It's in the Water! – Improving Energy Savings Calculations from CA Water Conservation

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ABSTRACT

In the summer of 2015, Governor Jerry Brown of California mandated a 25% reduction in urban water production relative to 2013. Water conservation efforts following the mandate resulted in parallel embedded energy reductions from avoided energy inputs that would otherwise have been required for the production, treatment and distribution of conserved water. Researchers have previously estimated embedded water energy savings by calculating an average energy intensity (EI) of water for each of California's ten hydrologic regions. In this study, we add to the emerging body of research on the water-energy nexus a more granular estimate of embedded water savings that is derived from the aggregation of water agency electric bills associated with urban water production (groundwater pumping, potable water treatment, and distribution to end users). The nonrandom selection of water agencies is broadly representative of the state's distribution of water supply sources and is inclusive of each hydrologic region. Results from the billing review indicate that reductions in water agencies' energy consumption in 2015 relative to 2013 are on average 25% smaller magnitude and more variable than those estimated using an average hydrologic region EI approach. In addition, the average annual energy intensity across all selected water agencies is shown to increase from 2013 to 2015 by approximately 7 percent, coincident with increasing drought severity. Increases in water agency energy intensities indicate that water agency energy reductions do not have a linear relationship with volumetric water savings and may instead be affected by a variety of mechanical and climatic factors. Finally, the evaluation team preliminarily investigated shifts in hydrologic region water supply sources for 2013-2015, providing macro insights on drought-driven changes in water EI across the state.

Introduction

Water-related energy use in California is responsible for a significant portion of the state's overall electricity consumption. Approximately 7% of the state's overall electricity use is embedded in the extraction, conveyance, treatment, and distribution of water upstream of end users.[1] When water is conserved, energy use is avoided that would otherwise be associated with the production,[2] treatment, and distribution of that water. In California, one study estimated the embedded energy savings coincident with the 25% reduction in urban water usage in July-September 2015 to be of comparable magnitude to the total savings from all traditional utility energy efficiency programming portfolios for that same period.[3]

While avoided energy inputs from conserved water have the potential to be a significant source of energy use reductions, there is a lack of an industry standard for evaluating these reductions. The development of such a framework and associated reporting standards can help facilitate the full realization of potential energy use reductions and the development of effective policies. This area has

[1] California Public Utilities Commission, Embedded Energy in Water Studies. Study 1: Statewide and Regional Water-Energy Relationship (prepared by GEI Consultants/Navigant Consulting, Inc., 2010).

[2] Production encompasses a mixture of groundwater pumping, surface water conveyance, water recycling, and desalination. This mix is different across varying regions of California.

[3] See https://cwee.shinyapps.io/greengov/

been a focus of ongoing effort by the California Energy Commission(CEC) and the California Public Utilities Commission(CPUC) and has yielded the CPUC Water Energy Calculator, which allows users to estimate embedded energy savings associated with a given volume of conserved water depending on the region of the state in which the savings take place.[4]

This report details the methods that the evaluation team used to directly observe changes in water utility electric bills for 2013-2015, capturing the 2015 statewide water conservation mandate (Executive Order B-29-15)[5] and the relevant baseline period prior to the mandate. Itron analyzed data from 32 water agencies by aggregating monthly electric bills to directly calculate annual electricity use by water agency for each study period year. Findings are presented parallel to energy reduction estimates calculated using the methods and values of the existing California state water-energy calculator. The evaluation team then calculated annual changes in water agency EI during the study period 2013-2015, to observe patterns in water agency EI under conditions of increasing drought intensity.

Finally, the study team explored shifts in regional water supply sourcing through comparison of the percent of water supply sourced from groundwater production versus water from the State Water Project (SWP), a long-distance conveyance system that transports water from the Sacramento River delta to end users across California. Trends in changing regional water sourcing are significant for the average regional and state EI of water, in part because the EI of long distance water conveyance informs the total embedded energy in water and the associated energy reductions from water conservation.

Background and Methods

California is divided geographically into 10 hydrologic regions defined by the Department of Water Resources based on regional water drainage basins and typical water supply sources.[6] Previous embedded water energy estimates have incorporated data at varying levels of granularity to calculate embedded water energy savings for individual water system components, water agencies, and the state. The study team conducted an intensive literature review of existing methods for estimating embedded water energy savings in California. The team primarily focused on studies that support the CPUC water-energy calculator and the later UC Davis (UC Davis Center for Water-Energy Efficiency 2016)[7] water-energy tool that applied the values and methods of the CPUC calculator (Navigant Consulting 2015b, Navigant Consulting 2015a).

