	Surface water supply
SWT	Surface water treatment
WA	Water Agency
WC	Water Company
WCD	Water Conservation District
WD	Water District
WS	Water Systems
WSC	Water Service Company
Wtr	Water

Notes for Table S1:

UTILITY TYPE: Designations as retail [R] and wholesale [W] agencies are shown in brackets. EI DATA SOURCE: Superscripts refer to data sources, shown in parentheses, followed by the water source(s) for which the utility-specific EI(s) are available. [1](5) GWS, GWT, DIST [2](5) GWS [3](5) DIST [4](5) GWS, RWS, DIST [5](5) GWS, DIST [6](5) RWS, DIST [7](5) BGWS, GWS, ODSLT, BDSLT; (6) GWR 8(5) SWS [9](6)GWS [10](6) IMPWS [11](6)IMPWS, SWS, SWT [12](5) GWS, SWS, DIST [13](5) GWS, IMPWS, SWT, DIST [14]IMPWS from utility's UWMP [15](6) ODSLT, BDSLT, DIST [16](5) GWS, GWT [17](6) GWS, DIST [18](6)LOCALWS [19](5) GWS, RWT, DIST

Network Data Compilation: Strategies, Challenges, and Limitations

A partial discussion of the challenges to compiling the California urban water system network data was provided in the main text. A more complete description follows.

- Supplies and demand for different water quality categories (raw, potable, and/or recycled water) were evaluated separately. If a particular utility's supplies of a particular quality of water exceeded their customers' demand, we assumed supplies for that quality were used proportionally to meet demand. The average percentage of water needed to meet the demand (Demand volume / Supply volume) for each category of water was applied to the appropriate set of supply sources. For example, if a utility needs 90% of its mix of its potable water supplies obtained groundwater, imported water, and local surface water supplies to meet potable demand, it was assumed that 90% of each source was used. In reality, utilities may prioritize certain sources to be consumed fully before using the next. However, the "loading order," to borrow a term for the energy industry, is rarely explicitly stated by water utilities. We did not assume one for this study.
- When utilities considered conservation as a water source rather than as a demand decrease, the volume attributed to conservation was subtracted from the utility's reported water demand.
- We assigned a general water source node when no specific information was available about the source (e.g., groundwater basin or reservoir) or volumes for multiple sources were aggregated in the UWMP. This is shown as a general source designator plus the utility code. Examples of general source designators include: groundwater (GW), local surface water (SW), imported or wholesaler water (IMP), wastewater treatment plant (WWT) providing recycled water (REC). Table S5 provides a complete list. Local surface water sources were generally unidentified.
- Groundwater sources were assigned to basins when data existed to identify the correct basin and allocate the water volume accurately. Basins were identified using GIS if the utility service area did not cross basin or subbasin boundaries and, otherwise, using the UWMP. In some cases, groundwater basin names did not match the DWR-specified naming convention and the aquifers listed in the UWMP could not be matched with their source. In other cases, the groundwater basin was not provided or multiple basins were used but volumes could not be disaggregated between them. In either case, the general "GW" designation was used.
- Desalinated water for coastal utilities was assumed to be from seawater and inland utilities from brackish groundwater, unless more specific information was available.
- Flows reported by multiple cascading wholesale agencies could be inconsistent (i.e., Wholesaler 1 sells water to Wholesaler 2 who sells water to a retail agency and some or all of them report different volumes). Generally, we used the most locally-reported volume (i.e., from the retail agency) to reconcile the data.
- UWMPs did not always clearly segregate wholesale from retail sales and/or categorized all wholesale transactions as "Sales to other agencies". When this happened, if the wholesaler was

named in the retail UWMP, the volume was subtracted from the wholesale utility's total to minimize double counting. This was not possible in all cases.

- In a few cases, a utility transferred raw water to a wholesaler and bought back treated water. These transfers were ignored as circular transfers cannot be evaluated by WESTNet. It was assumed that the wholesaler provided treated water.
- For proposed projects listed in the California Water Plan but not in utility's UWMP, if a project is anticipated to come online in 2020 or 2030, the expected yield was divided by half, assuming that the facility would not be available to operate at the full expected yield at the beginning of the year.

