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Response to Invitation to Submit Proposals - Landscape Irrigation Controllers

Additional submitted attachment is included below.

Landscape Irrigation Controllers

Codes and Standards Enhancement (CASE) Initiative
For PY 2017: Title 20 Standards Development

Analysis of Standards Proposal for
Irrigation Controllers
Docket # 17-AAER-10

September 18, 2017

Prepared for:

PACIFIC GAS & ELECTRIC COMPANY

SOUTHERN CALIFORNIA EDISON

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1. Purpose

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (CEC) efforts to update California's Appliance Efficiency Regulations (Title 20 Standards). The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and SoCalGas® – sponsored this effort (herein referred to as the Statewide CASE Team). The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve the energy and water efficiency of various products sold in California. This report and the code change proposal presented herein is part of the effort to develop technical and cost-effectiveness information for potential appliance standards. This CASE Report covers a standard proposal for landscape irrigation controllers.

2. Product / Technology Description

An automatic in-ground landscape irrigation system consists of four basic components: (1) the timer or controller, (2) irrigation valves, (3) underground piping, and (4) sprinkler heads or other emission devices (see Figure 1).

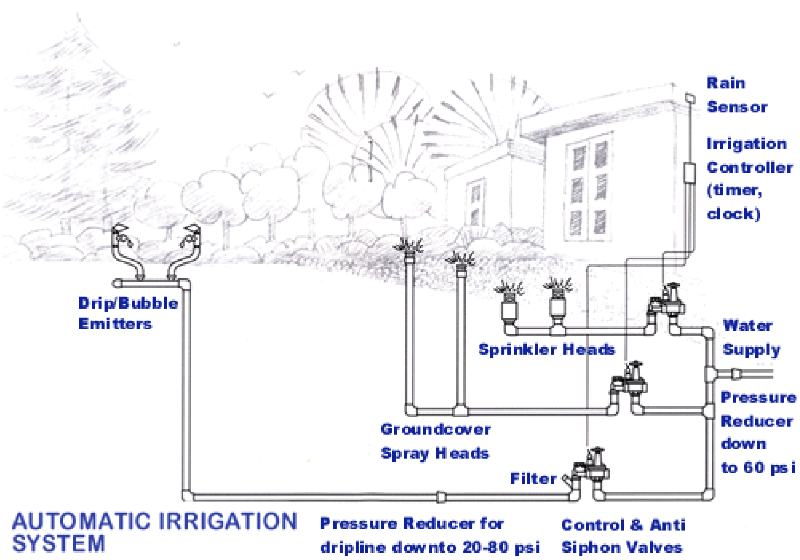

Figure 1: Schematic of a typical in-ground automatic irrigation system.
Source: Town of Portland Connecticut

Irrigation controllers are often considered to be the "brains" of an irrigation system. Irrigation controllers will at a minimum control the frequency, start times, and duration of watering for one or more irrigation stations (also called "zones"). Modern controllers contain microprocessors for clock/timer, memory, and control functions and use the flow of electricity to activate solenoid valves that release and stop the flow of irrigation water for different landscape zones.[1] The solenoid is an additional source of energy consumption during active irrigation.[2]

Controllers must be programmed to supply the appropriate amount of water based on plant requirements and soil type. Plant water requirements are expressed as evapotranspiration or "ET", which is the quantity of moisture that is evaporated from the soil and plant surface plus moisture transpired by the plant. From summer to fall, and fall to winter, a landscape's water requirement declines significantly. Basic controllers rely on the property owner or maintenance contractor to adjust irrigation schedules as ET (and irrigation) needs decrease from maximum summertime ET.

2.1 Water Efficiency Opportunities

Traditional automatic irrigation systems typically operate with an irrigation efficiency of 50 percent or less (Hanak and Davis 2006).[3] Excess water is lost to deep percolation, runoff and evaporation due to inefficient scheduling by the controller and due to irrigation emitter device, installation, and maintenance inefficiencies (the Statewide CASE Team has also prepared a proposal for spray sprinkler body water efficiency standards). Water efficient controllers better match irrigation schedules and rates to actual landscape water requirements thereby reducing the amount of water that is overapplied while maintaining or improving plant health.

Some water saving features do not require current or historic weather data or sensor inputs. Examples of these features include the following:

- **Non-volatile memory** to retain programming information in the event of a power outage
- **Independent programming by station** to allow for more precise watering based on plant types or landscape area
- **Multiple station start times per day** to allow for repeated watering in a zone on a given day, which can reduce runoff caused by overwatering an area without allowing time for water to soak into the soil
- **Advanced internal calendars** that can implement municipal restrictions into the watering schedule
- **A water-budgeting feature** that adjusts normal run times by a percentage without needing to manually re-program each individual station. "Optimal" ET values do not consider the cost savings and other benefits of water conservation; thus, watering can typically be reduced while still maintaining landscapes with an acceptable appearance.

Replacing a basic controller or timer with a controller that uses environmental data to automatically adjust irrigation scheduling can generate significant water savings. In a 2014 review of 47 distinct reference sources, Lawrence Berkeley National Laboratory (LBNL) researchers estimated water savings of 15 percent for weather-based controllers, 38 percent for soil moisture sensor-based controllers, and 21 percent for rain shut-off devices. Additionally, researched found that weather-based irrigation controllers have higher

[1] Hose-end timers, which can directly control a garden hose with an attached moveable sprinkler or single zone permanent irrigation system, are not addressed in this report.

[2] Typically, a rod supported by a coil lies at the center of the solenoid valve. When the solenoid is not activated, springs hold the rod in place to cover the inlet port hole that allows water through the main line. Applying electricity through the valve's two wires energizes the coil and causes the rod to contract into the solenoid, opening the valve to allow water flow until electricity is stopped and the valve returns to its inactive, closed position.

[3] According to the California Department of Water Resources (DWR), irrigation efficiency is defined as the amount of water beneficially used divided by the amount of water applied. Irrigation efficiency is derived from measurements and estimates of irrigation system characteristics and management practices (DWR 2015).

savings potential of 21 percent in nonresidential applications (e.g., light commercial, public areas) as compared to residential applications (Williams 2014). Each of these three types of controller is described further below.

2.1.1 Weather-Based Irrigation Controllers

Weather-based (sometimes called climate-based) irrigation controllers schedule irrigation based on current or historic weather conditions. The controller will use this information, along with soil and plant type, to determine ET. Weather-based controllers are available as: (1) an add-on module or sensor that works in coordination with a compatible base controller (some basic controllers can accept add-ons while others cannot), or (2) standalone controllers with integrated weather-based features.

