NAVIGANT

# Water/Energy Cost-Effectiveness Analysis

## Final Report

**Prepared for:**
**California Public Utilities Commission**


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# Executive Summary

## *Overview*

Water-energy nexus issues have been a focus of the California Public Utilities Commission's (CPUC's, or the Commission's) time and attention for a number of years. More specifically, the energy used by the water sector in California was a topic of prior CPUC proceedings,[1] which authorized studies of this energy use, as well as pilot projects to attempt to quantify energy savings from water efficiency projects. Throughout this work, the CPUC has stated its goal of determining the cost-effectiveness of joint water-energy projects for investor-owned utility (IOU) ratepayers. The CPUC has also recognized that understanding the potential benefits to both IOU ratepayers and water ratepayers is a prerequisite to any expansion of demand-side programs aimed at energy use in the water sector.

To this end, the CPUC engaged Navigant Consulting, Inc. (Navigant) and GEI Consultants (the Navigant team) to help develop a comprehensive cost-effectiveness framework for analyzing demand-side programs aimed at saving water and energy. Pacific Institute served in an advisory role to the Navigant team.

Cost-effectiveness is a minimum threshold that the CPUC requires before an energy IOU can pay an incentive for an energy efficiency measure. In simplistic terms, an energy efficiency measure or program is cost effective if its energy benefits exceed its costs. It is important to note that cost-effectiveness is an *estimate*. If programs are not shown to be cost effective to energy IOU ratepayers, then IOU ratepayer funds cannot be used to fund the programs. Conversely, if programs or measures are deemed cost effective, there is no requirement that the program has to be funded or the measure has to be incentivized. Program design and funding decisions are still in the hands of the utilities.

## *Scope of this Study*

The tools and analyses developed in this study have very specific functions in informing CPUC Energy Division decisions about the use of energy ratepayer funds on joint water-energy programs. The intended uses of the tools and analysis developed by this study include the following:

- Estimate the IOU and non-IOU embedded energy savings that result from joint water-energy programs
- Assess the benefits that accrue to energy utilities and to water utilities from programs and measures that save both energy and water
- Determine if incentivizing measures and programs that save both energy and water is a cost-effective use of IOU energy utility funds

[1] R.09-11-014; D.07-12-050.

This study examines three benefits of water efficiency not previously considered by the CPUC cost-effectiveness framework. These can be added to cost-effectiveness framework to allow the CPUC to better assess programs that save both energy and water. These three added benefits are as follows:

- **Avoided Cost of Embedded IOU Energy in Water.** The economic value (in dollars) from embedded energy savings. We focus only on IOU embedded energy savings, as these savings will result in benefits to the energy IOU ratepayers.
- **Avoided Costs of Water Capacity.** The economic value (in dollars) from the avoided investment in constructing and operating new capacity in water supply and treatment infrastructure. These benefits do not accrue to the energy IOU ratepayers; they accrue to the water utilities and its ratepayers.
- **Environmental Benefits of Reduced Water Use.** The economic value (in dollars) of environmental services from water that is left in the environment to serve other purposes (e.g., wildlife habitats, instream flows, etc.). These benefits do not generally accrue to either the energy or water utility, but accrue to society.

One additional benefit that could be considered is the avoided commodity cost of water. Water commodity cost is defined on a volumetric basis (i.e. dollars per acre foot) whereas water capacity cost is defined on a daily production basis (i.e. dollars per Million Gallons/Day [MGD]). By analogy commodity costs for electricity are reported in $/kWh (dollars per kilowatt-hour) while capacity costs are reported in $/kW (dollars per kilowatt).[2] Commodity costs in the water sector can vary significantly across the state and even within a region. For some water agencies the avoided commodity cost is the cost of purchasing of water from a state or regional water wholesaler; such data is readily available. The avoided capacity cost; however, is less straightforward to estimate, it is not a data set that is readily available. The scope of this study includes developing a model to estimate avoided capacity cost to fill this data gap; avoided commodity cost is not considered in the scope of this study.

The Navigant team was scoped with developing a set of models and calculators to enable the estimation of these three additional benefits listed previously in this section. The Navigant team was also scoped with populating these models and tools with reasonable default assumptions based on available secondary data and interviews with experts.

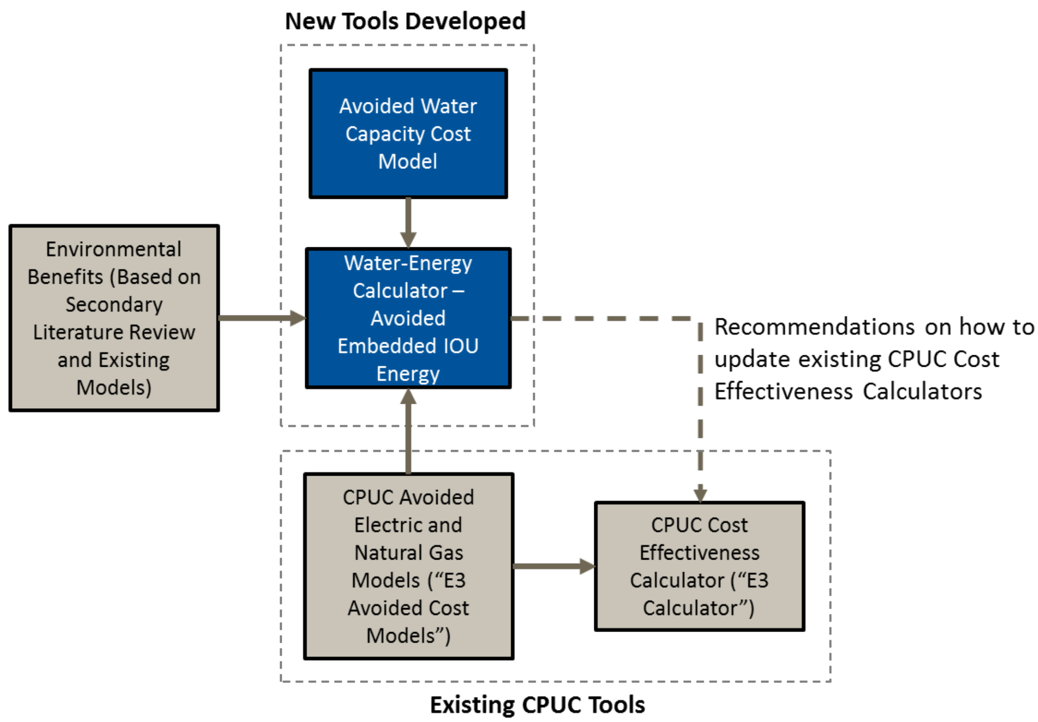
Figure ES-1 provides an overview of tools and analysis developed in this study as well as their relationship to existing tools. The Water-Energy Calculator includes all three water-related benefits are in a single tool that can be used for analyzing the benefits of water conservation measure.

- Analysis of the **Avoided Embedded IOU Energy in Water** is contained within the Water Energy Calculator.
- The **Avoided Capacity Cost of Water**, is calculated by the Avoided Water Capacity Cost Model (developed by the Navigant team). These values feed into the Water Energy Calculator.

[2] Capacity costs for the natural gas industry are typical reported in cubic feet per day.

- **Environmental Benefits of Reduced Water Use** is obtained from secondary data review of existing environmental benefits models.

**Figure ES-1. Overview of Tools and Analysis Developed**




*Source: Navigant team analysis*

The Water Energy Calculator and the Avoided Water Capacity Cost Model are highly flexible tools capable of handling edits to key inputs from users.

The Navigant team engaged stakeholder throughout the process of this study. From the study's inception through July 2014, the CPUC convened a water-energy Project Coordination Group (PCG) that provided feedback on the Navigant team's methodology for the tools developed and process for analyzing marginal supply. In April and July the CPUC hosted two formal public workshop at which the Navigant team presented its methodology and draft findings to date. The April workshop focused on the embedded energy analysis methodology and marginal supply analysis. The July workshop focused on the avoided water capacity methodology and findings on water system components costs. After each public workshop a workshop report was published for stakeholder review and comment. The Navigant team worked with the CPUC to review written stakeholder comments. Comments from the PCG as well as the two public workshops were taken into account in the development of the final models and report.

### *Modifying the Cost Effectiveness Framework*

The common cost-effectiveness tests used in California are defined by the Standard Practice Manual (SPM)[3] as follows:

- **Total Resource Cost (TRC) Test –** net costs of a demand-side management program as a resource option based on the total costs of the program, including both the participants' and the utility's costs.[4]
- **Program Administrator Cost (PAC) Test –** net costs of a demand-side management program as a resource option based on the costs incurred by the program administrator (i.e. the utility) excluding any net costs incurred by the participant.
- **Participant Test** - measure of the quantifiable benefits and costs to the customer due to participation in the program.
- **Ratepayer Impact Measure (RIM) Test –** measure of what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program.

The CPUC is considering a multi-part cost-benefit test that is "viewed from multiple perspectives". For example, the Total Resource Cost (TRC) test can be calculated from the energy utility perspective, the water utility perspective, a combined energy and water utility perspective, or a societal perspective. When considering the different perspectives of the TRC, different components of the avoided costs and benefits should be included. The CPUC previously proposed a framework to approach this, as illustrated in Table ES-1.

[3] *California Standard Practice Manual - Economic Analysis of Demand-Side Programs and Projects*. October 2001. Available at: http://www.cpuc.ca.gov/NR/rdonlyres/004ABF9D-027C-4BE1-9AE1-CE56ADF8DADC/0/CPUC_STANDARD_PRACTICE_MANUAL.pdf
Note: the SPM was corrected by the 2007 SPM clarification memo, available at: http://www.cpuc.ca.gov/NR/rdonlyres/A7C97EB0-48FA-4F05-9F3D-4934512FEDEA/0/2007SPMClarificationMemo.doc

[4] This is different than the Societal Cost Test (SCT) which is used in other jurisdictions. The SCT often includes benefits to society as a whole that do not accrue to either the customer or the utility such as environmental benefits

**Table ES-1. Components of Possible Updated CPUC Cost-Effectiveness Framework**

| Perspective | TRC | | | | PAC | | | RIM | | Participant | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy | Water | Combined | Societal | Energy | Water | Combined | Energy | Water | EndUser | Water Agency |
| Administrative costs to energy utility | Cost | | Cost | Cost | Cost | | Cost | Cost | | | |
| Administrative costs to water agency | | Cost | Cost | Cost | | Cost | Cost | | Cost | | Cost |
| Avoided costs of supplying electricity and natural gas | Benefit | | Benefit | Benefit | Benefit | | Benefit | Benefit | | | |
| Avoided costs of water capacity* | | Benefit | Benefit | Benefit | | Benefit | Benefit | | Benefit | | Benefit |
| Avoided embedded IOU energy in water* | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | | Benefit |
| Environmental benefits of reduced water use* | | | | Benefit | | | | | | | |
| Energy and water bill reductions | | | | | | | | | | Benefit | Benefit |
| Capital (measure) costs to participant | Cost | Cost | Cost | Cost | | | | | | Cost | Cost |
| Capital (measure) costs to energy utility | Cost | | Cost | Cost | Cost | | Cost | Cost | | | |
| Capital (measure) costs to water utility | | Cost | Cost | Cost | Cost | | Cost | | Cost | | |
| Incentives paid by energy utility | | | | | Cost | | Cost | Cost | | Benefit | Benefit |
| Incentives paid by water utility | | | | | | Cost | Cost | | Cost | Benefit | |
| Increased supply costs | Cost | Cost | Cost | Cost | Cost | Cost | Cost | Cost | Cost | | |
| Revenue loss from reduced energy sales | | | | | | | | Cost | | | |
| Revenue loss from reduced water sales | | | | | | | | | Cost | | |
| Tax Credits | Benefit | Benefit | Benefit | | | | | | | Benefit | Benefit |

* New benefits being addressed by this study. All other cost and benefit components are currently incorporated in existing CPUC cost-effectiveness frameworks.

*Source: Adapted from CPUC. Water-Energy Cost Effectiveness Project Update. January 2014*

### *Methodology*

Generally, avoided costs represent the expense the utility would incur to produce new resources in the absence of efficiency programs. The avoided cost places an economic value on each unit of resource saved. Avoided costs contains consideration of both fixed costs (including both capital and fixed operations and maintenance [O&M]) as well as variable costs (variable O&M). Efficiency reduces, defers, or eliminates new infrastructure investments, and these saving are referred to as avoided costs. Avoided capacity cost analysis specifically focuses on avoiding the next increment of capacity needed to serve the system. This next increment is referred to as the "marginal" capacity.

Standard practice in California electric avoided cost analysis is to assume efficiency reduces reliance on a proxy resource. California's cost-effectiveness framework assumes the proxy resource can be treated as the "marginal" resource for all resources consumed within a region. Using a proxy resource to represent the marginal supply makes valuing the benefits of efficiency easier and allows for more transparent calculations. Even if the proxy resource is not "accurate" in all cases, the California energy industry has generally accepted it as a reasonable basis for developing avoided costs for a region as a whole. This study follows a similar approach; the Navigant team selected a proxy marginal water supply to define the avoided water capacity cost. The selection of the proxy resource also informs the calculation of Avoided Embedded Energy Savings.

The Navigant team determined a proxy marginal supply of recycled water (wastewater treated to tertiary, unrestricted standards) as applicable to all regions in California. Using recycled wastewater as the default proxy marginal supply is reasonable based on several facts. All regions currently are developing and have available recycled water supplies. Although the predominant use of these supplies is currently for irrigation, these supplies are approved for numerous other uses. Many utilities include recycled wastewater as a key element of their future supply portfolios. Recycled water is a more conservative supply option than ocean water, which addresses concerns raised by some stakeholders who question the availability of treated ocean supplies to more inland water utilities. Lastly, recycling of wastewater is consistent with the State Water Resources Control Board (SWRCB) goals which encourage water agencies to significantly increase the development and use of these supplies.

The selected proxy marginal supply affects the results of all three benefits. However, the Navigant team developed flexible tools irrespective of the selected marginal supply. These tools use information about the user selected marginal supply to estimate the three water-related benefits.

The avoided embedded energy cost methodology combines data on the energy intensity of water, the measures water savings and lifetime, and the avoided cost of electricity and natural gas. The calculation uses only the IOU portion of the energy intensity of water system components. Furthermore it uses the energy intensity of the marginal supply when totaling energy intensity. This results in a marginal IOU energy intensity for each measure (which includes intensities of the other system components such as distribution and wastewater systems as appropriate).

The avoided water capacity cost methodology uses a similar approach to that used in to quantify marginal capacity costs for other utility services such as electric power. Marginal capacity costs are associated with three function of providing water service (supply, water treatment, and wastewater treatment). The analysis uses default inputs for system component costs as well as financial assumptions to calculate the avoided capacity cost.

The environmental benefits of reduced water use are estimated using available secondary data. The Navigant team leveraged the California Urban Water Conservation Council (CUWCC) framework for estimating the economic value of environmental benefits of conserved water. While the CUWCC provides values for surface water and groundwater, it does not include environmental benefits of conserving other water supplies, i.e., recycled water, brackish surface water, and ocean water. In the absence of an agreed-upon methodology or values for the environmental benefits of these supplies, the project team examined practices within the energy sector for comparison. Further research is needed to fully quantify environmental benefits.

The Water Energy Calculator also estimates IOU and non-IOU embedded energy savings. These embedded energy savings take into account the energy intensity of the weighted average mix of water supplies to a given region as well as energy intensities of the other system components (treatment, distribution, and wastewater systems as appropriate).

### *Results*

Analysis of secondary data results in a default IOU marginal energy intensity of water (Table ES-2). The marginal energy intensity (EI) represents IOU energy use only. Marginal EI is an intermediate data set used to value the avoided embedded energy cost

**Table ES-2. IOU Marginal Energy Intensity (kWh/AF)**

| Region | Extraction and Conveyance | Treatment | Distribution | Wastewater Collection + Treatment | Outdoor (Upstream of Customer) | Indoor (All Components) |
|---|---|---|---|---|---|---|
| NC | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| SF | 0 | 490 | 918 | 1,245 | 1,408 | 2,653 |
| CC | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| SC | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| SR | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| SJ | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| TL | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| NL | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| SL | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| CR | 0 | 490 | 51 | 1,245 | 541 | 1,786 |

*Source: Navigant team analysis*

Table ES-3 lists the resulting average IOU energy intensity of water used in this analysis. The average energy intensity is based on the average regional mix of supplies. While values in Table ES-3 falls in a relatively narrow range, total (IOU + non-IOU) energy intensity exhibits a larger range with significantly higher values in select regions (see Table 17 in Section 4.2). The South Coast has the highest total average energy intensity given its large use of imported water. Imported water from the State Water Project and Colorado River has high energy intensities but are not powered by IOU energy.

**Table ES-3. Average IOU Energy Intensity (KWh/AF)**

| Region | Extraction, Conveyance, and Treatment | Distribution | Wastewater Collection + Treatment | Outdoor (Upstream of Customer) | Indoor (All Components) |
|---|---|---|---|---|---|
| NC | 343 | 470 | 1,245 | 813 | 2,058 |
| SF | 394 | 918 | 1,245 | 1,312 | 2,557 |
| CC | 316 | 470 | 1,245 | 787 | 2,032 |
| SC | 446 | 470 | 1,245 | 916 | 2,161 |
| SR | 372 | 51 | 1,245 | 423 | 1,668 |
| SJ | 351 | 51 | 1,245 | 401 | 1,646 |
| TL | 338 | 51 | 1,245 | 388 | 1,633 |
| NL | 375 | 51 | 1,245 | 425 | 1,670 |
| SL | 301 | 470 | 1,245 | 771 | 2,016 |
| CR | 414 | 51 | 1,245 | 465 | 1,710 |

*Source: Navigant team analysis*

Table ES-4 lists the resulting annual avoided water capacity cost for all water system components analyzed. These costs also assume new capacity is needed starting in 2015. The avoided capacity cost of the default selected marginal supply in this study (tertiary treated recycled water) is $0.31M/MGD under a municipally owned utility entity. When analyzing indoor water conservation measures, wastewater treatment capacity should also be considered with an additional avoided capacity cost of $2.15M/MGD.

**Table ES-4. Annual Avoided Water Capacity Cost (2014$M/MGD)**

| Water System Component | Ownership Entity Type | |
|---|---|---|
| | Investor-Owned Utility | Municipally Owned Utility |
| Ocean Desalination | $4.92 | $3.03 |
| Brackish Desalination | $1.41 | $1.11 |
| Recycled - Tertiary + Disinfection | $0.49 | $0.31 |
| Recycled - Membrane Treatment | $1.19 | $0.82 |
| Groundwater Facility | $0.39 | $0.21 |
| Treatment - Chlorine Disinfection | $0.02 | $0.02 |
| Treatment - Contaminant Removal & Disinfection | $0.56 | $0.31 |
| Wastewater Treatment | $3.06 | $2.15 |

*Source: Navigant team analysis*

Environmental benefits were quantified where secondary data were available. The Navigant team observed data for the following supply types: State Water Project, federal projects, groundwater and surface waters. Environmental benefits for the observed supplies vary by hydrologic region and month. Table 19 and Table 20 in Section 4.4 list the environmental benefits for the San Francisco and South Coast Regions, respectively. Data for other regions are used in the model, though not presented in the report for simplicity.

The Navigant team conducted an example calculation of the savings and benefits from a high-efficiency toilet. The resulting analysis across all regions can be found in Table ES-5. The example analysis shows the measure is cost effective (TRC > 1.0) from a combined utility perspective (including benefits to both energy and water utilities). Environmental benefits are $0 for this example and are not shown in the table.

**Table ES-5. Example Measure Analysis Results**

| Region | Equipment Cost | Program Admin Cost | Annual IOU Embedded Energy Savings (kWh) | Annual Non-IOU Embedded Energy Savings (kWh) | Net Present IOU Avoided Electric Embedded Energy Benefits (2014$) | Net Present Avoided Water Capacity Benefits (2014$) | Combined Total Resource Cost Test Result |
|---|---|---|---|---|---|---|---|
| NC | $200 | $10 | 50.54 | 2.74 | $70.63 | $700.95 | 3.67 |
| SF | $200 | $10 | 62.83 | 7.52 | $84.96 | $700.95 | 3.74 |
| CC | $200 | $10 | 49.86 | 7.47 | $70.63 | $700.95 | 3.67 |
| SC | $200 | $10 | 53.10 | 38.44 | $70.63 | $700.95 | 3.67 |
| SR | $200 | $10 | 40.96 | 2.11 | $57.19 | $700.95 | 3.61 |
| SJ | $200 | $10 | 40.42 | 2.62 | $57.19 | $700.95 | 3.61 |
| TL | $200 | $10 | 40.09 | 4.95 | $57.19 | $700.95 | 3.61 |
| NL | $200 | $10 | 41.01 | 2.04 | $57.19 | $700.95 | 3.61 |
| SL | $200 | $10 | 49.50 | 16.37 | $70.63 | $700.95 | 3.67 |
| CR | $200 | $10 | 41.94 | 3.59 | $57.19 | $700.95 | 3.61 |

*Source: Navigant analysis using the Water-Energy Calculator*

## *Recommendations*

The models developed as part of this study will help the CPUC better understand the benefits of water efficiency. Per the scope of this study, the tools calculate new benefits not currently included in the CPUC cost effectiveness framework. For a full understanding of the cost effectiveness of measures that save both water and energy, the CPUC cost effectiveness frameworks should be updated to incorporate these additional benefits. Section 5.1 of this report contains detailed recommendations on the necessary modifications to the existing cost effectiveness frameworks.

The Navigant team considers this study necessary first step but also recommends updates in the future as new data and understanding become available. Future updates to this study could be aligned with a number of different timelines, some of which are related to regular updates of water-planning documents. The primary consideration in determining an update cycle is the frequency at which relevant data from the water sector becomes available. The Navigant team suggests a major and minor update cycle.

- Major update cycle (recommended)
    - Based on water planning data (e.g., DWR water plan, UWMPs)
    - Updates should include reassessing marginal supplies, updating component cost data, and updating financial assumptions and/or methodology
- Minor update cycle (optional)

- o Based on energy utility needs, and program planning cycles
- o Updates can include energy intensity data, energy avoided costs, and changes to the core methodology of cost-effectiveness equations.

The scope of this study is to develop tools to include consideration of water use in the CPUC's current cost-effectiveness framework. While many measure- and project-specific inputs (such as savings, lifetime, and cost) are necessary input to the calculator, this study was not meant to discuss or evaluate project-related data. It is still up to the users to accurately collect project-related data to use as inputs to the tools. Nevertheless, key points to consider when collecting and quantifying project-related data are included in this study.

- Determining incremental measure cost for water efficiency measures should generally follow the CPUC's 2013 Energy Efficiency Policy Manual guidelines. Many water efficiency measures are primarily "widget-based". One measure in particular will require further investigation to properly identify incremental measure cost: leak-loss detection.[5] Leak detection is one step in a multi-step water loss control program. Leak detection services come at a cost that could be classified as design assistance, surveys, and/or labor costs. The water utility receiving the services is still left with the decision to act on the recommendations; acting on those recommendations typically requires additional labor and material costs. In considering incremental costs (and subsequent water savings) associated with leak-loss detection, the CPUC should examine how it currently treats incremental costs (and subsequent energy savings) for energy audits, pump efficiency testing, and retro-commissioning.
- Preliminary research into effective useful life (EUL) for various water saving measures found a range of EUL values for certain key measures. Additional research may be needed to better quantify EUL. The Navigant team noted the upper range of EUL for a high efficiency toilet is 25 years, beyond the typical maximum EUL of most energy efficiency measures.
- Various discount rates may need to be applied to each of the benefits that result from water efficiency measures. Avoided embedded energy costs can be discounted using energy IOU discount rates. Avoided water capacity costs should use discount rates consistent with the water industry. Environmental benefits should use a societal discount rate.

CPUC policy states that the source of cost-effectiveness parameters are those defined in the DEER.[6] Additionally, updates to cost-effectiveness calculations and the measure parameters necessary to estimate avoided cost benefits will be an integral part of the ex-ante process, for both DEER and non-DEER work paper measures. As water-energy considerations enter the CPUC cost-effectiveness framework, DEER will need to be updated to store new information on embedded energy savings from water measures and water-related avoided costs. This includes necessary updates to the existing data in the DEER, new fields to be incorporated in the DEER, and new measures that may need to be added to

[5] CPUC decision 12-05-015 directed the IOUs "to propose 2013-2014 efforts (either through limited, water sector focused pilot programs or through targeted efforts within the existing calculated savings programs) on leak-loss detection and remediation and pressure management services for water entities that are IOU customers."
[6] Energy Efficiency Policy Manual, Version 4.0, August 2008, (EEPMv4) Rule II.11.

the DEER. D.11-07-030 required Energy Division (ED), with utilities' cooperation, to compile all Commission-adopted Frozen Ex Ante energy savings values into one location, which is the basis for referencing claims. The CPUC ED is currently leading the integration of all DEER and non-DEER IOU work paper measures into a single database called the Ex-Ante Database (EAD). Upon completion, the EAD will store all ex ante (DEER and non-DEER work paper) measure, energy, cost, and any other parameters necessary to calculate cost-effectiveness for deemed measures. Section 5.4 of this report contains detailed recommendations on the recommended modifications to DEER and EAD.

Analysis of the avoided cost of water is a new area of research. As previously mentioned, the Navigant team considers this study a much needed first step, but future research could expand and refine the avoided costs considered and assumptions made.

- **Develop an Energy Intensity Data Tool:** While the Water-Energy Calculator is populated with default values for the energy intensity of water system components, users can modify these assumptions as they see fit to better reflect their systems. Nevertheless, using water-utility specific data may not be possible for all utilities as it may not be readily available. An accepted methodology and associated tool could be developed to help water agencies calculate the energy intensity of their water system components.
- **Consider Avoided Commodity Cost of Water:** The scope of this study did not include consideration of the avoided commodity cost of water. Future research could consider developing default data to serve as a proxy for the commodity cost.
- **Consider the Use of a Resource Balance Year**: Stakeholder comments asked the study team to consider the use of a resource balance year in the analysis. The Navigant team responded by adding the functionality into the model. However, it was not in the scope of the Navigant team's study to conduct an analysis to determine the appropriate resource balance year.
- **Conduct additional Environmental Benefits Research**: The body of observed secondary data on the environmental benefits of reduced water use is limited. While past studies have examined benefits of reducing reliance on surface and groundwater, other supplies (such as recycled water, ocean desalination, and brackish desalination) have limited information. Additional research may be necessary if the CPUC moves towards using a societal cost test for cost effectiveness screening.

# 1 Introduction

## *1.1 The Water-Energy Nexus*

In 2005, the California Energy Commission (CEC) found that water-related energy consumption and demand accounted for nearly 20 percent of the California's electricity requirements.[7] This finding launched a series of initiatives related to increasing understanding and quantifying the interdependencies of water and energy resources and infrastructure in California. In 2007, the California Public Utilities Commission (CPUC, or the Commission) issued Decision 07-12-050 authorizing three "embedded energy in water studies" as well as numerous pilot projects to study the savings potential of programs targeted at embedded energy in water. These three studies marked the beginning of the CPUC's efforts to consider whether energy embedded in water can be quantified and relied upon as an energy efficiency resource, and whether it is worthwhile for the CPUC to pursue energy efficiency through water efficiency programs.

The CPUC-funded embedded energy in water studies stemming from D.07-12-050 includes the following:

- **Study 1: Statewide and Regional Water-Energy Relationship.** Study 1 developed a model of the functional relationship between water use in California and energy used to extract and supply that water. The model allows users to forecast future energy use under various scenarios. To achieve this, Study 1 collected and analyzed data from nine large wholesale water systems and additional supply sources (such as groundwater, local surface water, recycled water, and desalination). Study 1 was conducted by a joint team of GEI Consultants and Navigant.
- **Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles.** Study 2 examined the range of energy intensities for water agencies in California at the water system component level (e.g., treatment, distribution, and wastewater collection). Study 2 also examined the energy load profiles for water agencies in California at the water system component level. To achieve this, Study 2 collected and analyzed detailed historic energy use and water delivery data from 22 water and wastewater agencies around the state. Study 2 was conducted by a joint team of GEI Consultants and Navigant.
- **Study 3: End-Use Water Demand Profile Study.** Study 3 was conducted to provide hourly water end-use profile data. The study examined cold-water use for six customer categories, plus urban irrigation. Flow trace analysis was conducted to provide information about water use patterns: where, when, and how much water is used by a variety of devices at the sites that were studied in the analysis. The results of the study include 24-hour end-use water demand profiles for each category. Study 3 was conducted by Aquacraft, Inc.
- **Embedded Energy in Water Pilot Programs Impact Evaluation**: This study conducted an impact evaluation of nine water-energy pilot programs that were implemented by Pacific Gas

[7] California Energy Commission, November 2005, "California's Water-Energy Relationship," Final Staff Report CEC-700-2005-011-SF.

and Electric Company, Southern California Edison, and San Diego Gas & Electric Company from July 2008 to December 2009. For each program, water and wastewater savings were measured, and embedded energy savings were either measured or estimated based on the energy intensities of the water and wastewater systems that serve the participants. The evaluation was led by EcoNorthwest with support from multiple partners, including Pacific Institute.

These studies (along with other past studies from the CEC and the U.S. Department of Energy [DOE]) have taught us that it takes energy to produce water, and water to produce energy. Approximately 4 percent of the nation's electricity is used to extract, pump, treat, and deliver water. (The figure is closer to eight percent in California.) Conversely, about 40 percent of the nation's freshwater withdrawals are used for cooling thermoelectric power plants. Saving water saves energy and saving energy saves water.

Saving water saves energy. Some of these energy savings occur on the customer's side of the meter, referred to as end use energy savings. The remainder occurs within the upstream and downstream water systems that extract, pump, treat, and deliver water as well as collect and treat wastewater and are referred to as "embedded energy savings." Embedded energy savings are calculated based on data obtained on the water savings of an efficiency measure and the "energy intensity (EI)" of water and wastewater. Energy intensity and embedded energy are two important terms that will be used throughout this report:

- **Energy Intensity**
    - The average amount of energy needed to extract, transport or treat water or wastewater on a per-unit basis (kilowatt-hours per acre-foot of water [kWh/AF] or therms per acre-foot of water [therms/AF])
    - EI is associated with a particular facility
    - The EIs of individual facilities within a water and wastewater system can be aggregated to represent the total energy intensity of water and wastewater service to customers
- **Energy Embedded Savings**
    - The amount of energy that is saved in the water system as a result of reduced water use
    - Represents the entire energy picture both upstream and downstream of an end-use customer
    - Embedded Energy Saving = water saved (AF) x EI (kWh/AF or therms/AF)

## 1.2 *Defining Cost-Effectiveness*

Cost-effectiveness is a minimum threshold that the CPUC requires before an energy IOU can pay an incentive for an energy efficiency measure. In simplistic terms, an energy efficiency measure or program is cost effective if its energy benefits exceed its costs. It is important to note that cost-effectiveness is an *estimate*. If programs are not proven cost effective to energy IOU ratepayers, then IOU ratepayer funds cannot be used to fund the programs. Conversely, if programs or measures are deemed cost effective, there is no requirement that the program has to be funded or the measure has to be incentivized. Program design and funding decisions are still in the hands of the utility.

Cost-effectiveness for energy efficiency programs can be estimated from multiple “perspectives.” The common perspectives used in California are defined by the Standard Practice Manual (SPM)[8] as follows:

- **Total Resource Cost (TRC) Test** - Net costs of a demand-side management (DSM) program as a resource option based on the total costs of the program, including both the participants' and the utility's costs[9]
- **Program Administrator Cost (PAC) Test –** The net costs of a DSM program as a resource option based on the costs incurred by the program administrator (i.e., the utility), excluding any net costs incurred by the participant
- **Participant Test** - Measure of the quantifiable benefits and costs to the customer due to participation in a program
- **Ratepayer Impact Measure (RIM) Test –** Measure of what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program

Various components are included in each of the tests as either a benefit or a cost. Some components appear as benefit in one test and a cost in another. These key components of each test are summarized in Table 1; for additional details on the existing cost-effectiveness tests, we refer readers to the SPM.

**Table 1. Components of Current CPUC Cost-Effectiveness Framework**

| Component | Benefit/Cost Test | | | |
|---|---|---|---|---|
| | TRC | PAC | RIM | Participant |
| Administrative costs to energy utility | Cost | Cost | Cost | |
| Avoided costs of supplying electricity and natural gas | Benefit | Benefit | Benefit | |
| Energy and water bill reductions | | | | Benefit |
| Capital (measure) costs to participant | Cost | | | Cost |
| Capital (measure) costs to energy utility | Cost | Cost | Cost | |
| Incentives paid by energy utility | | Cost | Cost | Benefit |
| Increased supply costs | Cost | Cost | Cost | |
| Revenue loss from reduced energy sales | | | Cost | |
| Tax credits | Benefit | | | Benefit |

*Source: Adapted from CPUC. Water-Energy Cost Effectiveness Project Update. January 2014*

[8] CPUC. *California Standard Practice Manual - Economic Analysis of Demand-Side Programs and Projects*, October 2001.
[9] This is different than the Societal Cost Test (SCT), which is used in other jurisdictions. The SCT often includes benefits to society as a whole that do not accrue to either the customer or the utility, such as environmental benefits.