Electricity Intensity Data

Table S2 shows the incremental electricity intensities (EI) for California's wholesale interbasin conveyance systems, including the SWP, CVP, and several local projects. These are designated as "incremental" because the EIs are additive as you move through the system. Figure 3a in the main text shows many of the locations of and connections between the SWP facilities; numerical labels in the Figure 3a correspond to the last two digits of the node name.

Table S3 summarizes the default supply and treatment EIs for alternative water sources which are applied when utility-specific data is not available. Estimates for all three scenarios are given, except as noted.

Table S4 gives the default EIs for groundwater supply, groundwater recharge, and all distribution for each hydrologic region. These EIs are correlated to geography: depth to aquifer for groundwater pumping and surface topology for distribution.

Table S2: Incremental electricity intensities for California's wholesale interbasin conveyance systems

Wholesale Supply System	Node Name	Incremental Electricity Intensity (kWh/m^3)		
		Low[1]	Moderate[2]	High[2]
State Water Project				
North Bay Aqueduct (NBA)				
NBA: Barker Slough Pumping Plant (PP)	SW1802SWP04	0.18	0.21	0.23
NBA: Cordelia to Benecia	SW1805SWP05	0.30	0.34	0.39
NBA: Cordelia to Vallejo	SW1805SWP05a	0.23	0.27	0.30
NBA: Cordelia to Napa	SW1805SWP05b	0.026	0.03	0.03
NBA: Area of Settlement transfer	SW1805SWP05c	0.34	0.39	0.44
California Aqueduct (CalA)				
CalA: Banks PP	SW1804SWP06	0.24	0.28	0.31
CalA: Gianelli Pumping-Generating Plant (PGP)	SW1804SWP09	0.27	0.31	0.35
CalA: Dos Amigos PP	SW1804SWP10	0.11	0.13	0.14
CalA: Buena Vista PP	SW1803SWP16	0.20	0.23	0.26
CalA: Teerink PP	SW1803SWP17	0.22	0.25	0.28
CalA: Chrisman PP	SW1803SWP18	0.51	0.58	0.65
CalA: Edmonston	SW1803SWP19	1.8	2.12	2.39
South Bay Aqueduct (SBA)				
SBA: South Bay PP	SW1804SWP07	0.68	0.78	0.88
SBA: Del Valle PP	SW1805SWP08	0.059	0.07	0.08
Coastal Branch (CB)				
CB: Las Parillas PP	SW1803SWP11	0.062	0.07	0.08
CB: Polonio_Pass_PP	SW1806SWP15	0.58	0.67	0.75
West Branch (WB)				
WB Alamo Power Generating Plant (GP)	SW1809SWP20	0	0	0
WB: Oso PP	SW1809SWP21	0.22	0.25	0.29
WB: Warne GP	SW1807SWP22	0	0	0
WB: Castaic PGP	SW1807SWP23	0	0	0
East Branch (EB)				
EB: Pearblossom PP	SW1809SWP24	0.55	0.63	0.72
EB: Mojave Siphon GP	SW1809SWP25	0	0	0
EB: Devil Canyon GP	SW1807SWP26	0	0	0
East Branch Extension (EBE)				
EBE: Greenspot PP	SW1807SWP27	0	0	0
EBE: Crofton Hills PP	SW1807SWP28	0.48	0.55	0.62
EBE: Cherry Valley PP	SW1807SWP29	0.31	0.35	0.40
Federal Project- Central Valley Project (CVP)				
CVP deliveries to Tracy	CVPTracy	0.019	0.020	0.022
CVP: Jones (Tracy) PP	CVPDMC	0.19	0.205	0.221
CVP: O'Niell PGP	CVPONLP	0.048	0.052	0.056
CVP: Dos Amigos	CVPDA	0.11	0.120	0.129
CVP: Pacheco PP	CVP_SB1	0.19	0.207	0.224
CVP: Coyote	CVP_SB2	0	0.004	0.004
CVP- Jones (Tracy) PP	CVPTracy	0.019	0.020	0.022
CVP- O'Neill PP	CVPONLP	0.048	0.052	0.056
CVP: Friant-Kern Canal[3]	SW_CVPFKC	0.017	0.019	0.020
San Francisco PUC (SFPUC) Hetch Hetchy Aqueduct				
SFPUC: East Bay	SFPUCE	0.00057	--	--
SFPUC: Peninsula	SFPUCP	0.092	--	--
SFPUC: SF City	SFPUCC	0.0065	--	--
Los Angeles (LADWP) Aqueduct (LAA)	LAAS	0	0	0
East Bay Municipal Utiltiy District (EBMUD) Mokelumne Aqueduct	EBMUDIMP	0	0	0
Metropolitan WD of Southern CA: Colorado River Aqueduct (CRA)	CRAS	1.6	--	--