Weather-based controllers gather weather information in a variety of ways. Some weather-based controllers use stored historical weather information based on site location (for example, zip code or latitudinal and longitudinal coordinates) to adjust irrigation schedules. Other controllers gather weather data in real time using on-site devices such as rainfall, humidity, solar radiation, wind, and/or temperature sensors. Some controllers receive regular location-specific updates from a local weather station or network of weather stations via a cellular, internet, or other cloud connection. These "connected" controllers may determine irrigation schedules locally or upload data to a remote central server or cloud that conducts analytics and determines the irrigation schedule. Connected devices have access to the Internet and can perform ancillary functions in standby mode, such as pulling weather information from nearby weather stations, interacting with mobile applications, and system performance or diagnostic analytics. Connected controllers may also receive or send alerts, receive software updates, and upload run time data to a remote central server or cloud system.

2.1.2 Soil Moisture Sensor-Based Irrigation Controllers

Soil moisture sensors check soil conditions at regular intervals (for example, every ten minutes) and provide data, such as soil conductivity, that can be used to estimate the water content of soil and determine whether irrigation is needed. A soil moisture sensor-based controller can then adjust the irrigation schedule accordingly. Most of the currently available soil moisture sensors function as an add-on to an existing irrigation controller, although some manufacturers offer an integrated controller/soil moisture sensor product. In the past, soil moisture sensors and controllers were less common in the landscape irrigation market compared to the agricultural irrigation market, but they are gaining popularity as new products become available. The significant technical potential of these devices to determine soil moisture at specific point(s) and provide data for irrigation scheduling could increase their popularity.

2.1.3 Rain Shut-off Devices

Weather based controllers are often designed to accept inputs from a rain shut-off device or rain gauge and may be sold with this device (DOI 2015). Some basic controllers can accept this input as well. Rain shut-off devices are designed to interrupt a scheduled irrigation cycle when a certain amount of rainfall has occurred. Some devices allow consumers to adjust the rainfall detection level that will trigger a shut-off in increments of 3 millimeters (mm) or 1/8 inch (in) of precipitation, though some research indicates that small differences in shut-off thresholds, such as the 3 mm (1/8 in) and 6 mm (1/4 in) settings, will not significantly affect performance (Meeks 2012). Every device with adjustable settings tested by Meeks (2012) could be set for a detection level of 6 mm or less (1/4 in), and each demonstrated the ability to consistently shut-off irrigation at 6 mm or lower when set for a 6-mm shut-off over a period of 1,150 to

1,182 days.[4] Another study found that one device (Hunter Wireless Rain-Clik) was extremely consistent and suspended irrigation at extremely low levels, on average below 3 mm (Cardenas-Lailhacar and Dukes 2008). A second common device (the Hunter Mini-Clik) detected more than 97 percent of significant rainfall events (the study does not report data specific to the potential 6 mm shut-off threshold for this device).[5]

The most commonly used type of rain shut-off device contains an expansion disk sensor (Dukes and Haman 2002) made of cork or another material that expands proportionally to the quantity of rainfall. This expansion triggers a pressure switch and then sends a signal to override the normal irrigation schedule and prevent irrigation. The switch will remain open until the disk(s) begin to dry out. Certain types of controllers can use rain shut-off device data as an input and suspend irrigation for a specific amount of time, such as 24 or 48 hours, rather than relying on the amount of time necessary for a disk to dry out.

Other types of rain shut-off devices use a rain gauge to measure and report the quantity of rain, which can be used to tailor irrigation more accurately than an expanding disk sensor with on/off irrigation interruption capability. Rain gauges contain a receptacle to collect the water and either weigh the water or detect the water level with electrodes.

Rain shut-off devices provide control via either a wired or wireless connection. Both wired and wireless rain sensors must be installed at an unobstructed location that can detect rainfall away from irrigation spray or rain accumulation and submersion, such as next to a roof gutter. Compared to wired rain sensors, wireless devices can provide more flexibility for the placement of the device and may be easier and cheaper to install since there is no need to run additional wiring. Wireless devices have a rain sensor, a transmitter that is mounted at an optimal location, and a separate receiver module that is wired to the controller in a location with a strong signal to the sensor. Wired rain shut-off sensors or the receivers for wireless sensors are typically wired to a specific input location on the controller.

Table 1 below shows some examples of commercially-available basic and water efficient irrigation controllers.

Table 1: Select Examples of Commercially-Available Irrigation Controllers

	**Basic Irrigation Timer** Example: Orbit Easy Set Logic Timer Allows for irrigation scheduling by day, time, and duration. Also allows for user programmable rain delay scheduling of 24, 48, or 72 hours. No site or historical weather data is considered when scheduling irrigation. Will not automatically adjust for weather conditions or data; the user must manually adjust the device to account for weather. **Source:** https://www.orbitonline.com/products/sprinkler-systems/timers/timers/easy-set-logic-all-weather-sprinkler-timer/4-station-outdoor-swing-panel-timer.

[4] Meeks (2012) recommended replacement of one model after a year for highest accuracy. As noted earlier, the product still provides the capability to shut-off irrigation after a 6-mm rainfall event at the end of the study period.

[5] 174 days of rainfall occurred at four units set at 3 mm and four units set at 13 mm. These eight units failed to detect 35 large rainfall events (typically from 11 to 42 mm with a few higher) from 1380 total rainfall events in aggregate across the eight units. The failure rate was comparable for units with both settings. The study does not separately report response rate of events of 6 mm or greater.