Figure 1 symbolically represents California's framework for estimating the energy embedded in water, where each level of the framework has an EI. The most granular level is the water agency system component EIs of water extraction, treatment, and distribution. These can then be rolled up to a water agency EI as the sum of the individual system component EIs. Averaging EIs across a set of geographically bound water agencies represents a hydrologic region EI. Note that these hydrologic region EI's can be expressed as either including or excluding the embedded energy associated with the state's long-distance water conveyance systems, such as the State Water Project (SWP), whose power supply is independent of investor owned utility (IOU) power. The default EIs in the CPUC water energy calculator are "IOU-only" and exclude energy associated with these conveyance systems.

[4] See http://www.cpuc.ca.gov/nexus_calculator/
[5] See https://www.gov.ca.gov/docs/4.1.15_Executive_Order.pdf
[6] See http://www.water.ca.gov/waterplan/cwpu2013/final/index.cfm
[7] See https://cwee.shinyapps.io/greengov/

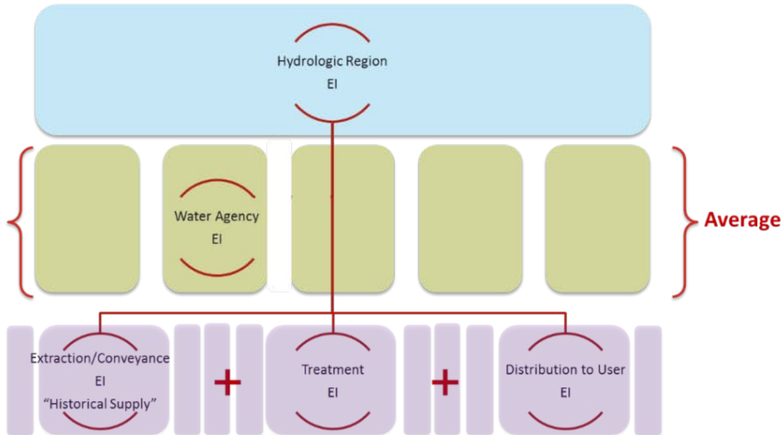

Figure 1. Symbolic Representation of California's Embedded Water Energy Evaluation Framework

The 2016 UC Davis water-energy web tool, developed as part of the 2016 CA Water Board Data Innovation Challenge, relies on the default methods and values of the CPUC water-energy calculator (UC Davis Center for Water-Energy Efficiency 2016). The web tool multiplies CPUC IOU-only water-energy calculator EIs by the water agency-reported volumetric water savings available through the State Water Board (SWB)[8] to calculate Q3 2015 embedded water energy reductions relative to a 2013 baseline for each individual water agency and for the state. The Itron team recalculated the UC Davis estimates as part of investigating and corroborating the research methods and sources underlying the calculations, making any adjustments in the calculations that the team deemed were warranted to reflect outdoor energy use that could be compared to savings from energy efficiency programs.

The study team then pursued the primary objective of this study, which was to use a billing data review approach for the electric accounts of water agency pumps and to compare water energy use reductions 2013-2015 based on changes in billing data with estimates derived using average hydrologic region EI values. Itron calculated energy reductions for a selection of approximately 30 water agencies throughout the state at the annual level for 2015 relative to a 2013 baseline. The energy reductions calculated for water agencies using the billing review method include groundwater extraction, treatment, and distribution to water end users. In Itron's billing data review approach, each selected water agency's electric accounts are identified, aggregated, and monthly totals are summed to provide total annual water pumping electricity for 2013-2015. The scope of the billing review is comparable to IOU-only outdoor embedded water energy reduction estimates using the CPUC water energy calculator, as both approaches exclude the energy consumption associated with imported water sources upstream of a given water agency as well as the energy associated with wastewater treatment downstream of end users.

The study team used both a bottom-up and top-down strategy to collect water agencies' energy consumption data. The bottom-up approach consisted of using criteria within the California IOUs' Customer Information Systems (CIS) billing data, such as customer name and address, to identify the specific set of water pumping accounts for a given agency. Data collected from the CIS billing database was refined using publicly available data and online satellite imagery tools to isolate the relevant water accounts through visual billing address verification. Individual water agency billing accounts were identified as being specifically associated with groundwater pumping, water transport, potable water storage, treatment, waste water treatment, or not relevant to the study. If an address was associated with wastewater treatment or its association with the water agency was not identifiable by the evaluation team's methods, it was removed from later analysis.

[8] http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/conservation_reporting.shtml

The top-down approach consisted of seeking cooperation directly from water agency managers to identify the list of electric billing accounts associated with water provision to end users, as well as the total electricity consumption and water production associated with those accounts. In some cases, the team had the opportunity to compile data for a selected water agency through both bottom-up and top-down methods, and this served as a check on the accuracy of the bottom-up methods generally. Disaggregating electric accounts associated with water pumping from all other civic electric accounts is a potentially onerous task. Because this study was exploratory in nature from its inception and not meant to provide a statistically representative estimate of statewide energy use reductions associated with the 2015 mandate, Itron's water agency selection was accomplished through a stratified sample of convenience, using the presence of "water district" or "water agency" in the account name in some cases as one useful means of distinguishing water related accounts from other civic electric accounts.