The key benefit captured in three of the four benefit/cost tests is the "avoided costs of supplying electricity and natural gas". The benefits of demand-side resources are the avoided costs related to generation and distribution of energy from conventional power plants and natural gas lines. The avoided costs of electricity are modeled based on the following components: generation energy, generation capacity, ancillary services, transmission and distribution (T&D) capacity, environment (i.e., avoided greenhouse gases [GHGs]), and avoided renewable portfolio standard [RPS] compliance costs. Additional details on the avoided cost of electricity and natural gas can be found on the CPUC website.[10]

The CPUC currently maintains two core tools to assist the energy utilities in determining the cost-effectiveness of programs. These are the *Demand Side Avoided Cost Calculator* and the *E3 Cost Effectiveness Calculator*.[11] The Avoided Cost Calculator determines the avoided costs of supplying electricity and natural gas on a per-unit basis ($/kWh, $/kW, and $/therm). These avoided costs are one of the benefit components as reported in Table 1. The Cost-Effectiveness Calculator incorporates all energy costs and benefits listed in Table 1 into one tool to estimate TRC, RIM, PAC, and Participant Test results.

## *1.3 Current Policy Context*

Water-energy nexus issues have been a focus of the CPUC for a number of years. More specifically, the energy used by the water sector in California was a topic of prior CPUC proceedings,[12] which authorized studies of this energy use, as well as pilot projects to attempt to quantify energy savings from water efficiency projects. Throughout this work, the CPUC has stated its goal of determining the cost-effectiveness of joint water-energy projects for energy IOU ratepayers. The CPUC has also recognized that understanding the potential benefits to both IOU energy ratepayers and water ratepayers is a prerequisite to any expansion of demand-side programs aimed at joint water-energy programs.

The CPUC is currently exploring if incentivizing embedded energy savings using Investor-Owned Utility (IOU) ratepayer funds is cost effective. The CPUC issued Decision 12-05-015 giving guidance to IOUs on energy efficiency programs. In this decision the Commission "recognize[d] the need to develop robust methodologies for measuring embedded energy savings from efficiency measures and determining the cost-effectiveness of energy efficiency projects in the water sector" (p.287). The decision also directed Staff to "address appropriate methods for calculating energy savings and cost-effectiveness in the water-energy context, issues associated with the joint funding and implementation of water-energy programs by the IOUs and water entities, and the development of an updated water-energy cost-effectiveness calculator and appropriate methodologies for calculating the GHG emission reductions associated with water-energy nexus programs." (p.289). To this end, the CPUC engaged the Navigant team to help develop a comprehensive cost-effectiveness framework for analyzing demand-side programs aimed at saving water and energy.

[10] Available at: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/Cost-effectiveness.htm.

[11] Available at: https://ethree.com/public_projects/cpuc4.php.

[12] R.09-11-014; D.07-12-050.

## 1.4 Scope of this Study

This study examines three benefits of water efficiency as requested by the CPUC. These can be included in the current CPUC cost- effectiveness framework to allow the CPUC to better assess programs that save both energy and water. These three added benefits are as follows:

- **Avoided Cost of Embedded IOU Energy in Water.** The economic value (in dollars) from embedded energy savings. We focus only on IOU embedded energy savings, as these savings will result in benefits to the energy IOU ratepayers.
- **Avoided Costs of Water Capacity.** The economic value (in dollars) from the avoided investment in constructing and operating new capacity in water supply and treatment infrastructure. These benefits do not accrue to the energy IOU ratepayers; they accrue to the water utilities.
- **Environmental Benefits of Reduced Water Use.** The economic value (in dollars) of environmental services from water that is left in the environment to serve other purposes (e.g., wildlife habitats, instream flows). These benefits generally accrue to society but not to energy and water utilities.

One additional benefit that could be considered is the avoided commodity cost of water. Water commodity costs are defined on a volumetric basis (i.e. dollars per acre foot) whereas water capacity costs are defined on a daily production basis (i.e. dollars per Million Gallons/Day [MGD]). By analogy commodity costs for electricity are reported in $/kWh while capacity costs are reported in $/kW.[13] Commodity costs in water sector can vary significantly across the state and even within a region. For some water agencies the avoided commodity cost is the cost of purchasing of water from a state or regional water wholesaler (such data is readily available). The avoided capacity cost; however, is less straightforward to estimate, it is not a data set that is readily available. The scope of this study is to focus on developing models to estimate avoided capacity cost to fill this data gap; avoided commodity cost is not considered in the scope of this study.

The Navigant team was scoped with developing a set of models and calculators to enable the estimation of these three additional benefits listed previously in this section. The Navigant team was also scoped with populating these models and tools with reasonable default assumptions based on available secondary data and interviews with experts.

## 1.5 Updating Cost-Effectiveness Calculations to Include Water

The CPUC is considering a multi-part cost-benefit test that is "viewed from multiple perspectives". For example, the TRC can be calculated from the energy utility perspective, the water utility perspective, a combined energy and water utility perspective, or a societal perspective. When considering the different perspectives of the TRC, different components of the avoided costs and benefits should be included. The CPUC previously proposed a framework to approach this, as illustrated in Table 2.

[13] Capacity costs for the natural gas industry are typical reported in cubic feet per day.

### Table 2. Components of Possible Updated CPUC Cost-Effectiveness Framework

| Perspective | TRC | | | | PAC | | | RIM | | Participant | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy | Water | Combined | Societal | Energy | Water | Combined | Energy | Water | EndUser | Water Agency |
| Administrative costs to energy utility | Cost | | Cost | Cost | Cost | | Cost | Cost | | | |
| Administrative costs to water agency | | Cost | Cost | Cost | | Cost | Cost | | Cost | | Cost |
| Avoided costs of supplying electricity and natural gas | Benefit | | Benefit | Benefit | Benefit | | Benefit | Benefit | | | |
| Avoided costs of water capacity* | | Benefit | Benefit | Benefit | | Benefit | Benefit | | Benefit | | Benefit |
| Avoided embedded IOU energy in water* | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | Benefit | | Benefit |
| Environmental benefits of reduced water use* | | | | Benefit | | | | | | | |
| Energy and water bill reductions | | | | | | | | | | Benefit | Benefit |
| Capital (measure) costs to participant | Cost | Cost | Cost | Cost | | | | | | Cost | Cost |
| Capital (measure) costs to energy utility | Cost | | Cost | Cost | Cost | | Cost | Cost | | | |
| Capital (measure) costs to water utility | | Cost | Cost | Cost | Cost | | Cost | | Cost | | |
| Incentives paid by energy utility | | | | | Cost | | Cost | Cost | | Benefit | Benefit |
| Incentives paid by water utility | | | | | | Cost | Cost | | Cost | Benefit | |
| Increased supply costs | Cost | Cost | Cost | Cost | Cost | Cost | Cost | Cost | Cost | | |
| Revenue loss from reduced energy sales | | | | | | | | Cost | | | |
| Revenue loss from reduced water sales | | | | | | | | | Cost | | |
| Tax credits | Benefit | Benefit | Benefit | | | | | | | Benefit | Benefit |

** New benefits being addressed by this study. All other cost and benefit components are currently incorporated in existing CPUC cost-effectiveness frameworks.*

*Source: Adapted from CPUC. Water-Energy Cost Effectiveness Project Update. January 2014*

### 1.6 *Uses of the Water-Energy Cost-Effectiveness Analysis*

As previously stated in this chapter, cost-effectiveness is a minimum threshold that the CPUC requires before a utility incentive can be paid for an energy efficiency measure. The tools and analyses developed in this study have very specific functions in informing CPUC Energy Division decisions about the use of energy ratepayer funds on joint water-energy programs.

The intended uses of the tools and analysis developed by this study include the following:

- Estimate the IOU and non-IOU embedded energy savings that result from joint water-energy programs
- Assess the benefits that accrue to energy utilities and to water utilities from programs and measures that save both energy and water
- Determine if incentivizing measures and programs that save both energy and water is a cost-effective use of IOU energy utility funds

This study does:

- **Not** require publicly owned utilities (POUs) or municipal utilities to use these tools
- **Not** require water utilities to change their water supply planning decisions
- **Not** require water utilities to fund water efficiency programs
- **Not** require energy utilities to fund water efficiency programs (Requirements would come from a CPUC decision.)
- **Not** require water utilities to report their energy use
- **Not** dictate any goal or mandate for the level of funding, water savings, or energy savings for joint water energy programs from either energy or water utilities
- **Not** address the monetary benefits of non-IOU embedded energy savings
- **Not** include avoided water commodity costs

### 1.7 *Structure of this Report*

The remainder of this report provides the detailed methodology and supporting documentation of our analysis.

- Section 2 describes the analysis methodology including sources of data.
- Section 3 describes the inputs and outputs of the cost-effectiveness analysis tools.
- Section 4 discusses key results including an example calculation of a water efficiency measure.
- Section 5 presents our recommendations.

# 2 Methodology

## 2.1 Overview

As previously discussed in Section 1.4, this study examines three additional benefit components to consider adding to the existing CPUC cost-effectiveness framework: Avoided Embedded IOU Energy in Water, Avoided Costs of Water Capacity, and the Environmental Benefits of Reduced Water Use.

Generally, avoided costs represent the expense the utility would incur to produce new resources in the absence of efficiency programs. The avoided cost places an economic value on each unit of resource saved. Avoided costs have both fixed costs (including both capital and fixed operations and maintenance [O&M]) as well as variable costs (variable O&M). Efficiency reduces, defers, or eliminates new infrastructure investments, and these saving are referred to as avoided costs. Avoided capacity cost analysis specifically focuses on avoiding the next increment of capacity needed to serve the system. This next increment is referred to as the "marginal" capacity.

Standard practice in California avoided cost analysis is to assume efficiency reduces the reliance of a proxy resource. California's cost-effectiveness framework assumes the proxy resource can be treated as the marginal resource for all resources consumed within a region. In reality, this may not be the case. Actual utility operations must take into account multiple considerations, such as legal frameworks, quality, reliability, and economics.

It is not feasible or practical to accommodate actual operational intricacies of a utility when attempting to examine the cost-effectiveness of efficiency. Using a proxy resource to represent the marginal supply makes valuing the benefits of efficiency easier and allows for more transparent calculations. Even if the proxy resource is not "accurate" in all cases, the California energy industry has generally accepted it as a reasonable basis for developing avoided costs for a region as a whole.

This study follows a similar approach as the electric avoided capacity cost methodology. The Navigant team selected a proxy marginal water supply to define the avoided water capacity cost. The Navigant team prepared estimates of the avoided cost of providing water and wastewater service to consumers by calculating marginal capacity cost. The input cost assumptions supporting these calculations are discussed elsewhere in this report. The actual calculations were produced using a Marginal Capacity Cost model. The selection of the proxy resource also informs the calculation of Avoided Embedded Energy Savings.

### 2.1.1 Theory Behind Calculating Marginal Capacity Costs

#### *2.1.1.1 Definition of a Marginal Capacity Cost*

Marginal capacity cost are defined as the cost associated with producing an additional unit of capacity. The calculation of marginal costs differs from that of average costs (used in the estimation of a utility revenue requirement) due to the following factors:

- Marginal capacity costs estimates are based upon the technology that will provide the ability to serve the next unit of demand, regardless of the price of the commodity.
- The selection of the specific technology will reflect the resource choices that will be available in the future, and ignore those resources which have traditionally been available in the past.
- The relevant unit of measure is triggered by demand, which is defined by gallons per day (or million gallons per day [MGD]). The choice is gallons per day because it is a measure of capacity. The Navigant team recognizes that volumetric measures (e.g., cubic feet, gallons, acre-feet) have traditionally been used for water utility pricing. However, the objective of quantifying marginal capacity cost is to assign a value to the cost associated with incremental additions or reductions to load at a given period in time.

The approach used by the Navigant team to calculate marginal water capacity cost is generally consistent with that used to quantify marginal capacity costs for other utility services such as electric power.

In general, marginal capacity costs are defined as those costs incurred to overcome a potential scarcity of resources (i.e., a shortage) or provide the ability to provide service on demand to customers. When applied to the water sector, the definition of marginal capacity cost still holds: it is the cost incurred to increase daily water production capacity. The cost of producing water for customers on a volumetric basis is the marginal commodity cost. As mentioned in Section 1.4, the scope of this study excluded consideration of marginal commodity costs and focuses on marginal capacity costs.

Marginal capacity costs are potentially associated with each function of providing water service. However, in some cases the marginal costs are defined by something other than capacity. For example, in some cases the cost of distributing potable water is driven more by the number of customers connected than the demand which they place on the distribution system. In this example, the marginal capacity cost is not relevant.

#### *2.1.1.2 Relevant Units in Quantifying the Marginal Capacity Cost of Water Services*

Water is traditionally measured volumetrically (e.g., in units of hundred cubic feet, gallons, or acre-feet). This volumetric convention is commonly used in water system planning and the development of tariff pricing. However, the Navigant team believes that for the purposes of estimation of marginal capacity costs, the use of acre-feet is inappropriate. Marginal capacity costs are those costs which are incurred to avoid a shortage. Therefore, in the absence of large-scale storage, a definition of capacity must be used which is limited to a discrete period of time such as one day.

Navigant recommends that the relevant unit that should be used to measure marginal capacity cost is gallons per day (which can be converted to MGD).[14] Considering development of **new** longer term storage (e.g., multiyear) was deemed out of scope of this study through direction from the CPUC. Short-term storage, such as for one day, is captured in the proposed unit of measure. Therefore, the estimated

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[14] Use of Gal/Day versus MGD is analogous to the use of kilowatt (kW) versus gigawatt (GW) when defining electric capacity.

costs of specific investments were divided by gallons per day in order to estimate the marginal capacity of each function.

### 2.1.2 Regional Analysis

The types of water available and their associated energy intensities can vary across the state. For this reason, the Navigant team set up analysis and tools to operate at a regional level. This allows varying assumptions about water supply, cost, and energy intensity across regions.

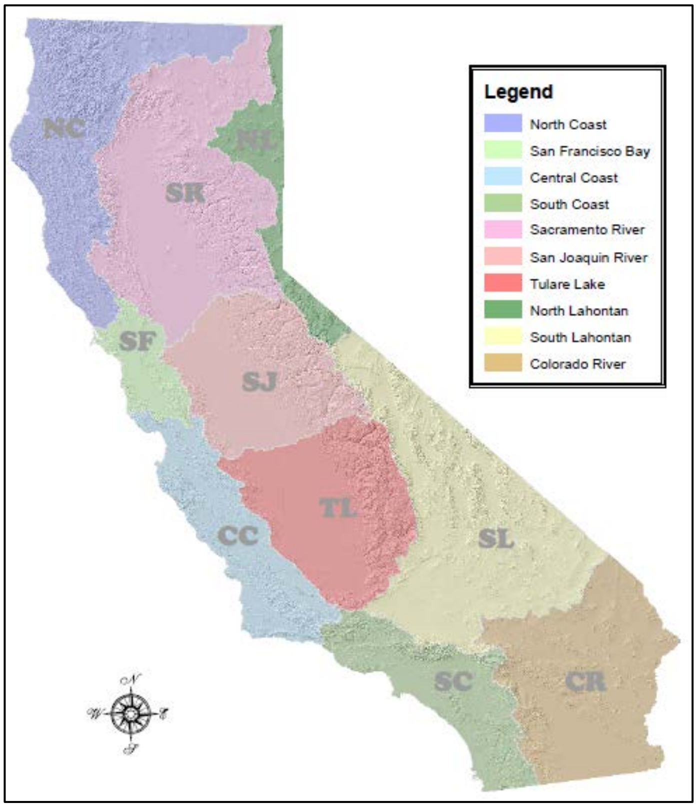
The Navigant team selected the California Department of Water Resources (DWR) hydrologic regions (illustrated in Figure 1) as the basis for regional analysis. We recommend using hydrologic regions because many water supply planning activities and data are available at the hydrologic region level and water supply options are relatively consistent within a hydrologic region. This recommendation was presented to and agreed upon by the CPUC and the Water-Energy Project Coordination Group in January 2014.

By conducing analysis at the DWR hydrologic region, the Navigant team was able to leverage the multitude of existing studies and reports that already document water supplies and their energy intensities at the hydrologic region. Such sources of information include the following:

- CPUC. *Embedded Energy in Water Study 1: Statewide and Regional Water-Energy Relationship*. 2010 (Study 1)
- DWR. *Bulletin 160-09: California Water Plan*. 2009
- DWR. *Bulletin 160-09: Volume 3 - Regional Reports*. 2009
- DWR's Regional Water Balances[15]
- DWR. *California Water Plan Update 2013- DRAFT*. 2014

[15] Part of Bulletin 160-09, located in Volume 5 - Technical Guide.

**Figure 1. Basis of Regional Analysis: DWR Hydrologic Regions**




*Source: DWR*

The Navigant team considered multiple additional geographic distinctions related to either water or energy analyses for use in this study. All were ultimately determined to be insufficient for the purposes of the study. The decision was driven by the availability of water planning-related data at the regional level. Many of the other geographic distinctions considered did not have the amount of preexisting water-related data as the DWR hydrologic regions. The other region delineations considered were the following:

- Energy utility service territories
- Water agency service territories
- DWR hydrologic planning regions (56 total)
- DWR groundwater basins (431 total)
- CEC/Database for Energy Efficient Resources (DEER) building climate zones (16 total)
- CEC demand forecasting planning zones (16 total)
- California Reference Evapotranspiration (ETo) zones (18 total)
- Regional Water Quality Control Board (RWQCB) regions (9 total)

- Association of California Water Agencies (ACWA) Regions

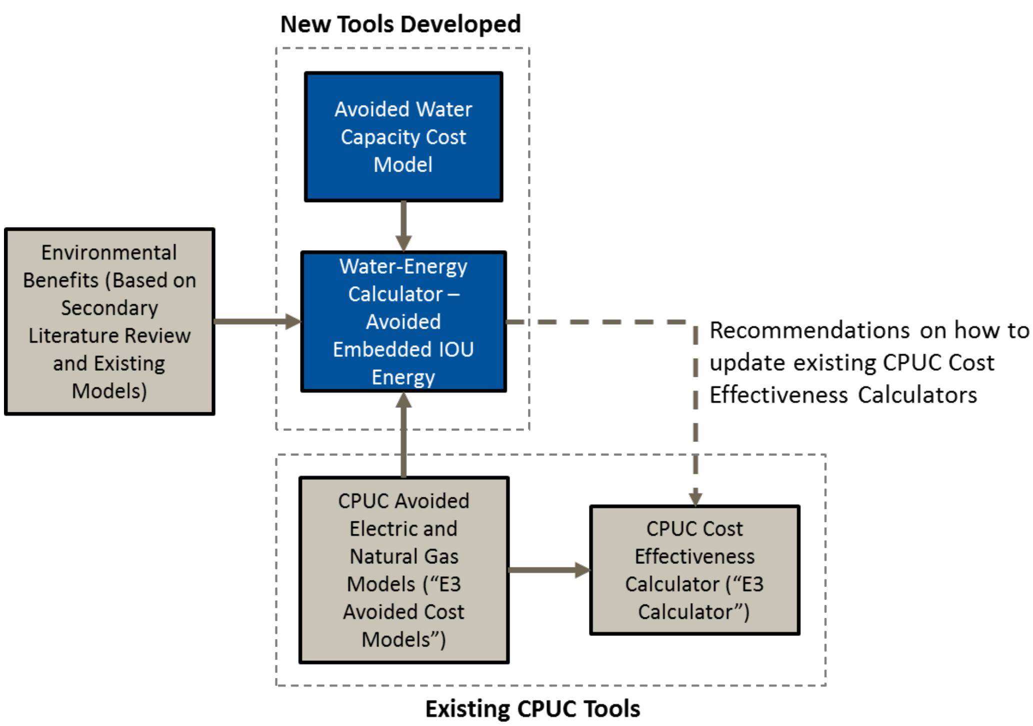
We recognize variations in water supply availability, costs, and energy use can occur within hydrologic regions. Default values are populated in the tools developed by this analysis. Water utilities can enter data specific to their agencies if such data is available.

### 2.1.3 New Water-Energy Tools and Analysis

Figure 2 provides an overview of tools and analysis developed in this study as well as their relationship to existing tools. The Water Energy Calculator includes all three water-related benefits are in a single tool that can be used for analyzing the benefits of water conservation measure.

- Analysis of the **Avoided Embedded IOU Energy in Water** is contained within the Water Energy Calculator.
- The **Avoided Capacity Cost of Water**, is calculated by the Avoided Water Capacity Cost Model (developed by the Navigant team). These values feed into the Water Energy Calculator.
- **Environmental Benefits of Reduced Water Use** is obtained from secondary data review of existing environmental benefits models.

**Figure 2. Overview of Tools and Analysis Developed**




*Source: Navigant team analysis*

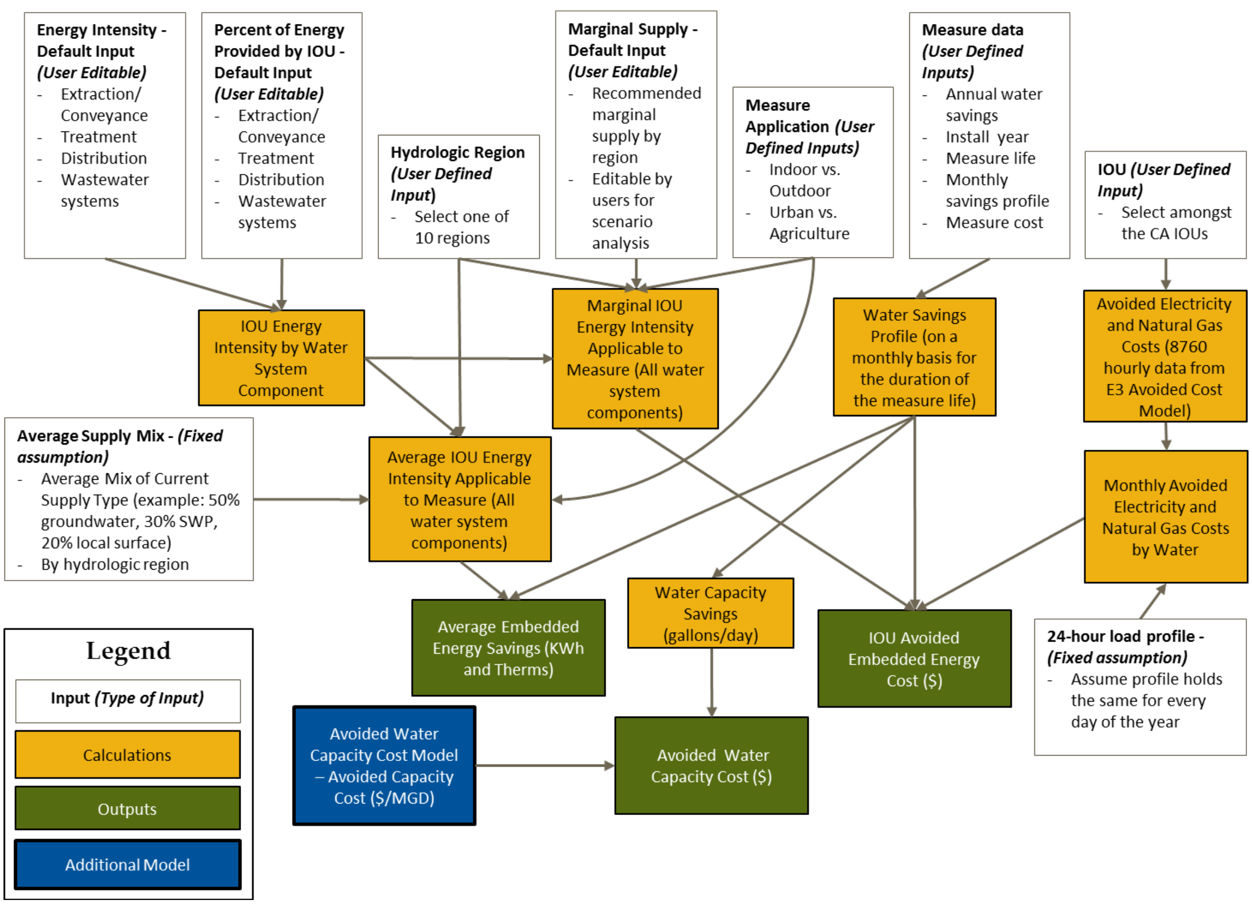
The following sections describe the analysis approach (Section 2.2) and sources of data and information (Section 2.3) used to estimate each of the three water-related benefits.

## 2.2 *Analysis Methodologies*

### 2.2.1 Embedded Energy Avoided Cost

The methodology to calculate embedded energy avoided costs is illustrated in Figure 3. A key feature of the model is the use of both marginal and average energy intensity values. The marginal energy intensity value is the avoided embedded energy cost, and the marginal energy intensity is the energy intensity of the selected marginal supply. The marginal energy intensity is not appropriate to estimate embedded energy savings as part of IOU energy efficiency programs. The average energy intensity of existing supplies is used to estimate, measure, and evaluate embedded energy savings (kWh or therms) from individual projects, as it better represents the actual energy savings that will occur. Using average energy intensity is analogous to estimating GHG savings from energy efficiency using the average carbon intensity of the electricity grid.

**Figure 3. Overview of Embedded Energy Avoided Cost Methodology**




*Source: Navigant team analysis*

For each water measure, the Water-Energy Calculator performs three major calculations:

- Average Embedded Energy Savings: The annual embedded energy savings given the historical supply mix for the associated hydrologic region, in kWh and therms
- IOU Avoided Embedded Energy Cost: The net present value, in 2014 dollars, of the avoided embedded energy costs accrued over the life of the measure. Embedded energy is valued using the energy intensity of the marginal supply (plus additional associated treatment, distribution and wastewater systems).
- Avoided Water Capacity Cost: The net present value, in 2014 dollars, of the cumulative avoided water capacity costs based on the monthly profile of water savings

The intermediate steps for each of these calculations are detailed below. As each calculation is performed, the calculator selects the appropriate values for each of up to 20 water measures input by the user.

#### *2.2.1.1 Average Embedded Energy Savings*

The Average Embedded Energy Savings calculation begins with the **IOU energy intensity of each water system component** (kWh/AF). The historic average supply mix is used to calculate a weighted average energy intensity of supply, which is combined with the energy intensities of the other system components (treatment, distribution, and wastewater systems as appropriate). The average energy intensity can vary by measure depending on user selections for end use (indoor vs. outdoor) as this either includes or excludes wastewater system energy use. This **average IOU energy intensity for each measure**, multiplied by the monthly **water savings profile** (gallons), produces a profile for average embedded energy savings throughout the year, which is summed to provide an annual value.

#### *2.2.1.2 IOU Avoided Embedded Energy Cost*

The IOU Avoided Embedded Energy Cost calculation starts with the same **IOU energy intensity of each water system component** (kWh/AF), but uses only the energy intensity of the marginal supply instead of the average supply mix. This results in a **marginal IOU energy intensity for each measure (**which includes intensities of the other system components such as distribution and wastewater systems as appropriate). This energy intensity, multiplied by the **monthly avoided electricity and natural gas costs** ($/kWh, $/therm), multiplied by the monthly **water savings profile** (gallons) over the entire time horizon of the calculator, produces a value stream for each measure that is discounted to 2014 dollars and summed for a single net present value.

#### *2.2.1.3 Avoided Water Capacity Cost*

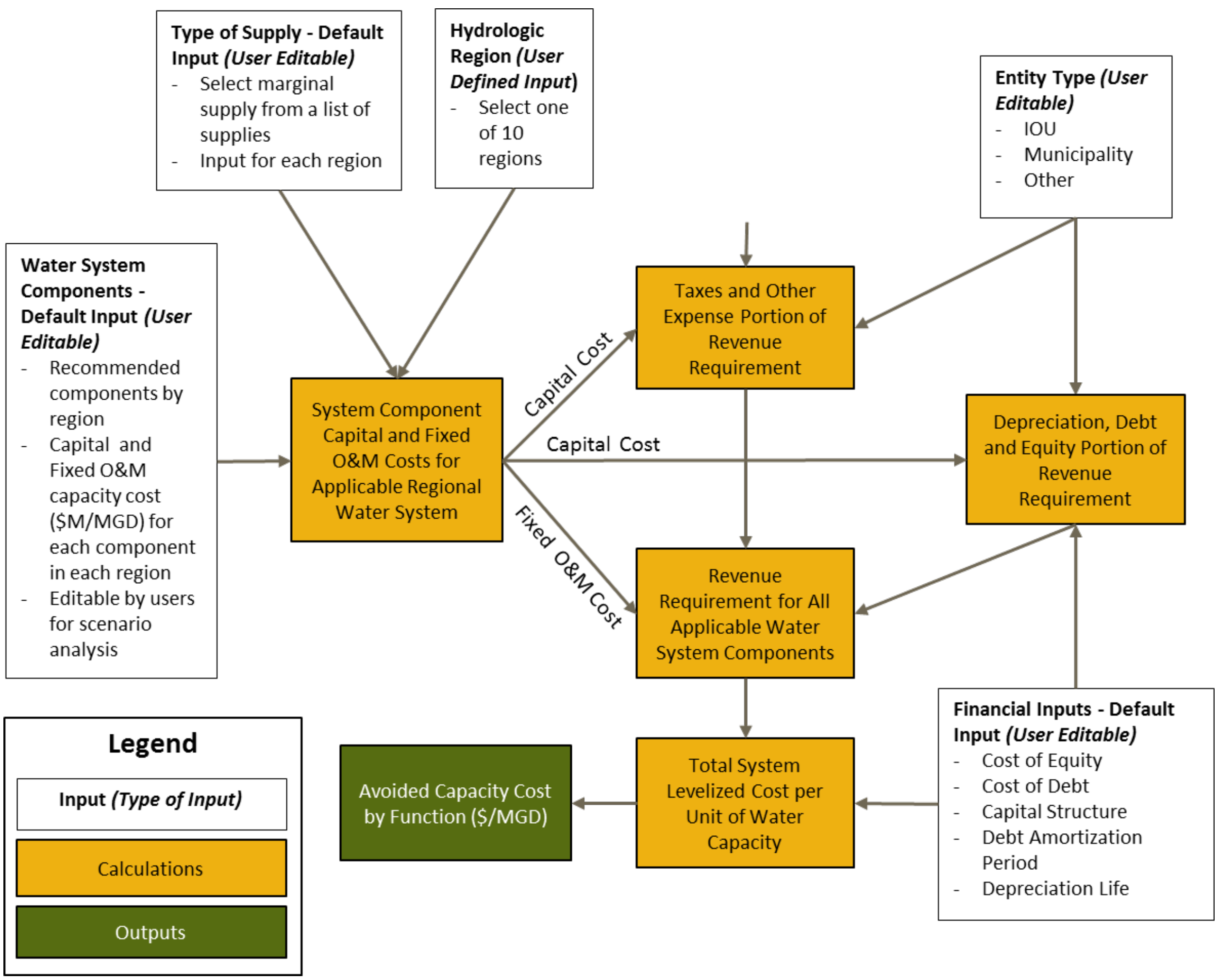
The Avoided Water Capacity Cost calculation uses the **water savings profile** to determine **water capacity savings** (gallons/day). Multiplied by the **avoided capacity cost** ($/million gallons per day [MGD]) of each facility type from the Avoided Water Capacity Cost Model (Task 2), this produces the monthly value stream of the avoided water capacity cost that is discounted to 2014 dollars and summed for a single net present value.

### 2.2.2 Water Capacity Avoided Cost

The methodology to calculate avoided water capacity cost is illustrated in Figure 4. Navigant applied this methodology to calculate capacity costs for water service into the following functions:

1. Supply
2. Potable Treatment
3. Wastewater Treatment

**Figure 4. Overview of Avoided Water Capacity Cost Methodology**




*Source: Navigant team analysis*

#### 2.2.2.1 *Fixed Charge Rate Calculation*

The provision of water service is capital intensive. A single capital investment provides useful service over a number of years. Therefore, it is necessary to convert the one-time capital investment and annual fixed operation and maintenance (O&M)[16] and sustaining capital investments into an annualized marginal cost. In keeping with past practices in California, Navigant uses a Fixed Charge Rate (FCR) approach to estimate marginal capacity costs.

A fixed charge rate accounts for the capital investments and fixed O&M expenses associated with an investment and provides an annualized cost over the useful life of the investment. The Net Present Value (NPV) of the revenue requirement is calculated and then recovered as a level payment over the useful life of the asset. The annual level payment is considered the annual avoided cost of capacity for the length of time a certain measure causes additional capacity to be avoided.

The FCR includes the following components:

- Depreciation Expense
- Return on Equity
- Interest Expense
- Fixed O&M Expense
- Asset lifetime

#### 2.2.2.2 *Cost of Capital Assumptions*

Costs of capital assumptions were prepared for the two common ownership structures: IOUs and Municipal-Owned Utilities (MOUs). The IOU cost of capital default assumption was estimated based on CPUC authorized return levels for four large water utilities and five small water utilities. The default assumption for MOU cost of capital was based on an estimation of the implied yield on tax exempt debt.