 	**Weather-Based Controller (add-on on-site ET/Weather Sensor)** Example: Hunter Solar Sync ET sensor measures data that can be used to calculate ET and adjust irrigation scheduling daily based on local weather conditions and estimated plant water needs. Measures solar radiation and temperature and includes rain and freeze sensors. Compatible with most Hunter controllers. Can be sold packaged with a compatible controller or as a separate add-on component. **Source**: http://www.hunterindustries.com/irrigation-product/sensors/solar-syncr
	**Weather-Based Controller (Signal-Based, Standalone Device)** Example: Rachio Iro Connected to the Rachio cloud platform through home wi-fi. Rachio monitors the controller and the local weather forecast around a home over the internet using online weather data, continually adjusting the irrigation schedule to use the optimal amount of water for specific zones based on the current season and home location. **Source**: https://rachio.com/store
	**Soil Moisture Sensor-Based Controller (add-on on-site Soil Moisture Sensor)** Example: Acclima SC6 This controller is sold with an Acclima digital Time Domain Transmissometry (TDT) moisture sensors to control irrigation based on measured soil moisture levels. **Source:** http://www.efficientirrigation.com/08products/sc6.htm

2.1.4 Installation and Configuration

Proper installation, programming, and adjustment are critical for fully achieving the water savings potential of landscape irrigation controller systems with water saving features. The initial programming step varies in length and complexity for each controller, and requires the installer to program a variety of factors for each watering station into the controller. These factors may include plant type, soil type, sun exposure, irrigation type, application rate, root depth, and/or slope. Many consumers self-install landscape irrigation controllers. Mayer (2009) found that self-installed weather/ET controllers could achieve at least as much or potentially greater savings as contractor-installed units.

2.2 Energy Efficiency Opportunities

Electronically-driven irrigation controllers require energy from household power supplies. Battery-powered units are available but less common. Electronically-driven controllers use an alternating current (AC)-to-AC power supply that converts 110-120 voltage alternating current (VAC) to 24 VAC required by most solenoid valves for landscape watering. Controllers have a secondary power supply to convert alternating current to (typically) five-volt direct current (DC), which powers the electronics of the controller. Although landscape controllers can be installed either indoors or outdoors, most residential controllers are installed indoors (Hunter Industries 2005). Indoor controllers typically use external power supplies (EPS) (sometimes referred to as "wall warts" or "power bricks"), while outdoor controllers typically have an internal power supply located inside a weather-resistant and tamper-proof controller cabinet that is either plug-based or hard-wired to the main's power (Figure 2).

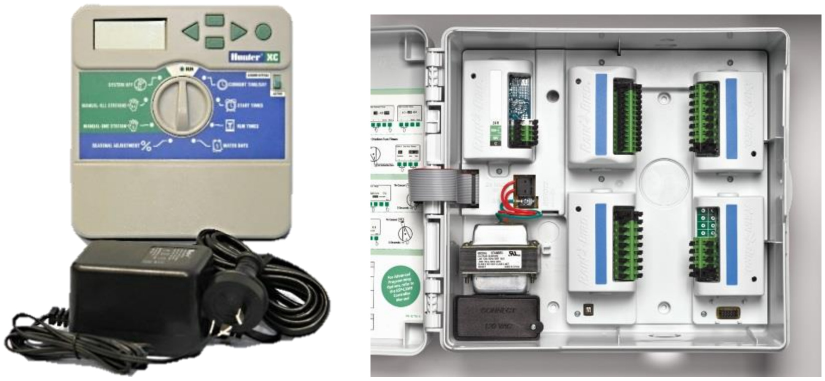

Figure 2: Indoor irrigation controller with an exterior power supply (left)[6] and an outdoor irrigation controller with an interior power supply (right).[7]

The Statewide CASE Team defines the energy consumption of a controller when performing its primary function of energizing a solenoid valve or valves for watering as **active mode** energy consumption. Basic controllers and water-efficient controllers may behave differently in **standby mode**. Basic controllers typically do not perform any active or information-transferring functions in standby mode. Conversely, weather-based or other sensor-based controllers can have standby-passive and standby-active modes. The **standby-passive** mode is defined as the controller not performing any functions but remaining available to be activated through a remote activation signal. **Standby-active** mode is defined as the controller accessing environment and/or weather data to calculate any needed adjustments in watering schedules or performing other exchange of information through the internet. Controller energy use may also be affected by whether the controller collects environmental data from local sensors or an internet connection. Some water-efficient controllers with local sensors may draw more power in standby-active mode since they need to collect and analyze on-site weather data to determine the amount of irrigation that is needed. Alternatively, the irrigation calculation for some connected controllers may occur off-site in a cloud server or other location.

3. Standards Proposal Overview

Table 2: Summary of Proposal

Topic	Description
Description of Standards Proposal/Framework of Roadmap	The proposed water efficiency standards described in this report would require landscape irrigation controllers to be shipped and sold with water saving sensors or technology. Irrigation controllers would have to meet product specifications from WaterSense Version 1.0 for Weather-Based Irrigation Controllers. Additionally, irrigation controllers would be required to comply with minimum energy efficiency standards.

[6] Source: Hunter Industries. http://www.irrigationstore.com.au/Library/xc%20indoor.jpg.
[7] Source: Rain Bird. http://www.rainbird.com/images/products/turf/controllers/ESP-LXME_Base-12-8-8-4.jpg.

Technical Feasibility	Water Efficiency Measures • Likely met by existing products available from multiple manufacturers. Over 20 manufacturers sell United States (U.S.) Environmental Protection Agency (EPA) WaterSense labeled weather-based irrigation controllers, and at least five manufacturers offer soil moisture sensors for landscape irrigation controllers. At least eight manufacturers sell landscape rain sensors on the California market. Energy Efficiency Measures • Additional testing of irrigation controllers would bolster existing evidence, determine a technically feasible level of energy savings, and support a potential energy efficiency standard.
Water and Energy Savings and Demand Reduction	• Water and energy savings should be determined by future product testing.
Environmental Impacts and Benefits	• More efficient application of irrigation water and direct energy savings. • Avoided greenhouse gas emissions from energy savings. • Other potential benefits, such as avoidance of runoff contaminated with sediment and pesticides.
Economic Analysis	• Required changes are expected to have minimal impact on the industry as a whole and small businesses in particular. • Consumers and California businesses are expected to financially benefit from reduced overall irrigation energy and water use.
Consumer Acceptance	• Minimal expected impact to consumer acceptance. Proposed devices will offer similar or improved form to what is typical for consumers today. Increased consumer benefit from more capable irrigation systems that do not waste water in periods of rainfall and that are better equipped to irrigate landscapes based on changing environmental conditions. • Inclusion of consumer information with products required to maximize consumer savings.
Other Regulatory Considerations	• Partially addresses a mandate from the California legislature (AB 1928 2016) to adopt Title 20 Standards for landscape irrigation products, as well as related water efficiency statutory and policy goals.