Visual inspection on Google Earth was informed and corroborated wherever possible with the information supplied in each of the water agencies' 2015 Urban Water Management Plans (UWMP), which are publicly available online. The corroboration process provided a valuable tool for identifying the correct set of accounts to use in the evaluation, as well as assigning a pump type to each account. However, the evaluation team was not always able to disaggregate the energy consumption associated with pumping wastewater from the end user to a wastewater facility from that associated with pumping potable water to end users. Further considerations that were not directly accounted for through the bottom-up methods in this study include any changes in water agency technology, pump efficiencies, or implementation of solar power and net metering that may have taken place over the study period 2013-2015, as well as any presence of gas powered water pumping accounts.

The absolute comparability of the Itron billing review and average hydrologic region EI derived water energy reduction estimates requires some additional considerations pertaining to the volume of water included in the frame of analysis. The average EI-derived approach as applied on the UC Davis website uses water volumes as reported to the State Water Board (SWB) by each water agency. Based on reporting requirements of the SWB, these volumes represent "water in use" i.e., treated water consumed within water agency boundaries. These volumes therefore exclude raw water (any water that is produced and consumed without being treated, which may include rainwater, water from infiltration wells, and water from bodies like lakes and rivers), recycled water (wastewater that is re-used but is not treated back to potable water status before re-use), and water exports that are produced within the water agency but consumed elsewhere.

The billing data review approach, by contrast, bypasses the formal consideration of water volume altogether in energy reduction calculations per se, in favor of directly calculating changes in energy consumption. As such, the volume of water associated with that consumption, form a boundary definition standpoint, is the total volume of water generated, consumed, or moved through a given water agency using power supplied by an IOU. A groundwater-dependent water agency that produces and consumes its own water and does not make use of raw or recycled water would yield the same water volume across these two approaches. But for a water agency that exports much of the groundwater it produces, the volume reported to the SWB would exclude these exports, whereas the billing data review, by its nature, would capture electricity consumption associated with extracting and exporting that water.

This difference in boundary definition means that the average EI approach and the billing data review approach are not a true apples-to-apples comparison of energy use reductions. To help characterize this difference and frame its impact, the evaluation team calculated the percent difference between the reported SWB volume and the total supply reported in the 2015 UWMPs for each water agency where parallel data were available. Water agencies whose total supply differs by more than 10% from that reported to the SWB are removed from calculations where a comparison is being made between the billing data review and the average EI approaches.

The study team also tested whether empirical changes in EI could be observed in parallel with the increasing drought intensity over the study period (USGS n.d.). The evaluation team used the SWB conservation data set for water agencies' historical monthly water production 2013-2015, supplemented where possible with water conservation data supplied directly to Itron by water agencies. Annual EI values for each water agency were then calculated by dividing annual energy consumption by annual water production and comparing values for 2013 and 2015. The year of 2014 was not included, since the SWB conservation water data include only the months of June-December for that year. For determining changes in EI for 2013 and 2015 at the water system component level (extraction, treatment, and distribution), the evaluation team determined that only water agencies whose energy consumption data were corroborated through top-down methods would be used, in order to maximize the accuracy of attributing a given pump to a given water system component. The attribution of changes in EI over the study period to one or more specific causes was beyond the scope of this study. Rather, the study team simply sought to characterize the magnitude of change and note some potential causal factors.

Finally, the team considered potential changes in hydrologic region EI associated with shifts in regional supply mix. In particular, the team focused on the percent change of each hydrologic region's supply mix that is sourced from either groundwater or water imports from long-distance conveyance systems such as the State Water Project (SWP)[9] for 2013-2015. The evaluation team used a set of publicly available data sets to calculate the water volumes associated with 2013 and 2015 groundwater production[10] and SWP deliveries[11] which were then compared as the proportion of each hydrologic region's total urban water supplies[12].

Results

In recalculating the UC Davis water energy savings estimates for 2015Q3 that rely on the default methods and values of the CPUC water-energy calculator, the Itron team found that the UC Davis estimate includes the EI of wastewater treatment downstream of end users. Itron recalculated outdoor energy use upstream of end users by applying IOU-only average hydrologic region EI values from the calculator and excluding the EI of wastewater. The UC Davis estimate of 460 GWh water energy use reductions for 2015Q3, when recalculated without the EI of wastewater treatment, yielded 223 GWh. Itron also noted that the EI values in the CPUC water-energy calculator were derived based on annual data. As such, the Itron team determined that the EI values should be applied to annual, rather than quarterly, volumetric water savings. This, in part, serves to reduce potential distortions in apparent water savings associated with seasonal storage and reservoir pumping (Board 2017). This also makes the comparison between water energy reductions and statewide energy efficiency program savings more parallel, since savings from energy efficiency program measures are calculated on a first year and lifetime basis. When expressed as an average 2015 quarter, outdoor energy use reductions drop from 223 GWh drop to 130 GWh for 2015Q3.