Notes:

[1] SWP, CVP, SFPUC, and CRA data from (7), unless noted. The EIs for the low and high scenarios were taken from the minimum and maximum EIs calculated for five different hydrologic conditions; the moderate scenario uses the average of those two values.

[2] CVP and Friant-Kern Canal EI was obtained from Vince Tidwell of Sandia National Laboratory as background data for (8).

Table S3. Default electricity intensities (kWh/m^3) for water supply and treatment alternatives.

Water sources	Supply Low	Supply Moderate	Supply High	Treatment Low	Treatment Moderate	Treatment High
Groundwater - typical quality	use regional value (Table S4)			0.0024 (9)	0.027 [2]	0.052 (5}
Groundwater - low quality	use regional value (Table S4)			0.10 (5)	0.27 [2]	0.44 (5}
Groundwater recharge	0 [3]	0.28 (10)	0.50 (10)	use groundwater treatment value		
Surface water (local and imports)	0.020 (9)	0.070 [2]	0.12 (6)	0.052 (11)	0.081 [2]	0.11 (9)
Recycled water- non-potable	0.0081 (7)	0.087 [2]	0.17 (11)	0.28 (6)	0.59 [2]	0.90 (6)
Recycled water- groundwater augmentation	use regional value (Table S4)			0.89 (6)	-- [1]	--
Ocean desalination	0.0081 [4]	0.081 [2]	0.16 (11)	2.99 (11)	3.2 [2]	3.5 (5)
Stormwater capture	included in treatment value			4.1 (12)	--	--
Intrabasin transfer- unspecified source	0.0081 [4]	0.20 [2]	0.40 (6)	use surface water treatment value		
Brackish groundwater	use regional value (Table S4])			0.33 (6)	0.61 [2]	0.90 (6)

Notes: Numbers in parentheses refer to the reference list.

[1] "-" indicates low assumptions were used for all scenarios.

[2] The "moderate" value is the average of the low and high estimates if no citation is given.

[3] Assumes natural recharge.

[4] Assumed minimal value.

Table S4: Default electricity intensities (kWh/m^3) for groundwater supply, groundwater recharge, and all distribution by hydrologic region

Region	Supply: Groundwater Supply Low[1]	Groundwater Supply Moderate[2] 2020	Groundwater Supply Moderate[2] 2030	Groundwater Supply High[3] 2020	Groundwater Supply High[3] 2030	Groundwater Recharge[4] Low	Groundwater Recharge[4] Moderate 2020	Groundwater Recharge[4] Moderate 2030	Groundwater Recharge[4] High 2020	Groundwater Recharge[4] High 2030	Distribution[1] Potable (All scenarios)	Distribution[1] Non-potable[5] (All scenarios)
NC	0.14	-	-	-	-	0.27	-	-	-	-	0.13	0.16
SR	0.15	-	-	-	-	0.28	-	-	-	-	0.014	0.017
TL	0.32	0.34	0.36	0.37	0.42	0.45	0.47	0.49	0.51	0.58	0.014	0.017
SJ	0.20	0.21	0.21	0.22	0.25	0.32	0.33	0.35	0.36	0.41	0.014	0.017
SF	0.29	-	-	-	-	0.41	-	-	-	-	0.26	0.31
CC	0.38	0.40	0.42	0.44	0.50	0.50	0.53	0.55	0.58	0.65	0.13	0.16
SC	0.47	0.49	0.52	0.54	0.61	0.59	0.62	0.65	0.68	0.77	0.13	0.16
NL	0.14	-	-	-	-	0.27	-	-	-	-	0.014	0.017
SL	0.29	0.31	0.32	0.34	0.38	0.42	0.44	0.46	0.48	0.54	0.13	0.16
CR	0.39	-	-	-	-	0.51	-	-	-	-	0.014	0.017

Notes:

[1] Groundwater supply and potable distribution assumptions for the low scenario are from (5). "-" indicates low assumptions were used for all scenarios.