4. Proposed Standards and Recommendations

4.1 Proposal Description

Potential Title 20 Standards for landscape irrigation controllers would address water and energy efficiency for all new landscape irrigation controllers sold in California.[8] The Statewide CASE Team proposes a compliance date of twenty-four months after the adoption of the standard. This compliance date allows time for relevant test procedures and product testing for weather-based and soil moisture sensor-based controllers to be completed and also allows time for manufacturers to address any needed product modifications for these more complex devices.

4.1.1 Water Efficiency

The proposed water efficiency standards described in this report would require landscape irrigation controllers to be shipped and sold with water saving sensors or technology.

The California Department of Water Resource's Independent Technical Panel (ITP) addressed potential Title 20 Standards for irrigation controllers in their 2016 Recommendations Report to the Legislature on Landscape Water Use Efficiency (ITP 2016). They recommended that standards that could be adopted in two stages, summarized as the following:

- The first stage would be adopted quickly and would address basic controllers that are neither weather-based or soil moisture sensor-based. The standard would mandate that the basic controllers contain the following features:
    - Controls capable of accommodating local watering restrictions;
    - Preservation of program settings when the controller's power source is lost;
    - Limits on standby power consumption; and
    - Controller to be packaged and sold with an automatic rain shut-off device.
- The second stage would apply to weather-based and soil moisture sensor-based controllers and would be adopted soon after the evaluation of a test method and performance metric for these controllers is completed.
    - For weather-based controllers, the standards would require manufacturers to meet the U.S. EPA WaterSense Specification Version 1.0.
    - For soil moisture sensor-based controllers, the standards would be adopted upon review and approval of a test method under development by the American Society of Agricultural and Biological Engineers (ASABE) to align with a potential WaterSense specification for soil moisture sensor-based controllers once it is released.

The ITP recommendations could be considered as the basis for a potential Title 20 standard; however, since these recommendations have been released, considerable progress has been made on developing new and updated test methods for weather-based and soil moisture sensor-based controllers, and these test procedures are nearing completion. Additionally, prices for WaterSense labeled weather-based irrigation controllers have fallen since the WaterSense specification was released in 2011, and at the time of writing,

[8] Existing California regulations require the inclusion of landscape irrigation controllers meeting specific requirements in new construction as noted below in Section 4.2.2.

it is possible to purchase at least one low-cost model WaterSense controller for about the same price as a low-cost basic controller at major retailers.

Therefore, the Statewide CASE Team proposes Title 20 Standards to require that all irrigation controllers sold in California offer water efficiency features, including weather-based or soil moisture sensor-based control. This could be implemented in one stage with a compliance date twenty-four months after adoption, or in multiple stages with a sooner compliance date for some features. The standards would phase out basic controllers that primarily schedule irrigation based on day, time, and duration. These basic products do not utilize signal- or sensor-based inputs, or historical weather data to modify irrigation scheduling based on environmental data. Additionally, the standard would require that landscape irrigation controllers suspend irrigation during rainfall events, such as is required in the California Model Water Efficient Landscape Ordinance (MWELO) Section 492.7 (a)(1)(D) for new landscapes. Typically, this functionality is achieved with a rain shut-off sensor, but some controllers may have this functionality integrated into the base device.

Furthermore, the Statewide CASE Team proposes that landscape irrigation controllers must meet the supplemental capability requirements in Section 4.0 of U.S. EPA's WaterSense Specification for Weather-based Irrigation Controllers (Version 1.0). These include the following:

1 The controller shall be capable of preserving the contents of the irrigation program settings when the power source is lost and without relying on an external battery backup.

2 The controller shall either be capable of independent, zone-specific programming or storing a minimum of three different programs to allow for separate schedules for zones with differing water needs.

3 The controller shall be capable of indicating to the user when it is not receiving a signal or local sensor input and is not adjusting irrigation based on current weather conditions.

4 The controller shall be capable of interfacing with a rainfall device.

5 The controller shall be capable of accommodating watering restrictions as follows:

5.1 Operation on a prescribed day(s)-of-week schedule (e.g., Monday-Wednesday-Friday, Tuesday-Thursday-Saturday; any two days; any single day, etc.).

5.2 Either even day or odd day scheduling, or any day interval scheduling between two and seven days.

5.3 The ability to set irrigation runtimes to avoid watering during a prohibited time of day (e.g., between 9:00 a.m. and 9:00 p.m.).

5.4 Complete shutoff (e.g., on/off switch) to accommodate outdoor irrigation prohibition restrictions.

6 The controller shall include a percent adjust (water budget) feature.

7 If the primary source of weather information is lost, the controller shall be capable of reverting to either a proxy of historical weather data or a percent adjust (water budget) feature.

8 The controller shall be capable of allowing for a manual operation troubleshooting test cycle and shall automatically return to smart mode within some period of time as designated by the manufacturer, even if the switch is still positioned for manual operation.

For the water budget feature, the Statewide CASE Team proposes requiring that the consumer be able to easily reduce irrigation levels by 25 percent, which is the difference between the maximum beneficial level of irrigation and acceptable deficit irrigation levels, to accommodate potential water agency drought requirements. Studies have shown that acceptable turf appearance can be maintained at 25 percent less than theoretical turf ET needs (ASIC 2014; GCSAA 2016). Greater or lesser reductions in irrigation may also be possible through more detailed programming, but the 25 percent reduction feature would be available as a stand-alone option that would not require reprogramming the base case watering schedule.

The proposed standards would require that controllers be tested by accepted test procedures and meet performance requirements based on those procedures. Specific performance requirements would depend on the results of product testing that is currently occurring to support the development of new and revised test procedures for weather-based and soil-moisture based irrigation controllers, but for weather-based controllers performance requirements could also include requirements similar or equivalent to those found in WaterSense,[9] including testing for irrigation adequacy and irrigation excess.

At full implementation, consumers will be able to choose the product (a weather-based irrigation controller or a soil moisture sensor-based irrigation controller, both with the ability to suspend irrigation during rainfall events) that will provide the most water savings and other features best suited for their climate preferences.

Rain shut-off devices would be required to be tested and certified using a proposed test method based on an existing Irrigation Association (IA) test method with additional added elements described below in Section 4.3.2. Since U.S. EPA has not issued a specification for rain shut-off devices, the Statewide CASE Team proposes a new performance benchmark for rain shut-off devices. The proposed benchmark would require that rain shut-off devices as shipped detect 95 percent of rainfall events of 1/4 in or 6 mm.[10] Rain shut-off devices must be tested and certified based on a proposed test method as described in Section 4.3.2.1.