The evaluation team's empirical investigation of embedded water energy reductions from water agency electric bills for 2013-2015 was carried out on a selection of 31[13] water agencies. Results from

[9] See http://www.water.ca.gov/swpao/deliveries.cfm

[10] Hydrologic region groundwater production values were calculated from reported annual retail groundwater production values supplied as part of the 2015 UWMP

[11] Hydrologic region State Water Project values were calculated from published water deliveries see footnote 11. Urban end uses on average represent less than 20% of SWP deliveries.

[12] Hydrologic region annual urban water supplies were calculated from the SWB dataset see footnote 10

[13] This is exclusive of Contra Costa Water District, a district included in the overall water agency selection but whose data was excluded from overall averages in reporting. This was due to data quality concerns on the part of

that review are detailed in the sections that follow, with water agencies organized into three distinct groups:

- **Groundwater-reliant**: Water agencies that obtain more than 70% of their urban potable water from groundwater pumping within the water agency boundaries.
- **Import-reliant**: Water agencies that obtain more than 70% of their urban potable water by importing it from other regions.
- **Mixed-source**: Water agencies whose overall supply is a relatively even mix of supply sources.

Figure 3 shows how the selected water agencies were distributed throughout California and the 10 hydrologic regions into which the state is divided.

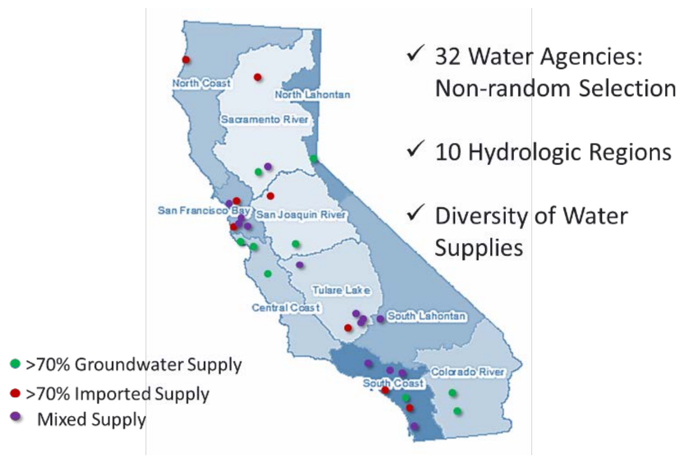

Figure 1: Itron Water Agency Sample Selection

The overall water supply mix distribution of the 31 selected water agencies broadly matches the supply mix distribution for the state overall, as shown in Figure 4. Figure 4 shows the distribution of water agencies relative percent of water sourced from each supply type, where each box shows the interquartile range across water agencies for a given water source, and the line within the box shows the mean value. Notably, imported water and groundwater make up approximately 80% of the total source mix, both for the state overall and for the set of water agencies selected in this study. While water agencies in the study showed a somewhat higher proportion of recycled water and correspondingly lower proportions of surface water and Other water sources (including desalinized water) relative to the state overall, the Itron sample mean is within 10% of the California mean for each supply mix source.

the study team. In particular, the number of water-related accounts for this water agency was deemed to be abnormally and unexpectedly high based on the satellite imagery approach used in this study. This may be due to incorrect identification of pump infrastructure and associated electric billing accounts.

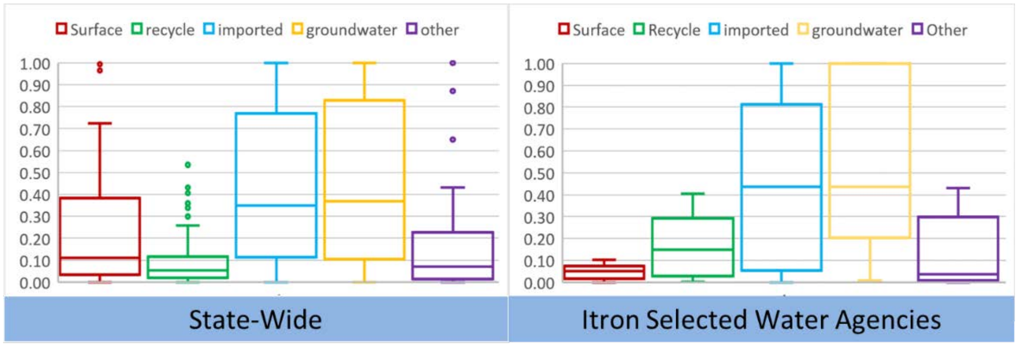

Figure 2: Distribution of Water Agency Supply Types to Water Agency Total Supply Aggregated Across All Water Agencies in 2015 UWMP (Left) and Itron Water Agency Selection (Right)