**Investor-Owned Utilities**

Navigant calculated the default capital structure and cost assumption using the CPUC decisions for large and small water utilities for the periods 2011–2014 and 2012–2015[17], respectively. The capital structure is provided in Table 3.

**Table 3. Capital Structure - Investor-Owned Utilities**

| | Average of 4 Utilities and 5 Small Class A Water Utilities | | |
|---|---|---|---|
| | Capital Ratio | Capital Cost | Weighted Cost |
| Debt | 41.78% | 6.93% | 2.89% |
| Equity | 58.22% | 9.86% | 5.73% |
| WACC | | | 8.62% |

*Source: Navigant team analysis of CPUC decisions for large and small water utilities*

[16] Fixed O&M costs are those considered non-variable. They are annual operating expenses incurred by the facility that are not proportional to the volume of water produced. They are, however, proportional to the maximum capacity of the facility.

[17] http://www.dra.ca.gov/waterCOC.aspx

**Municipal Utility**

Navigant calculated the default assumption for municipal cost of debt using the tax equivalent bond yield equation. Municipal debt is often tax exempt, so the yield on municipal debt is lower than taxable debt by the average marginal tax rate of its investors, all else equal. Because the cost of debt for water utility IOUs reflects the business and systemic risk inherent in water utility investments, we made this adjustment for tax exempt status to our estimate of the IOU cost of debt. We assumed a marginal investor tax rate of 35 percent to determine the implied cost of tax exempt debt, as shown in Table 4. Our implied yield on municipal debt falls within the generally observed range municipal bond rates (3-5%). This assumption can be edited by users in the model.

**Table 4. Cost of Debt for Municipal Utilities**

| Estimate of Municipal Water Utility Cost of Debt | |
|---|---|
| Municipal Debt Investor Marginal Federal Tax Rate | 35% |
| Implied Yield on Municipal Debt | 4.51% |

*Source: Navigant team analysis of CPUC decisions for large and small water utilities*

**Tax Rates**

Navigant has assumed a marginal federal tax rate of 35 percent and a marginal state tax rate of 8 percent for IOUs.

### *2.2.2.3 Book and Modified Accelerated Cost Recovery System (MACRS) Depreciation Life Assumptions*

Each technology has a unique, useful life representing the shorter of the physical or economically useful life of the investment. The useful life of the investment was adopted as the term of the FCR calculation. In the case of investor-owned utilities, the useful life established the book life of the asset.

MACRS is an accelerated depreciation approach used in income tax calculations for investor-owned utilities and included in the calculation of the FCRs for investor-owned utilities. The book and MACRS depreciation life assumptions are provided in Table 5.

**Table 5. Book and MACR Depreciation Life Assumptions in Years**

| Technology | Book Depreciation Life | MACRS Depreciation Life |
|---|---|---|
| Ocean Water Desalination Plant | 40 | 20 |
| Brackish Water Desalination Plant | 40 | 20 |
| Recycled Water – Tertiary Plus Disinfection | 40 | 10 |
| Recycled Water – Membrane Treatment | 40 | 10 |
| Groundwater Facility | 30 | 20 |
| Chlorine Disinfection | 40 | 10 |
| Contaminant Removal Plus Disinfection | 40 | 10 |
| Wastewater Treatment | 24 | 15 |

*Source: Navigant team analysis*

### 2.2.3 Environmental Benefits

Water efficiency and conservation provide a number of environmental benefits. In particular, conserving water can increase water availability in rivers and streams, thereby diluting pollutants, maintaining flows for fish populations, providing habitat for fish and wildlife, and sustaining freshwater and nutrient inflows in coastal and estuarine systems. Likewise, conserving water decreases withdrawals from groundwater aquifers, reducing salt water intrusion in coastal areas, and providing base flow for rivers and streams. While there are rarely any direct market values for these services, there is growing recognition that they have an economic value and should be included in policy- and decision-making processes.

Nearly a decade ago, the California Urban Water Conservation Council (CUWCC) developed a framework for estimating the economic value of environmental benefits of conserved water.[18] As part of that effort, the CUWCC developed an Excel-based model, focusing on withdrawals from raw water sources, such as streams, reservoirs, and groundwater resources. The model includes six environmental services, including lake-reservoir recreation, riparian habitat, wetlands, fish-salmonids, Bay-Delta x2 position, and nitrogen oxide ($NO_x$) emissions.[19] The economic value of these services was based on market values where they exist, or on estimates of the willingness-to-pay (WTP) or willingness-to-accept (WTA) obtained from a literature review.[20]

While the CUWCC provides values for surface water and groundwater, it does not include environmental benefits of conserving other water supplies, i.e., recycled water, brackish surface water, and ocean water. In the absence of an agreed-upon methodology or values for the environmental benefits of these supplies, the project team examined practices within the energy sector for comparison.

[18] California Urban Water Conservation Council (CUWCC), 2006, CUWCC Environmental Benefits Model Operating Instructions. Spreadsheet v5.0., Sacramento, CA.

[19] The Bay-Delta x2 position is a measure of salt intrusion into the San Francisco Bay-Delta estuary.

[20] K. Coughlin, C. Bolduc, P. Chan, C. Dunham-Whitehead, and R. Van Buskirk, 2007, Valuing the Environmental Benefits of Urban Water Conservation, Berkeley, CA.

In California, the environmental benefits of energy efficiency are considered to some extent in cost-benefit analyses. In particular, energy efficiency measures avoid greenhouse gas emissions, and the avoided cost of emissions is included in the cost benefit analysis.[21] Other environmental benefits are not explicitly captured in the methodologies used by the state. However, some environmental benefits may be implicit in the avoided capital and fixed O&M costs if measures to mitigate environmental impacts, such as scrubbers to remove $NO_x$ and sulfur oxides ($SO_x$), are embedded within those costs.

## *2.3 Data and Information Sources*

This section summarizes the key input information and assumptions made in our analyses. Full details of all inputs and assumptions are contained within the Water-Energy Calculator and the Avoided Water Capacity Cost Model.

### 2.3.1 Selecting Marginal Technologies

#### *2.3.1.1 Supply*

The Navigant team identified a proxy marginal supply of recycled water (wastewater treated to tertiary, unrestricted standards) for all hydrologic regions in California. Appendix B documents the approach the Navigant team took to come to this conclusion. This section summarizes our approach and rationale.

At the April 25th workshop, the Navigant team presented draft selections of marginal supplies for each hydrologic region in California. After receiving additional input from parties via verbal and written comments, as well as guidance from the CPUC, the Navigant team recommends that a default marginal water supply of recycled water (wastewater treated to tertiary, unrestricted standards) be used in the model for all hydrologic regions in California. In addition, the Navigant team concurs with stakeholder comments that the functionality of a "resource balance year" approach (similar to that used in energy avoided cost calculations) should be incorporated into the model to enable future updates.

Using recycled wastewater as the default proxy marginal supply is reasonable for several reasons. All regions currently are developing and have available recycled water supplies. Although the predominant use of these supplies currently is irrigation, these supplies are approved for numerous other uses. Many utilities include recycled wastewater as a key element of their future supply portfolios. Recycled water is a more conservative supply option than ocean water, which addresses concerns raised by some stakeholders who question the availability of treated ocean supplies to more inland coastal agencies. Lastly, recycling of wastewater is consistent with the SWRCB goals, which encourage water agencies to significantly increase development and use of these supplies.

When recycled water is used for non-potable end uses, it can displace potable or raw water that was previously serving that end use. The displaced potable water can be used to increase supply available to potable end uses; the displaced raw water could be treated further for potable uses. Thus, developing a recycled water supply can still increase the amount of supply available for potable end uses.

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[21] California Public Utilities Commission (CPUC). 2013, Energy Efficiency Policy Manual California Public Utilities Commission, San Francisco, CA.

The Navigant team supports incorporating the functionality of a resource balance year approach for several reasons. Incorporating the functionality addresses concerns raised by stakeholders regarding the use of the project's initial definition of "near" (0-10 years) and "long" (10-20 years) term-time frames and the concern that new capacity may not be needed immediately. The default assumption in this analysis is that new capacity is needed in immediately. This assumption can be modified in future updates.

Water agencies use a portfolio management approach with regard to their available supplies. At any point in time, these agencies must consider numerous factors and conditions to maximize the beneficial use of any supplies available to them. As explained in Appendix B, these available supplies are essentially the same over time—it is only the degree to which, in any given year, a supply is developed based on these considerations.

#### *2.3.1.2 Treatment*

The Navigant team collected information on treatment technologies for this analysis. Energy and cost data for the selected marginal supply (recycled water) already include the treatment component. Therefore, when examining recycled water in our analysis, there is no need to consider additional treatment technologies. Similarly, if one were to consider ocean water membrane desalination as the marginal supply technology, no additional treatment technology needs to be considered. Table 6 documents the relationship of marginal treatment technologies to marginal supply technologies. The Navigant team did collect information on conventional treatment technologies should future analysis consider a different set of marginal supplies.

**Table 6. Marginal Treatment Technology Considerations**

| Marginal Supply Technology | Additional Marginal Treatment Technology |
|---|---|
| Ocean water – membrane desalination | None |
| Brackish groundwater – membrane desalination | None |
| Recycled water – membrane treatment | None |
| Recycled water – tertiary treatment + disinfection | None |
| Fresh groundwater | Chlorine Disinfection |
| Surface water – imported or local | Contaminant Removal Plus Disinfection |

*Source: Navigant team analysis*

#### *2.3.1.3 Wastewater Treatment*

The Navigant team considered the various possibilities of wastewater treatment technologies in selecting the marginal wastewater treatment technology. Many wastewater treatment facilities under construction or expansion are utilizing tertiary treatment technology.[22] Thus, the Navigant team identifies tertiary

[22] Meeting current discharge requirements in many cases may require the use of tertiary treatment technologies.

treatment as the marginal wastewater treatment technology. However, it's important to note that not all existing wastewater treatment facilities use tertiary treatment technologies.

### 2.3.2 Energy Intensity Data

Energy intensity data is broken down into four water system components:

- Extraction and Conveyance
- Water Treatment
- Distribution
- Wastewater Systems

Extraction and conveyance energy intensities vary by hydrologic region. Default values used by the Water-Energy Calculator are shown in Table 7. DWR provided values from the Draft 2013 Water Plan for the State Water Project, Central Valley Project and other federal deliveries, Colorado River Aqueduct, local imported deliveries, local deliveries, and groundwater. The extraction and conveyance energy intensity for ocean water desalination is 7% of the total facility energy intensity.[23] The energy intensity of extraction and conveyance for brackish desalination was assumed to be similar to that of groundwater because most brackish supplies are from groundwater basins. Finally, recycled water is assumed to have a negligible extraction and conveyance energy intensity because most recycled water facilities are co-located with the source – a wastewater treatment plant. This is the assumption used by the Pacific Institute's Water-Energy Simulator (WESim) model.[24]

[23] Pacific Institute, 2013, *Key Issues for Seawater Desalination in California: Energy and Greenhouse Gas Emissions*.
[24] Pacific Institute, 2012, the Water–Energy Simulator (WESim).

**Table 7. Total Electric Energy Intensity of Extraction and Conveyance for Each Hydrologic Region (kWh/AF)**

| Supply Type | NC | SF | CC | SC | SR | SJ | TL | NL | SL | CR |
|---|---|---|---|---|---|---|---|---|---|---|
| Ocean Water Desalination | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 |
| Brackish Desalination* | 168 | 342 | 461 | 566 | 181 | 231 | 389 | 167 | 352 | 466 |
| Recycled Water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Groundwater | 178 | 352 | 471 | 576 | 191 | 241 | 399 | 177 | 362 | 476 |
| Local Deliveries | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Local Imported Deliveries | 10 | 43 | n/a | 10 | n/a | n/a | n/a | n/a | n/a | n/a |
| CRA | n/a | n/a | n/a | 2,500 | n/a | n/a | n/a | n/a | n/a | 0 |
| CVP and Other Federal Deliveries | 0 | 273 | 254 | 0 | 15 | 75 | 174 | n/a | n/a | n/a |
| SWP | n/a | 926 | 2,155 | 3214 | 0 | 287 | 495 | n/a | 3,495 | 4,468 |

**EI is assumed to be 10 kWh/AF less than Groundwater to account for additional pressure many groundwater pumps must provide once the water reaches the surface.*

*Source: Navigant team analysis*

Treatment energy intensities vary by technology, as shown in Table 8. Conventional treatment energy intensity was derived from the data collected for the CPUC Embedded Energy Study 2. Energy intensities of the other technologies are based on the median value used in the WESim model. Chlorination EI is relatively low as it requires minimal processing (mostly chemical injection and monitoring). Conventional potable treatment EI is next largest as it required removal of solids and disinfection; water is pumped through multiple processes during treatment. Recycled water treatment using tertiary treatment and disinfection has an EI on the same order of magnitude as conventional potable treatment. Tertiary treated recycled water EI represents only the incremental treatment requirements beyond secondary wastewater treatment. Membrane treated recycled water has an even higher EI as high pressure pumps are used to force water through membranes in a reverse osmosis process. Brackish and ocean desalination also uses as reverse osmosis processes. Their EIs are respectively higher than membrane treated recycled water as the TDS content of their sources are much higher. The higher the TDS, the more pressure (and energy) is required for the reverse osmosis process.

**Table 8. Total Electric Energy Intensity of Treatment (kWh/AF)**

| Treatment Technology | Energy Intensity (kWh/AF) |
|---|---|
| Conventional Potable Treatment | 443 |
| Chlorination | 3 |
| Recycled Water - Membrane Treatment | 1,303 |
| Recycled Water - Tertiary Treatment + Disinfection | 521 |
| Brackish Desalination | 2,715 |
| Ocean Desalination | 4,546 |

*Source: Navigant team analysis based on Study 2 and WESim*

Distribution energy intensity was calculated by topography, broken down into flat, moderate, and hilly. The Navigant team assigned an assumed topography to each hydrologic region, as shown in Table 9. The energy intensity of each topography was derived from the data collected for Study 2. EI for flat moderate and hilly areas progressively increase relative to one another. Hilly areas require pumping to higher pressures and elevations which results in increased energy use compared to moderate and flat areas.

**Table 9. Total Electric Energy Intensity of Distribution (kWh/AF)**

| Region | Topography | Energy Intensity (kWh/AF) |
|---|---|---|
| NC | Moderate | 501 |
| SF | Hilly | 977 |
| CC | Moderate | 501 |
| SC | Moderate | 501 |
| SR | Flat | 54 |
| SJ | Flat | 54 |
| TL | Flat | 54 |
| NL | Flat | 54 |
| SL | Moderate | 501 |
| CR | Flat | 54 |

*Source: Navigant team analysis based on Study 2*

Wastewater systems energy intensities are derived from the data collected for Study 2. Wastewater systems energy intensity encompasses both treatment and collection pumps, as shown in Table 10.

**Table 10. Total Electric Energy Intensity of Wastewater Systems (kWh/AF)**

| Technology | Energy Intensity (kWh/AF) |
|---|---|
| Primary + Secondary | 1,055 |
| Primary + Secondary + Tertiary | 2,809 |
| Wastewater Collection Pumps | 229 |

*Source: Navigant team analysis based on Study 2*

Not all water systems are powered by an IOU. Thus, the IOUs may not be able claim credit for all embedded energy savings. The Navigant team developed values for each supply type and system component for the percent of energy supplied by an IOU, as shown in Table 11. The data for the default values in the Water Energy Calculator were derived from the Water Energy Load Profiling Tool, as augmented by the Pacific Institute for uses in the CPUC Water-Energy Pilot Evaluations.

**Table 11. Percent of Energy Supplied by an IOU**

| System Component | Supply Type | % IOU |
|---|---|---|
| Extraction and Conveyance | Ocean water Desal. | 94% |
| | Brackish Desal. | 94% |
| | Recycled Water | 97% |
| | Groundwater | 59% |
| | Local Deliveries | 27% |
| | Local Imported Deliveries | 27% |
| Treatment | | 94% |
| Distribution | | 95% |
| Wastewater Systems | | 97% |

*Source: Navigant team analysis based on CPUC Water-Energy Pilot Evaluations*

The Navigant team found no statewide representative gas energy intensity values. However, individual studies have been conducted on selected water systems. Nevertheless, the Water-Energy Calculator can accept gas energy intensity data, in therms/AF, at the same level of granularity the electric energy intensities for each system component.

As part of the average embedded energy savings calculation, an average supply mix was developed for each hydrologic region. Data from DWR's 2013 Draft Water Plan was adjusted to match the supplies as used by the Water Energy Calculator to produce the default values shown in Table 12.

**Table 12. Historic Average Supply Mix for Each Hydrologic Region**

| Supply Type | NC | SF | CC | SC | SR | SJ | TL | NL | SL | CR |
|---|---|---|---|---|---|---|---|---|---|---|
| Ocean water Desal. | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Brackish Desal. | 0.0% | 0.3% | 0.0% | 1.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Recycled Water | 20.4% | 3.2% | 8.3% | 9.9% | 20.2% | 23.3% | 11.6% | 34.1% | 15.5% | 11.1% |
| Groundwater | 28.8% | 19.1% | 79.1% | 31.0% | 19.8% | 31.0% | 49.6% | 22.0% | 63.7% | 8.9% |
| Local Deliveries | 27.7% | 14.9% | 2.5% | 3.7% | 31.0% | 29.1% | 16.2% | 43.9% | 6.7% | 0.1% |
| Local Imported Deliveries | 1.5% | 37.9% | 0.0% | 5.1% | 0.0% | 0.1% | 0.1% | 0.0% | 0.0% | 0.2% |
| CRA | 0.0% | 0.0% | 0.0% | 21.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 78.6% |
| CVP and Other Federal Deliveries | 21.5% | 12.2% | 7.5% | 0.2% | 28.8% | 16.4% | 15.0% | 0.0% | 0.0% | 0.0% |
| SWP | 0.0% | 12.2% | 2.7% | 27.2% | 0.1% | 0.2% | 7.6% | 0.0% | 14.1% | 1.4% |

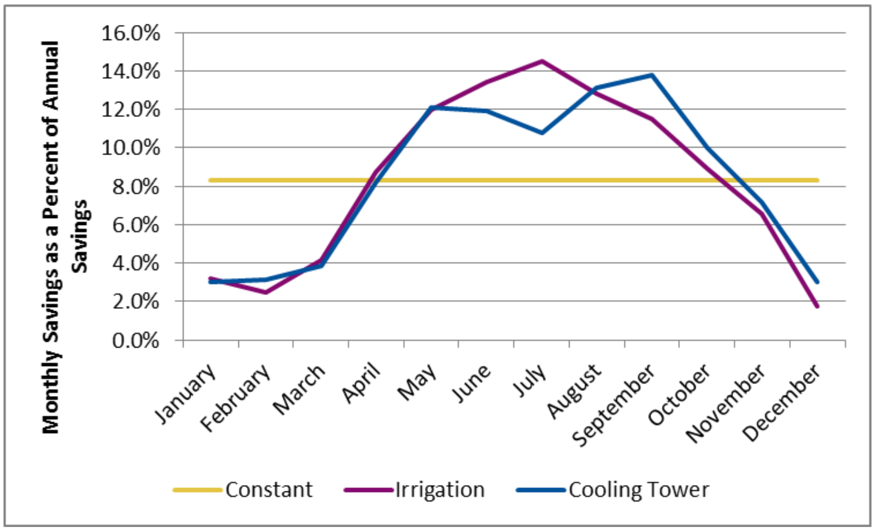
*Source: Navigant team analysis based on DWR's 2013 Draft Water Plan*

All intensity data, IOU fractions, and average supply mix values can be edited by users in the calculator. Additional discussion on model customization can be found in Section 3.3.

### 2.3.3 Water Load Shapes

Some water efficiency measures save more water in certain months of the year based on equipment usage patterns compared to other measures. The Water-Energy Calculator employs water savings profiles to indicate when savings occur over the course of a year. Default profiles were sourced from work done by the California Sustainability Alliance[25] – one each for a constant, irrigation, and cooling tower profile, as shown in Figure 5. The calculator also has space available for the user to enter two custom profiles.

**Figure 5. Water Savings Profiles**



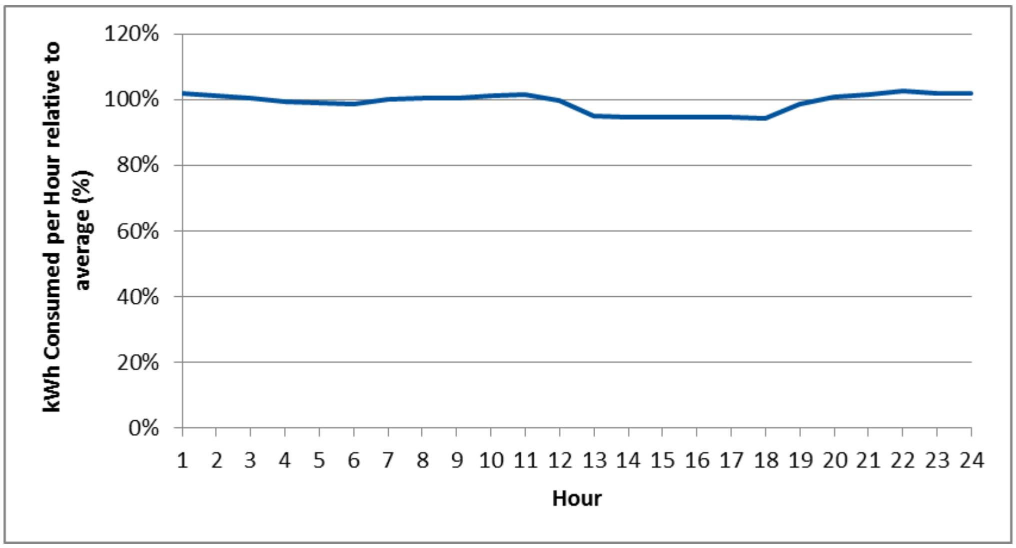

*Source: Adapted from California Sustainability Alliance, On-Site Water Generation: An Analysis of Options and Case Study. 2013*

There is also hourly variation in the energy use of the water infrastructure. The Navigant team used the Water-Energy Load Profiling (WELP) Tool, as augmented by the Pacific Institute for the CPUC water-energy pilots, to develop an average 24-hour load profile representative of all water system components, as shown in Figure 6. This load profile represents actual energy consumption in 2008 from more than 30 water and wastewater utilities throughout California. This 24-hour profile is assumed to hold every day of the year. It was applied to the hourly avoided cost of electricity for IOUs before aggregating the avoided cost into a monthly stream of values for the Water Energy Calculator.

[25] California Sustainability Alliance, *On-Site Water Generation: An Analysis of Options and Case Study*. 2013. www.sustainca.org

Figure 6 shows a relatively constant load profile throughout the day. Many water facilities must operate around the clock to serve the needs of customers. A slight decrease in energy use can be noted in the profile between hours 14 and 19. This is an average effect of time-of-use (TOU) prices on the operation of water systems. Some water utilities are able to respond to higher TOU prices by shutting down selected facilities during peak time. However, based on observed data, this trend is limited across all water utilities in the state.

**Figure 6. Hourly Load Profile of Water System Energy Use**




*Source: Navigant team analysis based on CPUC Water-Energy Pilot Evaluations data*

### 2.3.4 Avoided Electric and Natural Gas Cost

The Water-Energy Calculator draws upon the avoided cost models produced by the CPUC's avoided cost of electricity and natural gas models (the "E3 Models") for both the electric and gas components.[26] Hourly electric avoided costs are made up of seven components: energy, capacity, T&D, losses, ancillary services, avoided RPS, and emissions. The transmission and distribution component varies by climate zone, so for each IOU, values for the applicable climate zones were averaged before combining these costs with those of the other six components. The resulting total avoided cost streams, as mentioned above in Section 2.3.3, were then adjusted using the average load profile of a water system component and aggregated to the monthly level. Monthly gas avoided costs are broken down into two components: commodity and environmental, and transmission and distribution. These value streams had to be extrapolated out from 2033 to the end of the Water-Energy Calculator's time horizon in 2050.[27] The utility discount rates in the avoided cost models are also used by the Water-Energy Calculator to calculate the NPV of benefits for each measure.

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[26] Electric avoided costs were sourced from the E3 NEM Avoided Cost Model (published October 28, 2013). Gas avoided costs were sourced from E3's avoided cost models for each IOU (published June 30, 2011).
[27] Data was extrapolated using a best fit line to the available data from 2014 through 2033 and linearly extrapolated to using the trend function in Excel.

### 2.3.5 Water System Component Cost Data

To prepare the estimates of avoided capacity costs, the Navigant team estimated certain cost and operational information about the technologies employed to provide water service in California. The required information included the installed (capital) costs and the associated fixed O&M costs. This section summarizes our approach and resulting data. Additional detail can be found in Appendix B, Section B.1.

The Navigant team evaluated information on the following components required to provide water service:

- Supply
- Potable Water Treatment
- Wastewater Treatment

We present cost data for candidate marginal technologies. The Navigant team did not analyze cost data on raw water conveyance, potable or recycled water distribution, or wastewater collection, as these components were determined to have an irrelevant marginal capacity costs. Recommended costs will serve as default inputs to the avoided water capacity cost model. These inputs can be modified by users to conduct additional scenario analysis. Similarly, the selections for marginal supply in each region will also serve as default inputs that can be edited by users.

To develop avoided costs, the Navigant team analyzed publicly available data to estimate capital and fixed O&M costs of water systems. We believe the public data sources we rely upon reasonably estimate the information required for our analysis. Data sources ranged from Integrated Regional Water Management Plans (IRWMPs) and Capital Improvement Plans (CIPs) to state and local agency reports. Additional sources came from the DWR, Pacific Institute, U.S. Environmental Protection Agency (EPA), Public Policy Institute of California (PPIC), U.S. Department of the Interior Bureau of Reclamation (USBR), and CPUC. The Navigant team gathered additional information from Internet searches to fill in the cost data gaps that could not otherwise been obtained from the other resources. To the extent possible, actual construction costs, engineering studies, and CIP estimates were favored and viewed as the most accurate data source. In the absence of such information, the Navigant team relied on other public sources (e.g., EPA reports, engineering firm case studies) to provide estimates of costs.

Analysis of fixed O&M costs attempted to exclude the cost of energy where possible (a variable O&M cost). Virtually all energy costs associated with the operations of these facilities are related to the output of the plant and therefore properly captured as avoided commodity costs as opposed to avoided capacity costs. The value of avoided energy consumption will be quantified by the avoided embedded energy portion of our analysis. Energy costs must be excluded from avoided capacity analysis to avoid any double counting of energy benefits.

The publicly available cost data and associated detail in California's water industry is limited. Thus, in our data collection and analysis, several assumptions were needed:

- Lump-sum costs represent overnight capital costs and do not include operations and maintenance costs unless otherwise specified.
- Permitting, environmental studies/mitigation, or financing costs were included in the cost data for both capital and fixed O&M, as appropriate.
- Cost estimates for demonstration facilities were generally excluded from our analysis, as they were deemed unrepresentative of real-world costs.
- Variations based solely on location for similar water infrastructure elements could not be discerned from the available data. We therefore assume a single average cost is representative of all regions in California.

Our avoided cost analysis focuses on the avoided cost of capacity. This is consistent with CPUC avoided capacity cost analysis for the electric sector in which the avoided cost of electric generation capacity (reported in $/megawatt [MW]) is a key output. Capacity in our analysis is defined in terms of maximum daily production gallons per day. Observed water systems were of varying capacities. For the purposes of comparison, costs were normalized based on their capacity. Capital and fixed O&M costs were divided by the peak capacity of the facility. The resulting cost of capacity is reported in million dollars per million gallons per day ($M/MGD) for both capital and fixed O&M cost. For example, a 10-MGD treatment plant that cost $50M to build and $1M/year to operate and maintain has a capacity cost of $5M/MGD and a fixed O&M cost of $0.1M/MGD.

Based on the cost data presented in the previous section, the Navigant team developed recommended capital and fixed O&M costs per unit capacity ($M/MGD) for each component in each hydrologic region. Table 13 lists costs associated with developing new supply capacity. Table 14 lists costs associated with developing new potable and wastewater treatment capacity. Recommended capital and fixed O&M costs are weighted averages of observed facilities. Averages were weighted by total capacity (in MGD).

The following assumptions were made in populating Table 13 and Table 14:

- Large ocean water desalination facilities will be built primarily in the South Coast region. Desalination facilities in other coastal regions will primarily be small facilities.
- Brackish water desalination facilities in the San Francisco region will rely on surface water as the source, all other regions will primarily use brackish groundwater as the source.
- Capital and fixed O&M costs do not vary by region for the following: recycled water treatment facilities, groundwater facilities, chlorine disinfection facilities, contaminant removal plus disinfection facilities, and wastewater treatment facilities.

### Table 13. Summary Data for Supply Capital and Fixed O&M Costs (2013$)

| Region | Ocean Water Desalination Plant Costs ($M/MGD) | | Brackish Water Desalination Plant Costs ($M/MGD) | | Recycled Water Plant Costs – Tertiary Plus Disinfection ($M/MGD) | | Recycled Water Plant Costs – Membrane Treatment ($M/MGD) | | Groundwater Facility Costs ($M/MGD) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M |
| NC | $33.38 | $0.79 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SF | $33.38 | $0.79 | $5.77 | $0.47 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| CC | $33.38 | $0.79 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SC | $16.23 | $0.42 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SR | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SJ | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| TL | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| NL | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SL | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| CR | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |

*Source: Navigant team analysis*

**Table 14. Summary Data for Treatment Capital and Fixed O&M Costs (2013$)**

| Region | Potable Treatment - Chlorine Disinfection Costs ($M/MGD) | | Potable Treatment - Contaminant Removal Plus Disinfection Plant Costs ($M/MGD) | | Wastewater Treatment Plant Costs ($M/MGD) | |
|---|---|---|---|---|---|---|
| | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M |
| NC | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SF | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| CC | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SC | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SR | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SJ | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| TL | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| NL | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SL | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| CR | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |

*Source: Navigant team analysis*

### 2.3.6 Environmental Benefits

For valuing the environmental benefits of conserving brackish surface water and ocean water, the project team adopted a similar approach as is practiced by California's energy sector. Specifically, we assumed that some of the environmental benefits of conserving these water supplies are embedded within the avoided capital and fixed O&M costs. For example, for ocean water desalination plants along the California coast, project developers are required to mitigate the environmental impacts associated with the ocean water intakes by installing systems to minimize those impacts and paying a mitigation fee.

Recycled water is unique in that there are some environmental benefits associated with developing this supply. In particular, water recycling reduces freshwater discharge into sensitive water bodies, such as salt marshes. It also reduces pollutant loading into the receiving waters. Thus, by conserving recycled water, there may, in fact, be an environmental cost, i.e., a negative environmental benefit.

To estimate the environmental benefits of surface water and groundwater, the Navigant team relied on the methods and values used by the CUWCC in its Environmental Benefits Model. [28] In particular, a monthly value was calculated for each hydrologic region to represent the total environmental benefit for a given supply type ($/AF). The environmental benefit of surface waters was determined by aggregating the values for lakes, reservoirs, streams, and major rivers. The CUWCC model specifically calls out benefits of state and federal projects, that data was retained. The Navigant team excluded the emissions reduction component of environmental benefits quantified by the CUWCC model. Emissions reductions stem from reduced energy use; benefits of reduced energy use (including emissions) are already included in the energy avoided costs and thus included in the avoided embedded energy calculation.

While the CUWCC model provides values for surface water and groundwater, it does not include environmental benefits from conserving other marginal supplies, i.e., recycled water, brackish surface water, and ocean water.

Results of our environmental benefits analysis can be found in section 4.4.

[28] CUWCC, CUWCC Environmental Benefits Model. 2007,

# 3 Water Energy Cost-Effectiveness Analysis Tools

This section describes the inputs and outputs of the Water-Energy Calculator and the Avoided Water Capacity Cost Model. This section also discusses how users can conduct custom analysis with these tools. Appendix D contains a user's guide to the models for more details including illustrations of key inputs and outputs.

## *3.1 User Inputs*

### 3.1.1 Water-Energy Calculator

The Water-Energy Calculator has three primary sections of inputs. The first is for system-wide information, the second section is for measure-specific information, and the third is made up of optional override options, as discussed in Section 3.3.

The Water-Energy Calculator requires the user to provide three items that apply to all water measures: electric IOU, gas IOU, and whether the water utility is an IOU or non-IOU. These affect the avoided costs of electricity, gas, and water capacity used by the calculator.

The rest of the inputs are related to each measure individually on a per unit basis, e.g., per efficient shower head. There is a field for measure name, which will be displayed with the results, but has no bearing on the analysis. Monthly water savings over the calculator's time horizon are based on annual water savings in gallons, measure life in years, installation year, and savings profile. Installation year marks the beginning of savings, measure life indicates the duration over which savings can be claimed, and savings profile provides the monthly variation in savings over the course of the year.