[2] Moderate estimates (5% increase per decade) apply to critically overdrafted basins.

[3] High estimates for groundwater supply and recharge (15% increase per decade) apply only to critically overdrafted basins in the high scenario. Estimates for the moderate scenario are applied to basins described as overdrafted but which are not officially-designated as "critically overdrafted" (see Note 2).

[4] Groundwater recharge values are the sum of the regional groundwater supply estimate and the default groundwater recharge EI from Table S3.

[5] Non-potable distribution EI is 20% higher than potable distribution to account for extra pumping from the centralized WWTP, located at the low point in the service area, to customers.

Network Model

This section provides more detail on the process of developing the network model. Table S5 defines the convention for naming nodes within the network model.

Table S5: Node naming convention

Node type	Network role	Naming Convention	Color
Utility code	Sources or infrastructure associated with a retail or wholesale utility	HUC Code + unique 3-digit code	Varies
AAC	All-American Canal	"SW_AAC" + unique transfer code, if applicable	Tan
BDSL	Brackish desalination	For source, "BDSL" + utility code (node is connected to a basin or subbasin, if possible); if sold to retail utility, Utility Code +"BDSL"	None
CRA	Colorado River Aqueduct	"SWCRA" + unique transfer code, if applicable	Tan
CVP	Central Valley Project	CVP + Unique facility abbreviation	None
DSL	Desalination	"DSL" + utility code	None
E	End user or customer	Utility code + "E"	Yellow
GW	Groundwater	For water sources, "GW" + DWR basin/subbasin code, if basin is known OR "GW" + Utility Code, if not; for groundwater sold untreated to a retail utility, Utility code + "GW"	Pink
GWR	Groundwater recharge	Similar to groundwater codes described above, substituting "GWR" for "GW"	None
IMP	Imported	"IMP" + utility code for unspecified imported source; Utility + "IMP" for blended imported water that is sold untreated to a retail utility	Peach
LK	Lake	"LK" + Lake name	None
NPD	Non-potable distribution	Utility + "NPD" for treated non-potable water delivered to end-user	Blue
PD	Potable distribution	Utility + "PD" for treated potable water delivered to an end-user	Blue
R	River, stream, or creek	"R" + utility code or, if used by multiple utilities, "R" + name	Blue
REC	Recycled water	"REC" + utility code for recycled water source	Green
RES	Reservoir or lake (natural or manmade)	"RES" + utility code for reservoir or lake used by one utility or not specifically identified; if used by multiple utilities, "RES" + name	None
SW	Surface water	"SW" + utility code for unspecified surface water source	Tan
SWP	State Water Project	"SW" + HUC Code + "SWP" + Facility number	Tan
UNS	Unspecified source	"UNS" + utility code for unspecified source	None
WWT	Wastewater treatment plant	"WWT" + utility code indicates source of recycled water, if known	None
XF	Transfer or exchange	For sources, "XF" + utility code or, if it involves multiple retail utilities, a unique name; if sold to retail utility, Utility Code +"XF"	None

WESTNet

The WESTNet tool was designed to accept water-related data in format that can be easily updated using publicly-available sources. The input file for WESTNet contains a year code, source node ID, target node ID, the cumulative volume transferred along the link, the specific volume consumed at the target node (i.e., retail sales by that utility), and two embedded energy values associated with for conveyance and, when applicable, treatment for that link. The treatment value is zero unless the target node is a distribution system, denoted by a suffix of "PD" for potable distribution and "NPD" for non-potable distribution. At each node, total electricity use is the sum of the conveyance and treatment electricity intensity of the upstream link. For all utilities, the potable and, if applicable, non-potable distribution systems were connected to an end-use node (suffix “E”) which represents that utility’s customers.