For a subset of six water agencies within the overall selection, the study team obtained the direct cooperation of water agency managers to help verify the accuracy of the billing data review approach. Figure 5 shows a comparison of total water agency electricity consumption in 2015 for each water agency in the study based on the billing data review, matched with primary data from the six water agencies where the study team obtained the direct cooperation of water agency managers. As shown in the figure, total kWh consumption from the billing data review generally showed a close match with the data provided by water agency managers, with the billing data review total ranging from 72% to 112% of the total supplied by the water agency managers. This serves as reasonably strong corroboration for the validity and accuracy of the billing data review approach.

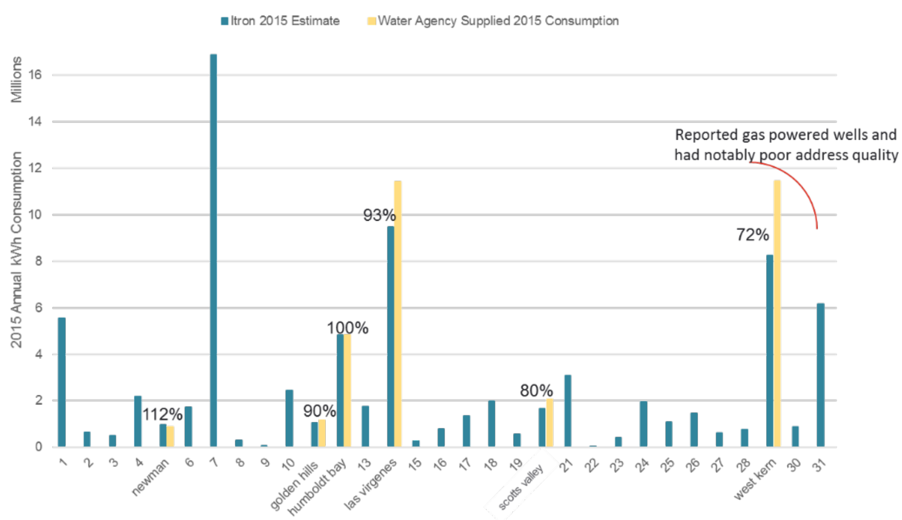

Figure 3: 2015 Annual Energy Consumption Top-Down Corroboration of Bottom-Up Results

Of the 31 water agencies in the study, nine rely on groundwater pumping within the water agency boundary for at least 70% of their total water supply. Percent energy use reductions from the billing data review and from the average hydrologic region EI approach are shown for each water agency in Figure 6 below. The yellow bars show the estimated percent energy reduction for each water agency using the average EI approach. Note that this approach ties the energy reduction directly to the volume of water conserved, since estimated energy reductions are the product of hydrologic region EI multiplied by volumetric water reduction as reported to the SWB. The red bars show the actual percent energy reduction for each water agency based on billing data of aggregated accounts for the same time period. As can be seen from the figure, results from the billing data review have a greater range than those from the average EI approach. The yellow and red dotted lines in the figure show that the average EI-derived approach yields an average 23% reduction in 2015 electricity use relative to 2013 across these nine groundwater-dependent water agencies, while the billing data review yields an average 16% reduction. In general, the billing data review does not show the linear relationship between volume of water conserved and energy use reductions 2013-2015 at the individual water agency level that is a basic feature of the average hydrologic region EI approach.

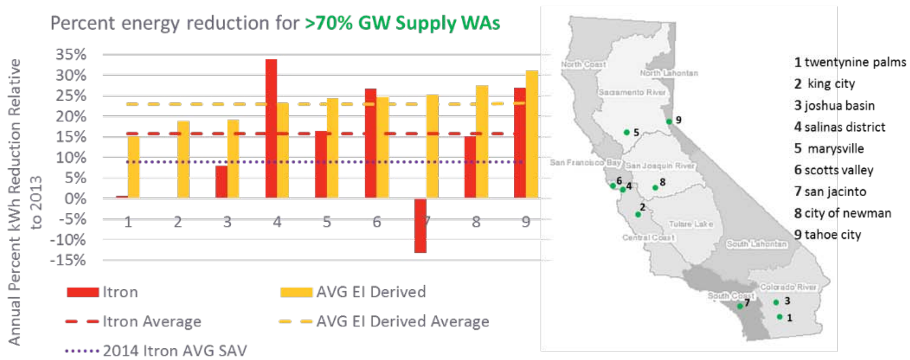

Figure 4: 2015 Annual % Energy Savings Relative to 2013 from Itron Billing Review and Application of Average EI Values for Water Agencies that Source > 70% Groundwater for Supplies

In addition to water agency electricity reductions in 2015 relative to 2013, the purple dotted line in the figure also captures the average electricity reduction in 2014 of 9% relative to 2013 for the set of groundwater-reliant water agencies. The 2015 reductions can be seen as building on the 2014 reductions, with a 9% reduction occurring in 2014 and an additional 7% reduction occurring in 2015. This is consistent with multi-year groundwater management plans that incrementally reduce groundwater pumping in response to multi-year drought conditions.