Hydrologic region determines the marginal supply applicable to the measure. It also affects the energy intensity of extraction and conveyance, and distribution. Sector refers to whether the measure applies to an urban or agricultural setting. This impacts the treatment requirements, both water and wastewater. Water use refers to whether the measure is implemented indoors or outdoors. The model defaults to no distinction within the agricultural system, but assumes outdoor urban water is not captured and directed through wastewater systems.

The final four inputs for each measure relate to costs. These values do not affect the avoided cost calculations, but are used in the cost benefit analysis. They are the rebate, installation cost, incremental equipment cost, and program administration cost, and all are input as nominal dollars.

### 3.1.2 Avoided Water Capacity Cost Model

The water capacity avoided cost tool has default assumptions that are based on three primary user choices: (1) hydrologic region, (2) water system component, and (3) ownership entity type. After selections have been made, the model is populated with default assumptions for two categories of inputs: (1) water system component costs, and (2) financial input assumptions. This section will discuss generally each of the inputs under the two main categories and the basis for the default assumption, as appropriate.

The water system component cost category is composed of two critical model inputs: Capital Cost per Unit and Marginal Fixed O&M Cost per Unit. Capital Cost per Unit is the total installed capital cost of a water system component facility cost measured in million dollars per million gallons per day of capacity. Likewise, Marginal Fixed O&M Cost per Unit is the annual operations and maintenance cost of a water system component facility measured in million dollars per million gallons per day of capacity. The data collection and analysis process for these inputs is discussed in Appendix C.2.

The financial assumptions category is composed of four subcategories of seventeen inputs. The subcategories contain the following: two general inputs, two depreciation life inputs, six capital cost inputs and seven tax inputs.

The general inputs are Inflation Rate, which is the escalation rate applied to Marginal Fixed O&M Cost per Unit, and Working Capital, which is the amount of working capital required by the water system component facility.

The depreciation life inputs are straight line depreciation and MACRS depreciation. Straight line depreciation is an accounting cost based on the economic life of the facility. Our assumptions for economic life are based on California State Controller estimates. MACRS depreciation life is based on IRS allowances for a given facility type.

The cost of capital assumptions are: Years to Capital Outlay, Cost of Equity, Equity Percentage of Capital Structure, Cost of Debt, Debt Percentage of Capital Structure. Years to Capital Outlay is defaulted to zero years, but can be adjusted to assume a delay in capacity need and the corresponding capital outlay. Cost of equity and debt are the levels of return required by debt and equity holders to fund a water system component facility. Percentage of debt and equity in the capital structure are combined with equity and debt cost in a weighted average to determine the Weighted Average Cost of Capital (WACC). The WACC is the applied discount rate used to determine the levelized marginal cost and corresponding avoided cost of capacity.

The tax input assumption to the model are Federal Income Tax Rate, State Income Tax Rate, Value Added Tax Rate, Payments In Lieu of Taxes (PILOTs), Property Tax Rate, and Basis for Property Tax Rate. For IOUs, federal and state income tax are assumed to be 35% and 8%, respectively. Municipalities are assumed to pay no income tax. The tax input assumptions for value added tax, PILOTs, and property tax are set to a default value of zero. Basis for property tax rate is set to default as depreciated cost, but can be switched to installed cost.

All inputs to the model are completely customizable and can be revised by users as desired. General instructions on editing inputs and revising assumptions can be found in Section 3.3.2 and Appendix D.2 of this report.

## 3.2 Outputs

### 3.2.1 Water-Energy Calculator

The outputs of the Water-Energy Calculator are displayed across seven tabs. Clicking the "Run" button on the inputs tab will bring the user to the Summary Outputs tab. The six tabs to the right of the Summary Outputs tab display more detailed results.

The Summary Outputs tab displays two printable results tables. The first is comprised of the average embedded energy and avoided cost of embedded energy for each measure. The average annual embedded energy is reported as electric energy and gas energy. Embedded electric savings are further split by IOU and non-IOU to provide a broader perspective, even if not all savings can be claimed by IOUs. The avoided cost of marginal embedded energy is also split by electric and gas and is presented as the NPV of the avoided costs over the lifetime of each measure in 2014 dollars.

The second table on the Summary Outputs tab displays the cost-benefit analysis with all values in 2014 dollars. The rebate, installation cost, incremental equipment cost, and program administration cost are all brought to bear here as costs. The benefits calculated by the Water-Energy Calculator are the same avoided marginal embedded energy costs as in the first table, the avoided water capacity cost, and the environmental benefits. The combined total resource cost test and societal total resource cost test are performed on each measure. The difference between the two tests is that the societal test includes the environmental benefits while the combined total resource cost test does not.

Results in both tables are totaled at the bottom, providing an overall look that can be used to evaluate the set of measures together as a program.

The six tabs to the right of the Summary Outputs tab six tabs provide monthly values (or annual in the case of avoided water capacity cost) for the average annual embedded electric and gas energy savings and the four benefit components (discussed above) of each measure over the time horizon of the calculator.

### 3.2.2 Avoided Water Capacity Cost Model

The primary output of the water capacity avoided cost tool is the annual avoided cost of capacity. This is the level annualized payment that would be required for an additional unit of capacity, and is interpreted as the value of avoided capacity. The output can be found in the selection tab and the output tab. The model also calculates the present value of installed capacity, which can be found on the selection tab. the value of future cash flows required to finance and operate the facility discounted at the weighted average cost of capital.

## 3.3 Conducting Custom Analysis

### 3.3.1 Water-Energy Calculator

The Water-Energy Calculator affords the user the flexibility to alter many of the default inputs to the calculations. The Inputs tab has a section below the "Run" button for all of these optional overrides.

Values displayed in these tables are the default and each table has a reset button to restore these original values. Any cell left blank in one of these tables will result in the calculator using the default value in calculations.

The first override table is for the selection of marginal supply for each hydrologic region. The default values are discussed in Section 2.3.1.1. The dropdown menu for each region allows the user to select one of the supplies available to that region.

As discussed in Section 2.3.2, the Water-Energy Calculator accounts for water systems that don't get all of their electricity from an IOU. This percentage may be different by system component or supply type for extraction and conveyance, and the user may override each of these individually. The exceptions are the extraction and conveyance values for Local Imported Deliveries, CRA, CVP, and Other Federal Deliveries, and SWP. These are discrete systems for which the percent of electricity supplied by an IOU is known.

Energy intensity values are all open to user override – both electric and gas. In extraction and conveyance, this again excludes the values for the discrete water systems that are known, as outlined above.

Two further questions allow users to indicate specifics regarding their water system. The user may select one of two technologies used to recycle water: conventional tertiary treatment or membrane treatment. Also users are prompted if urban runoff enters the user's sewer system. The default assumption is urban runoff does not enter a sewer system and thus does not save any energy in the wastewater system.

The last override table is the historic supply mix by hydrologic region. This is used in the average embedded energy calculations and can be altered to better represent the user's current supply mix if the user has better data. The mix of supplies for each hydrologic region must sum to 100%.

### 3.3.2 Avoided Water Capacity Cost Model

The water capacity avoided cost tool input assumptions are completely customizable. Users are able to adjust or completely revise cost and financial input assumption. The model has two input tabs, one for cost assumptions and one for financial assumptions.

Custom cost assumptions can be input for each technology in a "User Defined Region" or input for a "User Defined Technology" in any of the default hydrologic regions or a user defined region. The model was designed in this manner to give users the ability to input a series of custom cost inputs to efficiently analyze different scenarios.

Likewise, the financial inputs can be adjusted or completely revised for a "User Defined Entity" for each of the three water system component categories: water supply, potable water treatment, and wastewater treatment. Financial input customization was designed in this manner because each water system component could potentially be owned by a different entity type, and financial inputs are determined by the type of ownership entity.

Once customer inputs are made, the user can select and compare user defined scenarios against default scenarios and other custom scenarios. Revisions to calculation methodologies in the current model are not allowed. However, calculation sheets can be copied and altered in a separate workbook if so desired.

# 4 Results

## 4.1 Marginal Energy Intensities

Table 15 lists the resulting default IOU marginal energy intensity of water used in this analysis. The marginal energy intensity represents IOU energy use only in the extraction and conveyance, treatment, distribution and wastewater collection and treatment systems. In this example, tertiary treated recycled water was selected as the default marginal supply. There is no extraction and conveyance energy associated with recycled water supply. Treatment energy use represents the incremental treatment required above secondary wastewater treatment to produce recycled water. Marginal EI used to evaluate outdoor water efficiency represents energy use upstream of the customer (Extraction and Conveyance, Treatment, and Distribution) and does not include wastewater treatment systems. Marginal EI used to evaluate indoor water efficiency includes all components (Extraction and Conveyance, Treatment, Distribution, and Wastewater Collection and Treatment systems).

**Table 15. IOU Marginal Energy Intensity (kWh/AF)**

| Region | Extraction and Conveyance | Treatment | Distribution | Wastewater Collection + Treatment | Outdoor (Upstream of Customer) | Indoor (All Components) |
|---|---|---|---|---|---|---|
| NC | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| SF | 0 | 490 | 918 | 1,245 | 1,408 | 2,653 |
| CC | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| SC | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| SR | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| SJ | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| TL | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| NL | 0 | 490 | 51 | 1,245 | 541 | 1,786 |
| SL | 0 | 490 | 470 | 1,245 | 961 | 2,206 |
| CR | 0 | 490 | 51 | 1,245 | 541 | 1,786 |

*Source: Navigant team analysis*

### 4.2 *Average Energy Intensities*

Table 16 lists the resulting average IOU energy intensity of water used in this analysis; Table 17 lists the total (IOU + non-IOU) energy intensity. The average energy intensity represents energy use in the Extraction and Conveyance, Treatment, Distribution, and Wastewater Collection and Treatment systems. The average energy intensity is based on the average regional mix of supplies. Average EIs used to evaluate outdoor and indoor water conservation are listed in Table 16 and are determined in a similar fashion as described in Section 4.1.

While IOU energy intensity falls in a relatively narrow range, total energy intensity exhibits a larger range with significantly higher values in select regions. The South Coast has the highest total average energy intensity given its large use of imported water. Imported water from the SWP and Colorado River have high energy intensities but are not powered by IOU energy.

**Table 16. Average IOU Energy Intensity (KWh/AF)**

| Region | Extraction, Conveyance, and Treatment | Distribution | Wastewater Collection + Treatment | Outdoor (Upstream of Customer) | Indoor (All Components) |
|---|---|---|---|---|---|
| NC | 343 | 470 | 1,245 | 813 | 2,058 |
| SF | 394 | 918 | 1,245 | 1,312 | 2,557 |
| CC | 316 | 470 | 1,245 | 787 | 2,032 |
| SC | 446 | 470 | 1,245 | 916 | 2,161 |
| SR | 372 | 51 | 1,245 | 423 | 1,668 |
| SJ | 351 | 51 | 1,245 | 401 | 1,646 |
| TL | 338 | 51 | 1,245 | 388 | 1,633 |
| NL | 375 | 51 | 1,245 | 425 | 1,670 |
| SL | 301 | 470 | 1,245 | 771 | 2,016 |
| CR | 414 | 51 | 1,245 | 465 | 1,710 |

*Source: Navigant team analysis*

**Table 17. Total IOU Energy Intensity (KWh/AF)**

| Region | Extraction, Conveyance, and Treatment | Distribution | Wastewater Collection + Treatment | Outdoor (Upstream of Customer) | Indoor (All Components) |
|---|---|---|---|---|---|
| NC | 391 | 495 | 1,284 | 886 | 2,170 |
| SF | 614 | 966 | 1,284 | 1,580 | 2,864 |
| CC | 558 | 495 | 1,284 | 1,053 | 2,337 |
| SC | 1,948 | 495 | 1,284 | 2,443 | 3,727 |
| SR | 417 | 53 | 1,284 | 470 | 1,754 |
| SJ | 416 | 53 | 1,284 | 470 | 1,753 |
| TL | 498 | 53 | 1,284 | 552 | 1,835 |
| NL | 417 | 53 | 1,284 | 470 | 1,754 |
| SL | 904 | 495 | 1,284 | 1,399 | 2,683 |
| CR | 520 | 53 | 1,284 | 573 | 1,856 |

*Source: Navigant team analysis*

## 4.3 *Avoided Capacity Cost*

Table 18 lists the resulting annual avoided water capacity cost for all water system components analyzed. The costs are reported as in terms of 2014$ and have the units of $M/MGD. These costs also assume a resource balance year of 2015. (New capacity is assumed to be needed starting in 2015.) The avoided capacity cost of the default selected marginal supply in this study (tertiary treated recycled water) is $0.31M/MGD under a municipally owned utility entity. When analyzing indoor water conservation measures, wastewater treatment capacity should also be considered with an additional avoided capacity cost of $2.15M/MGD.

**Table 18. Annual Avoided Water Capacity Cost (2014$M/MGD)**

| Water System Component | Ownership Entity Type | |
|---|---|---|
| | Investor-Owned Utility | Municipally Owned Utility |
| Ocean Desalination | $4.92 | $3.03 |
| Brackish Desalination | $1.41 | $1.11 |
| Recycled - Tertiary + Disinfection | $0.49 | $0.31 |
| Recycled - Membrane Treatment | $1.19 | $0.82 |
| Groundwater Facility | $0.39 | $0.21 |
| Treatment - Chlorine Disinfection | $0.02 | $0.02 |
| Treatment - Contaminant Removal & Disinfection | $0.56 | $0.31 |
| Wastewater Treatment | $3.06 | $2.15 |

*Source: Navigant team analysis*

## 4.4 *Environmental Benefits*

Environmental benefits were quantified where secondary data were available. The Navigant team observed data for the following supply types: State Water Project, Federal Projects, and Surface Waters. The Navigant team assumes Surface Water applies to local deliveries, local imported deliveries, and Colorado River waters. While there are environmental benefits to reducing reliance on ocean water desalination, groundwater, and brackish groundwater, however, we found no secondary data sources that quantified these benefits. Additional analysis is needed.

Environmental benefits for the observed supplies vary by hydrologic region and month. Table 19 and Table 20 list the environmental benefits for the San Francisco and South Coast Regions, respectively. Data for other regions are used in the model, though not presented here for simplicity.

**Table 19. Environmental Benefits in the San Francisco Region (2014$/AF)**

| Month | Surface Waters | Federal Projects | State Projects |
|---|---|---|---|
| January | $29.72 | $2.18 | $2.18 |
| February | $30.25 | $2.18 | $2.18 |
| March | $31.66 | $2.18 | $2.18 |
| April | $32.87 | $2.18 | $2.18 |
| May | $41.36 | $2.18 | $2.18 |
| June | $42.03 | $2.18 | $2.18 |
| July | $42.23 | $2.18 | $2.18 |
| August | $41.56 | $2.18 | $2.18 |
| September | $40.42 | $2.18 | $2.18 |
| October | $31.66 | $2.18 | $2.18 |
| November | $30.25 | $2.18 | $2.18 |
| December | $29.58 | $2.18 | $2.18 |

*Source: Navigant analysis of CUWCC Environmental Benefits Model*

**Table 20. Environmental Benefits in the South Coast Region (2014$/AF)**

| Month | Surface Waters | Federal Projects | State Projects |
|---|---|---|---|
| January | $117.51 | $0.14 | $0.14 |
| February | $118.90 | $0.14 | $0.14 |
| March | $122.40 | $0.14 | $0.14 |
| April | $125.89 | $0.14 | $0.14 |
| May | $134.54 | $0.14 | $0.14 |
| June | $136.17 | $0.14 | $0.14 |
| July | $137.10 | $0.14 | $0.14 |
| August | $135.93 | $0.14 | $0.14 |
| September | $132.21 | $0.14 | $0.14 |
| October | $122.63 | $0.14 | $0.14 |
| November | $119.14 | $0.14 | $0.14 |
| December | $117.27 | $0.14 | $0.14 |

*Source: Navigant analysis of CUWCC Environmental Benefits Model*

### 4.5 Example Measure Analysis

The Navigant team conducted an example calculation of the savings and benefits from a high-efficiency toilet. An EPA WaterSense high-efficiency toilet uses 1.28 gallons per flush and can save more than 8,000 gallons per year.[29] The average cost for a new WaterSense toilet is approximately $200[30]; for this analysis, we assume a measure life of 20 years (see Table 23). Resulting analysis for a WaterSense high-efficiency toilet across all regions can be found in Table 21. The example analysis shows the measure is cost effective (TRC > 1.0) from a combined utility perspective (including benefits to both energy and water utilities). Environmental benefits are $0 for this example and are not shown in Table 21, as recycled water has no quantified environmental benefits in the model.

This analysis assumed

- The measures are installed in PG&E territory
- The measures are installed within a non-IOU water utility territory
- Water savings follows a constant monthly profile
- All other inputs in the models are set to their default values

[29] http://socalwatersmart.com/qualifyingproducts/hets.

[30] Based on the average of available WaterSense products at www.homedepot.com.

**Table 21. Example Measure Analysis Results**

| Region | Equipment Cost | Program Admin Cost | Annual IOU Embedded Energy Savings (kWh) | Annual Non-IOU Embedded Energy Savings (kWh) | Net Present IOU Avoided Electric Embedded Energy Benefits (2014$) | Net Present Avoided Water Capacity Benefits (2014$) | Combined Total Resource Cost Test Result |
|---|---|---|---|---|---|---|---|
| NC | $200 | $10 | 50.54 | 2.74 | $70.63 | $700.95 | 3.67 |
| SF | $200 | $10 | 62.83 | 7.52 | $84.96 | $700.95 | 3.74 |
| CC | $200 | $10 | 49.86 | 7.47 | $70.63 | $700.95 | 3.67 |
| SC | $200 | $10 | 53.10 | 38.44 | $70.63 | $700.95 | 3.67 |
| SR | $200 | $10 | 40.96 | 2.11 | $57.19 | $700.95 | 3.61 |
| SJ | $200 | $10 | 40.42 | 2.62 | $57.19 | $700.95 | 3.61 |
| TL | $200 | $10 | 40.09 | 4.95 | $57.19 | $700.95 | 3.61 |
| NL | $200 | $10 | 41.01 | 2.04 | $57.19 | $700.95 | 3.61 |
| SL | $200 | $10 | 49.50 | 16.37 | $70.63 | $700.95 | 3.67 |
| CR | $200 | $10 | 41.94 | 3.59 | $57.19 | $700.95 | 3.61 |

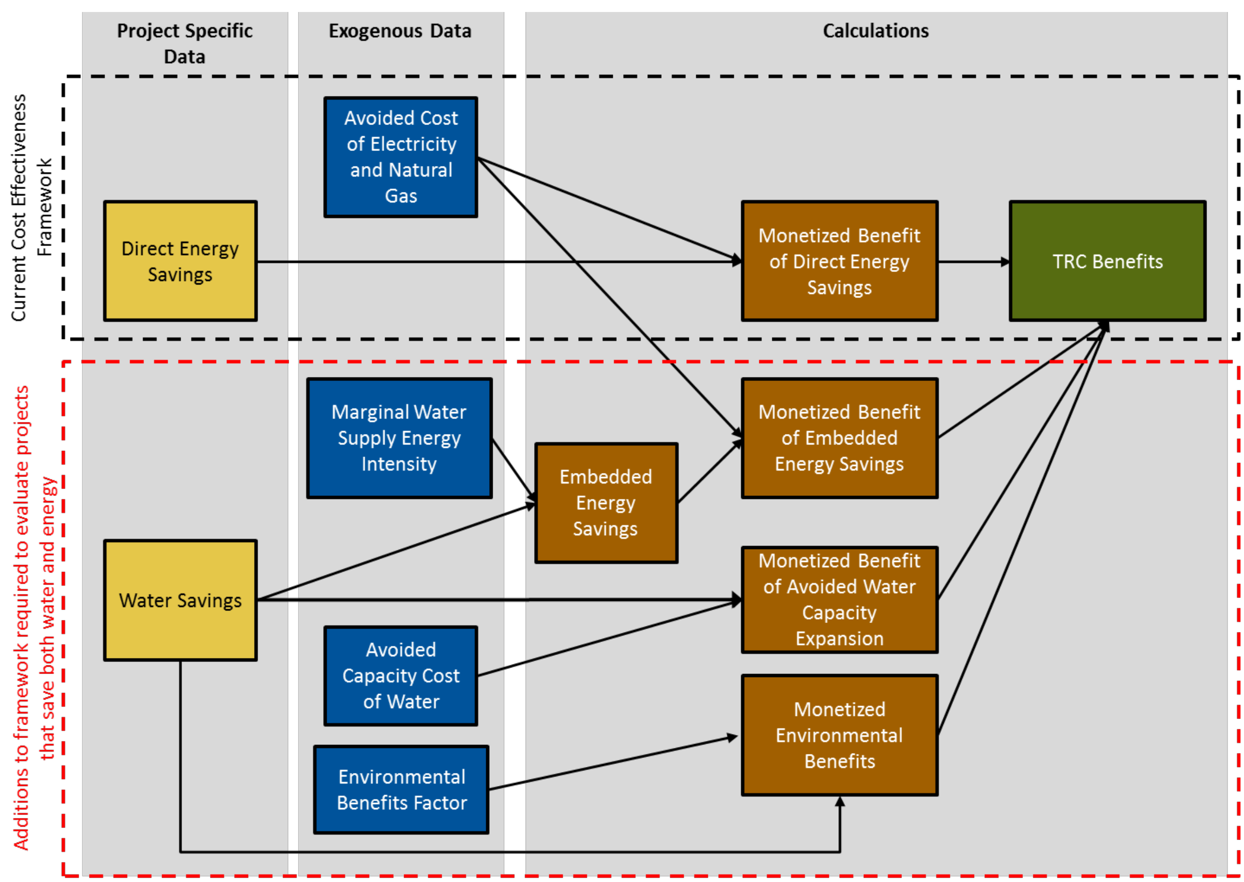
*Source: Navigant analysis using the Water-Energy Calculator*

# 5 Recommendations

## 5.1 *Necessary Modifications to the Existing Cost-Effectiveness Calculators*

The ultimate goal of the CPUC is to find a way to modify the existing cost-effectiveness calculators to allow analysis of water-saving programs and measures. Figure 7 illustrates the current framework for valuing the benefits of efficiency programs and the required modifications to fully evaluate water/energy projects and programs. Figure 7 is a simplified influence diagram depicting the key components of the benefits in the Total Resource Cost (TRC) test, as this test is the most widely used and applied by the CPUC. Furthermore Figure 7 illustrates a societal perspective of the TRC where benefits of avoided water capacity cost and environmental benefits are included in the TRC benefits.

**Figure 7. Influence Diagram of Water-Related Additions Required for Current TRC Benefit Calculation**




*Note: Considerations of EUL and IOU vs. Non-IOU Embedded Energy Savings are not illustrated for simplicity*

### 5.1.1 New Cost-Effectiveness Components Required

This study examines the following three benefits of water conservation not currently addressed by the CPUC cost-effectiveness framework. These should be added to the CPUC cost-effectiveness framework to allow the CPUC to better assess programs that save both energy and water. The three added benefits are:

- **Avoided Embedded IOU Energy in Water.** The economic value (in dollars) from the embedded energy savings. We focus only on IOU embedded energy savings, as these savings will result in benefits to the energy IOU ratepayers.
- **Avoided Costs of Water Capacity.** The economic value (in dollars) from the avoided investment in constructing and operating new capacity in water supply and treatment infrastructure. These benefits do not accrue to the energy IOU ratepayers; they accrue to the water utilities and its ratepayers. These benefits would be considered in a water-utility perspective TRC calculation and a societal perspective TRC calculation.
- **Environmental Benefits of Reduced Water Use.** The economic value (in dollars) of environmental services from water that is left in the environment to serve other purposes (e.g., wildlife habitats, instream flows). These benefits do not generally accrue to either the energy or water utilities; they accrue only to society. These benefits would be considered in a societal perspective TRC calculation.

Avoided embedded IOU energy in water is linked to the current electric and natural gas avoided costs. The Water Energy Calculator developed by the Navigant team imported avoided electric and natural gas avoided costs to be able to run embedded energy calculations. If the Water Energy Calculator is to be incorporated into existing cost-effectiveness tools, then the avoided energy costs could be directly linked to source data.

### 5.1.2 Cost-Effectiveness Calculations from Multiple Perspectives

As mentioned in Section 1.4, the CPUC is considering a multi-part cost-benefit test that is "viewed from multiple perspectives". For example, the TRC can be calculated from the energy utility perspective, the water utility perspective, a combined energy and water utility perspective, or a societal perspective. When considering the different perspectives of the TRC, different components of the avoided costs and benefits should be included. Table 22 below illustrates how the current calculation of TRC could be modified to be viewed from multiple perspectives, again limiting the illustration to the TRC test. The cost-effectiveness calculator would need to be modified to provide multiple CE calculations with varying logic, depending on perspective.

**Table 22. Components of Possible Updated CPUC Cost-Effectiveness Framework**

| Cost or Benefit Component | TRC Perspective | | | |
|---|---|---|---|---|
| | Energy | Water | Combined | Societal |
| Administrative costs to energy utility | Cost | | Cost | Cost |
| Administrative costs to water agency | | Cost | Cost | Cost |
| Avoided costs of supplying electricity and natural gas | Benefit | | Benefit | Benefit |
| Avoided costs of water capacity* | | Benefit | Benefit | Benefit |
| Avoided embedded IOU energy in water* | Benefit | Benefit | Benefit | Benefit |
| Environmental benefits of reduced water use* | | | | Benefit |
| Energy and Water Bill Reductions | | | | |
| Capital (measure) costs to participant | Cost | Cost | Cost | Cost |
| Capital (measure) costs to energy utility | Cost | | Cost | Cost |
| Capital (measure) costs to water utility | | Cost | Cost | Cost |
| Incentives paid by energy utility | | | | |
| Incentives paid by water utility | | | | |
| Increased supply costs | Cost | Cost | Cost | Cost |
| Revenue loss from reduced energy sales | | | | |
| Revenue loss from reduced water sales | | | | |
| Tax credits | Benefit | Benefit | Benefit | |

** New benefits being addressed by this study. All other cost and benefit components are currently incorporated in existing CPUC cost-effectiveness frameworks.*

*Source: Adapted from CPUC. Water-Energy Cost Effectiveness Project Update. January 2014*

As part of the consideration of multiple perspectives, it is necessary to allocate costs to multiple utility entities. This would require a change to the current cost-effectiveness calculator, adding complexity to the tool.

### 5.1.3 Water Impact Profiles

The current cost-effectiveness calculator contains gas and electric impact profiles, but does not currently address water impact profiles. Similar to the gas impact profiles, there are limited possible values: constant use and variations on seasonal use.

### 5.1.4 Hydrologic Region

The current cost-effectiveness calculator uses the climate zone of a measure installation to look up avoided costs. Similarly, for water-energy measures, hydrologic region will be used to look up several water-energy cost-effectiveness values.

## 5.2 *Frequency and Basis for Updates*

Analysis of the avoided cost of water is a new area of research. The Navigant team considers this study a much needed first step but also recommends updates in the future as new data and understanding become available. Future updates to this study could be aligned with a number of different timelines, some of which are related to regular updates of water-planning documents. The Navigant team considered the following activities in recommending an update schedule:

- Urban Water Management Plans are required to be updated every **five years** in California. Tthe next update will be 2015.) These documents provide a wealth of water supply planning data that may impact assumptions about future supplies.
- The California Water Plan issued by DWR has been updated every **four years** since 2005 (2005, 2009, and 2013). This trend will most likely continue. The Water Plan and its regional reports provide a wealth of regional water supply data and forecasts (aligning with the team's regional analysis).
- California IOU energy efficiency program funding cycles typically last **three years**. Updating the avoided water costs prior to a new program cycle will allow the CPUC and IOUs to use the latest available analysis for program planning. However, the CPUC is currently considering moving to a "rolling cycle" through which funding decision and approval timelines will change from their current schedule.
- California's avoided cost of energy values are updated on a regular basis. The Avoided Cost of Embedded Energy tool should be updated to reflect changes in avoided cost of energy.

The primary consideration in determining an update cycle is the frequency at which relevant data from the water sector becomes available. The Navigant team suggests a major and minor update cycle.

- Major update cycle (recommended)
    - Based on water planning data (DWR water plan, UWMPs)
    - Updates should include reassessing marginal supplies, updating component cost data, and updating financial assumptions and/or methodology
- Minor update cycle (optional)
    - Based on energy utility needs, and program planning cycles
    - Updates can include energy intensity data, energy avoided costs, and changes to the core methodology of cost-effectiveness equations.

## 5.3 *Evaluation of Project-Related Data*

The scope of this study is to develop tools to include consideration of water use in the CPUC's current cost-benefit framework. While many measure- and project-specific inputs (such as savings, lifetime, and cost) are necessary input to the calculator, this study was not meant to discuss or evaluate project-related data. It is still up to the users of the model to accurately collect project-related data to use as inputs to the tools. However, this section discusses key points to consider when collecting and quantifying project-related data.

### 5.3.1 Incremental Measure Cost

The CPUC's 2013 Energy Efficiency Policy Manual defines incremental cost as:

> *The additional cost of installing a more efficient measure calculated from the price differential between energy-efficient equipment and services and standard or baseline state. These costs include any direct or indirect incremental cost that is attributable to the energy efficiency activity. This may include design assistance, surveys, materials and labor, commissioning costs, etc.*[31]

Many water efficiency measures are primarily "widget-based"; these measures simply require an equipment cost and an installation cost (e.g., toilets, showers, faucets, and dishwashers). A few more complex water efficiency measures may also require costs associated with design assistance, surveys, and commissioning (e.g., cooling towers, large irrigation systems, and leak-loss detection). For most measures, the Navigant team sees no reason to divert from the existing incremental cost guidance provided in the Energy Efficiency Policy Manual.

One measure in particular will require further investigation to properly identify incremental measure cost: leak-loss detection.[32] Leak detection is one step in a multi-step water loss control program. The first step is to conduct a validated water system audit. The audit calculates the total volume of leakage throughout the water system. The water auditing process is analogous to an energy audit. It identifies previously unknown inefficiencies in a system and recommends actions to address those inefficiencies. The act of simply conducting an energy audit does not result in immediate energy savings; similarly, the act of simply compiling a water audit does not result in immediate water savings. However, both are necessary first steps to enable efficiency; without them, systems could remain inefficient. Upon calculating the volume and types of leakage in a water system, recommendations are made on the appropriate types and levels of intervention (e.g., leak detection survey and pressure management) to reduce water losses.

Leak detection is a second step in a water loss control program. It is one of the recommended interventions against water losses and is an exercise through which distribution system water leaks are located. A typical leak detection effort surveys a portion or all of a distribution network. Upon identifying leakage, the surveyor will notify the water utility to initiate the appropriate repair. Leak detection is a necessary step in revealing the location of the loss; upon repairing the leak the water savings are realized.

Water system auditing and leak detection services come at a cost that could be classified as design assistance, surveys, and/or labor costs. The water utility receiving the services is still left with the decision to act on the recommendations; acting on those recommendations typically requires additional labor and material costs. In considering incremental costs (and subsequent water savings) associated

[31] R.09-11-014.

[32] CPUC decision 12-05-015 directed the IOUs "to propose 2013-2014 efforts (either through limited, water sector focused pilot programs or through targeted efforts within the existing calculated savings programs) on leak-loss detection and remediation and pressure management services for water entities that are IOU customers."

with leak-loss detection, the CPUC should examine how it currently treats incremental costs (and subsequent energy savings) for energy audits, pump efficiency testing, and retro-commissioning.

### 5.3.2 Expected Useful Life (EUL)

The EUL of an efficiency measure is defined by the California Energy Efficiency Policy Manual as "an estimate of the median number of years that the measures installed under the program are still in place and operable." A high-efficiency toilet, for example, has an average lifetime of 20-25 years. The lifetime provides the time period over which the device's costs and benefits are distributed. For this study, the project team collected data on the lifetime of various water efficiency devices for the commercial and residential sector as seen in Table 23. The data were provided from the Metropolitan Water District of Southern California, East Bay Municipal Utility District, and Contra Costa Water District. Many measures that save hot water (such as showerheads, faucet aerators, dishwashers, and clothes washers) already have deemed EUL values. We focused our efforts on collecting the EUL of cold-water-saving measures.