Since products are typically manufactured for national markets, the proposed standards do not prohibit the inclusion of alternative settings (i.e., higher or lower detection levels), so long as the products meet the Title 20 Standards as shipped for sale in the California market. The device must also carry at least a three-year warranty to facilitate water savings persistence (note that expected actual lifespan is much higher).

4.1.2 Energy Efficiency

The proposed standards described in this report would also limit standby mode electricity usage. There is potential for improvement in the standby power draw of irrigation controllers, and although some studies are available that estimate controller standby energy use, more robust data is needed on which to base a technically feasible energy efficiency standard. The Statewide CASE Team proposes additional product testing to determine a feasible standard level and technical pathways for meeting an energy efficiency standard.

The standby power use of all controllers would be regulated, limiting power use to prescribed level and requiring that products reenter standby passive or no-load (off) mode within a certain amount of time after product or network inactivity. Products that do not have add-on sensors and that do not use networked communications would comply with a base power requirement, and additional power draw allowances in excess of the base requirements could be allowed for devices with sensors or network activity. Standby

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[9] *WaterSense Specification for Weather-Based Irrigation Controllers*. Volume 1.0. November 3, 2011.

[10] While California emergency regulations ban irrigation for 48 hours after measurable precipitation (SWRCB 2015), rain shut-off devices lack sufficient precision to implement this requirement.

power draw would be tested using the International Electrotechnical Commission (IEC) 62301 test procedure with additional setup instructions.

External power supplies (EPS) sold with irrigation controllers already need to comply with the existing federal standard for Class A EPS that operate consumer products, and no additional standards for those devices are proposed in this report.

4.2 Proposal History

4.2.1 Federal Regulatory Background

There are no federal energy efficiency standards that directly affect landscape irrigation controllers. Therefore, California is not preempted from setting standards for controllers. However, there are federal Title 10 Standards that apply to EPS (10 CFR 430) used in a broad range of consumer appliances. The federal standards require that single-voltage 50-250 watt (W) EPS meet efficiency limits of 87-88 percent, and "no load" losses cannot exceed 0.210 W. Many irrigation controllers have EPS with power losses that are incidental to landscape irrigation controller energy use (no more than 12-13 percent).[11] EPS are by definition an independent component that is attached to the end use product to reduce voltage and/or convert from AC to DC power. Since federal standards do not specifically regulate irrigation controller energy consumption, the EPS standard does not preempt state regulation of irrigation controllers. The federal standard (42 USC 6295(u)(7)) states, "An energy conservation standard for external power supplies shall not constitute an energy conservation standard for the separate end-use product to which the external power supplies is connected."

4.2.2 California Regulatory Background

Several California regulations currently address landscape irrigation controllers for certain types of newly constructed landscapes, though not for existing landscapes.

In July 2015, the California Department of Water Resources (DWR) adopted updated standards for the statewide Model Water Efficient Landscape Ordinance (MWELO) for new landscapes over 500 square feet and rehabilitated landscapes over 2,500 square feet requiring a building or landscape permit, plan check, or design review.[12] The regulations include a requirement that automatic irrigation controllers utilize either evapotranspiration (ET)[13] or soil moisture sensor data. Evapotranspiration rate is defined in the MWELO (23 CCR Division 2 Section 491) as "the quantity of water evaporated from adjacent soil and other surfaces and transpired by plants during a specified time." Additionally, the MWELO requires the use of sensors, either integral or auxiliary, that suspend or alter irrigation during rainfall and other unfavorable weather conditions (such as freezing conditions). The regulation also requires non-volatile memory so that device settings are retained in the event of a power loss.

The MWELO also includes a streamlined compliance option that is available for certain landscapes using graywater (i.e., water collected after use and then reused on-site) located in Appendix D of the MWELO, which also specifies that landscape irrigation controllers must include a rain shut-off device.

The California Green Building Standards Code, "CALGreen" (CCR Title 24, Part 11), also contains requirements for landscape irrigation controllers. CALGreen residential (24 CCR Division 2 section

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[11] Based on federal limits for efficiency, as well as the comparison of no load losses to total product no load losses described later.

[12] California Code of Regulations or "CCR", Title 23, Division 2, Sections 490.1 and 492.7 (DWR 2015).

[13] Landscape evapotranspiration or ET is derived by multiplying ETo, the evapotranspiration rate for grass under specific conditions, by the appropriate landscape coefficient for other crops. ETo can be calculated using the Penman-Monteith equation (IA Irrigation 6th Edition) based on solar radiation, wind, air temperature and humidity.

4.304.1) and nonresidential (24 CCR Division 2 section 5.304.3.1) codes require that automatic irrigation system controllers installed at the time of final inspection be either weather- or soil moisture-based and automatically adjust irrigation in response to changes in plants' needs as weather conditions change. Weather-based controllers must have an integral rain shut-off device, a separate rain shut-off device, or a communications system that accounts for local rainfall.

In addition, on March 14, 2012, the Energy Commission released an Order Instituting Rulemaking (12-0314-16) that included "irrigation equipment" as a topic for potential standards (CEC 2012). The Water Landscaping Act of 2006[14] required that the Energy Commission adopt efficiency performance standards and labeling requirements for landscape irrigation controllers and sensors by January 1, 2010. The Energy Commission had previously initiated a rulemaking in March 2009, during which the Statewide CASE Team prepared a CASE Report with proposed standards for irrigation controllers. The Energy Commission ultimately suspended the rulemaking on July 29, 2009 until "sufficient funding resources become available to pursue and complete the evidence-gathering, studies, and analyses necessary to re-initiate the proceeding" (CEC 2009b). California AB 1928 (Campos 2016) updates prior legislation and requires the Energy Commission to establish performance standards and labeling requirements for irrigation controllers and other landscape irrigation products on or before January 1, 2019. The legislation also requires that the Energy Commission consider IA Smart Water Application Technology Program test protocols.

4.3 Proposed Changes to the Title 20 Code Language

The proposed changes to the Title 20 Standards are provided below. Changes to the 2017 standards are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

Section 1601. Scope.

…

(   ) landscape irrigation controllers

…

Section 1602. Definitions.

…

(   ) Landscape irrigation controller means: "A device intended to remotely control valves to operate an irrigation system for landscapes, which may consist of grass, shrubs, trees and/or other vegetation. This product does not include devices that are typically sold separately and used primarily for other purposes, such as a network router, and may be used incidentally for a landscape irrigation controller. This definition does not include battery powered hose-end timers. This definition does not include devices primarily for use in agricultural applications."