Of the 31 water agencies in the study, an additional 9 water agencies rely on imported water for more than 70% of their total water supply. Proportional electricity reductions from 2013 to 2015 are shown in Figure 7. In comparison to the groundwater-reliant water agencies, there is somewhat closer agreement between the billing data review and the average EI-derived method for the average percent reduction in water agency kWh consumption for these water agencies, though the billing data values continue to show greater variability. The average EI-derived approach yields an average 24% reduction, while the billing data review yields an average 22% electricity reduction. For these water agencies, the purple dotted line shows an energy reduction of approximately 6% in 2014 relative to 2013, with the larger remainder of reductions taking place in 2015.

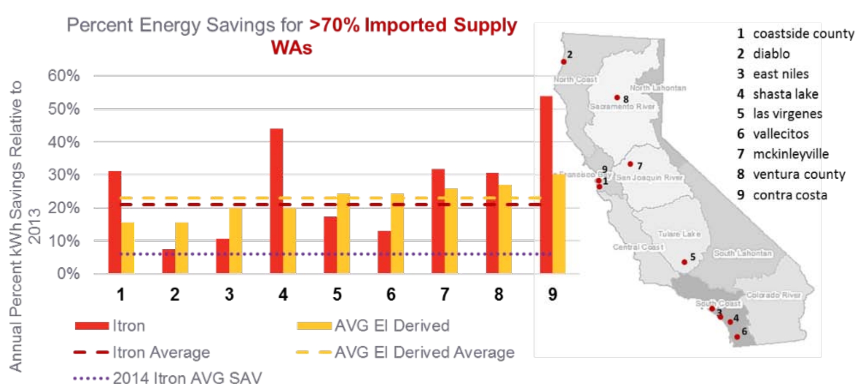

Figure 5: 2015 Annual % Energy Savings Relative to 2013 from Itron Billing Review and Application of Average EI Values for Water Agencies that Source > 70% Import Supplies

The remaining 13 water agencies in the study rely on a mix of groundwater, imported, and surface water for their total water supply, along with smaller contributions from other water sources such as raw and recycled water. The average percent energy reduction from 2013 to 2015 for mixed supply water agencies is similar to import-reliant water agencies with the EI derived approach yielding 24% and the billing review average of 22%. However, there is a high degree of variability among water agencies compared to the EI derived estimates.

Looking across all 31 water agencies in the study, the results from the billing data review show an 18% absolute reduction in energy consumption for 2015 relative to 2013, coincident with the 24% reduction in water consumption for that same period. For the same set of water agencies, the average hydrologic region EI approach yields an energy consumption reduction estimate of 24%. Overall, this finding suggests that actual electricity reductions associated with water conservation are somewhat lower than previously estimated.

The inherent difference in system boundary definitions between the billing data review and the average hydrologic region EI with respect to the volume of water considered in the analysis requires additional discussion. Recall that the billing review captures the energy associated with total water supply, whereas the average EI approach relies only on urban "water in use" reported to the SWB. Figure 8 adds a layer to the energy reductions from Figure 6, showing the comparability of the water volumes across the two methods, with the difference in water volumes shown as a blue bar overlaid on the percent change in energy for each water agency. A blue bar above the zero line indicates that total water supply as reported in the 2015 Urban Water Management Plan for a given water agency is greater than the volume reported to the State Water Board as water in use. A blue bar below the line indicates that reported water in use is greater than the total water supply as noted in the UWMP. The absence of a blue bar indicates that the relevant water volumes are an exact match between these two data sources. For all but Twentynine Palms and Scotts Valley, there is little or no difference in water volumes. For all groundwater reliant agencies the difference between the total water supply in the UWMPs and that reported in the SWB conservation dataset are less than 20 percent. This finding signifies that the comparability between the Itron billing review and EI derived estimates, based off the equivalency of associated water volumes, is quite robust for groundwater reliant water agencies.