**Table 23. Observed Effective Useful Life of Common Water Effeminacy Measures**

| Water Efficiency Devices | Sector | Lifetime (years) |
|---|---|---|
| High Efficiency Toilet (Melded Rate) | Commercial | 20-25 |
| Zero/Ultra Low Water Urinal | Commercial | 20 |
| Connectionless Food Steamer (per Compartment)* | Commercial | 8-10 |
| Air-cooled Ice Making Machine* | Commercial | 8-10 |
| Dry Vacuum Pump (/1/2 hp) | Commercial | 7 |
| Cooling Tower Conductivity Controller | Commercial | 5 |
| pH Cooling Tower Controller | Commercial | 5 |
| Weather-Based Irrigation Controller (per Station) | Commercial | 8-10 |
| Central Computer Irrigation Controller (per Station) | Commercial | 8-10 |
| Rotary Multi-Stream Nozzle | Commercial | 5-8 |
| Large Rotary Nozzle | Commercial | 5-10 |
| Turf Removal | Commercial | 10-15 |
| Laminar Flow Restrictor | Commercial | 3-5 |
| In-Stem Flow Regulator | Commercial | 3-5 |
| Soil Moisture Sensor | Commercial | 8-10 |
| Plumbing Flow Control ( per pair) | Commercial | 10 |
| High Efficiency Toilet (Melded Rate) | Residential | 20-25 |
| Weather Based Irrigation Controller (each; < 1 acre) | Residential | 10 |
| Weather Based Irrigation Controller (per station; > 1 acre) | Residential | 10 |

| Water Efficiency Devices | Sector | Lifetime (years) |
|---|---|---|
| Rotary Multi-Stream Nozzle | Residential | 5 |
| Turf Removal | Residential | 10-15 |
| Soil Moisture Sensor (each; < 1 acre) | Residential | 10 |
| Soil Moisture Sensor ( per station; > 1 acre) | Residential | 10 |
| Rain Barrel | Residential | 5 |
| High Efficiency Clothes Washer* | Residential | 12-14 |

**Measures that also save energy either from direct appliance energy savings or hot water savings. These measures may already have deemed EUL values in DEER. EULs for these measures are provided here for informational purposes to document the common assumptions made by the water sector.*

Further EUL research may be needed. The Navigant team was unable to find reliable data on several key water efficiency measures such as leak detection and pressure management and behavior-based conservation programs.

#### 5.3.3 Discount Rates

Various discount rates may need to be applied to each of the benefits that result from water efficiency measures. We focus on the appropriate discount rates to be used in the TRC test.

Avoided Embedded IOU Energy in Water should be discounted using current IOU discount rates. Water-energy measures have the potential to save both embedded electric and embedded gas energy. In these cases, electric and gas benefits may need different discount rates based on current CPUC assumptions. The Water-Energy Calculator currently assumes an 8.15 percent discount rate for gas benefits and a 6.92 percent discount rate for electric benefits.

Avoided Costs of Water Capacity should be discounted using discount rates that are typically used in the water industry. The Navigant team recognizes investor-owned water utilities and municipally owned water utilities likely have different discount rates. The Water-Energy Calculator assumes two different discount rates, depending on the user input of an IOU (8.64%) vs. MOU (4.51%) analysis.

Environmental Benefits of Reduced Water Use should be discounted using as societal discount rate as these benefits only accrue to society. In 2013, the CPUC began to consider development of a Societal Cost Test. Through this consideration, societal discount rates were discussed. We recommend aligning with CPUC efforts to better define societal discount rates. The Water-Energy Calculator currently assumes a 3 percent societal discount rate consistent with the observed ranges from CPUC's existing secondary research.[33]

[33] E3, June 2013, *CPUC Workshop on Societal Cost Test*.

## 5.4 *Integration with DEER*

CPUC policy states the source of cost-effectiveness parameters are those defined in the DEER.[34] Additionally, updates to cost-effectiveness calculations and the measure parameters necessary to estimate avoided cost benefits will be an integral part of the ex ante process, for both DEER and non-DEER work paper measures. As water-energy considerations enter the CPUC cost-effectiveness framework, DEER will need to be updated to store new information on embedded energy savings from water measures and water-related avoided costs. This includes necessary updates to the existing data in the DEER, new fields to be incorporated in the DEER, and new measures that may need to be added to the DEER.

### 5.4.1 ExAnte Database (EAD)

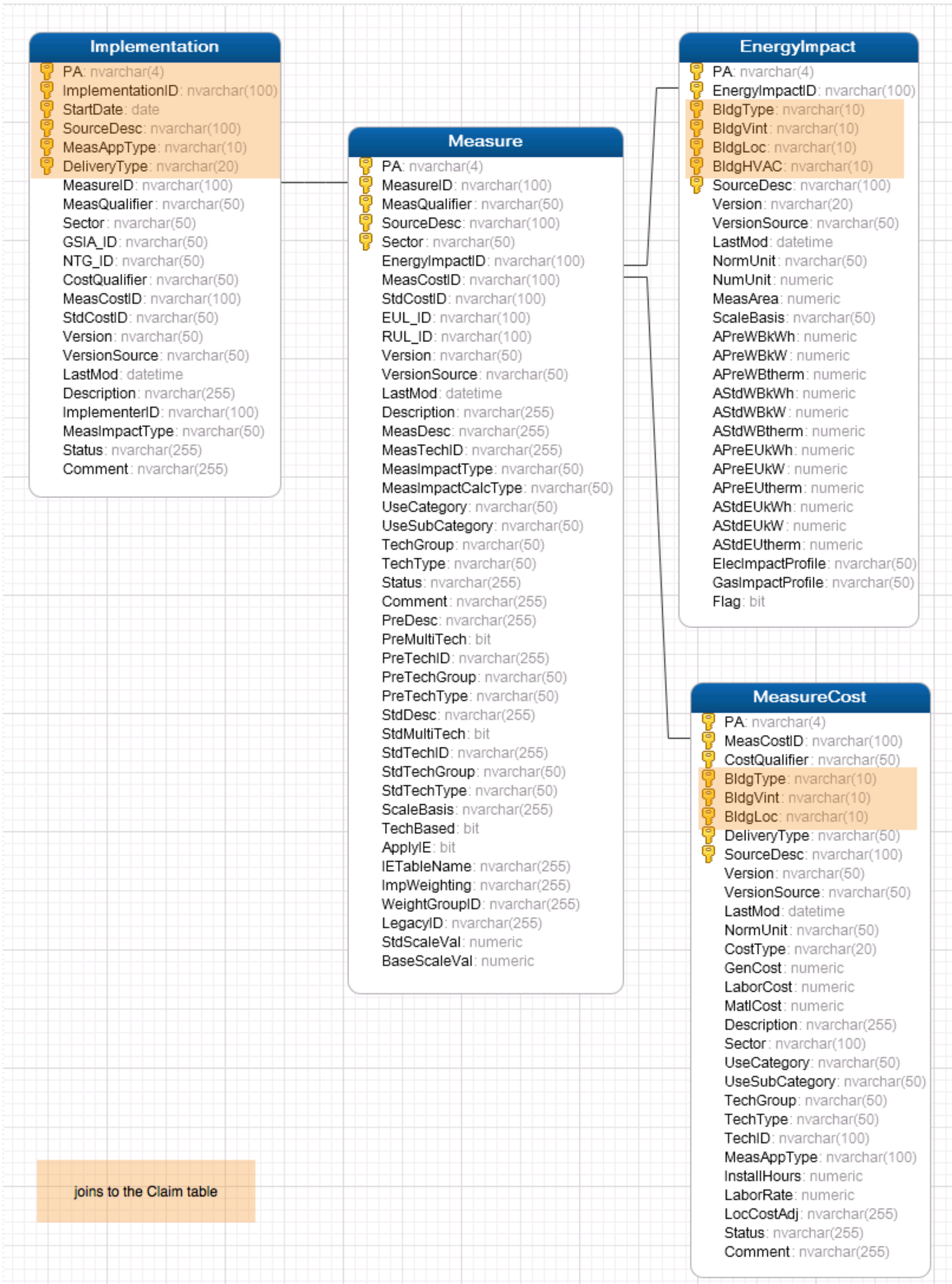
D.11-07-030 required Energy Division, with utilities' cooperation, to compile all Commission-adopted Frozen Ex Ante energy savings values into one location, which is the basis for referencing claims. The CPUC ED is currently leading the integration of all DEER and non-DEER IOU work paper measures into a single database called the EAD. Upon completion, the EAD will store all ex ante (DEER and non-DEER work paper) measure, energy, cost, and any other parameters necessary to calculate cost-effectiveness for deemed measures. This database will be publicly accessible, likely via the current DEER database interface, READi.

#### *5.4.1.1 Current EAD/DEER Structure*

The EAD and DEER share the same relational structure, shown in Figure 8 below. Therefore, any recommendations for modification to the DEER apply to the EAD. In addition, the EAD has support tables, which specify lists of possible values for several of the fields listed in Figure 8. Modifications to the EAD structure and related value lists will be necessary to capture the water-energy data necessary for cost-effectiveness calculations.

[34] Energy Efficiency Policy Manual, Version 4.0, August 2008, (EEPMv4) Rule II.11.

**Figure 8. ExAnte Database/DEER Structure**



#### 5.4.1.2 *Recommended Modifications to Current ExAnte Database Tables*

Navigant recommends the following modifications to the current EAD tables to support these new fields necessary for water-saving measures:

- Water Impact Profile
- Hydrologic Region
- Water Use Category
- Savings Type

**EAD Table: EnergyImpact**

- Rename *EnergyImpact* Table ⟹ *Impacts* Table
- Add the following fields

| Field | Description |
|---|---|
| WaterImpactProfile | Water use profile (i.e., seasonal vs. constant) |
| APreWaterGal | Unitized annual water savings (gallons), above preexisting scenarios |
| AStdWaterGal | Unitized annual water savings (gallons), above standard replacement scenarios |
| SavingsType | Indicates water-only, energy-only, or water-energy savings |

*Source: Navigant team analysis*

**EAD Table: Implementation**

- Add the following fields

| Field | Description |
|---|---|
| HydroRegion | CA Hydrologic Region |

*Source: Navigant team analysis*

**EAD Table: Measure**

- Add the following fields

| Field | Description |
|---|---|
| WaterUseCategory | Indicates either potable or non-potable water use |

*Source: Navigant team analysis*

#### 5.4.1.3 *Recommended New Support Tables*

Navigant recommends the addition of the following support tables to the EAD structure. The new support tables define standardized value lists associated with the new water data fields above.

### Water Impact Profile

| WaterImpactProfile | Description |
|---|---|
| ConstantUse | Water use does not vary seasonally (e.g., residential showers) |
| Seasonal | Seasonal water use (e.g., irrigation or cooling towers) |

*Source: Navigant team analysis*

### Hydrologic Region

| HydroRegion | Description |
|---|---|
| NCoast | North Coast |
| Bay | San Francisco Bay |
| CCoast | Central Coast |
| SCoast | South Coast |
| SacramentoR | Sacramento River |
| SanJoaquinR | San Joaquin River |
| TulareL | Tulare Lake |
| NLahontan | North Lahontan |
| SLahontan | South Lahontan |
| ColoradoR | Colorado River |

*Source: Navigant team analysis*

### Water Use Category

| WaterUseCategory | Description |
|---|---|
| Potable | Potable water |
| NonPotable | Non-potable water (e.g., agriculture) |

*Source: Navigant team analysis*

### Savings Type

| SavingsType | Description |
|---|---|
| Water-Only | Water savings only |
| Energy-Only | Energy savings only |
| Water-Energy | Water and energy savings |

*Source: Navigant team analysis*

#### 5.4.1.4 Recommended Modifications to Current Support Tables

As IOU EE programs incorporate new water-saving measures into their portfolios, and water-saving measures are included in DEER, the current measure categorization scheme will necessarily change. The following support tables will be expanded as necessary to properly categorize new water-saving measures:

- UseCategory
- UseSubCategory
- TechGroup
- TechType

## 5.5 Recommendations for Future Research

As previously mentioned, analysis of the avoided cost of water is a new area of research. The Navigant team considers this study a much needed first step, though future research could expand and refine the avoided costs considered and assumptions made.

- **Develop an Energy Intensity Data Tool:** While the Water-Energy Calculator is populated with default values for the energy intensity of water system components, users can modify these assumptions as they see fit to better reflect their systems. Nevertheless, using water-utility specific data may not be possible for all utilities as it may not be readily available. An accepted methodology and associated tool could be developed to help water agencies calculate the energy intensity of their water system components.
- **Consider Avoided Commodity Cost of Water:** The scope of this study did not include consideration of the avoided commodity cost of water. Future research could consider developing default data to serve as a proxy for the commodity cost.
- **Consider the Use of a Resource Balance Year**: Stakeholder comments asked the study team to consider the use of a resource balance year in the analysis. The Navigant team responded by adding the functionality into the model. However, it was not in the scope of the Navigant team's study to conduct an analysis to determine the appropriate resource balance year.
- **Conduct additional Environmental Benefits Research**: The body of observed secondary data on the environmental benefits of reduced water use is limited. While past studies have examined benefits of reducing reliance on surface and groundwater, other supplies (such as recycled water, ocean desalination, and brackish desalination) have limited information. Additional research may be necessary if the CPUC moves towards using a societal cost test for cost effectiveness screening.

# Appendix A Acronyms and Glossary

## *A.1 Acronyms*

| | |
|---|---|
| ACWA | Association of California Water Agencies |
| AF | acre-foot |
| CC | Central Coast hydrologic region |
| CEC | California Energy Commission |
| CIP | capital improvement plan |
| CPUC | California Public Utilities Commission |
| CR | Colorado River hydrologic region |
| CRA | Colorado River Aqueduct |
| CUWCC | California Urban Water Conservation Council |
| CVP | Central Valley Project |
| DEER | Database for Energy Efficiency Resources |
| DOE | United States Department of Energy |
| DWR | Department of Water Resources |
| EAD | ExAnte Database |
| EI | energy intensity |
| EPA | United States Environmental Protection Agency |
| ETo | evapotranspiration |
| EUL | expected useful life |
| FCR | fixed charge rate |
| GHG | greenhouse gas |
| IOU | investor-owned utility |

| | |
|---|---|
| IRWMP | integrated regional water management plan |
| kWh | kilowatt-hour |
| MACR | modified accelerated cost recovery |
| MGD | million gallons per day |
| MOU | municipally-owned utility |
| NC | North Coast hydrologic region |
| NL | North Lahontan hydrologic region |
| NOx | nitrogen oxides |
| NPV | net present value |
| O&M | operations and maintenance |
| PAC | Program Administrator Cost test |
| PCG | Project Coordination Group |
| PG&E | Pacific Gas & Electric |
| PPIC | Public Policy Institute of California |
| RIM | Ratepayer Impact Measure cost test |
| RPS | renewable portfolio standard |
| SC | South Coast hydrologic region |
| SCE | Southern California Edison |
| SCG | Southern California Gas Company |
| SDG&E | San Diego Gas & Electric |
| SF | San Francisco Bay hydrologic region |
| SJ | San Joaquin River hydrologic region |
| SL | South Lahontan hydrologic region |

| | |
|---|---|
| SOx | sulfur oxides |
| SPM | Standard Practice Manual |
| SR | Sacramento River hydrologic region |
| SWP | State Water Project |
| SWRCB | State Water Resources Control Board |
| TL | Tulare Lake hydrologic region |
| TOU | time of use |
| TRC | Total Resource Cost test |
| USBR | United States Bureau of Reclamation |
| WELP | water energy load profile |
| WESim | the Water-Energy Simulator |
| WTA | willingness to accept |
| WTP | willingness to pay |
| WWTP | wastewater treatment plant |

## *A.2 Glossary*

**Acre-Foot** The volume of water that would cover one acre to a depth of one foot.

**Avoided Capacity Cost** Costs incurred to overcome a potential scarcity of resources (i.e. a shortage) or provide the ability to provide service on demand to customers.

**Avoided Energy Cost** Costs incurred to provide a unit of energy to customers.

**Brackish Water** Water with a salinity that exceeds normally acceptable standards for municipal, domestic, and irrigation uses, but less than that of ocean water.

**Central Valley Project and Other Federal Deliveries**

The delivery of project water to Central Valley Project contractors, and deliveries from federal projects other than the Central Valley Project.

**Colorado River Aqueduct**

Water diverted from the Colorado River by the Metropolitan Water District of Southern California.

**Desalination** Water treatment process for the removal of salt from water for beneficial use. Source water can be brackish or ocean water

**Distribution** System of ditches or conduits and their controls that conveys water from the supply canal to the farm points of delivery

**Embedded Energy Savings**

The amount of energy that is saved in the water system as a result of reduced water use.

**Energy Intensity** The average amount of energy needed to transport or treat water or wastewater on a per unit basis (kilowatt hours per acre-foot of water [kWh/AF] or therms per acre-foot of water [therms/AF]).

**Energy Load Profile** The hourly variation in energy use over the course of a day.

**Environmental Benefits**

Environmental services from water that is left in the environment to serve other purposes (wildlife habitats, recreation, etc.).

**Extraction and Conveyance**

The removal of water from its source and its relocation to the next water system component.

**Groundwater** Water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

**Hydrologic region** A geographical division of the state based on the local hydrologic basins. The Department of Water Resources divides California into 10 hydrologic regions, corresponding to the state's major water drainage basins.

**Incremental Equipment Cost ($)**

Cost of the efficient equipment being installed minus the cost of the baseline equipment.

**Installation Cost ($)** Cost to install the measure.

**Local Deliveries** Water delivered by local water agencies and individuals. It includes direct deliveries of water from stream flows, as well as local water storage facilities.

**Local Imported Deliveries**

Water transferred by local agencies from other regions of the state.

**Marginal Water Supply**

The next increment or unit of water supply developed within a region to meet demand in the absence of water conservation and efficiency.

**Measure Life (years)** An estimate of the median number of years that the measure installed will remain in place and operable.

**Participant Test** Measure of the quantifiable benefits and costs to the customer due to participation in a program.

**Program Administration Cost ($)**

Cost to the utility to run the program installing the measure.

**Program Administrator Cost Test**

The net costs of a demand-side management program as a resource option based on the costs incurred by the program administrator (i.e. the utility) excluding any net costs incurred by the participant.

**Ratepayer Impact Measure Test**

| | |
|---|---|
| | Measure of what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program. |
| **Rebate ($)** | Amount of money provided to the customer by the utility for implementing the measure. |
| **Recycled Water** | The application of treated water/reclaimed water to meet a beneficial use, supplanting a potable or potentially potable supply. |
| **Resource Balance Year** | The year in which new capacity will be required to meet water demand. |
| **Total Resource Cost Test** | The net costs of a demand-side management program as a resource option based on the total costs of the program, including both the participants' and the utility's costs. |
| **Treatment** | Processing a water supply such that it can be delivered to customers. |
| **Wastewater Systems** | The systems that both collect and treat water leaving the customer site. |
| **Water Savings Profile** | The profile of monthly variation in water savings over the course of a year. |

# Appendix B Marginal Supply Selection

## B.1 Overview

Californians rely on a combination of two sources of water - surface and groundwater - to meet our water needs. These supplies can vary regionally both in quantity and quality (see Table B-1), but all are replenished by precipitation (i.e., rain and snow). California's hydrologic conditions result in two-thirds of California's overall water supplies located in the northern part of the state while two-thirds of the demand occurs in the southern part of the state.[35] As a result, an expansive and elaborate system of storage facilities, conveyance structures, interties, and distribution systems have been built to move water from where it occurs to where it is used. Contractual mechanisms (i.e., water transfers and exchanges) have also been developed to facilitate the transactions needed to move water from where it naturally occurs to areas of high demand. California's water market has allowed water managers the increased flexibility needed to address temporary and long-term water scarcity conditions in their communities.[36] Even with California's existing infrastructure, approximately half of this precipitation returns to the atmosphere or flows to the ocean.[37]

**Table B-1: California's Water Supply Options**

| Surface Water Supply Types | Groundwater Supply Types |
|---|---|
| • Fresh (these can be local or imported resources)<br>• Degraded (can be contaminated or poor quality water)<br>• Wastewater (sources suitable for re-use and recycling)<br>• Brackish<br>• Ocean/Sea | • Fresh (local)<br>• Degraded (can be contaminated or poor quality)<br>• Brackish |

In addition to this existing infrastructure, California has developed and implements numerous "Resource Management Strategies" (RMS)38, such as:

- Reducing water demand through efficiency and conservation
- Managing surface and groundwater conjunctively to increase groundwater storage and supply reliability

[35] Water Education Foundation. August 13, 2008. "Where Does California's Water Come From?" http://www.aquafornia.com/index.php/where-does-californias-water-come-from/ Accessed March 15, 2014.
[36] Hanak, Ellen and Elizabeth Stryjewski. November 2012. *California's Water Market, By the Numbers: Update 2012*. Public Policy Institute of California.
[37] Brostrom, Peter. February 14, 2013. "California Water Demand: Water 101 – the Basics and Beyond." Presentation for the Water Education Foundation. DWR.
[38] As defined by DWR, an RMS is a project, program, or policy that helps federal, State or local agencies manage water and related resources.

- Increasing storm water capture, retention, and storage within a community (this can include changes to or new methods for management of rainfall, flood flows, and urban run-off) to increase local supplies
- Desalinating brackish and ocean water to increase local supplies
- Improving water quality through various treatment methods
- Transferring water supplies from one region to another
- Treating wastewater to allow for increased recycling and re-use to increase local supplies and water use efficiency

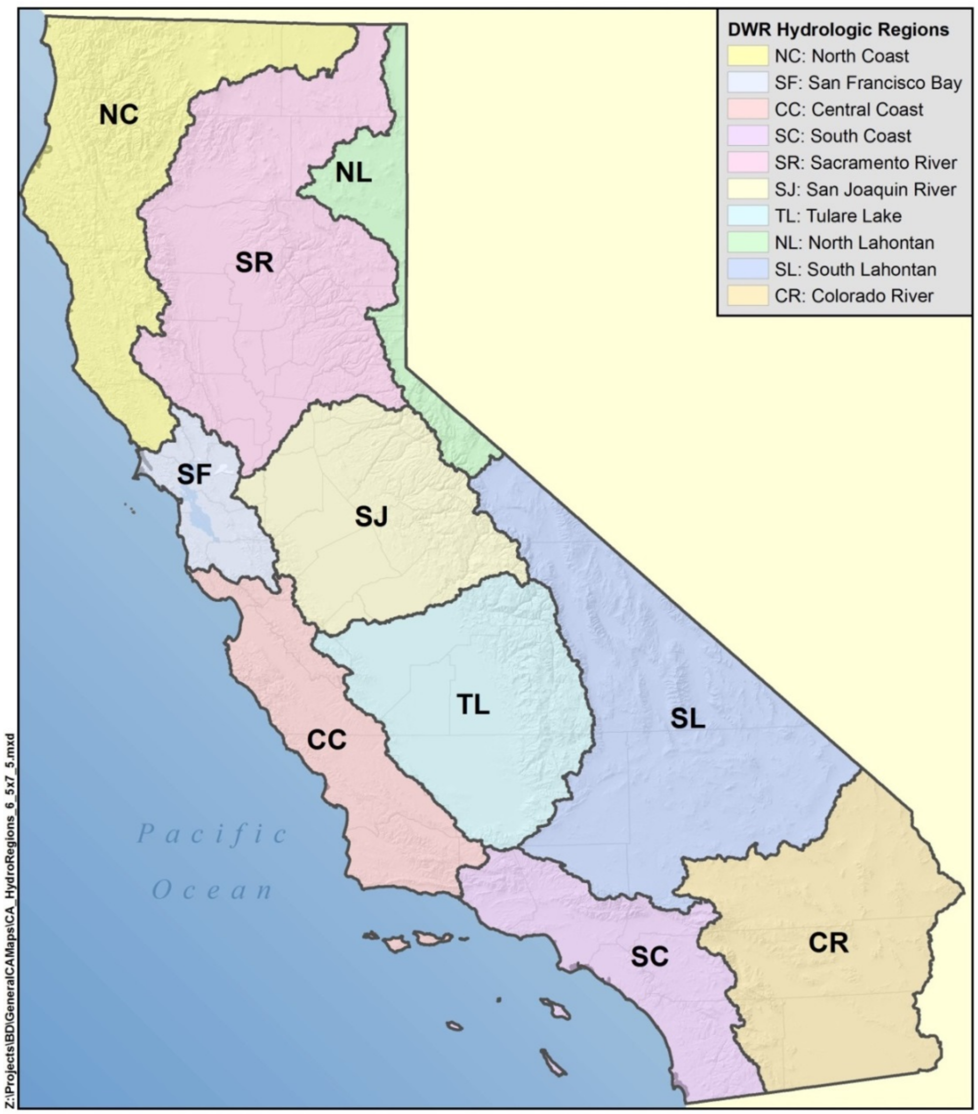
Water availability and distribution varies throughout California. To assist in identifying the supply options available to a given region and the options for future supplies, the Navigant team used the geographical breakdown developed by the California Department of Water Resources (DWR). These ten Hydrologic Regions (see Figure B-1) correspond to the state's major drainage basins comprised of watersheds with similar clime that support water management planning.39 As defined by DWR, the Hydrologic Regions of California are:

1. **North Coast.** Klamath River and Lost River basins, and all basins draining into the Pacific Ocean from Oregon south through the Russian River basin.
2. **San Francisco Bay.** Basins draining into San Francisco, San Pablo, and Suisun bays, and into the Sacramento River downstream from Collinsville in western Contra Costa County, and basins directly tributary to the Pacific Ocean below the Russian River watershed to the southern boundary of the Pescadero Creek basin.
3. **Central Coast.** Basins draining into the Pacific Ocean below the Pescadero Creek watershed to the southeastern boundary of Rincon Creek basin in western Ventura County.
4. **South Coast.** Basins draining into the Pacific Ocean from the southeastern boundary of Rincon Creek basin to the Mexico border.
5. **Sacramento River.** Basins draining into the Sacramento River system in the Central Valley, including the Pit River drainage, from the Oregon border south through the American River drainage basin.
6. **San Joaquin River.** Basins draining into the San Joaquin River system from the Cosumnes River basin on the north through the southern boundary of the San Joaquin River watershed.
7. **Tulare Lake.** The closed drainage basin at the south end of the San Joaquin Valley, south of the San Joaquin River watershed, encompassing basins draining to Kern lakebed, Tulare lakebed, and Buena Vista lakebed.
8. **North Lahontan.** Basins east of the Sierra Nevada crest and west of the Nevada state line from the Oregon border south to the southern boundary of the Walker River watershed.

[39] DWR. December 2013. "*California Water Plan Update 2013*". Public Review Draft.

9. **South Lahontan.** The interior drainage basins east of the Sierra Nevada crest, south of the Walker River watershed, northeast of the Transverse Ranges, and north of the Colorado River region. The main basins are the Owens and the Mojave River basins.
10. **Colorado River.** Basins south and east of the South Coast and South Lahontan regions, areas that drain into the Colorado River, Salton Sea, and other closed basins north of the Mexico border.

**Figure B-1: California's Hydrologic Regions**



## B.2 Approach and Assumptions

The Navigant team consulted with the CPUC and the Water/Energy Project Coordination Group (PCG) to develop an approach to determine the regional water supplies, now and in the future. This approach and associated tasks are summarized in this section.

***Determining Water Supplies***

As part of the project, the Navigant team was tasked with identifying water supplies available to and developed in California's Hydrologic Regions and which of these supplies are the marginal or the next incremental supply to be developed. In addition, the Navigant team was to determine how these marginal supplies may change over time. As defined in the project work plan, the Navigant team:

- Collected regional historic water supply and use data from DWR reports, regional water management plans, and other relevant sources
- Solicited input directly from water managers and others expert in California water resource management as well as the CPUC and PCG
- Used this information to determine the current and future supply options for each Hydrologic Region
- Characterized how each region develops these supplies considering economic and physical characteristics of each supply as well as legal and institutional issues
- Identified the marginal water supply developed in each region
- Updated the marginal supply selection based on feedback as needed

As defined by the Navigant team, "marginal water supply" does not refer to water quality, but rather is the next increment or unit of water supply developed within a region to meet demand in the absence of water conservation and efficiency. This definition is consistent with the definition of marginal power supply used in the electricity industry for determining marginal cost and price.[40]

The Navigant team relied primarily on the DWR *2013 California Water Plan Update* and integrated regional water management plans (IRWMPs) distributed among the Hydrologic Regions. These plans provided information on available water supplies, demand, RMS, regional priorities and challenges, and infrastructure requirements.

Additional information was obtained through internet searches, primarily local water agency websites and those of non-governmental organizations, such as the Natural Resources Defense Council (NRDC) and Public Policy Institute of California (PPIC). These resources provided more statewide perspectives,

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[40] California Energy Commission. Copyright 1994-2014. "Marginal Cost", Glossary of Energy Terms.
California ISO. "Locational Marginal Pricing (LMP): Basics of Nodal Price Calculation". CRR Educational Class #2, CAISO Market Operations. http://www.caiso.com/docs/2004/02/13/200402131607358643.pdf . Accessed May 15, 2014.

information, and analysis. A list of references that were consulted to collect this information can be found in Appendix E.

Due to the availability of information, the schedule, and the scope of the project some assumptions were needed.

- Since the Navigant team primarily used publicly available plans that have gone through a public vetting process of their data, analyses, and results, these plans were assumed to be valid, credible and defensible. Thus, no additional analysis on the part of the Navigant team was required of the data and results presented in these plans.
- It also is assumed that the IRWMPs relied upon by the Navigant team complied with DWR's guidelines available at the time the reports were prepared and are the best available regional assessments of water portfolios and future plans for a given region.[41]
- The marginal supplies identified by the Navigant team are the most likely supplies to be developed in the absence of conservation/efficiency efforts.
- Potable grade water is used for urban residential outdoor landscape irrigation.
- Developing specific projections of future water demand in the various Hydrologic Regions is outside the scope of this project. The Navigant team instead has relied on the future demand projections developed by DWR. DWR's methods and assumptions used for their scenario planning are well documented and publicly vetted.[42] It is assumed that these projections are appropriate for use and represent the best available information.

Recognizing that the marginal water supplies may change over time, the Navigant team initially identified two future timeframes. The Navigant team noted that the planning horizon for many of the documents consulted extended 20 years into the future, and the time required to develop certain infrastructure projects exceeds five years in many cases (i.e., large conveyance and storage structures, treatment facilities, etc.). Considering this information, the Navigant team initially defined a "near term" of 0 to 10 years and a "long term" of 11+ years. Through our research we found no differences between the near term and long term supply planning options being considered throughout the state.

***Expert Input and Public Vetting***

Based on the information gathered, a preliminary list was prepared of developed and future water supply options for each region. Using this preliminary list, the Navigant team requested feedback from water agency representatives and other experts to obtain additional input and insights used to refine the

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[41] For example, several IRWMPs consulted follow the 2012 Integrated Regional Water Management Guidelines for Proposition 84 and 1E (DWR Guidelines) published by DWR in November 2012.
[42] For more information regarding DWR's methods and assumptions, please see
http://www.waterplan.water.ca.gov/docs/cwpu2013/ae/future_scenarios-plan_of-study.pdf
http://www.lao.ca.gov/2008/rsrc/water_primer/water_primer_102208.aspx
http://www.acwa.com/news/delta/state-water-contractors-release-fact-sheet-comparing-economic-analyses-bdcp
http://westernfarmpress.com/irrigation/california-s-water-supply-and-demand

list of supplies. The Navigant team then presented this information at a public workshop held by the CPUC on April 25, 2014, to gather more input and address participants' comments. This appendix incorporates this input and presents the Navigant team's marginal water supply determination for inclusion in the Water/Energy Cost Effectiveness Framework. Table B-2 provides a listing of the organizations these individuals represent.

**Table B-2: Organizations Providing Input**

| Organizations |
|---|
| San Diego County Water Authority |
| Sonoma County Water Agency |
| Eastern Municipal Water District |
| Victor Valley Wastewater Reclamation Authority |
| Inland Empire Utility Agency/ Association of California Water Agencies |
| California American Water |
| Metropolitan Water District |
| USD Law |
| UC Santa Barbara |
| UC Davis |
| Natural Resources Defense Council |
| California Farm Bureau |
| Office of Ratepayer Advocates |
| US EPA Region 9 |
| Department of Water Resources |

## *B.3 Findings*

Based on the materials reviewed and input from the interviews and public workshop, the Navigant team identified several factors that influence the choices made by water managers regarding their regional supply portfolios. In addition, the Navigant team observed trends among the regions and conditions that dictate future water supply options. Using this information, the Navigant team compiled the list of water supplies relied upon in each region.

Several factors influence the types of water resources developed as part of a region's water supply portfolio. These include, but are not limited to:

- Demand and end use application of the developed water (agricultural, industrial, commercial, institutional, residential)
- Location and availability of the water supplies
- Quality of the water supply and associated treatment requirements

- Costs (including extraction, conveyance, transfer/exchange, treatment, and delivery costs)
- Regulations and legal restrictions

As a result of these factors, water managers tend to develop initially those resources that are the best quality, locally available, and the least costly. Not surprisingly, those resources that require the most amount of treatment and have the highest associated costs tend to be developed last for both urban and agricultural uses. This is true for local supplies such as recycled or reclaimed water, brackish or contaminated groundwater, and saline surface supplies like ocean water.

***Demand Drives Water Resource Development***

The California Department of Finance projects California's population to increase from 38 million in 2013[43] to more than 52 million by 2060, tipping the 50 million mark in 2049.[44] This growth is expected to occur mostly in California's urban centers, putting pressure on the state's agriculture sector. According to DWR, water use by agriculture is expected to decrease over time while urban uses are expected to increase as population grows.[45] Urban uses tend to require higher quality resources, with water supplied to urban customers treated to potable standards, even if the end use doesn't require potable water.[46]

California's water demand tends to vary over time, influenced by water year type (wet, dry, average, etc.), location (inland or coastal), and end use. Even with current conservation and efficiency efforts, population growth is likely to increase urban water demand and increase the tension between urban and agricultural use in some regions.[47] Water demand is highest during the driest years, driven mostly because of irrigation (both urban and agricultural) requirements.[48] Storing water in wet years to meet demands during dry years is a common RMS.