Basic landscape irrigation controller means: "A landscape irrigation controller which primarily schedules irrigation based on day, time, and duration without signal- or sensor-based inputs, or historical weather data to modify irrigation scheduling based on environmental data."

Rain shut-off device means: "A device designed to interrupt a scheduled cycle of a landscape irrigation controller when a certain amount of rainfall has occurred. A rain shut-off device may be an integral product feature for a landscape irrigation controller or an add-on device."

Standby-passive mode for landscape irrigation controllers means: "The controller is not performing any functions but is available to be activated through a remote activation signal."

[14] Assembly Bill 1881, Laird. Chapter 559, Statues of 2006.

Standby-active mode for landscape irrigation controllers means: “The controller is accessing environmental data to calculate any needed adjustments in watering schedules or is performing other exchange of information through the Internet.”

Active mode for landscape irrigation controllers means: “The controller is performing its primary function of energizing a solenoid valve or valves for watering and irrigation.”

Section 1604 Test Methods

…

1) Rain shut-off devices shall be measured in accordance with the Irrigation Association “Turf and Landscape Irrigation Equipment Rainfall Shut-Off Devices Testing Protocol” version 3.0 dated October 2009 with the following additional criteria:
   i. Each individual model will be tested 15 times consisting of 5 repetitions of scenarios 1, 2, and 3 shown in Table *X*. Units with multiple settings need only be tested at their setting as shipped and the next higher setting.

Table *X*: Rain shut-off device testing scenarios

Scenario	Simulated precipitation rate	Simulated precipitation duration
1	0.10 inches per hour	300 minutes +/- 0.5 minutes
2	0.25 inches per hour	75 minutes +/- 0.5 minutes
3	0.75 inches per hour	30 minutes +/- 0.5 minutes

   ii. Units shall be thoroughly dried between tests. Each replicate shall not weigh, prior to each test, in excess of 0.05 ounces more than the product as shipped prior to any wetting.
   iii. Test water pH shall not be less than 6.8 and shall not be greater than 7.5. Conductivity of test water shall not exceed 1,000 microSiemens per centimeter (μS/cm) at 25°C.
   iv. Maximum humidity shall not exceed 40rh and maximum temperature within the testing environment shall not exceed a maximum of 90°F (averaged over the testing period).
   v. Device to be tested shall be configured as shipped, except as for additional configurations needed to perform basic irrigation control functions (i.e., connecting to controller and/or solenoid).
   vi. Device shall be pre-conditioned by operating one testing cycle with each of the scenarios listed under Table *X*. Testing conditions, but not device scores, shall be measured during pre-conditioning.
2) The test method for standby power (standby-passive and standby-active) consumption is:

a. Power consumption measurement according to IEC 62301. Stand-by active shall be determined based on the IEC 62301 result for "network" mode. Stand-by passive shall be determined based on the IEC 62301 result for "standby" mode.

3) *Test methods for weather-based and soil moisture sensor-based controllers to be determined based on test methods currently under development.*

Section 1605.3. State Standards for Non-Federally-Regulated Appliances.

…

(___) landscape irrigation controllers

1) All landscape irrigation controllers manufactured after *[date, twenty-four months after date of standard adoption]* must meet the following standard:
   a. The controller must be able to control irrigation based on the following features:
      i. Either, weather-based control features which schedule irrigation based on local precipitation and weather conditions using an onsite weather sensor, stored historical weather data, weather data retrieved from the internet or another service provider,
      ii. Or, soil moisture sensor-based control features which schedule irrigation based on soil moisture conditions and needs.
   b. The controller must suspend irrigation during rainfall events using either integral functionality or an add-on sensor packaged with the controller.
   c. Products must contain a feature that allows consumers to reduce irrigation by 25 percent without changing the base irrigation schedule.
   d. Products must meet the supplemental capability requirements listed in Section 4.0 of United States Environmental Protection Agency WaterSense Specification for Weather-Based Irrigation Controllers Version 1.0.
   e. Rain shut-off devices must meet the following performance criteria:
      i. The device must detect precipitation totaling 0.25 inch and trigger irrigation shut-off no later than 1 minute following such event.
      ii. The device must meet this Specification for no less than 95 percent of the aggregate of test results from all replicates.
2) Landscape irrigation controllers manufactured after *[date, twenty-four months after date of standard adoption]* must meet the following standby power loss limits:
   a. Base limit on standby power loss, as defined in Section 1602: *X* watts in standby-passive mode. *("X" would be determined based on product testing)*
   b. Power loss for "off" mode shall not exceed standby-passive power loss limit.
   c. Energy use for solenoids that are controlled by a controller, and marketed and sold separately, are not included in these limits.
   d. The device must enter standby passive or off mode not more than *X* minutes after last use in active mode, including direct and remote activation. *("X" would be determined based on product testing)*
   e. The device must enter standby-passive or off-mode within *X* minutes of last network activity in standby-active mode, including network activity to upload or download data, or update software. *("X" would be determined based on product testing)*

Section 1606

…

	Appliance	Required Information	Permissible Answers
( )	Landscape irrigation controllers	Primary intended use	single family building; multifamily building; commercial building
		Features type	weather-based controller; rain shut-off device; soil moisture sensor-based controller
		WaterSense weather-based controller certification (Version 1.0)	yes, no
		Number of stations	
		Lowest setting for rain shut-off device (if rain shut-off device does not have adjustable settings answer "none")	no rain shut-off device; none; 3 mm; 6 mm; 9 mm; other
		Second lowest setting for rain shut-off device (if rain shut-off device does not have adjustable settings answer "none")	no rain shut-off device; none; 3 mm; 6 mm; 9 mm; other
		Percent of time detecting rainfall events per sections 1604 and 1605.3	
		Soil moisture sensor performance data *(placeholder)*	
		Standby-passive mode power (W)	
		Standby-active mode power (W)	
		Active mode power (W)	
		Power source	battery; 110/120 VAC; other

Section 1607

…

d) …. ( ) Landscape irrigation controllers and any add-on devices must be packaged with clear instructions for proper installation, programming, and maintenance. Instructions must state that any rain shut-off device should be installed in a location exposed to unobstructed rainfall and outside the spray path of emitters. For example, the sensor should not be installed under tree canopies, roof overhangs, walls, or other obstructions. Instructions for expanding disk rain shut-off devices and soil moisture sensors must also include recommended maintenance and replacement. Instructions for soil moisture sensors must include optimal placement recommendations. Weather-based controllers must include clear instructions for configuring controllers by determining and inputting irrigation application rate, soil types, plant factors, slope, exposure where used to determine irrigation rate, and any other factors necessary for determining accurate irrigation schedules. These instructions must also explain how a user could directly input irrigation schedules.