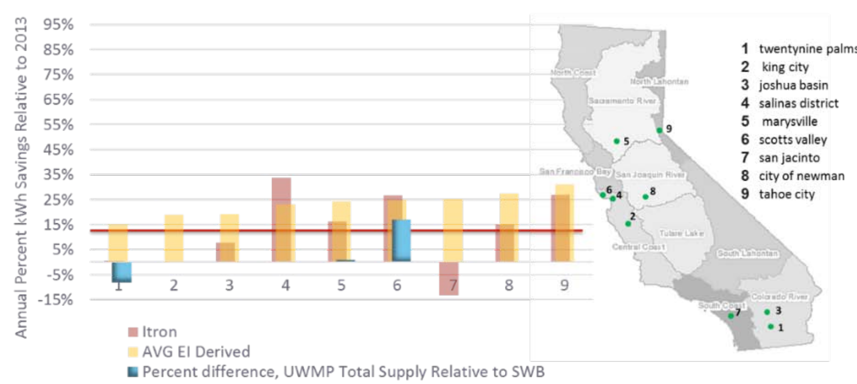

Figure 8: Comparability of 2015 UWMP Total Water Supply to 2015 SWB Volume for Water Agencies Reliant on Groundwater

Whereas most of this study represents water energy usage reductions as a proportional change relative to a 2013 baseline, Table 1 shows the actual MWh differences between the billing data review and average EI derived estimates for groundwater-reliant agencies. For water agencies where ([Itron – EI Derived] MWh) is negative, the Itron billing results yielded a lower estimate for the amount of energy consumed by the water agency in 2015 than the average EI method. The sum of these values indicates that the average EI method may overestimating embedded water energy savings. Since the sample for this study was not a stratified random sample targeting a specific confidence interval, this finding is best viewed as preliminary and directional in nature. Comparing the empirically derived 2015 MWh consumption with the CPUC water-energy calculator may indicate that the EI values of the water energy calculator are not capturing the full dynamic relationship of conserved water and actual energy reductions for groundwater reliant water agencies in the study period.

Table 1: Comparison of Actual 2015 MWH Savings Relative to 2013 from Itron Billing Review and Application of Average EI Values for Groundwater-Reliant Water Agencies

Water Agency	Itron minus average EI MWh	Itron divided by average EI MWh
KING CITY	-145	0%
MARYSVILLE	-20	84%
SALINAS	-791	58%
CITY OF NEWMAN	1	101%
JOSHUA BASIN	84	227%
SAN JACINTO	-568	-69%
SCOTTS VALLEY	450	388%
TWENTYNINE PALMS	-77	11%
TAHOE CITY	210	283%
GROUNDWATER TOTAL:	-856 MWh	72%

Across all 31 water agencies in this study the results of the billing review indicate that weighted average percent energy reductions associated with water conservation are lower than estimates derived from the average EI values. This is especially true for groundwater-reliant water agencies, where energy reduction calculations based on the billing data are significantly lower than estimates derived using average EI values. For water agencies reliant on imported and mixed supplies the billing review percent energy reductions were only slightly lower than the average EI values. While the selection of water agencies was not a random sample, these results clearly show wide differences between estimated embedded water energy savings and empirically measured energy usage reductions for many of the water agencies in the study. Results from the review of water agency electric bills support the conclusion that the relationship between volumetric water and energy reductions is not directly proportional.

This study concluded analysis with an investigation on EI patterns of change at each level of the embedded water energy framework. Based on the billing data review, overall water agency IOU-only EI increased for all water agencies during the study period 2013-2015, whether they received their water primarily from imports, from local groundwater pumping, or from mixed supplies. The overall average EI across all 31 water agencies in the study increased by 7 percent, from 371 kWh/acre-ft to 397 kWh/acre-ft. EI for groundwater-reliant water agencies rose an average of 10 percent over the study period, while EI for import-reliant water agencies rose approximately 7 percent. Data from the four water agencies whose managers supplied information on reliably labeled water system components (extraction, treatment, and distribution) show that the EI of both water production and distribution increased over the study period. Based on these data, EI of water production rose 9 percent, and EI of water distribution rose 17 percent during the study period.

In the context of increasing drought conditions and declining overall urban water usage during that period, shifts also took place in water supply mix throughout the state. This was especially true in terms of the relative balance of groundwater pumping and imports from the state's long distance conveyance systems. In particular, the volume of water pumped by the SWP declined significantly over the 2013-2015 period. Consistent with this, as shown in Figure 10 , all but 2 of California's 10 hydrologic regions saw groundwater production grow as a proportion of total water supply, even as the total pumped volume was declining in an absolute sense. The largest proportional increases were seen for the Central Coast, San Joaquin River, and South Lahontan hydrologic regions.

The proportion of total water supplied by the SWP decreased for 8 out of 10 hydrologic regions. As shown in Figure 9 , the most dramatic proportional reductions in overall SWP water use were for the San Joaquin River and the Colorado River hydrologic regions. Note that much of the SWP water in those regions is used for agriculture and does not therefore specifically represent urban water use.