DWR developed a series of scenarios as part of the *California Water Plan* process to identify potential future water demand. Table B-3 presents DWR estimates for future agricultural and urban demand statewide and the ten Hydrologic Regions under different urban growth and climate change scenarios. Water resource managers use this type of information to develop their plans and implement strategies to meet projected demands.

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[43] Department of Finance, December 12, 2013 Press Release. Downloaded April 14, 2014. http://www.dof.ca.gov/research/demographic/reports/estimates/e-2/documents/E2_press_release_Jul2013.pdf
[44] Department of Finance, January 31, 2013 Press Release. Downloaded April 14, 2014. http://www.dof.ca.gov/research/demographic/reports/projections/P-1/documents/Projections_Press_Release_2010 to 2060.pdf
[45] DWR 2013.
[46] Urban water uses can include: residential landscape; large landscape; indoor residential (toilets, showers, leaks, faucets, clothes washers, etc...); commercial, institutional, and industrial and other, unspecified uses.
[47] Hanak, Ellen. January 2014. "*California's Future: Water*", Public Policy Institute of California.
[48] California Legislative Analyst's Office. 2008. "California Water: An LAO Primer", October 2008.

**Table B-3: Ranges of California's Projected Water Demand**

| Hydrologic Regions | Historical Average (TAF) 1998-2005 (Ag) | Historical Average (TAF) 1998-2005 (Urban) | Demand Range (TAF) 2043-2050 (Ag) | Demand Range (TAF) 2043-2051 (Urban) |
|---|---|---|---|---|
| North Coast | 748 | 149 | 571 - 808 | 145 - 228 |
| San Francisco | 121 | 1,066 | 93 - 135 | 1,033 – 1,844 |
| Central Coast | 1031 | 271 | 766 - 995 | 299 - 487 |
| South Coast | 786 | 3,846 | 351 - 605 | 3,716 – 6,058 |
| Sacramento River | 7,493 | 838 | 6,928 – 8,083 | 1,118 – 1,831 |
| San Joaquin | 6,347 | 589 | 5,100 – 6,057 | 966 – 1,439 |
| Tulare Lake | 9,466 | 676 | 8,069 – 9,241 | 957 – 1,479 |
| North Lahonton | 432 | 38 | 398 – 464 | 32 – 70 |
| South Lahonton | 348 | 231 | 289 – 644 | 304 – 653 |
| Colorado River | 3,489 | 494 | 1,718 – 1,890 | 510 - 847 |
| Statewide | 30,261 | 8,197 | 24,381 – 28,237 | 9,239 – 14,903 |

### *Regional Water Supply Options*

In each region of the state, local, high-quality (fresh) surface water supplies are typically the first-choice supply and significant infrastructure has been put in place to capture and store these supplies (including storm water, flood flows, and run-off). When possible these local supplies are augmented by imports of other surface water supplies through intra- and inter-basin transfers. Imported resources can also be used to reduce the amount of local groundwater that needs to be pumped and, when possible, may be used to add to the local stored supplies (both groundwater and surface). For example, the State Water Project (SWP) water contractors routinely request delivery of their full allotments regardless of availability of local surface or groundwater supplies. This imported water allows these contractors to displace the use of and, whenever possible, recharge of local groundwater.[49]

Nearly 40 percent of California's overall water demand is met by groundwater (see Appendix B); during dry years this percentage is as much as 60 percent. Unfortunately, groundwater in California is largely unregulated and supplies in many parts of the state are over-drafted.[50] As a result of conflicts between groundwater users in these regions, 22 groundwater basins are adjudicated where the courts have decided those that can extract from the basins, how much each can extract and who will oversee these extractions.[51, 52] Recent reports draw attention to these issues and make several recommendations to address the threats to groundwater supplies.[53]

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[49] Lin, Jin Lu. April 24, 2014. DWR. Personal Communication.
[50] Groundwater Resources Association of California. March 23, 2006. "California Groundwater Management," Second Edition, p.9.
[51] Public Policy Institute of California. "California Water" Part I, p. 78. http://www.ppic.org/content/pubs/report/R_211EHChapter2R.pdf. Accessed May 15, 2014.

Use of lesser-quality water supplies, whether surface or groundwater, requires treatment prior to most urban uses, but these supplies may be of sufficient quality for direct agricultural applications. As regional water supply portfolios expand to include more types of sources, water managers can work with customers to better match the quality of supplies to specific end uses (also referred to as supply switching). As a result, some resource managers are using degraded supplies for non-potable uses, such as agriculture or industrial processes, to reserve the higher quality supplies for potable uses. However, even some poor quality supplies require some degree of treatment regardless of end uses. This is especially true of brackish and ocean water supplies that require treatment for both urban and agricultural use.

***Imported Water Supplies Resources***

All but two Hydrologic Regions import surface water supplies to supplement regional supplies. Primary sources for these imported water supplies exchanged among regions include the Colorado River (Southern California), Sacramento-San Joaquin River Delta (most regions south of the Delta), Sierra Nevada/Hetch Hetchy Reservoir (Bay Area), and Owens River Valley (Los Angeles). As much as 60 percent of Southern California's water supply is imported. However, these supplies are increasingly constrained and at risk because of ecosystem deterioration, hydrologic conditions, regulatory requirements (particularly those related to water quality and endangered species), and aging infrastructure.[54] As seen in Figure B-2, these constraints have had a significant impact on the reliability of State Water Project deliveries in recent years. These constraints and risks are likely to continue to make these resources less reliable in the future.

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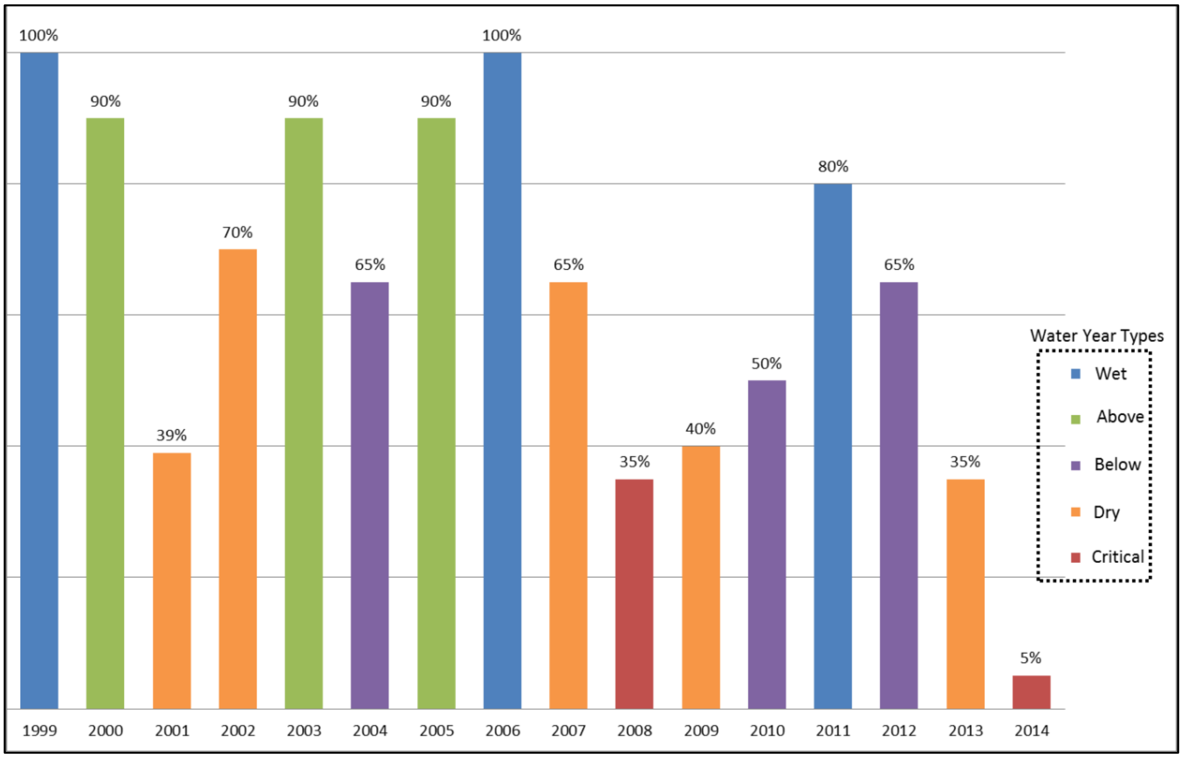
[52] DWR, http://www.water.ca.gov/groundwater/gwmanagement/court_adjudications.cfm. Accessed May 23, 2014.
[53] Water in the West. April 2014. "Before the Well Runs Dry: Improving the Linkage Between Groundwater and Land Use Planning." A joint program of the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West.
[54] Freeman, Gregory. January 2008. "Securing Reliable Water Supplies for Southern California," Los Angeles County Economic Development Corporation. Prepared for the Southern California Leadership Council Future Issues Committee.

**Figure B-2: State Water Project Allocations 1999-2014[55],[56]**




***State Water Resources Control Board's Recycled Water Policy***

As discussed above, approximately half of the precipitation that falls in California makes its way directly to the ocean or evaporates without first being exploited for urban or agricultural use. In addition, most of California's treated sanitary wastewater is discharged to rivers and streams despite options to re-use or recycle these local supplies.

In 2013, the State Water Resources Control Board (SWRCB) adopted an amendment to the Recycled Water Policy to reduce demands on imported supplies and encourage local water managers to take full advantage of locally available water supplies to enhance local reliability and resiliency. As stated in the revised policy, the SWRCB "strongly encourage(s) local and regional water agencies to move toward clean, abundant, local water for California by emphasizing appropriate water recycling, water conservation, and maintenance of supply infrastructure and the use of storm water (including dry-weather urban runoff) in [salt/nutrient management] plans; these sources of supply are drought-proof, reliable, and minimize our carbon footprint and can be sustained over the long-term."[57]

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[55] Leahigh, John. October 2013. "State Water Project Operations Outlook for 2014", DWR. Presentation.
[56] DWR. Notice to State Water Project Contractors. Number 14-07, April 18, 2014. http://www.water.ca.gov/swpao/docs/notices/14-07.pdf. Accessed April 29, 2014.
[57] SWRCB. Amended April 25, 2013. Policy for Water Quality Control for Recycled Water. p. 1.

To meet these goals, the SWRCB established specific targets for the increased development of sanitary wastewater recycling – more than two million acre-feet a year by 2030 – and increasing the local capture and use of storm water by at least one million acre-feet by 2030.[58] Local water managers are modifying their approach to the management of storm water locally, seeking not to merely move the water downstream as efficiently as possible, but to capture and retain these supplies locally through expansion of reservoirs and additional groundwater recharge programs.

***Desalination***

Advances in treatment technologies have made less traditional sources of water supplies, such as wastewater and brackish or saline water, a more viable option in many parts of California. More than 20 brackish groundwater facilities are located in California, with the majority located in the greater Los Angeles area (see Figure B-3). DWR reports that as many as 20 additional facilities are planned to be constructed by 2040. Most of California's current ocean water desalination supports non-potable uses, with only four facilities used for potable supplies.[59] Technological improvements, reduced reliability and availability of imported supplies, and pressures in the water market are making ocean water desalting more cost competitive (see Table B-4). As a result, interest in developing these sources is high (see discussion above regarding recycled water), with 15 ocean desalination projects proposed along California's coast[60] and one under construction in San Diego County.

[58] Ibid.

[59] DWR. December 2013. *California Water Plan Update 2013*, Volume 3, Chapter 10, p. 10-14 &15

[60] Pacific Institute. May 2013. "Key Issues in Seawater Desalination in California: Energy and Greenhouse Gas Emissions", http://pacinst.org/publication/energy-and-greenhouse-gas-emissions-of-seawater-desalination-in-california/. Accessed April 14, 2014.

**Figure B-3: Existing Brackish and Sea Water Treatment Facilities[61]**


**Table B-4: Cost Comparison of Water Supply Options – San Diego[62]**

| Water source | Cost per acre-foot |
|---|---|
| Imported water | $875-$975 |
| Surface water | $400-$800 |
| Groundwater | $375-$1,100 |
| Desalinated water | $1,800-$2,800 |
| Recycled water | $1,200-$2,600 |

***California's Water Supplies by Hydrologic Regions***

**General Observations**

After gathering and reviewing numerous resources, the Navigant team made several observations:

[61] DWR. December 2013. *California Water Plan 2013,* Volume 3, Chapter 10. Public Review Draft. Figure 10-5.

[62] Equinox Center. July 2010. "San Diego's Water Sources: Assessing the Options". http://www.equinoxcenter.org/assets/files/pdf/AssessingtheOptionsfinal.pdf. Accessed April 29, 2014.

- Water managers use a portfolio approach to optimize diverse water supplies available to them considering many factors which they face.
- Types of water supplies common to all regions include surface (rivers, reservoirs) and groundwater (fresh, high quality), and wastewater supplies that are being recycled or reclaimed to some degree. Additional types of water supplies that may be available to certain regions can include imported water supplies (State Water Project, Central Valley Project, and the Colorado River); treated brackish and contaminated groundwater; and ocean desalination.
- Water resource managers tend to develop water portfolios through the use of a variety of strategies to maximize the beneficial uses of water supplies available to them.
- Water resource managers are implementing more RMS aimed at maximizing the use of local supplies such as recycled water and storm water. These strategies include intra- and inter-basin transfers of surface water supplies primarily, and groundwater to the extent possible; developing and expanding conjunctive use and groundwater banking programs to maximize surface and groundwater supplies simultaneously; and developing new and expanding existing reclaimed/recycled wastewater resources (starting from secondary treatment levels in most cases).
- Brackish water supplies (mostly brackish groundwater) are commonly desalted to augment fresh water supplies, mostly in Southern California, with several regions planning to significantly increase development of these supplies.[63]
- Ocean/sea water is desalted today in the Central Coast and South Coast regions for potable and non-potable water supplies. A large desalination plant is under construction in the South Coast Region with plans to begin delivery of potable water to the San Diego area in 2016. A couple of inactive operational facilities exist along the coast and can be activated if needed, especially under drought conditions. Several water agencies are considering the construction of additional plants to meet future water demands, although the size, timing, and likelihood of development remains uncertain.[64]
- All regions reported the need for making their systems more sustainable and included projects such as above-ground storage tanks, new wells, and additional distribution lines to support required water services to customers.

**Current Water Supply Portfolios**

The current water supplies relied upon by the various Hydrologic Regions are listed in Table B-5. The order in which these supply types are listed appears to be the order in which these regions generally develop these resources. Those supplies towards the end of the list for a given region tend to be the most expensive and are needed to meet growing demand in the face of constraints on more traditional supply options.

[63] DWR. December 2013. *California Water Plan Update 2013*, Chapter 10. Public Review Draft.
[64] Ibid.

**Table B-5: Hydrologic Region Water Supply Portfolios**

| Hydrologic Region | Water Supply Types |
|---|---|
| North Coast | Surface Water (includes Storm water)<br>Groundwater<br>Recycled/Reused Water* |
| San Francisco Bay | Surface Water (includes Storm water)<br>Imports<br>Groundwater<br>Recycled/Reused Water*<br>Brackish Surface and Groundwater* |
| Central Coast | Surface Water (includes Storm water)<br>Imports<br>Groundwater<br>Recycled/Reused Water*<br>Brackish Groundwater*<br>Ocean/Sea Water* |
| South Coast | Surface Water (includes Storm water)<br>Imports<br>Groundwater<br>Recycled/Reused Water*<br>Brackish Groundwater*<br>Ocean/Sea Water* |
| Sacramento River | Surface Water (includes Storm water)<br>Imports<br>Groundwater<br>Recycled/Reused Water* |
| San Joaquin River | Surface Water<br>Imports<br>Groundwater<br>Recycled/Reused Water*<br>Brackish Groundwater* |
| Tulare Lake | Surface Water (includes Storm water)<br>Imports<br>Groundwater<br>Brackish Groundwater*<br>Recycled/Reused Water* |
| North Lahontan | Surface Water (includes Storm water)<br>Groundwater<br>Recycled/Reused Water* |

| Hydrologic Region | Water Supply Types |
|---|---|
| South Lahontan | Surface Water<br>Imports<br>Groundwater<br>Recycled/Reused Water* |
| Colorado River | Surface Water (includes Storm water)<br>Imports<br>Groundwater<br>Recycled/Reused Water*<br>Brackish Groundwater* |

*Candidates for Marginal Supply

As previously discussed the findings in Table B-5 were discussed with the organizations listed in Table B-2. Questions asked of the organizations included:

- Are the supply options listed in the table representative of the various Hydrologic Regions' water supply portfolios being used or planned to be used for both near term and long term timeframes in your opinion?
- Is the order in which the supply options listed roughly the order in which a region would choose to develop or expand its water resources portfolio? Is this order consistent with your agency's approach? If not, what is the ordering of the supply development options you pursue?
- What are your region's contingencies, not including conservation or efficiency for new water supplies?
- What water supply source would you most likely avoid developing if you could in your Hydrologic Region?

## *B.4 Future Regional Marginal Water Supplies*

To a large extent, current water supply portfolios reflect the future water supply portfolios water resource planners and managers will support both in the near and long-term futures for a given Hydrologic Region.

At the April 25th workshop the Navigant team presented draft selections of marginal supplies for each hydrologic region in California. After receiving additional input from parties via verbal and written comments, as well as guidance from the CPUC, the Navigant team recommends that a default marginal water supply of recycled water (wastewater treated to tertiary, unrestricted standards) be used in the model for all hydrologic regions in California. In addition, the Navigant team concurs with stakeholder comments that the functionality of a "resource balance year" approach (similar to that used in energy avoided cost calculations) should be incorporated into the model to enable future updates.

Using recycled wastewater as the default proxy marginal supply is reasonable based on several facts. All regions currently are developing and have available recycled water supplies. Although the predominant use of these supplies currently is irrigation (even used to augment agricultural supplies), these supplies are approved for numerous other non-potable uses. Many agencies include recycled wastewater as a key element of their future supply portfolios. Recycled water is a more conservative supply option than ocean water which addresses concerns raised by some stakeholders who question the availability of treated ocean supplies to more inland coastal agencies. Lastly, recycling of wastewater is consistent with the SWRCB goals which encourage water agencies to significantly increase development and use of these supplies.

When recycled water is used for non-potable end uses it can displace potable or raw water that was previously serving that end use. The displaced potable water can be used to increase supply available to potable end uses; the displaced raw water could be treated further for potable uses. Thus developing a recycled water supply can still increase the amount of supply available for potable end uses.

The Navigant team supports incorporating the functionality of a resource balance year approach for several reasons. Incorporating the functionality addresses concerns raised by stakeholders regarding the use of the projects initial definition of "near" (0-10 years) and "long" (10-20 years) run time frames and the concern that new capacity may not be need immediately. Allowing users to conduct analysis for a selected marginal supply also addresses concerns about the short and long run marginal supplies essentially being the same for the hydrologic regions.

Water agencies use a portfolio management approach with regard to their available supplies. At any point in time, these agencies must consider numerous factors and conditions to maximize the beneficial use of any supplies available to them. As explained in the report, these available supplies are essentially the same over time - it is only the degree to which, in any given year, a supply is developed based on these considerations.

***General Discussion***

Most individuals interviewed believe that the water portfolios listed in Table 6 appear reasonable and accurate. Several water managers confirmed that all reasonably cost-effective water supplies in a given region are developed to meet demands. It is the degree to which any one of these resources will be relied upon in the future that is likely to change. For example, as demand grows, and surface and groundwater resources are increasingly constrained in the San Diego area of the South Coast region, the degree to which this region depends on non-traditional supplies like recycled water, treated degraded groundwater, and ocean desalination will increase.[65]

Interviewees also mentioned that depending on the water year (wet or dry) the relative reliance on existing supplies listed may change. For example, regions such as South Coast, Tulare Lake, San Joaquin, and South Lahontan tend to use imported water before groundwater. As imported supplies become more constrained, these regions may have no choice, but to increase reliance on available groundwater supplies, especially degraded and brackish resources. Some regions such as the Central Coast and Colorado River may not have access to imported supplies in the 10 to 20 year timeframe and are thus

[65] Swanson, Lori and Toby Roy. April 23, 2014. Personal Communication. San Diego County Water Authority.

seeking ways to increase local supplies. Regardless of the degree to which relative reliance on existing supplies changed for the more traditional water resources, the marginal water supply (the next increment of water supply developed) did not change.

The Navigant team was also encouraged to call out storm water as a separate water supply[66]; however, as discussed earlier in this report, storm water replenishes the state's surface and groundwater resources and is therefore already counted as part of these resources. In addition, several standard RMS already exist to either increase the amount of precipitation a region may receive (i.e., cloud seeding) or the amount that is captured and stored locally (surface and groundwater storage, limits on hardscape, or treat and reuse storm flows). These strategies seek to increase local supplies by capturing and storing additional storm water which currently may be going to a salt sink or out to the ocean. As a result, the Navigant team believes these resources are appropriately considered part of the surface water supplies.

***Regional Details***

The following sections detail the Navigant team's regional findings. The statewide default assumption of the marginal supply (tertiary treated recycled water) holds as a reasonable proxy for new supply across all regions. While recycled water is being developed across all regions in California, the following regional discussions indicate a few regions are also considering other supply options beyond recycled water. We present the findings to support scenario analysis at a regional level and future discussions about marginal supply selections.

**North Coast**

Total water supplies for the region are estimated at one million acre-feet per year, with 35 percent of this supply developed from groundwater resources. Several communities are producing recycled water from their sanitary wastewater to help meet demand. Currently, the North Coast Regional Water Quality Control Basin (RWQCB) Plan requires tertiary treatment of discharges to the Russian River and restricts discharges to other rivers to protect water quality.[67] Recycled water is used for agriculture, golf courses, landscaping, and to recharge The Geysers steam fields in Sonoma and Lake counties.[68] The North Coast IRWMP calls for increased development of recycled and reclaimed wastewater to meet future demand and to help resolve environmental management challenges. The region expects to have sufficient local resources to meet future demand in the near and long-term with its current water portfolio; there are no plans to import water supplies or develop any brackish or ocean water sources in the foreseeable future.[69]

**San Francisco Bay**

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[66] Public comments, April 25, 2014. CPUC public workshop.

[67] North Coast Regional Water Quality Control Board. May 2011. Water Quality Control Plan for the North Coast Region.

[68] DWR. December 2013. *California Water Plan Update 2013*, Volume 2 – Regional Reports, North Coast. Public Review Draft.

[69] North Coast Regional Partnership. July 2007. *North Coast Integrated Regional Water Management Plan: Phase 1*. Del Norte, Humboldt, Mendocino, Modoc, Siskiyou, Sonoma and Trinity Counties.

Approximately 70 percent of the San Francisco Bay region's water supply is imported from the Bay-Delta or the Sierra Nevada Mountains (Tuolumne and Mokelumne river supplies). To reduce the demand for imported supplies, local water managers are implementing projects to boost local supplies. These projects include recycling of wastewater, collection and storage of storm water, and desalting of brackish groundwater.[70,71] The region is projecting the need to continue to develop these types of local supplies to ensure reliability and resiliency in the face of uncertain imported supply availability and growing demand.[72] As stated in the region's IRWMP, "(a)s a high-quality, drought-proof local supply, desalination is an increasingly competitive water supply alternative for Bay Area Region water agencies." Regional water managers are considering additional regional desalination projects using the brackish Bay waters as the primary source to improve water supply reliability in the future. For example, the Bay Area Water Supply and Conservation Agency (BAWSCA) is conducting a Brackish Groundwater Field Investigation Project (Brackish Groundwater Project) which is evaluating the use of brackish surface water desalination to provide additional supplies for the Bay Area.[73]

**Central Coast**

Approximately 83 percent of the Central Coast Regions water supply comes for groundwater. The region is also dependent on imported surface water supplies. Small amounts of recycled wastewater are also available and currently ocean water is desalted to meet a small portion of the non-potable water demand, as mentioned earlier in this report.[74]

All of the sub-regions in the Central Coast Region are using or exploring additional desalted ocean water to address increase water demands due to population growth, constraints on existing supplies from the Carmel River, and reduced opportunities for new water imports.[75] For example, the City of Santa Barbara owns a desalination facility that can be brought into operation if needed during severe drought or water shortage conditions; the high costs for desalination, and the time needed to bring the plant into operation, make the desalination plant the last supply option to be used during drought periods.[76] The City of Morro Bay, on the other hand, operates an ocean water and brackish groundwater treatment facility to augment local supplies and is actively pursuing energy recovery technologies that could lower the operational and maintenance costs from approximately $1,700 an acre-foot to approximately $1,200

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[70] Kennedy/Jenks Consultants. September 2013. *San Francisco Bay Area Integrated Regional Water Management Plan*.
[71] DWR. December 2013. *California Water Plan Update 2013*, Volume 2 – Regional Reports, San Francisco Bay. Public Review Draft
[72] Reinhard, M. et al. (2008). "Evaluation of Reverse Osmosis for Brackish Groundwater Desalination at Gilroy and Hollister, CA." Final Report submitted to Santa Clara Valley Water District, August 2008.
[73] Kennedy/Jenks Consultants, et al. September 2013. *San Francisco Bay Area Integrated Regional Water Management Plan*.
[74] DWR. December 2013. *California Water Plan Update 2013*, Volume 2 – Regional Reports, Central Coast. Public Review Draft.
[75] Robinson, Susan. February 22, 2008. *Comparison of the Six Central Coast Integrated Regional Water Management Plans and Recommendations for Collaborative Programs.*
[76] RMC Water and Environment, Dudek, and GEI Consultants, Inc. 2013. *The Santa Barbara County Integrated Regional Water Management (IRWM) Plan 2013.* Prepared for the Santa Barbara County Water Agency.

an acre-foot.[77][78] In 2010, Sand City's Coastal Desalination Plant began producing potable water for the city's supply. The plant is capable of producing as much as 300 AFY using reverse osmosis technology.[79,80] The San Luis Obispo IRWMP update includes a project to study desalination options to boost local supplies.[81]

**South Coast**

Numerous water supply challenges face the South Coast Region and have resulted in a history of water managers leveraging all available supplies. Recognizing that surface water supplies are likely to decrease over time while demand increases, the region is implementing strategies to reduce their dependency on imported water supplies and boost local supplies. Even with conservation and efficiency, the region has set aggressive targets for increasing recycled water production, storm water capture, and ocean water desalination.[82] Groundwater accounts for approximately 28 percent of the total water supplies for the region and active conjunctive use programs are needed to address issues of overdraft and declining water quality. Currently, recycled wastewater helps to offset non-potable water demands, predominately for agriculture and landscaping. However, Orange County has been injecting highly treated recycled water into their local aquifer to combat salt water intrusion and augment the potable groundwater supplies.[83] The region already has several groundwater desalters that are needed to supplement potable supplies and prevent the migration of brackish groundwater to areas of higher groundwater quality. [84] Additional investments in desalting facilities are planned.[85]

Currently, a $1 billion ocean water desalination facility is under construction in the City of Carlsbad and is expected to provide the region with approximately 50 million gallons of water daily. The availability of the desalinated water is expected to address diminishing imported water supplies and significantly boost the reliability of local water supplies.[86] By reducing the dependency of imported water in various

[77] DWR. December 2013. *California Water Plan Update 2013*, Volume 2 – Regional Reports, Central Coast. Public Review Draft.
[78] Hemping, Ashley 2011. "Economic Analysis of Reverse Osmosis Desalination of Water for Agricultural Irrigation Applications," California Polytechnic State University. March 2011.
[79] "Sand City Coastal Desalination Plant" (2014). water-technology.net is a product of Kable. Copyright 2014 Kable, a trading division of Kable Intelligence Limited. Accessed June 9, 2014.
[80] City of Sand City. (2014) "Sand City Water Supply Project" http://www.sandcity.org/News_and_Events/Sand_City_Water_Supply_Project.aspx Accessed June 9, 2014.
[81] San Luis Obispo IRWMP Update: Full Project List Finalized. Volume 5, October-December 2013. http://www.slocountywater.org/site/Frequent%20Downloads/Integrated%20Regional%20Water%20Management%20Plan/IRWM%20Plan%20Update%202014/pdf/SLOC%20IRWMP%20Vol%205%20Brochure%20d10.pdf. Accessed March 17, 2014.
[82] Santa Ana Watershed Project Authority (SAWPA). 2014. "One Water One Watershed (OWOW) 2.0 Plan: the Integrated Regional Water Management Plan for the Santa Ana River Watershed". Adopted February 4, 2014.
[83] Environmental Protection Agency (2014). "Water Recycling and Reuse: The Environmental Benefits" http://www.epa.gov/region9/water/recycling/. Accessed June 9, 2014.
[84] DWR. December 2013. *California Water Plan Update 2013*, Volume 2 – Regional Reports, South Coast. Public Review Draft.
[85] SAWPA 2014.
[86] http://carlsbaddesal.com/. Accessed March 17, 2014.

communities in the South Coast, the water managers can use transfers and exchanges to address demands in other portions of the region.

**Sacramento River**

The Sacramento River Region relies predominately on surface and groundwater to meet its water needs. However, with increasing demands and concerns regarding the long-term sustainability and reliability of these supplies, the region is pursuing additional water supplies. These efforts include expanding the development of recycled water supplies and seeking additional applications and markets for these supplies. The region is also remediating contaminated groundwater for re-use to the extent possible.[87, 88]

**San Joaquin River**

Water demand in the San Joaquin River Basin is dominated by agriculture. Local surface water supplies are insufficient to meet demand so the region imports water through state and federal programs. These supplies also support the conjunctive use programs and groundwater storage in the region.[89] Certain communities in the region are treating wastewater to tertiary standards to comply with waste discharge requirements, making this supply more attractive for recycling and re-use. As a result, increased production of recycled water is a key part of the region's efforts to increase local water supplies.[90] Other resources, such as brackish or saline supplies, are not considered practical supply options for the region in the foreseeable future.

**Tulare Lake**

Increasing demand and reduced imported supplies have significantly intensified the competition for available water supplies in the Tulare Lake Region. This coupled with declining groundwater levels has required increased dependence on alternate water supplies that require much more treatment, such as recycled water and degraded groundwater, and expanded interconnections among the agencies.[91] As a result, recycled wastewater has become an important part of the region's water supply. This supply is used to recharge groundwater and irrigate crops. Beginning in the 1980s, water districts in the region began receiving oil field produced water that they then blended to provide water of sufficient quality to be reused for groundwater recharge and irrigation purposes.[92] With constrained imported supplies, the region is now investigating cost-effective treatment methods to increase the amount of produced water that can be re-used to meet demands without relying on imported higher quality water supplies for blending. For purposes of this report, re-usable and recycled water supplies are classified together.

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[87] Regional Water Authority. 2013. *The American River Basin IRWMP – 2013 Update*.
[88] Yuba County IRWMP Water Management Group. February 2008. *Yuba County Integrated Regional Water Management Plan*.
[89] WRIME. July 2007. *Upper Kings Basin Integrated Regional Water Management Plan (IRWMP)*. Prepared for the Upper Kings Basin Water Forum and Kings River Conservation District.
[90] Nakagawa, Brandon P.E., et al. July 2007. *Eastern San Joaquin Integrated Regional Water Management Plan*. Prepared for the Northeastern San Joaquin County Groundwater Banking Authority.
[91] GEI Consultants, Inc. July 2007. *Poso Creek Integrated Regional Water Management Plan*.
[92] Kennedy/Jenks Consultants. November 2011. *Kern Integrated Regional Water Management Plan*.

### North Lahontan

Characterized by the smallest population of the 10 Hydrologic Regions, the North Lahontan region is home to only 0.3 percent of the state's residents. With widespread forests and a short growing season, the primary agricultural activity is cattle ranching. The region expects to have sufficient local resources to meet future demand in the near and long-term with its current water portfolio, consisting primarily of surface and groundwater and limited recycled water production.[93]

### South Lahontan

Nearly a million people live in the South Lahontan Region, a region that has shown steady growth over the last decade concentrated mostly in its southern portion. With its arid climate, the South Lahontan region relies on surface and groundwater, imported, and recycled water supplies to meet the water needs of its communities and irrigated agricultural lands. Recycled water uses are increasing, providing needed water for groundwater recharge as well as for landscape irrigation. In the future, the demand for recycled water is expected to increase as fresh water supplies (especially imports) become more constrained and new uses, such as equipment cooling, and existing uses expand.[94]

### Colorado River

The Colorado River and groundwater are the primary supplies for the Colorado River Region.[95] Other supplies include a small amount of imports from the Delta and recycled water. Water resource managers in the Colorado River Region anticipate significant increases in overall water demand as a result of population growth despite per capita demand reductions required under state law and increased development of energy projects in the area. Agricultural water use is decreasing in part due to fallowing programs and changes in land use. Water from the Colorado River is also used for groundwater recharge and banking efforts are expected to be increased. Additional recycled water supplies and desalination of irrigation drain water and brackish groundwater are identified strategies to provide needed supplies in the future.[96]

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[93] DWR. December 2013. *California Water Plan Update 2013,* Volume 2 – Regional Reports, North Lahontan. Public Review Draft.
[94] DWR. December 2013. *California Water Plan Update 2013,* Volume 2 – Regional Reports, South Lahontan. Public Review Draft.
[95] DWR. December 2013. *California Water Plan Update 2013*. Volume 2 - Regional Reports, Colorado River. Public Review Draft.
[96] GEI Consultants, Inc. October 2012. *Imperial Irrigation District's Integrated Regional Water Management Plan.*

# Appendix C Water System Component Cost Analysis

## *C.1 Introduction*

To prepare the estimates of avoided capacity costs, the Navigant team was required to estimate certain cost and operational information about the technologies employed to provide water service in California. The required information included the installed (capital) costs and the associated fixed operations and maintenance (O&M) costs.