4.3.1 Proposed Definitions

The Statewide CASE Team proposes to define "rain shut-off device" based on IA Smart Water Application Technologies (SWAT) Turf and Landscape Irrigation Equipment Rainfall Shutoff Devices Testing Protocol Version 3.0 (October 2009), Section 2.1 (IA 2009).

The Statewide CASE Team definition of "landscape irrigation controller" was adapted from the 2015 MWELO, Section 491 (b) (DWR 2015).

The Statewide CASE Team proposes new definitions for other terms that we did not find adequately defined in existing standards.

- The proposal contains a proposed definition for basic landscape irrigation controller to describe those devices that do not schedule irrigation based on environmental data.
- The proposal contains proposed definitions for landscape irrigation controller active mode power draw, standby-passive mode power draw, and standby-active mode power draw.

4.3.2 Proposed Test Procedure

4.3.2.1 Rain shut-off devices

The IA organizes the SWAT initiative, which functions as a national partnership between the irrigation industry and water purveyors. This initiative includes promoting more efficient landscape irrigation by using state-of-the-art irrigation technologies. IA has developed a SWAT testing protocol for rain shut-off devices to determine their ability to respond to rainfall events in Turf and Landscape Irrigation Equipment Rainfall Shutoff Devices Testing Protocol version 3.0, October 2008. The protocol requires testing eight replicates of each model.[15] Precipitation data is recorded at 0.01 in intervals by calibrated tipping bucket gauges. The device is then dried at 30 degrees Celsius prior to the next test. The protocol does not include variation of simulated precipitation rates below 0.80 in per hour nor specifications for pH and salinity of water used to simulate rainfall. The protocol provides performance data without setting performance standards. It also requires reporting test results, such as accuracy, precision, and coefficient of variation.

The Statewide CASE Team proposes that the Energy Commission adopt the IA SWAT test method for rain shut-off devices with several modifications. First, products should be tested to detect rainfall levels of ¼ in (comparable to 6 mm) consistent with the proposed standard. A wide variety of products have demonstrated through testing the ability to detect rainfall at this level or lower levels over an extended time period (Meeks 2012). Products should also be tested at different simulated precipitation rates, especially given that precipitation rates in some areas of California are significantly lower than national averages.

In addition, the proposed test method addresses ambient humidity, and water pH and salinity levels. For instance, pH and salinity levels could affect the performance of units that detect rain based on conductivity between two receptors, while humidity could affect the performance of units based on disk expansion and overestimate ability to detect a rainfall event.

[15] More than one model could potentially be included in a test batch.

Since the proposed standards for landscape irrigation controllers addresses the ability to detect measurable precipitation as shipped rather than ability to differentiate quantity of rainfall, testing for units with multiple settings would only be required for the default setting rather than each setting as stated in the IA protocol. This would result in a shorter testing period (i.e., four weeks). An additional four weeks would be allowed for preparation of the test report (IA 2009).

The test method also includes reporting test results for accuracy, precision, and coefficient of variation. While these metrics are not directly related to the proposed standard, the Energy Commission could require reporting of this information to provide additional performance data for consumers.

4.3.2.2 Weather Based Controllers

The WaterSense program relies on the IA's SWAT "Turf and Landscape Irrigation System Smart Controllers Climatologically Based Controllers: 8th Testing Protocol" (September 2008) to determine irrigation adequacy and irrigation excess values with a few modifications, as stated in the WaterSense Specification. Products are tested across six zones with variations in soil type, grade, vegetation type and irrigation emitter type. The test method itself does not mandate efficiency levels.

For weather-based controllers, the Energy Commission could adopt the test procedure used in the WaterSense Specification Version 1.0 (U.S. EPA 2011a).

Additionally, the American Society of Agricultural and Biological and Engineers (ASABE) is developing a new standard for weather-based irrigation controllers under American National Standards Institute (ANSI)-accredited standardization processes – ASABE X627: Environmentally Responsive Landscape Irrigation Control Systems. This testing protocol is meant to be more rigorous, especially in determining how the controller handles rainfall events, and it addresses issues lacking in the current test procedure adopted by the U.S. EPA WaterSense program (Mecham 2017). This protocol is currently undergoing testing. Depending on the results of this testing, the Energy Commission could consider adopting this test protocol for certifying weather-based irrigation controllers later, either in conjunction with a similar WaterSense program revision or separately.

4.3.2.3 Soil Moisture Sensors

WaterSense does not currently label soil moisture sensors due to the lack of an established test method. CALGreen and the MWELO also do not contain test methods for this type of equipment. IA SWAT has developed a testing protocol for testing soil moisture-based controllers, but it does not include performance requirements. Phase one of the SWAT protocol evaluates how well the soil moisture-based sensor functions over a range of conditions that affect moisture (e.g., soil type, temperature, salinity). Phase two of the SWAT protocol focuses on the performance of the soil moisture sensor-based controller (IA 2011).

ASABE is also developing a new performance test standard for soil moisture sensors under ANSI-accredited standardization processes – ASABE X633: Testing Soil Moisture Sensors for Landscape Irrigation. The U.S. EPA WaterSense program is working with ASABE to develop this standard and has issued a notice of intent to develop a specification for soil moisture-based control technologies once this research is complete (U.S. EPA 2017). This protocol is currently undergoing beta testing. Depending on the results of this testing, the Energy Commission could adopt this test procedure and associated requirements for certifying soil moisture sensor-based irrigation controllers. An inherent challenge in creating an adequate test method for soil moisture sensors is determining a representative location during testing since a soil moisture sensor can only be placed in one specific location unless a controller is installed along with multiple sensors. Any proposed soil moisture sensor test method should address this barrier.