The WESTNet tool connects the source and target nodes shared by the utilities into an inter-connected network. Almost 370 utilities serve retail customers or sell to small systems not required to submit UWMPs. These are evaluated as endpoints in the network. The network can be visualized as a linear or web configuration or mapped if linked to a geographic information system (GIS) database or software. Example node and link configurations are illustrated in Figure S1 for several increasingly complex subnetworks of the California water system. They are shown as linear configurations

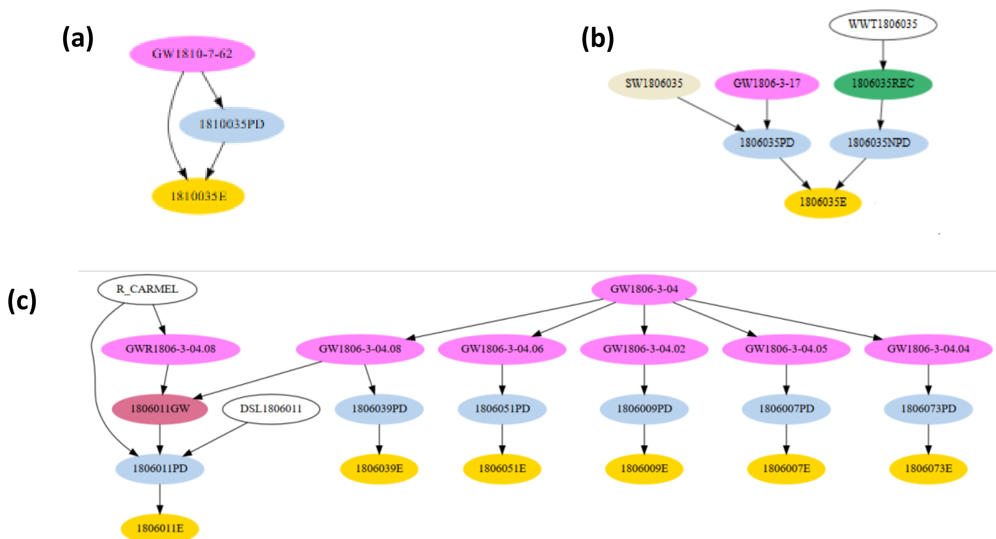

Figure S1: Example urban water subnetworks of increasing complexity. (a) A Colorado River (CR) region utility “1810035” that provides both potable and raw (untreated) water from a groundwater (GW) aquifer. (b) A Central Coast (CC) utility “1806035” that delivers water to their customers from a groundwater basin and a surface water source (SW) delivered via potable distribution and recycled water (REC) from a wastewater treatment plant (WWT) delivered via a non-potable distribution (NPD) network. (c) A Central Coast (CC) groundwater basin with five subbasins that serves six utilities and their customers. One utility “1806011” also gets water from desalination (DSL) and the Carmel River; it uses some river water to recharge groundwater (GWR).

WESTNet Algorithm Description

The WESTNet tool uses a network-based approach for calculating the EI of each facility (e.g., node). The algorithm is comprised of three major processes: initiation, maintenance, and termination. The model starts off at the furthest upstream nodes in the network, e.g., initialization nodes. At these nodes, water is in its natural state (ex., groundwater, pooled surface water, etc.) and is assigned an EI of zero. These nodes are connected to other nodes in the network by distribution edges, or linkages in the network such as pipes, conduits, etc.

After this initiation step, the model estimates EI using the following iterative process:

(1) Move from the current node (Node A) to a downstream node (Node Z) along an outgoing edge.
(2) At the downstream node (Node Z), check that all the upstream nodes (Nodes A, B, C, etc.) directly connected to Node Z have an estimated EI.
    a. If yes, move to Step (3).
    b. Otherwise, skip this node and move to node upstream of this node and run Step (1).

(3) Estimate the EI of Node Z by taking the weighted average EI of the incoming nodes. The model uses incoming water volumes as the weighting factor in the average.
(4) Run Step (1)

The algorithm terminates when all of the nodes have an associated EI estimate. The model reports the EI at each individual node in the network, at each end node, for each hydrologic region, and for the whole state based on the weighted average by demand volume for end-user nodes located in the appropriate boundary.