The Navigant team evaluated information on the following components required to provide water service:

- Supply
- Potable Treatment
- Wastewater Treatment

The focus of past public workshops related to this project has been to select marginal supplies. In the absence of water efficiency, water supply capacity must be expanded; the expansion requires investment in the development of the marginal supply. Additional potable and wastewater treatment capacity will also be required. Thus water efficiency can avoid water supply and potable and wastewater treatment capacity investments.

The Navigant team did not analyze cost data on raw water conveyance, potable or recycled water distribution, or wastewater collection, as these components were determined to have an irrelevant avoided capacity cost.

- Few significant conveyance projects have been developed in the last several decades, and many of the water supplies anticipated in the future will not rely upon distant water supplies. In cases where a specific water supply project requires the construction of significant conveyance infrastructure the costs associated with the conveyance should be captured as the cost of supply when analyzing avoided costs. The few proposed conveyance infrastructure projects being developed are to primarily increase reliability of existing supplies and not necessarily to increase capacity of conveyance.
- Investment in systems used to distribute potable and recycled water as well as those used to collect wastewater is driven by interconnection of customers and not the demand / quantity of water delivered or collected. Distribution and collection systems are not primarily capacity driven and are considered relatively fixed. Thus, incremental reductions in water consumption will not avoid capacity investment in such systems.

To develop avoided costs, the Navigant team surveyed publicly available data to estimate capital and fixed O&M costs of water systems. We believe the public data sources we rely upon reasonably estimate the information required for our analysis. These costs will be used as inputs to the avoided water capacity cost model (illustrated in the model flow charts provided to the CPUC along with this report).

Recommended costs will serve as default inputs to the avoided water capacity cost model. These inputs can be modified by users to conduct additional scenario analysis. Similarly, the selections for marginal supply in each region will also serve as default inputs that can be edited by users.

The objective of this report is to identify the technologies, capital costs, and fixed O&M expenses associated with each marginal supply and treatment technology required to provide water service to customers. The rest of this section describes our methodology, Section 2 details our cost data analysis, and Section 3 provides recommended capital and fixed O&M cost values. This report is an update to the analysis presented at the July 1, 2014 public workshop. Verbal feedback obtained from stakeholders during the workshop requested additional detail and presentation of the cost data and methodologies.

**Identification of the Marginal Treatment Technology**

Avoided cost analysis requires determining the marginal supply as well as the marginal treatment technology. While the marginal supply is the source of water, the marginal treatment technology defines the system used to convert the supply into a useable product.

For example, one option for marginal supply is ocean water. Ocean water itself is not usable in its natural state; it must be processed and treated to remove salts and other impurities. There are several treatment technologies that can be used to process ocean water, including (but not limited to): reverse osmosis, forward osmosis, multi-stage flash distillation, and solar desalination. For the purposes of this analysis, the Navigant team selected one or two particular marginal technologies associated with each marginal supply. Marginal treatment technology decisions were made for ocean water, brackish groundwater, and recycled water supplies. Similarly, marginal technology decisions were required for potable and wastewater treatment plants.

The selected marginal treatment technologies are described in our results discussion. The Navigant team used its professional judgment, informed by our reviews of water agency capital improvement plans, to determine the appropriate marginal treatment technologies based on knowledge of current water system technologies and trends in the industry. To assist cost analysis, qualifying information about the technology used was collected. We present cost data only for the relevant marginal technologies.

**Data Collection**

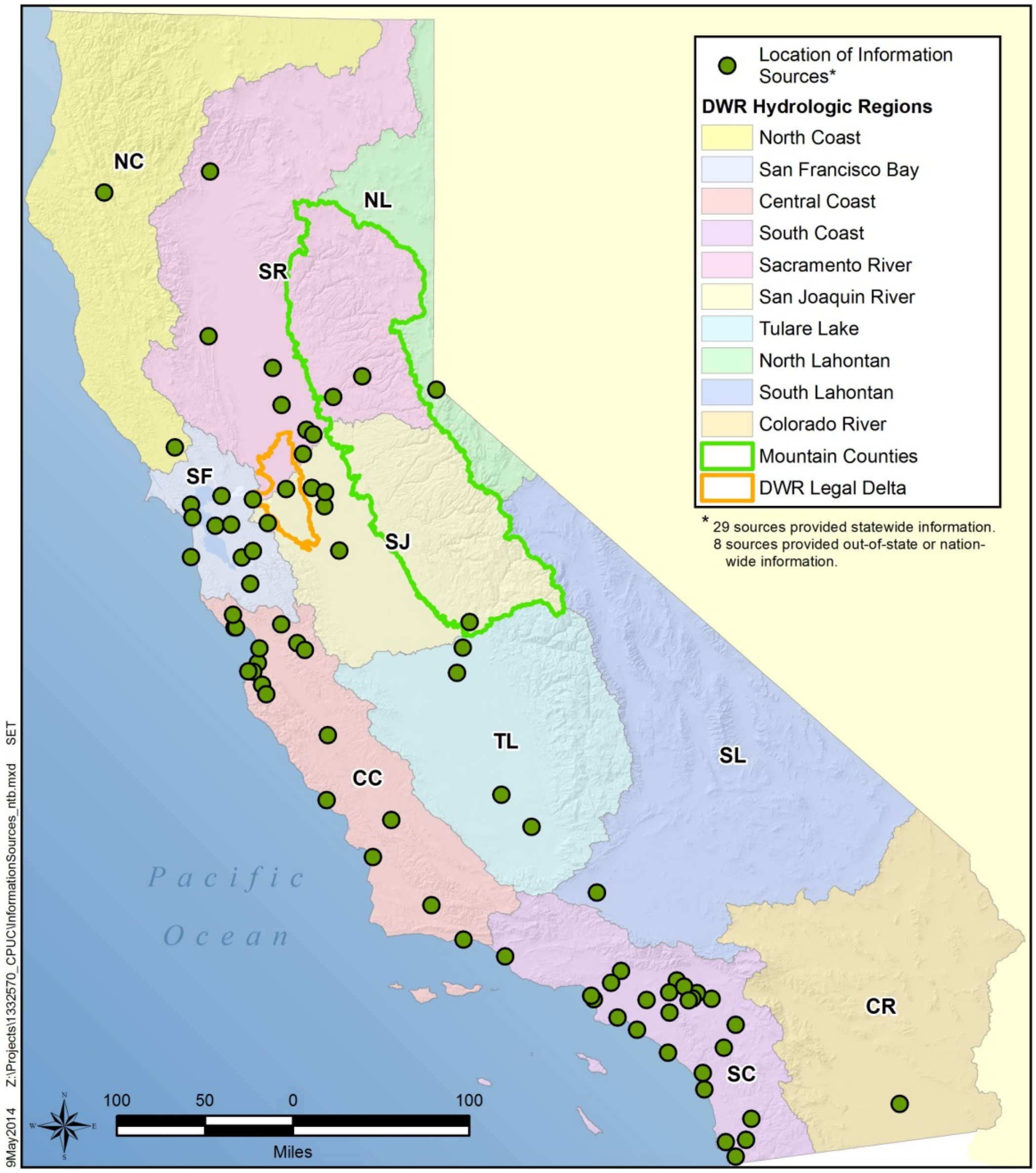
The Navigant team reviewed publicly available sources of information to collect capital and fixed O&M cost data. These sources ranged from Integrated Regional Water Management Plans (IRWMPs) and Capital Improvement Plans (CIPs) to state and local agency reports. Additional sources came from the California Department of Water Resources (DWR), Pacific Institute, U.S. Environmental Protection Agency (EPA), Public Policy Institute of California (PPIC), U.S. Department of the Interior Bureau of Reclamation (USBR), and California Public Utilities Commission (CPUC). The Navigant team gathered additional information from internet searches to fill in the cost data gaps that could not otherwise been obtained from the other resources.

The Navigant team's approach to data collection started off broad and was subsequently narrowed to review the most reliable resources, following these four steps:

1. Conduct a broad literature review for publicly available, free reports that contained water system cost data, ensuring that data is collected across all California hydrologic regions (see Figure C-1 for the locations represented by our data collection efforts)
2. Extract cost data from the reviewed sources and categorize by system component and region
3. Conduct quality assurance on collected data to determine those most complete, reliable, and relevant
4. Summarize the reliable, relevant data for each system component

To the extent possible, actual construction costs, publicly available engineering studies, and CIP estimates were favored and viewed as the most accurate data source. In the absence of such information, the Navigant team relied on other public sources (e.g., EPA reports, engineering firm case studies) to provide estimates of costs. A list of references that were consulted to collect this data can be found in Appendix E.

**Figure C-1: Regional Distribution of All Cost Data Sources**




Note: Each marker represents the location of a data set. Each data set may have contained one or multiple facilities from which the team collected cost data.

### Methodology for Analyzing Cost Data

The Navigant team extracted total capital cost as well as annual fixed O&M cost associated with each water system component from each reviewed data source. Additional information gathered for each component included description of technology, maximum capacity (i.e. MGD peak production), year of price estimate, and information on the specific items included or excluded in capital and fixed O&M costs.

Analysis of fixed O&M costs attempted to exclude the cost of energy where possible. Virtually all energy costs associated with the operations of these facilities is related to the output of the plant and therefore properly captured as avoided commodity costs as opposed to avoided capacity costs. The value of avoided energy consumption will be quantified by the avoided embedded energy portion of our analysis (discussed at the April 25, 2014 CPUC Water-Energy workshop). Energy costs must be excluded from avoided capacity analysis to avoid any double counting of energy benefits.

The publicly available cost data and associated detail in California's water industry is limited. Thus, in our data collection and analysis, several assumptions were needed:

- Lump sum costs represent overnight capital costs and do not include operations and maintenance costs unless otherwise specified.
- Permitting, environmental studies/mitigation, or financing costs were included in the cost data for both capital and fixed O&M, as appropriate.
- Cost estimates for demonstration facilities were generally excluded from our analysis, as they were deemed unrepresentative of real-world costs.
- Variations based solely on location for similar water infrastructure elements could not be discerned from the available data. We therefore assume a single average cost is representative of all regions in California.

Cost data were based on sources dated from 2003 to 2014. All cost data were brought to a common year (2013) for comparison purposes. Capital costs were adjusted using *Handy - Whitman Index of Public Utility Construction Costs*. The Navigant team specifically used the construction cost index for a Steam Production Plant for the capital cost adjustment. Fixed O&M costs were adjusted using the Gross Domestic Product Implicit Price Deflator.[97]

Our avoided cost analysis focuses on the avoided cost of capacity. This is consistent with CPUC avoided cost analysis for the electric sector in which the avoided cost of electric generation capacity (reported in $/Megawatt) is a key output. Capacity in our analysis is defined in terms of maximum daily production in million gallons per day (MGD). Observed water systems were of varying capacities. For the purposes of comparison, costs were normalized based on their capacity. Capital and fixed O&M costs were divided by the peak capacity of the facility. The resulting cost of capacity is reported in million dollars per million gallons per day ($M/MGD) for both capital and O&M cost. For example, a 10 MGD treatment plant that cost $50M to build and $1M/year to operate and maintain has a capacity cost of $5M/MGD and a fixed O&M cost of $0.1M/MGD.

Recommended capital and fixed O&M costs are weighted averages of observed facilities. Averages were weighted by total capacity (in MGD). The next section presents our observations and calculated weighted average costs.

[97] http://research.stlouisfed.org/fred2/series/GDPDEF/downloaddata

## *C.2 Cost Data Analysis and Results*

This section documents the costs associated with expanding capacity to supply and treat water. We focused our research on the components that have defined avoided costs and are likely candidates for the marginal supply for California's 10 hydrologic regions.

**Supply**

In a public workshop on April 25, 2014, the Navigant team discussed water supplies in great detail and identified draft marginal supplies for each hydrologic region in California. This report presents cost data collected for the draft marginal supplies as well as other supplies that could be likely candidates for the final marginal supplies. The following water supplies are available in California:

- Ocean water
- Brackish water
- Wastewater (feedstock for recycled water)
- Fresh groundwater
- Imported surface water
- Local surface water

The costs associated with developing ocean desalination, brackish desalination, and recycled water are largely associated with treatment systems. While some may categorize these as treatment facilities, we categorize them as supply facilities for the purposes of our analysis. In our observation of cost data, many of these facilities lumped extraction/intake costs along with treatment facility costs. The assignment of these facilities to the "supply" category is merely a matter of syntax; it does not affect the ultimate output of our analysis.

***Ocean Desalination***

Ocean Desalination is an option for marginal supply for the coastal regions of California. The Navigant team identified reverse osmosis as the marginal treatment technology and further defined the following data classes:

a. Small reverse osmosis facilities (less than 10 MGD)
b. Large reverse osmosis facilities (more than 10 MGD)

Table C-1 and Table C-2 provide summaries of the capital and fixed O&M costs collected for small and large ocean desalination facilities. Typical capital costs for both large and small ocean water desalination facilities include: land acquisition; design; permitting; construction and material costs for intake/outfall, pretreatment and residual handling, pumps, piping, desalination system, post-treatment, site structure;

legal fees; contingency allowance; and mitigation allowance. Typical O&M costs for both large and small ocean water desalination facilities include expendables, labor, and equipment replacement.[98]

The Navigant team recommends a weighted average of the costs of all six observed facilities in Table C-1 as the representative cost for small ocean desalination facilities. This results in a capital cost of $33.38M/MGD and annual fixed O&M costs of $0.79M/MGD. The Navigant team recommends a weighted average of the costs of all three observed facilities in Table C-2 as the representative cost for large ocean desalination facilities. This results in a capital cost of $16.23M/MGD and annual fixed O&M costs of $0.42M/MGD.

We find that the costs per unit capacity for large desalination facilities are lower than those of small desalination facilities. This is an expected trend as large facilities can take advantage of economies of scale in both capital and fixed O&M costs.

[98] Typical O&M costs also include the cost of energy; however, we have excluded the cost of energy from our analysis as previously discussed in this report.

**Table C-1: Summary Data for Small Ocean Desalination Projects**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SF | Marin Municipal Water District Desalination Project | 2007 | $111 | 5 | $22.24 | 123% | $27.39 | $3.25** | $0.65 | 110% | $0.71 |
| SC | Long Beach Ocean water Desalination Project | 2007 | $18.4 | 0.3 | $61.33 | 123% | $75.54 | | | | |
| CC | The Sand City Coastal Desalination Project | 2010 | $11.9 | 0.3 | $39.67 | 111% | $43.87 | $0.185 | $0.62 | 105% | $0.65 |
| CC | Monterey Peninsula Water Supply Project (MPWSP) | 2012 | $175 | 5.4 | $32.41 | 104% | $33.65 | $3.89** | $0.72 | 102% | $0.73 |
| CC | Deep Water Desalination Project | 2012 | $134 | 4.9 | $27.35 | 104% | $28.40 | $4.69** | $0.96 | 102% | $0.97 |
| CC | The People's Moss Landing Water Desalination Project | 2012 | $190 | 4.8 | $39.58 | 104% | $41.10 | $3.53** | $0.74 | 102% | $0.75 |
| | Average Weighted by Capacity | | | | | | $33.38 | | | | $0.79 |

*Energy is excluded from O&M costs

**These values have been adjusted to remove energy costs from annual fixed O&M costs. The Navigant team assumed energy costs represents 50% of total annual O&M costs for small ocean desalination facilities based on data from the Sand City Coastal Desalination Project.

**Table C-2: Summary Data for Large Ocean Desalination Projects**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SC | The Huntington Beach Desalination Facility | 2013 | $857 | 50 | $17.14 | 100% | $17.14 | $28.1 | $0.56 | 100% | $0.56 |
| SC | The Carlsbad Desalination Project | 2012 | $1,000 | 50 | $20.00 | 104% | $20.77 | $28.4** | $0.57 | 102% | $0.58 |
| SC | Camp Pendleton Ocean water Desalination Project | 2012 | $1,300 | 100 | $13.00 | 104% | $13.50 | $26.1** | $0.26 | 102% | $0.26 |
| | Average Weighted by Capacity | | | | | | $16.23 | | | | $0.42 |

*Energy is excluded from O&M costs

**These values have been adjusted to remove energy costs from annual fixed O&M costs. The Navigant team assumed energy costs represent 42% of total annual O&M costs for large ocean desalination facilities based on data from the Huntington Beach Desalination Facility.

***Brackish Desalination***

Brackish desalination is an option for the marginal supply for multiple regions in California. The Navigant team identified reverse osmosis as the marginal treatment technology and the following data classes for this supply:

a. Brackish groundwater extraction and reverse osmosis treatment
b. Brackish surface water diversion and reverse osmosis treatment

Typical capital costs for both brackish surface and ground water desalination facilities include design; permitting; construction and material costs for wells, intakes/outfalls, pumps, piping, desalination system, post-treatment, site structure; legal fees; and contingency allowance. Typical O&M costs for both brackish surface and ground water desalination facilities include expendables, labor, and equipment replacement.

Table C-3 provides a summary of the capital and fixed O&M costs collected for brackish groundwater desalination facilities. The Navigant team recommends a weighted average of the costs of all 13 observed facilities in Table C-3 as the representative cost for brackish groundwater desalination facilities. This results in a capital cost of $6.45M/MGD and annual fixed O&M costs of $0.48M/MGD.

Table C-4 provides a summary of the capital and fixed O&M costs collected for brackish surface water desalination facilities. The Navigant team recommends a weighted average of the costs of both observed facilities in Table C-4 as the representative cost for brackish surface water desalination facilities. This results in a capital cost of $5.77M/MGD and annual fixed O&M costs of $0.47M/MGD.

We find that the capital cost of brackish desalination is less than the cost for ocean desalination; however, fixed O&M costs are similar to those of brackish desalination plants when energy costs are excluded. This is an expected trend as ocean desalination facilities typically require more complex intakes and outfalls, higher permitting costs, and higher land costs. Fixed O&M costs are similar as both ocean and brackish water desalination facilities use similar treatment technologies, i.e., reverse osmosis.

A review of the data reveals that variations in costs (both capital and fixed O&M) can occur within and among hydrologic region. The Navigant team believes that the difference cannot be explained entirely by location and system size. Future investigation may be required to better understand the variations in the data. Items for future research (that cannot be answered by this study at this time) include:

- The effects of source water quality (i.e. salinity and TDS) on system costs
- The effects of extraction method (i.e. using surface or groundwater intakes and the as well as the depth to groundwater) on system costs;

Trends between total dissolved solids (TDS) and cost can be observed in the cases of surface diversion plants using a single point of diversion. This relationship is much harder to define for extracted brackish groundwater as systems use multiple wells with varying well depths. Based on the observed data, a reliable correlation between TDS and system cost could not be obtained.

**Table C-3: Summary Data for Brackish Groundwater Desalination Projects**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SC | Chino Basin (Chino Desalter I) | 2010 | $93.4 | 11.10 | $8.41 | 111% | $9.31 | | | | |
| SC | Chino Basin (Chino Desalter II) | 2010 | $59.0 | 10.60 | $5.57 | 111% | $6.16 | $13.4 | $1.26 | 105% | $1.33 |
| SC | Chino Basin (Phase 3) | 2010 | $111 | 10.60 | $10.43 | 111% | $11.54 | $6.00 | $0.57 | 105% | $0.60 |
| CR | East Brawley 25 KAFY Desalination with Well Field and Groundwater Recharge | 2012 | $112 | 22.00 | $5.11 | 104% | $5.30 | $6.34 | $0.29 | 102% | $0.29 |
| CR | South Salton Sea 50 KAF Desalination with Alamo River Water and Industrial Distribution | 2012 | $159 | 45.00 | $3.52 | 104% | $3.66 | $15.5 | $0.34 | 102% | $0.35 |
| CR | East Brawley 25 KAF Desalination with Well Field | 2012 | $100 | 22.32 | $4.50 | 104% | $4.67 | | | | |
| CR | East Mesa 25 KAF Desalination with Well Field | 2012 | $112 | 22.32 | $5.01 | 104% | $5.20 | | | | |
| CR | Keystone 50 KAF Desalination with Well Field | 2012 | $282 | 44.64 | $6.31 | 104% | $6.56 | | | | |
| CR | East Brawley 5 KAF Desalination with Well Field | 2012 | $24.8 | 4.64 | $5.33 | 104% | $5.54 | | | | |
| CR | Keystone 25 KAF Desalination with Well Field | 2012 | $161 | 22.32 | $7.20 | 104% | $7.48 | | | | |
| CR | Heber 5 KAF Desalination with Well Field | 2012 | $95.9 | 4.46 | $21.50 | 104% | $22.33 | | | | |

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CR | East Mesa 5 KAF Desalination with Well Field | 2012 | $33.0 | 4.46 | $7.41 | 104% | $7.69 | | | | |
| CR | South Salton Sea 5 KAF East Desalination with Well Field | 2012 | $62.2 | 4.46 | $13.94 | 104% | $14.48 | | | | |
| | Average Weighted by Capacity | | | | | | $6.45 | | | | $0.48 |

*Observed data did not indicate if energy costs were included or excluded from fixed O&M costs.

### Table C-4: Summary Data for Brackish Surface Water Desalination Projects

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SF | Bay Area Regional Desalination Project (BARDP) | 2014 | $169 | 10.00 | $16.85 | 98% | $16.43 | $10.4 | $1.04 | 98% | $1.01 |
| CR | Keystone Desalination with IID Drainwater/Alamo River Source | 2012 | $147 | 45.00 | $3.28 | 104% | $3.40 | $15.3 | $0.34 | 102% | $0.35 |
| | Average Weighted by Capacity | | | | | | $5.77 | | | | $0.47 |

*Observed data did not indicate if energy costs were included or excluded from fixed O&M costs.

***Recycled Water***

Recycled Water is an option for the marginal supply for multiple regions in California. The Navigant team identified the following marginal treatment technologies for this supply:

a. Tertiary treatment with disinfection
b. Membrane treatment (reverse osmosis) with disinfection

Tertiary treatment with disinfection has historically been used as the source of recycled water in California. Cost analysis for this technology only considers the incremental cost of constructing, expanding and operating tertiary treatment and disinfection systems at existing wastewater treatment plants. Costs do not consider secondary wastewater treatment or anything that precedes the secondary treatment process as these processes are required even if recycled water is not being produced by a facility.

Membrane treatment plants are increasingly being planned, constructed, and used in urban areas to increase recycled water production capacity. Cost analysis for this technology includes the incremental cost of constructing, expanding and operating membrane treatment and disinfection systems. Costs do not consider secondary wastewater treatment or anything that precedes the secondary treatment process.

Typical capital costs for both tertiary treatment and membrane treatment based recycled water facilities include design; permitting; construction and material costs for treatment processes (tertiary treatment or membrane treatment plus disinfection only), tanks, pumps, piping, and site structure; legal fees; and contingency allowance. Typical fixed O&M costs include expendables, labor, and equipment replacement.

Table C-5 provides a summary of the capital and fixed O&M costs collected for tertiary treatment with disinfection facilities. Navigant recommends using a weighted average of costs from the observed facilities in Table C-5 (excluding those noted in the table) as the representative cost for tertiary treatment with disinfection facilities. This results in a capital cost of $3.19M/MGD and annual non-energy O&M costs of $0.09M/MGD.

Table C-6 provides a summary of the capital and fixed O&M costs collected for membrane treatment with disinfection facilities. Navigant recommends using a weighted average of costs from the observed facilities in Table C-6 as the representative cost for membrane treatment with disinfection facilities. This results in a capital cost of $7.15M/MGD and annual non-energy O&M costs of $0.27M/MGD.

We find that costs per unit capacity of facilities using membrane treatment are lower than those of using tertiary treatment. This is an expected trend as membrane treatment equipment is a relatively new technology with the ability to produce higher quality recycled water while tertiary treatment is a well-established technology that produces lower quality recycled water. Membrane treatment equipment is also more expensive to maintain compared to tertiary treatment.

**Table C-5: Summary Data for Water Recycling Plants – Tertiary Treatment with Disinfection**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SR | Sacramento Regional County Sanitation District - Water Recycling Program | 2012 | $140 | 59 | $2.37 | 104% | $2.46 | | | | |
| SJ | Lodi Non-Potable Surface Water Distribution System | 2008 | $65.9 | 14.4 | $4.58 | 115% | $5.26 | $0.72 | $0.05 | 107% | $0.05 |
| SJ | North Valley Regional Recycled Water Program | 2011 | $96.0 | 54 | $1.78 | 107% | $1.90 | | | | |
| SL | Antelope Valley Recycled Water Project | 2005 | $119 | 25.7 | $4.63 | 135% | $6.24 | $3.45 | $0.13 | 116% | $0.16 |
| NC | Santa Rosa - Incremental Recycled Water Program (Recycled Water Master Plan) | 2006 | $265** | 27.4 | $9.67 | 129% | $12.51 | | | | |
| SC | Los Angeles Glendale Water Reclamation Plant (LAGWRP) | 2012 | $20.0 | 5 | $4.00 | 104% | $4.15 | | | | |
| | Average Weighted by Capacity | | | | | | $3.19 | | | | $0.09 |

*Observed data did not indicate if energy costs were included or excluded from fixed O&M costs.
** Includes both capital and O&M costs in one lump sum. Capital cost of this facility is excluded from the weighted average.

**Table C-6: Summary Data for Water Recycling Plants – Membrane Treatment with Disinfection**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SC | Orange County Ground Water Replenishment System - New Construction | 2008 | $480 | 60 | $8.00 | 115% | $9.19 | $20.7 | $0.35 | 107% | $0.37 |
| SC | Orange County Ground Water Replenishment System - Expansion | 2010 | $132 | 40 | $3.30 | 111% | $3.65 | $4.87 | $0.12 | 105% | $0.13 |
| SF | Silicon Valley Advanced Water Purification Center - New Construction | 2012 | $72.0 | 8 | $9.00 | 104% | $9.35 | | | | |
| | Average Weighted by Capacity | | | | | | $7.15 | | | | $0.27 |

*Energy is excluded from fixed O&M costs

*Groundwater*

Fresh groundwater is a supply option in every California hydrologic region. Although it was not initially identified as a marginal supply in any of the hydrologic regions, the Navigant team collected data pertaining to the construction and operation of groundwater wells. Typical capital costs include wells and associated systems for extracting the water from the ground. In some cases, the data also includes pipes to transport the water from the well to the point of interconnection with the existing system. The component costs are not always broken out, even though information indicates which components are included in the costs.

In general, key factors affecting the cost of groundwater include:

- Depth of well
- Diameter of well
- Pumping capacity

Table C-7 provides a summary of the capital and fixed O&M costs collected for groundwater facilities. Navigant recommends using a weighted average of costs from the observed facilities in Table C-7 (excluding those noted in the table) as the representative cost for new groundwater facilities. This results in a capital cost of $3.25M/MGD and annual O&M costs of $0.01M/MGD.

While additional variables beside capacity affect the cost of groundwater wells (such as depth and diameters), we are not quantifying these relationships. Well depth and diameter can vary across a hydrologic region (and even within a water utility's service area); a weighted average best accounts for these variations within a hydrologic region.

As expected, capital and O&M costs for fresh groundwater production facilities are lower than those required for brackish groundwater desalination facilities. Brackish groundwater facilities require additional treatment and system components beyond those needed for fresh groundwater wells.

**Table C-7: Summary Data for Groundwater Production Facilities**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CR | Western MWD - Arlington Basin Water Project | 2012 | $4.5 | 10 | $0.45 | 104% | $0.47 | $0.179 | $0.02 | 102% | $0.02 |
| SC | Rancho California WD - Replacement of Well 210 | 2013 | $1.9 | 2.02 | $0.94 | 100% | $0.94 | | | | |
| SC | Rancho California WD - Replacement of Well 215 | 2013 | $1.9 | 1.44 | $1.32 | 100% | $1.32 | | | | |
| SC | Rancho California WD - Replacement of Well 216 | 2013 | $2.05 | 0.86 | $2.38 | 100% | $2.38 | | | | |
| SC | Rancho California WD - Replacement of Well 205 | 2013 | $1.9 | 1.87 | $1.02 | 100% | $1.02 | | | | |
| SC | Rancho California WD - Replacement of Well 125 | 2013 | $2.1 | 0.45 | $4.67 | 100% | $4.67 | | | | |
| SC | Rancho Del Rey Groundwater Well Development** | 2012 | $5.1 | 0.58 | $8.79 | 104% | $9.13 | | | | |
| SC | City of Ventura - Saticoy Well 3 | 2012 | $6.36 | 3.6 | $1.77 | 104% | $1.83 | $0.04 | $0.01 | 102% | $0.01 |
| SC | City of Ventura - Foster Park Wellfield Production Restoration | 2012 | $39 | 14.4 | $2.71 | 104% | $2.81 | | | | |
| SC | City of Ventura - Golf Course Well 7 | 2012 | $12 | 3.96 | $3.03 | 104% | $3.15 | $0.04 | $0.01 | 102% | $0.01 |
| SC | City of Ventura - Mound Well 2 | 2012 | $5 | 3.96 | $1.26 | 104% | $1.31 | $0.04 | $0.01 | 102% | $0.01 |
| SJ | SSJID South County Water Supply Project | 2000 | $126 | 44 | $2.86 | 160% | $4.59 | | | | |

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CR | East Mesa Well Field Pumping to All- American Canal*** | 2012 | $39.5 | 22.32 | $1.77 | 104% | $1.84 | $0.20 | $0.20 | 102% | $0.20 |
| CR | East Mesa Well Field Pumping to All- American Canal with Percolation Ponds*** | 2012 | 48.61 | 22.32 | $2.18 | 104% | $2.26 | $0.24 | $0.24 | 102% | $0.25 |
| | Average Weighted by Capacity | | | | | | $3.25 | | | | $0.01 |

* Observed data did not indicate if energy costs were included or excluded from O&M costs.
** Not included in weighted average because the capital cost includes construction of a reverse osmosis treatment facility
*** Not included in weighted average as these are groundwater blending facilities. The future availability of freshwater supplies for use in blending is uncertain.

*Surface Water (Local and Imported)*

Surface water was not identified as a marginal supply in any of the hydrologic regions. Imported surface water must travel through existing conveyance systems to reach the intended user. Local surface water must be diverted from rivers, streams, or other bodies of water. These conveyance and diversion infrastructure were determined to have an irrelevant avoided capacity cost (as discussed earlier in Section 1). There is still an avoided cost associated with using surface water; the cost of treating the raw water for potable use.

Although the Navigant team determined imported has an irrelevant avoided capacity cost, the team compiled estimates of the average volumetric import costs from the State Water Project for informational purposes. Costs can vary within each hydrologic region depending on which turnout is used for delivery. Costs for imported water are reported on a volumetric basis: dollars per acre-foot ($/AF).

**Table C-8: Average Price of State Water Project Deliveries - 2013**

| Hydrologic Region | Price ($/AF) | Additional Notes |
|---|---|---|
| SJ and TL | $56 | Includes San Joaquin Valley Area: County of Kings, Dudley Ridge Water District, Empire West Side Irrigation District, Kern County Water Agency, Oak Flat Water District, Tulare Lake Basin Water Storage District |
| SF | $187 | Includes North Bay Area and South Bay Area: Napa County Flood Control and Water Conservation District, Solano County Water Agency, Alameda County Flood Control and Water Conservation District (Zone 7), Alameda County Water District, Alameda County Water District, Santa Clara Valley Water District |
| SR | $195 | Includes Feather River Area: City of Yuba City, County of Butte, Plumas County Flood Control and Water Conservation District |
| SC | $458 | Includes Southern California Area: San Gabriel Valley Municipal Water District, The Metropolitan Water District of Southern CA, Ventura County Watershed Protection District |
| SL | $464 | Includes Southern California Area: Antelope Valley-East Kern Water Agency, Crestline-Lake Arrowhead Water Agency, Littlerock Creek Irrigation District, Mojave Water Agency, Palmdale Water District, San Bernardino Valley Municipal Water District |
| CR | $913 | Includes Southern California Area: Coachella Valley Water District, Desert Water Agency, San Gorgonio Pass Water Agency. |
| CC | $1,545 | Includes Central Coast Area: San Luis Obispo County Flood Control and Water Conservation District, Santa Barbara County Flood Control and Water Conservation District |

**Treatment**

The Navigant team collected and analyzed cost data for potable treatment and wastewater treatment facilities. Expanding the capacity of potable treatment facilities is an important part of increasing the use of surface and (in some cases) groundwater supplies. Expanding the capacity of wastewater treatment is needed as indoor water use increases.