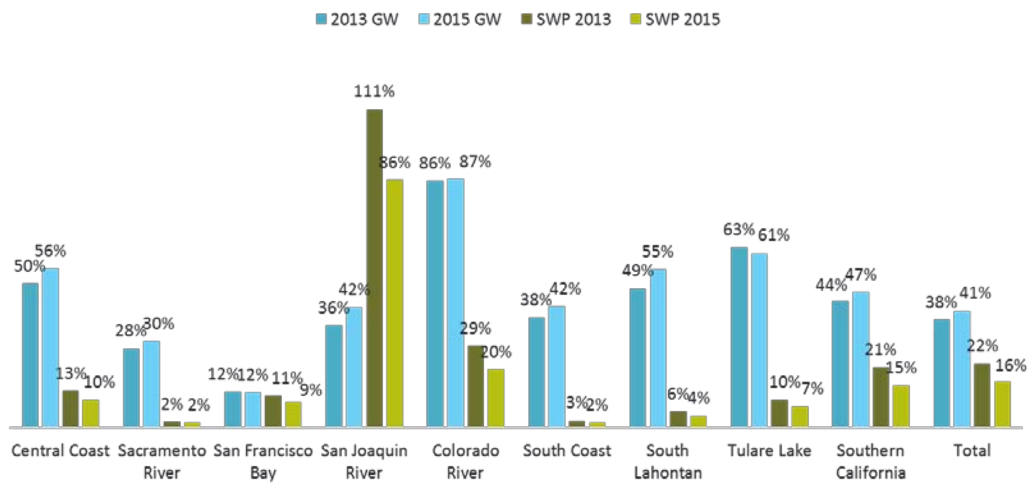

Figure 9: Annual Average Ratio of State Water Project (SWP) Deliveries and Retail Groundwater (GW) Production to SWB Production by Hydrologic Region

As shown in Figure 10, there is a large range in the energy intensity of SWP water, depending sensitively on how far the water is transported (this is especially a function of how many vertical feet the water must be raised) to get from its source in the Sacramento River Delta to its destination. Notably, SWP deliveries to the far southeastern corner of California, which include the largest amount of embedded energy from pumping stations along the route, have energy intensities exceeding 4,000 kWh/acre-ft. This is at least 7 to 10 times higher than typical EIs for locally pumped groundwater across different regions of the state. Applying this concept more broadly to the regions shown in Figure 10, the comparison suggests that, at least when taking non-IOU energy into account in the case of the SWP, a parcel of water saved in the southern half of the state may yield significantly higher embedded energy savings than an equivalent parcel saved in the northern half of the state. This dramatic difference in EI may serve as an argument in favor of investing in granular, methodical data collection and analysis to fully characterize this dynamic for the incorporation into water and energy conservation policies.

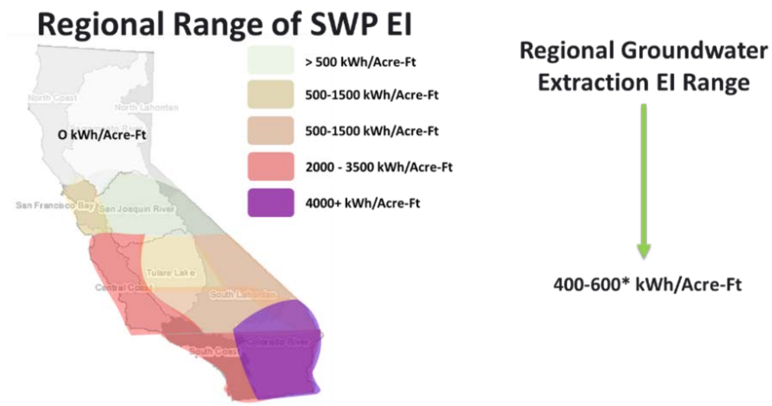

Figure 10: Approximate 2013-2015 State Water Project EI Range by Hydrologic Region (Left) Average Groundwater Extraction EI Range[14] (Right)

Conclusions

The primary objective of this research was to directly observe water agency electric energy reductions parallel with the 2015 California statewide urban water conservation mandate. Outcomes from the comparative billing analysis primarily show that embedded water energy savings are highly variable across all water agencies and yield lower energy savings than estimated using the average hydrologic region EI values that underlie the CPUC water-energy calculator. In addition, trends in EI at each level of granularity for 2013-2015 form the basis for a set of directional improvements to the CPUC water-energy calculator that suggest the need for adjustable values that respond to various influencers on hydrologic region water supply sources, whether it be varying hydrologic conditions or changes in water management policies. Broadly, the results of this study contribute to the continued trackability and comprehension of the true relationship between urban water conservation and realized energy reductions.

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[14] Groundwater EI is highly sensitive to specific pump efficiencies, geology of pump sites, water table depth, etc. Range is approximated from average groundwater production EIs but varies greatly across individual water agency service territories and across hydrologic regions.

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