Results

Table S6 summarizes regional demand evaluated in the analysis and per capita water use data used in calculations.

Table S6: Total regional water demand (calculated in this study) and per capita water consumption for California and its ten hydrologic regions for 2010, 2020, and 2030

		Total water demand (million m^3)			Per capita water use (m^3/person/day)		
	Hydrologic region	2010	2020	2030	2010	2020	2030
California		8,200	10,100	11,500	0.75	0.63	0.57
1801	North Coast (NC)	52	72	80	0.61	0.50	0.45
1802	Sacramento River (SR)	880	1,100	1,200	1.06	0.85	0.77
1803	Tulare Lake (TL)	540	620	750	1.03	0.83	0.75
1804	San Joaquin River (SJ)	330	420	530	0.90	0.74	0.67
1805	San Francisco Bay (SF)	1,300	1,500	1,600	0.59	0.50	0.45
1806	Central Coast (CC)	190	230	250	0.55	0.47	0.43
1807	South Coast (SC)	4,400	5,400	6,100	0.72	0.61	0.55
1808	North Lahontan (NL)	25	29	34	0.96	0.78	0.70
1809	South Lahontan (SL)	200	360	430	1.03	0.83	0.75
1810	Colorado River (CR)	270	390	520	1.41	1.15	1.04

Note: Per capita water use data from (4).

Tables S7, and S8 provide EI, per capita embedded electricity, and total electricity consumption results for all regions, years, and scenarios.

Table S7: Comprehensive EIs, per capita electricity and total annual electricity consumption embedded in water supply for California and its ten hydrologic regions for all scenarios and years

Result	Year	Scenario	California	NC	SR	TL	SJ	SF	CC	SC	NL	SL	CR
Electricity intensity (kWh/m3)	2010	Low	1.1	0.23	0.18	0.54	0.18	0.62	0.58	1.6	0.12	1.7	0.90
		Moderate	1.3	0.30	0.30	0.64	0.30	0.69	0.69	1.9	0.18	2.0	1.1
		High	1.5	0.36	0.40	0.72	0.40	0.75	0.78	2.1	0.22	2.3	1.2
	2020	Low	1.2	0.23	0.18	0.56	0.16	0.62	0.67	1.8	0.12	1.7	0.73
		Moderate	1.5	0.30	0.32	0.66	0.30	0.69	0.80	2.1	0.19	2.0	0.90
		High	1.7	0.36	0.42	0.76	0.41	0.75	0.91	2.4	0.24	2.3	1.1
	2030	Low	1.3	0.23	0.19	0.53	0.17	0.62	0.68	1.9	0.11	1.5	0.61
		Moderate	1.5	0.31	0.33	0.64	0.30	0.70	0.81	2.2	0.19	1.8	0.78
		High	1.7	0.37	0.44	0.74	0.41	0.76	0.93	2.6	0.25	2.1	0.93
Annual per capita embedded electricity (kWh/person/year)	2010	Low	310	52	68	200	61	130	120	430	41	640	460
		Moderate	360	67	118	240	99	150	140	490	62	750	550
		High	410	80	157	270	131	160	160	560	77	870	630
	2020	Low	281	43	60	169	44	110	120	400	33	520	310
		Moderate	330	56	98	200	80	130	140	470	53	610	380
		High	380	67	132	230	110	140	160	540	67	710	440
	2030	Low	260	38	50	140	40	100	110	380	29	410	230
		Moderate	310	51	90	170	70	110	130	440	49	490	290
		High	350	61	120	200	100	130	150	510	63	560	350
Annual total embedded electricity (GWh/year)	2010	Low	9,200	12	160	300	60	780	110	7,200	3.0	340	240
		Moderate	11,000	16	270	350	100	900	130	8,400	4.5	400	290
		High	12,000	19	360	390	130	900	150	9,500	5.6	460	330
	2020	Low	12,000	17	190	350	70	950	150	9,700	3.4	610	290
		Moderate	15,000	22	340	410	130	1,100	180	11,000	5.5	720	350
		High	17,000	26	450	470	170	1,100	210	13,000	6.9	830	420
	2030	Low	14,000	18	220	400	90	1,000	170	11,600	3.9	650	320
		Moderate	17,000	24	390	480	160	1,100	200	14,000	6.5	770	410
		High	20,000	29	500	600	200	1,200	200	16,000	8.4	900	500