***Potable Treatment***

Potable treatment facilities are needed in cases where raw, untreated water is intended for use in urban applications. The source of the raw water could be local surface supplies, imported water, or fresh groundwater that may need additional treatment. The Navigant team identified the following marginal technologies for potable treatment:

a. Chlorine disinfection (applicable to raw water sources of high quality that need only disinfection)
b. Contaminant removal (i.e. coagulation, flocculation, sedimentation, and filtration or membrane treatment) and disinfection

Typical capital costs include design; permitting; construction and material costs for treatment processes, tanks, pumps, piping, and site structure; legal fees; and contingency allowance. Typical O&M costs include expendables, labor, and equipment replacement.

Table C-9 provides a summary of the capital and fixed O&M costs collected for chlorine disinfection treatment facilities. The Navigant team recommends using a weighted average of costs from the observed data points in Table C-9 as the representative cost for new chlorine disinfection facilities. Observed data did not provide an estimate of annual O&M costs. In the absence of this data, the Navigant team assumes non-energy O&M costs for chlorine disinfection systems can be represented by those of groundwater pumps (data available in Table C-7). This results in a capital cost of $0.06M/MGD and annual O&M costs of $0.01M/MGD.

Table C-10 provides a summary of the capital and fixed O&M costs collected for contaminant removal and disinfection. The Navigant team recommends using a weighted average of costs from the observed facilities in Table C-10 as the as the representative cost for contaminant removal and disinfection facilities. This results in a capital cost of $4.23M/MGD and annual O&M costs of $0.06M/MGD.

As expected, capital and fixed O&M costs for chlorine disinfection treatment facilities are lower than those for contaminant removal and disinfection. The latter requiring significantly more treatment systems and ancillary equipment compared to the former.

### Table C-9: Summary Data for Chlorine Disinfection Treatment

| Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.12 | 0.03 | $3.96 | 147% | $5.80 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.19 | 0.1 | $1.88 | 147% | $2.76 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.21 | 0.3 | $0.71 | 147% | $1.04 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.24 | 0.75 | $0.32 | 147% | $0.47 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.29 | 2.2 | $0.13 | 147% | $0.20 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.49 | 7.8 | $0.06 | 147% | $0.09 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $1.02 | 23.5 | $0.04 | 147% | $0.06 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $2.07 | 81 | $0.03 | 147% | $0.04 |
| Chlorination with Chlorine Dioxide Estimate | 2003 | $0.12 | 0.03 | $3.96 | 147% | $5.80 |
| Averages Weighted by Capacity | | | | | | $0.06 |

Note: Data source is EPA's 2003 Drinking Water Infrastructure Needs Survey - Modeling the Cost of Infrastructure.

### Table C-10: Summary Data for Contaminant Removal and Disinfection

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost ($2013)/ Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SR | Woodland-Davis Regional Water Treatment Facility | 2013 | $228 | 30 | $7.60 | 100% | $7.60 | | | | |
| SC | Irvine Ranch Water District - Baker Treatment Plant | 2013 | $104 | 28.1 | $3.69 | 100% | $3.69 | | | | |
| SR | Freeport Water Authority Vineyard Surface Water Treatment Plant | 2011 | $207 | 50 | $4.14 | 107% | $4.42 | | | | |
| SC | City of Ventura - Saticoy Conditioning Facility Upgrades | 2013 | $10.0 | 3.8 | $2.63 | 100% | $2.63 | | | | |
| SJ | City of Stockton - Delta Water Supply Project | 2010 | $67.0 | 30 | $2.23 | 111% | $2.47 | $1.39 | $0.05 | 105% | $0.05 |
| SJ | City of Lodi - Water Treatment Plant Alternative | 2004 | $13.9 | 9.5 | $1.46 | 143% | $2.10 | $0.80 | $0.08 | 120% | $0.10 |
| | Averages Weighted by Capacity | | | | | | $4.23 | | | | $0.06 |

* Observed data did not indicate if energy costs were included or excluded from O&M costs.

***Wastewater Treatment***

The avoided capacity cost associated with wastewater treatment facilities will be applicable to the analysis of most water conservation measures. The Navigant team identifies primary, secondary, and tertiary treatment as the marginal wastewater treatment technology. Many wastewater treatment facilities under construction or expansion are utilizing tertiary treatment technology.

Typical capital costs include design; permitting; construction and material costs for treatment processes (screening, primary, secondary, and tertiary), tanks, pumps, piping, and site structure; legal fees; and contingency allowance. Typical fixed O&M costs include expendables, labor, water quality testing and monitoring, and equipment replacement.

Table C-11 provides a summary of the capital and fixed O&M costs wastewater treatment facilities. Navigant recommends using a weighted average of capital and O&M costs from the observed facilities in Table C-11 as the representative capital cost for new wastewater treatment facilities. This results in a capital cost of $17.98M/MGD and an O&M cost of $0.70M/MGD.

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**Table C-11: Summary Data for Wastewater Treatment**

| Hydrologic Region | Project Name | Year of Price Estimate | Capital Cost ($M) | Max Capacity (MGD) | Capital Cost / Capacity ($M/MGD) - $ in Year of Estimate | Construction Cost Index | Capacity Cost ($2013)/ Capacity ($M/MGD) – 2013$ | Annual Fixed O&M Cost ($M)* | Annual O&M / Capacity ($M/MGD) - $ in Year of Estimate | O&M Cost Index | Fixed O&M / Capacity ($M/MGD) – 2013$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TL | Bakersfield Wastewater Treatment Plant 3 Expansion | 2007 | $221 | 16 | $13.81 | 123% | $17.01 | | | | |
| SR | Woodland Water Pollution Control Facility | 2013 | $70.0 | 5 | $14.00 | 100% | $14.00 | 3.5 | $0.70 | 100% | $0.70 |
| CC | San Luis Obispo County - CMC WWTP | 2007 | $18.6 | 1.1 | $16.91 | 123% | $20.83 | | | | |
| SC | City of Riverside Plant Expansion | 2012 | $238 | 12 | $19.89 | 104% | $20.65 | | | | |
| | Average Weighted by Capacity | | | | | | $17.98 | | | | $0.70 |

## *C.3 Recommended Cost Values*

Based on the cost data presented in the previous section, the Navigant team developed recommended capital and fixed O&M costs per unit capacity ($M/MGD) for each component in each hydrologic region. Table C-12 lists costs associated with developing new supply capacity. Table C-13 lists costs associated with developing new potable and wastewater treatment capacity.

The following assumptions were made in populating Table C-12 and Table C-13:

- Large ocean water desalination facilities will be built primarily in the South Coast region. Desalination facilities in other coastal regions will primarily be small facilities.
- Brackish water desalination facilities in the San Francisco region will rely on surface water as the source, all other regions will primarily use brackish groundwater as the source.
- Capital and O&M costs do not vary by region for the following: recycled water treatment facilities, groundwater facilities, chlorine disinfection facilities, contaminant removal plus disinfection facilities, and wastewater treatment facilities.

**Table C-12: Summary Data for Supply Capital and Fixed O&M Costs (2013$)**

| Region | Ocean Water Desalination Plant Costs ($M/MGD) | | Brackish Water Desalination Plant Costs ($M/MGD) | | Recycled Water Plant Costs – Tertiary Plus Disinfection ($M/MGD) | | Recycled Water Plant Costs – Membrane Treatment ($M/MGD) | | Groundwater Facility Costs ($M/MGD) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M |
| NC | $33.38 | $0.79 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SF | $33.38 | $0.79 | $5.77 | $0.47 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| CC | $33.38 | $0.79 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SC | $16.23 | $0.42 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SR | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SJ | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| TL | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| NL | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| SL | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |
| CR | - | - | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 |

**Table C-13: Summary Data for Treatment Capital and O&M Costs (2013$)**

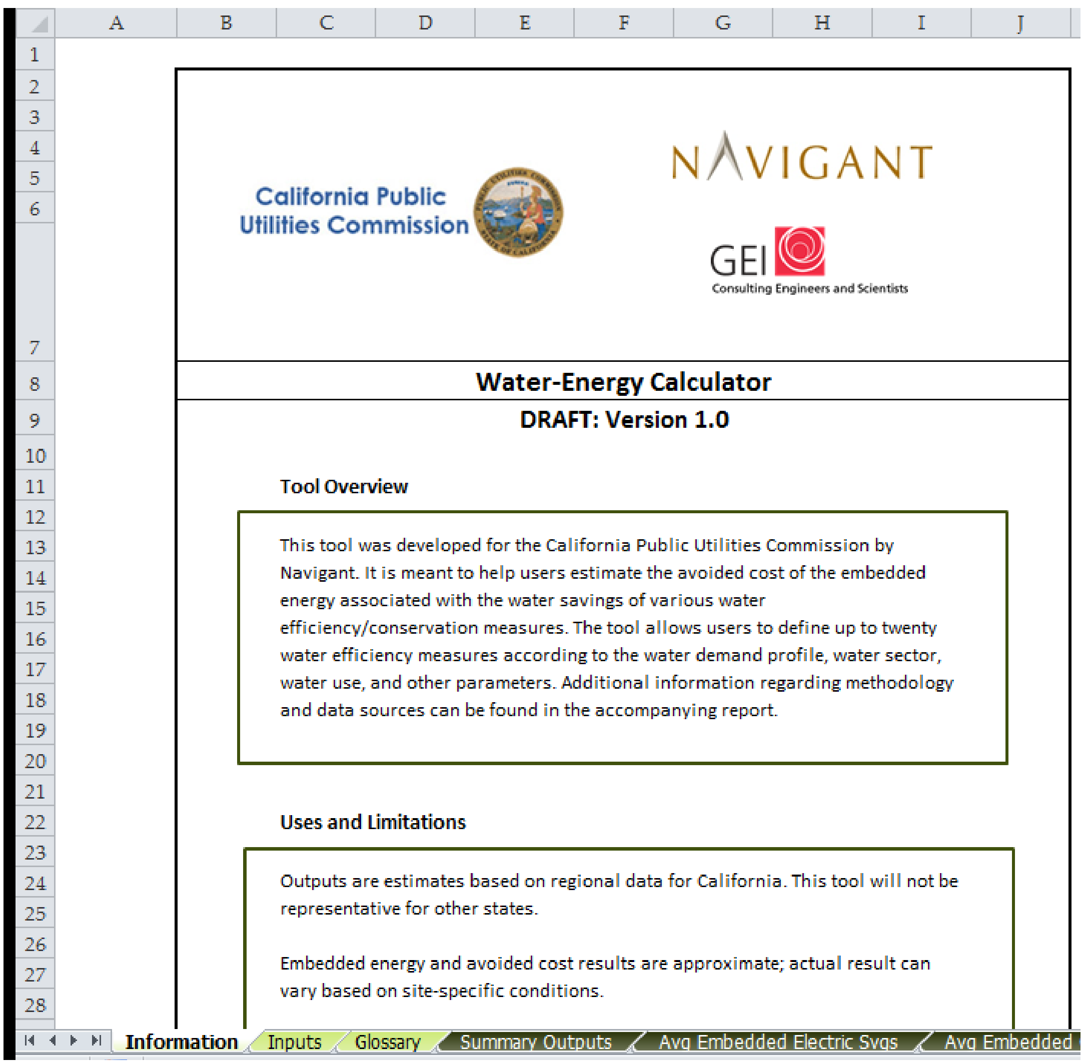
| Region | Potable Treatment - Chlorine Disinfection Costs ($M/MGD) | | Potable Treatment - Contaminant Removal Plus Disinfection Plant Costs ($M/MGD) | | Wastewater Treatment Plant Costs ($M/MGD) | |
|---|---|---|---|---|---|---|
| | Capital | Fixed O&M | Capital | Fixed O&M | Capital | Fixed O&M |
| NC | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SF | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| CC | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SC | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SR | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SJ | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| TL | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| NL | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| SL | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |
| CR | $0.06 | $0.01 | $4.23 | $0.06 | $17.98 | $0.70 |

# Appendix D Calculator Users Guide

## *D.1 Water-Energy Calculator*

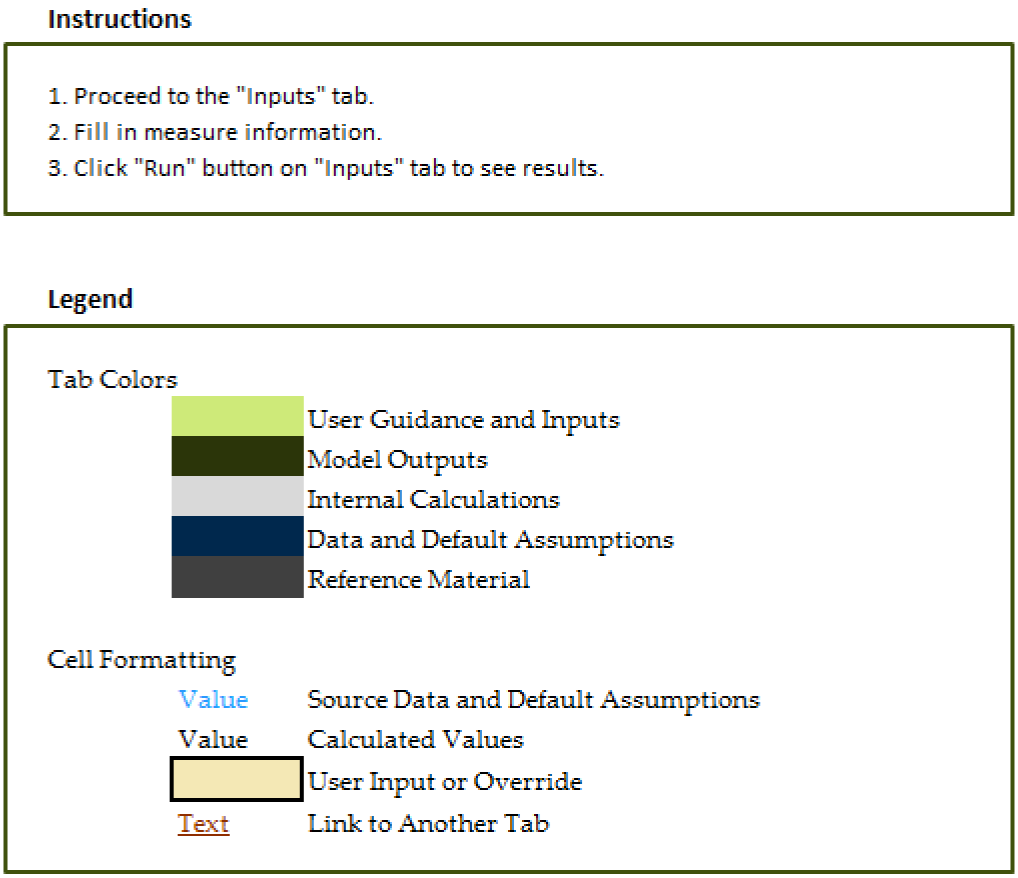
The Water-Energy Calculator strives to be simple to use. More advanced users have the option to customize the analysis, but default values are provided to enable those who may not have detailed system knowledge. The Calculator opens to the Information tab, as shown in Figure D-1.

**Figure D-1: Information Tab**



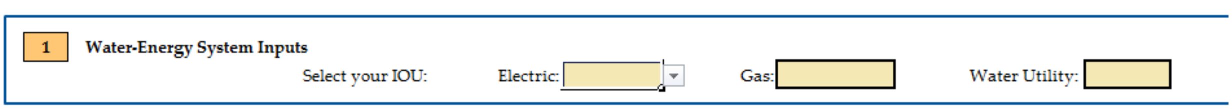

Scrolling down, the user will find the Instructions and Legend, as shown in Figure D-2. These instructions are the very basics, and do not account for any customization of the analysis.

**Figure D-2: Instructions and Legend**




Having oriented oneself with the formatting of the Calculator, proceed to the Inputs tab. Section 1 requires the user to select both an electric and gas IOU as well as whether the water utility is an IOU or non-IOU. These cells each have a dropdown menu, as shown in Figure D-3, with the range of available options.

**Figure D-3: Inputs Section 1**




Section 2 is for measure-specific inputs. These inputs are to be entered on a per-unit basis, e.g., per low flow shower head. There is space for up to 20 measures in this table, shown in Figure D-4. There is one input here that can be customized if needed: Savings Profile. If the user clicks the column heading, the Calculator will display the water savings profiles available to the user along with two opportunities to create custom profiles. The values in each custom profile must sum to 100%, and there is an error check for this below the input columns, as shown in Figure D-5. The user can then click the link at the top of the tab labeled, "Click to Return to Inputs tab" to continue entering measure-level inputs. Refer to Section 2.3.3 of the report for more information on each of these inputs.

**Figure D-4: Inputs Section 2**

2 Measure-Specific Inputs

Note: all metrics are on a per unit basis (Example: per low-flow shower head)

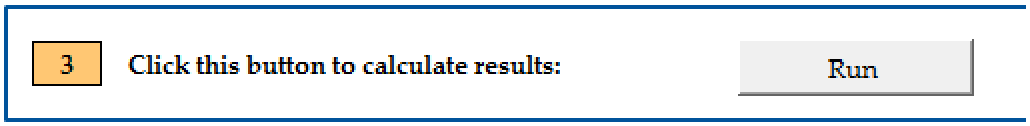
| Measure ID# | Measure Name | Annual Water Savings (gallons) | Measure Life (years) | Installation Year | Savings Profile | Hydrologic Region | Sector | Water Use | Rebate ($) | Installation Cost ($) | Incremental Equipment Cost ($) | Program Administration Cost ($) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |

**Figure D-5: Water Savings Profiles**

| Water Savings Profiles | | | Click to Return to Inputs tab | | |
|---|---|---|---|---|---|
| | | | | | |
| Month | Constant | Irrigation | Cooling Tower | Custom 1 | Custom 2 |
| January | 8.3% | 3.2% | 3.0% | | |
| February | 8.3% | 2.5% | 3.1% | | |
| March | 8.3% | 4.2% | 3.8% | | |
| April | 8.3% | 8.7% | 8.2% | | |
| May | 8.3% | 12.0% | 12.1% | | |
| June | 8.3% | 13.4% | 11.9% | | |
| July | 8.3% | 14.5% | 10.8% | | |
| August | 8.3% | 12.8% | 13.1% | | |
| September | 8.3% | 11.5% | 13.8% | | |
| October | 8.3% | 8.9% | 10.0% | | |
| November | 8.3% | 6.6% | 7.1% | | |
| December | 8.3% | 1.8% | 3.0% | | |
| | *Source: CSA (2012)* | | | | |
| Total Check | | | | ERROR: Values must add up to 100% | ERROR: Values must add up to 100% |

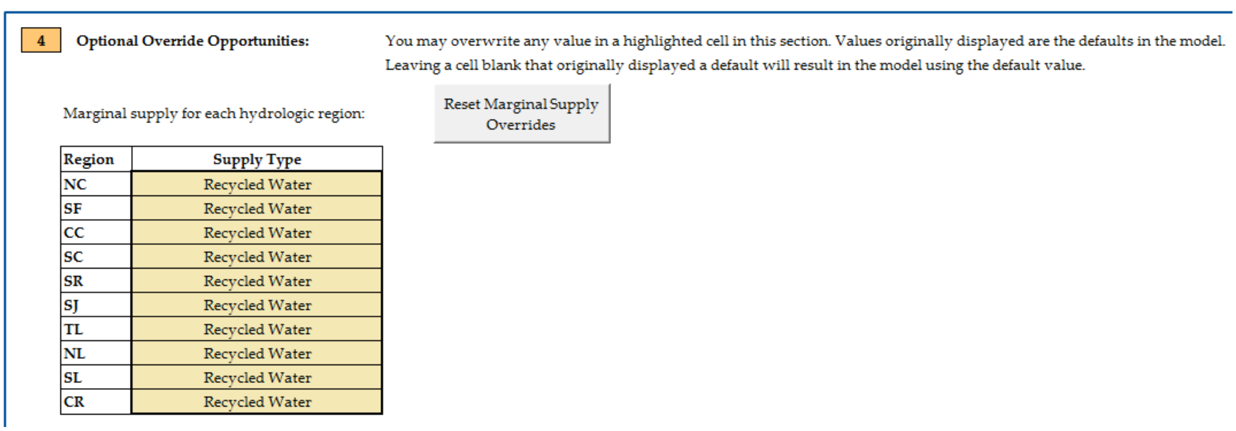
Once all measure inputs have been entered, scroll down to Section 3. Here is the “Run” button for the Calculator, as shown in Figure D-6. If no customization of the analysis is desired, click this button, and the user will be presented with the results.

**Figure D-6: Inputs Section 3**




If the user desires to view or edit the default values in the Calculator, scroll down to Section 4 of the Inputs tab, as shown in Figure D-7. These are the values which can be customized by the user. If the user leaves any of the cells in this section blank, the Calculator will use the default value. If the user changes any of these values, then wants to undo a change, a reset button is available next to each table, which will restore the default values. Each of these tables is discussed in more detail in Section 3.1.1 of the report. Once the user is satisfied with the customization of the model, scroll back up to Section 3 and click the “Run” button.

**Figure D-7: Inputs Section 4**



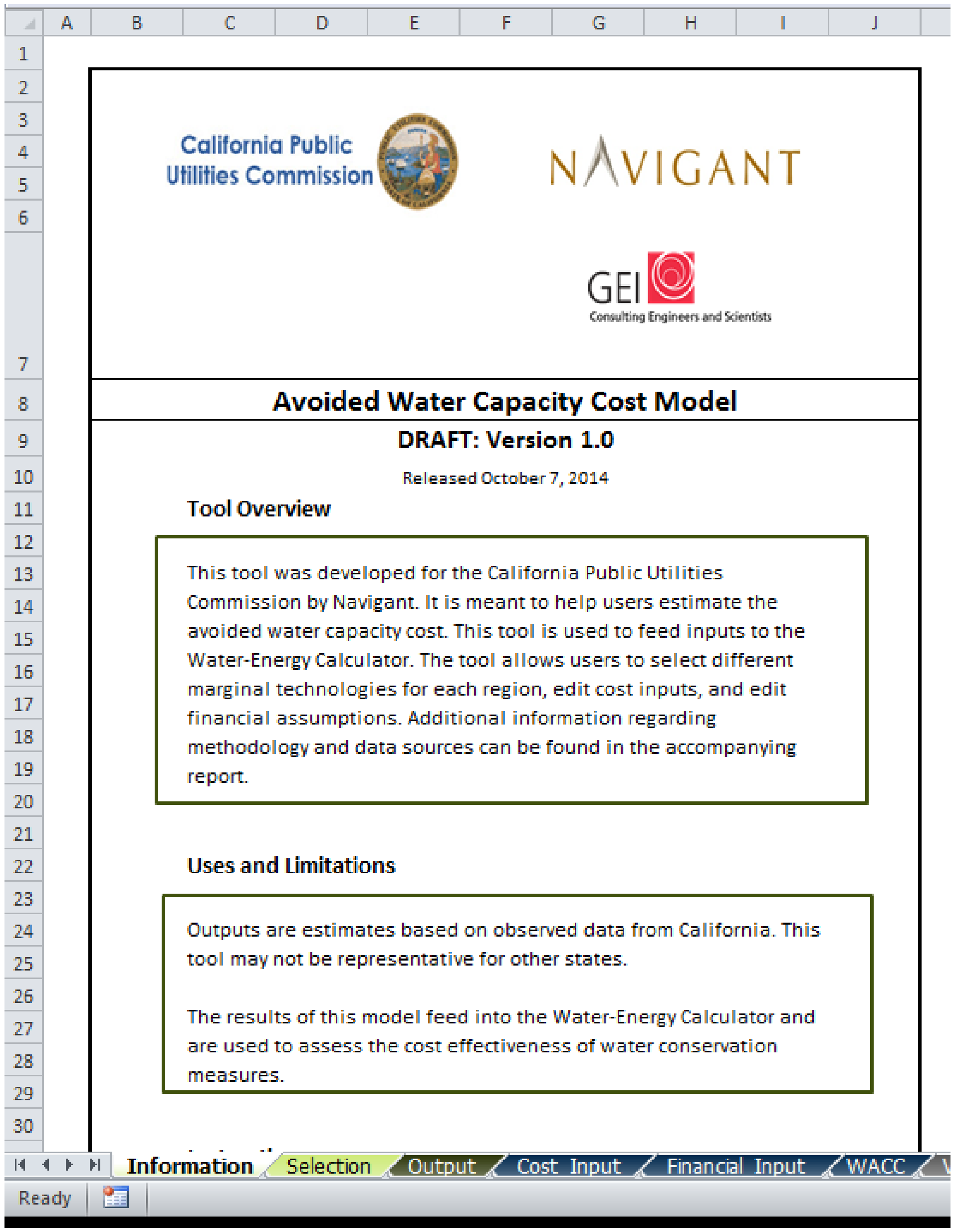

| Region | Supply Type |
|---|---|
| NC | Recycled Water |
| SF | Recycled Water |
| CC | Recycled Water |
| SC | Recycled Water |
| SR | Recycled Water |
| SJ | Recycled Water |
| TL | Recycled Water |
| NL | Recycled Water |
| SL | Recycled Water |
| CR | Recycled Water |

Clicking the “Run” button will automatically bring the user to the Summary Outputs tab. Descriptions of these results can be found in Section 3.2.1 of the report.

## *D.2 Avoided Water Capacity Model*

The Avoided Water Capacity Model is designed to be customized with user specific inputs. The model opens to the Information tab as shown below.

**Figure D-8: Information Tab**




Scrolling down, the user will find the Instructions and Legend, as shown in the figure below. These instructions are for basic model functionality and apply for default scenario analysis as well as custom analysis.

**Figure D-9: Instructions and Legend**

**Instructions**

1. Proceed to the "Inputs" tab.
2. Fill in measure information.
3. Click "Run" button on "Inputs" tab to see results.

**Legend**

Tab Colors

| | |
|---|---|
| [light green] | User Guidance and Inputs |
| [dark green] | Model Outputs |
| [light grey] | Internal Calculations |
| [dark blue] | Data and Default Assumptions |
| [dark grey] | Reference Material |

Cell Formatting

| | |
|---|---|
| Value | Source Data and Default Assumptions |
| Value | Calculated Values |
| | User Input or Override |
| Text | Link to Another Tab |

After reviewing the format legend of the Calculator, proceed to the Selection tab. The Selection tab is where users can see automatically updated summary output and make their three primary selections: hydrologic region, water system component technology, and owner entity type. The input assumptions are based on the three primary selections can be seen below each user input area.

**Figure D-10: Selection Tab – Summary Output**

**Avoided Water Capacity Cost Calculator**

Summary Output and Input Selection

| Summary Output | Water Supply | Potable Treatment | Wastewater Treatment |
|---|---|---|---|
| Annual Avoided Capacity Cost ($M/MGD) | $ 0.49 | $ 0.02 | $ 3.06 |
| PV-Total Capacity Cost ($M) | $ 5.44 | $ 0.22 | $ 31.86 |

**Figure D-11: Selection Tab – Input**

| Input Selection | | | |
|---|---|---|---|
| **Select Hydrologic Region** | | | |
| North Coast | | | |
| | **Water Supply** | **Potable Treatment** | **Wastewater Treatment** |
| **Water System Component Costs** | Recycled - Tertiary + Disinfection | Chlorine Disinfection | Wastewater Treatment |
| Capital Cost per Unit ($M/MGD) | $ 3.19 | $ 0.06 | $ 17.98 |
| Marginal O&M Cost per Unit ($M/MGD) | $ 0.09 | $ 0.01 | $ 0.70 |
| **Financial Assumptions** | | | |
| **Ownership Entity Type** | IOU | IOU | IOU |
| Inflation Rate | 3.0% | 3.0% | 3.0% |
| Working Capital | 0.0% | 0.0% | 0.0% |
| **Depreciation Life** | | | |
| Straight Line | 40 | 40 | 24 |
| MACRS | 20 | 10 | 15 |
| **Capital Costs** | | | |
| Year to Capital Outlay | - | - | - |
| Cost of Equity | 9.9% | 9.9% | 9.9% |
| Percentage of Cap Structure - Equity | 58.2% | 58.2% | 58.2% |
| Cost of Debt | 6.9% | 6.9% | 6.9% |
| Percentage of Cap Structure - Debt | 41.8% | 41.8% | 41.8% |
| Debt Amortization Period | 40 | 40 | 24 |
| **Tax Inputs** | | | |
| Federal Income Tax Rate | 35.0% | 35.0% | 35.0% |
| State Income Tax Rate | 8.0% | 8.0% | 8.0% |
| Composite Tax Rate | 40.2% | 40.2% | 40.2% |
| Value Added Tax Rate | 0.0% | 0.0% | 0.0% |
| Payments In Lieu of Taxes (PILOTs) | 0.0% | 0.0% | 0.0% |
| Property Tax Rate | 0.0% | 0.0% | 0.0% |
| Basis for Property Tax Rate | Depreciated Cost | Depreciated Cost | Depreciated Cost |

Detailed output for each year can be seen and copied in the output tab, as shown below.

**Figure D-12: Output**

## Avoided Capacity Cost Calculator

Detailed Output ($M/MGD capacity per year)

| Detailed Output - Annual Avoided Cost | | | |
|---|---|---|---|
| Technology | Recycled - Tertiary + Disinfection | Chlorine Disinfection | Wastewater Treatment |
| **Year** | **Water Supply** | **Potable Treatment** | **Wastewater Treatment** |
| **2015** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2016** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2017** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2018** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2019** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2020** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2021** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2022** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2023** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2024** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2025** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2026** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2027** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2028** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2029** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2030** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2031** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2032** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2033** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2034** | $ 0.49 | $ 0.02 | $ 3.06 |
| **2035** | $ 0.49 | $ 0.02 | $ 3.06 |

Cost inputs for each technology and each region can be reviewed in the Cost Input tab. Users can also input custom selections for each technology and region to develop their own scenario analysis. The default inputs are not editable, but capital and fixed O&M inputs can be entered for User Defined Regions 1 – 3 and for the User Defined Facility in any of the regions.

**Figure D-13: Cost Input**

| Region | Ocean Water Desalination Plant Costs ($M/MGD) | | Brackish Water Desalination Plant Costs ($M/MGD) | | Recycled Water Plant Costs – Tertiary Plus Disinfection ($M/MGD) | | Recycled Water Plant Costs – Membrane Treatment ($M/MGD) | | Groundwater Facility Costs ($M/MGD) | | User Defined Facility Costs ($M/MGD) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Supply - Default Input Recommendations** | | | | | | | | | | | | |
| | Capital | O&M | Capital | O&M | Capital | O&M | Capital | O&M | Capital | O&M | Capital | O&M |
| North Coast | $33.38 | $0.79 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| San Francisco Bay | $33.38 | $0.79 | $5.77 | $0.47 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| Central Coast | $33.38 | $0.79 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| South Coast | $16.23 | $0.42 | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| Sacramento River | | | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| San Joaquin River | | | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| Tulare Lake | | | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| North Lahontan | | | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| South Lahontan | | | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| Colorado River | | | $6.45 | $0.48 | $3.19 | $0.09 | $7.15 | $0.27 | $3.25 | $0.01 | <input> | <input> |
| User Defined Region 1 | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> |
| User Defined Region 2 | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> |
| User Defined Region 3 | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> | <input> |

Source: Navigant team Research. See accompanying final report

Financial assumptions can be reviewed and edited in the Financial Input tab, as shown below. Once again, the default assumptions for IOU and Municipality cannot be edited, but the User Defined Entity can be adjusted as the user sees fit. Inputs can be customized for each water system component type.

**Figure D-14: Inputs Section 4**

| | Water Supply | | |
|---|---|---|---|
| | IOU | Municipality | User Defined |
| Inflation Rate | 3.00% | 3.00% | <input> |
| Working Capital | 0.00% | 0.00% | <input> |
| **Capital Costs:** | | | |
| Year to Capital Outlay | 0 | 0 | <input> |
| Cost of Equity | 9.86% | 0.00% | <input> |
| Percentage of Cap Structure - Equity | 58.22% | 0.00% | <input> |
| Cost of Debt | 6.93% | 4.51% | <input> |
| Percentage of Cap Structure - Debt | 41.78% | 100.00% | <input> |
| **Tax Inputs** | | | |
| Federal Income Tax Rate | 35.00% | 0.00% | <input> |
| State Income Tax Rate | 8.00% | 0.00% | <input> |
| Composite Tax Rate | 40.20% | 0.00% | <input> |
| Value Added Tax Rate | 0.00% | 0.00% | <input> |
| Payments In Lieu of Taxes (PILOTs) | 0.00% | 5.00% | <input> |
| Property Tax Rate | 0.00% | 0.00% | <input> |
| Basis for Property Tax Rate | Depreciated Cost | Depreciated Cost | Depreciated Cost |

Source: CPUC Water Cost of Capital Proceedings, Navigant Assumptions

## Appendix E References

The following is a cumulative list of all references relied upon since the inception of the project to determine marginal supplies and water system component costs.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