Table S8: Comprehensive range of results for utilities in each of California's hydrologic regions for all scenarios and years

Region			**NC**	**SR**	**TL**	**SJ**	**SF**	**CC**	**SC**	**NL**	**SL**	**CR**
Number of utilities evaluated			13	32	26	19	45	29	164	5	16	14
2010	Average sources (#)		2.0	3.7	2.3	2.6	4.1	2.3	5.6	2.2	2.2	2.1
	Low	Median	0.23	0.16	0.39	0.19	0.44	0.57	1.4	0.16	0.66	0.40
		Minimum	0.19	0.025	0.16	0.049	0.26	0.020	0.19	0.045	0.26	0.078
		Maximum	0.28	1.8	4.3	0.50	1.3	1.5	4.8	0.16	3.3	2.2
	Moderate	Median	0.31	0.28	0.49	0.25	0.55	0.66	1.6	0.18	0.82	0.42
		Minimum	0.25	0.090	0.24	0.070	0.28	0.071	0.39	0.16	0.40	0.29
		Maximum	0.44	2.2	4.5	0.61	1.5	1.8	5.3	0.26	3.9	2.6
	High	Median	0.36	0.40	0.58	0.39	0.66	0.76	1.9	0.21	0.95	0.44
		Minimum	0.26	0.10	0.29	0.090	0.30	0.071	0.53	0.19	0.51	0.44
		Maximum	0.57	2.5	4.8	0.71	1.8	2.1	5.6	0.39	4.5	3.0
2020	Average sources (#)		2.3	4.2	2.5	2.9	4.2	2.9	6.6	2.2	2.5	2.6
	Low	Median	0.23	0.13	0.39	0.16	0.43	0.57	1.7	0.13	0.67	0.39
		Minimum	0.18	0.023	0.15	0.054	0.27	0.020	0.16	0.050	0.26	0.08
		Maximum	0.28	1.9	4.3	0.59	1.2	2.4	5.5	0.16	3.4	2.0
	Moderate	Median	0.31	0.28	0.50	0.27	0.55	0.69	2.0	0.18	0.82	0.42
		Minimum	0.25	0.078	0.25	0.089	0.30	0.071	0.25	0.18	0.41	0.29
		Maximum	0.44	2.3	4.6	0.72	1.5	2.6	6.2	0.26	4.0	2.4
	High	Median	0.38	0.41	0.63	0.40	0.69	0.85	2.3	0.26	0.96	0.46
		Minimum	0.26	0.084	0.32	0.11	0.33	0.071	0.34	0.19	0.52	0.42
		Maximum	0.57	2.7	4.8	0.85	1.8	2.8	6.7	0.39	4.6	2.8
2030	Average sources (#)		2.7	4.5	2.5	3.0	4.3	3.1	7.5	2.2	2.7	2.6
	Low	Median	0.23	0.13	0.39	0.16	0.43	0.57	1.8	0.13	0.66	0.39
		Minimum	0.18	0.023	0.14	0.049	0.27	0.020	0.16	0.054	0.26	0.078
		Maximum	0.28	1.9	4.3	0.61	1.2	2.4	5.4	0.16	3.4	1.9
	Moderate	Median	0.31	0.27	0.52	0.27	0.55	0.70	2.1	0.19	0.73	0.41
		Minimum	0.25	0.078	0.26	0.092	0.30	0.071	0.25	0.18	0.41	0.29
		Maximum	0.44	2.3	4.6	0.75	1.5	2.6	6.0	0.26	4.0	2.3
	High	Median	0.37	0.41	0.68	0.40	0.69	0.85	2.4	0.26	0.85	0.46
		Minimum	0.26	0.085	0.36	0.12	0.33	0.071	0.34	0.19	0.52	0.42
		Maximum	0.57	2.7	4.8	0.88	1.8	2.8	6.5	0.39	4.6	2.7

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