4.3.2.4 Power Consumption

The Statewide CASE Team did not identify a test method that specifically addresses landscape irrigation controller energy use. However, the International Electrotechnical Commission (IEC) has a test procedure for measuring standby power titled "62301 Household Electrical Appliances – Measurement of Standby Power" (Second edition, 2011). This test procedure provides a method for determining the power consumption of a range of appliances and equipment when operated in standby mode. See Section 2.2 of this report for standby power definitions. Although the Statewide CASE Team finds IEC 62301 sufficient for measuring standby power once the unit under test (UUT) is prepared for testing, the test procedure lacks set-up instructions for secondary functions, such as network connections or sensors. Several ENERGY STAR® specifications, including those for small network equipment, electric vehicle supply equipment with communications features, TVs, and displays specify UUT set-up conditions. The Statewide CASE Team is currently evaluating the applicability of drawing on these ENERGY STAR procedures to specify similar procedures for irrigation controller testing.

EPS used with irrigation controllers, which convert line voltage to 24 VAC, are covered under the federal standard for Class A EPS that operate consumer products and the California standard for state-regulated EPS (CEC 2008). The Statewide CASE Team assumes that EPS sold with irrigation controllers are regulated under this standard. The test method for Class A federally regulated and state-regulated power supplies is contained in the Title 10 Subpart B Appendix Z "Uniform Test Method for Measuring the Energy Consumption of External Power Supplier."

The Statewide CASE Team proposes the use of IEC 62301, with additional UUT set-up instructions for network connections, sensors, and other secondary functions, to test standby power of basic irrigation controllers, and standby-active and standby-passive power of weather- or soil moisture-based controllers. The Statewide CASE Team also proposes to include a method to measure the transition time from both active mode and standby-active mode to standby-passive mode. The Statewide CASE Team proposes testing this procedure and new UUT set-up instructions in a lab setting before it is adopted to ensure the suitability and repeatability of the proposed test procedure and set-up instructions.

4.3.3 Proposed Metrics

For rain shut-off sensors, the Statewide CASE Team proposes testing products' ability to detect rainfall levels of ¼ in (comparable to 6 mm), tested at different simulated precipitation rates.

For weather-based and soil-moisture based controllers, the metrics will depend on the result of ongoing test procedure development and beta test results. The metrics will likely require that controllers meet a certain level of irrigation adequacy in each zone and do not exceed a set irrigation excess level across all zones.

For irrigation controllers, product efficiency (such as the WaterSense standard) is typically based on the ability of the device to provide a landscape with enough water to fulfill optimal ET requirements, however, it is important to note that sufficient landscape quality can also be maintained by deficit irrigating (i.e., irrigating less than the optimal ET requirement). Thus, an ability to provide deficit irrigation is another important metric.

The energy efficiency standard is based on standby mode power draw, since controllers mostly operate in standby mode and this mode likely accounts for the majority of energy use as shown in Section 5.4.

4.3.4 Proposed Reporting Requirements

The Statewide CASE Team proposes requiring reporting of basic product information, performance data, and test results as shown in Section 4.3. This data will verify compliance with the proposed standards.

4.3.5 Proposed Marking and Labeling Requirements

The Statewide CASE Team proposes that manufacturers mark landscape irrigation controllers with the manufacturing date to facilitate determining whether an individual unit was manufactured after a compliance deadline for the standards. We note that several manufacturers currently certify and label weather-based controller products for the voluntary WaterSense program, which will assist with standards implementation.

The Statewide CASE Team also recommends marking whether products meet the proposed standby power consumption limits.

In addition, the Statewide CASE Team recommends requiring that manufacturers include consumer information with controllers to improve installation practices. The Statewide CASE Team assumes that the cost would be very minor on a per unit basis.[16]

5. Analysis of Proposal

5.1 Scope/Framework

This proposal includes landscape irrigation controllers, as defined in Section 4.3.1. The standard would apply to all landscape irrigation controllers. The proposal does not include hose end timers.

5.2 Product Efficiency Opportunities

According to the MWELO, irrigation efficiency is defined as the amount of water beneficially used divided by the amount of water applied. Irrigation efficiency is derived from measurements and estimates of irrigation system characteristics and management practices (DWR 2015). Greater irrigation efficiency can be expected from well-designed, programmed and maintained systems.

Landscape irrigation controllers features that increase the water efficiency of the device include those described in Section 2.1 above:

- Rain shut-off sensors, which suspend irrigation during and after periods of rainfall
- Weather inputs from weather sensors, internet connections or stored historical data, which modify irrigation scheduling based on measured, reported, or anticipated weather conditions
- Soil moisture sensors, which modify irrigation application based on soil moisture conditions

Energy efficient irrigation controllers perform the key functions of an irrigation controller – scheduling and initiating irrigation for a landscape – while minimizing energy use. Controller energy efficiency could be improved by the use of more efficient transformers and by eliminating operations such as polling sensors for data and cloud communications when the controller is in standby mode and such functions are not needed.

[16] For information on the potential cost of providing additional consumer information, please see the California IOU C&S Team Report "Air Filter Testing, Listing, and Labeling" dated July 29, 2013. That report estimated the incremental labeling cost at $0.02 per unit on a national basis. While the cost of providing consumer information for controllers may be higher on a per unit basis than air filters, for instance due to less sales volumes and economies of scale, we assume that it will be minor.

5.3 Technical Feasibility

5.3.1 Water Efficiency Measures

The potential water efficiency standards can likely be met by existing products available from multiple manufacturers today. At least eight manufacturers, including Hunter, Rain Bird, Toro, Irritrol, Weathermatic, Hydro-Rain, Signature, and K-Rain sell landscape irrigation rain sensors. Additionally, there are over 20 manufactures with U.S. EPA WaterSense labeled weather-based irrigation controllers, including Cyber-Rain, ETwater, HydroPoint, Orbit, Rachio and Skydrop, in addition to many of those listed above that market rain sensors. At least five manufacturers offer soil moisture control sensors, including Irrometer, Acclima, Hunter, Rain Bird and Toro.

5.3.2 Energy Efficiency Measures

In addition to the potential embedded energy savings due to the anticipated water savings of the features above, the direct energy use of irrigation controllers presents a savings opportunity. The Statewide CASE Team reviewed two studies that measured the standby power of irrigation controllers, which ranged from 1 W to 8 W (Brown 2009; Delforge 2015). Irrigation controllers are essentially small, simple computers, with timers, network connections, and sensors to wake them from standby to active mode. To make a preliminary estimate of technically achievable standby power levels of irrigation controllers, the Statewide CASE Team examined low power modes of two categories of ENERGY STAR-qualified computing devices: computers and audio-video products. These products provide sleep mode functionality similar to that of irrigation controllers in standby mode; they maintain volatile memory, network connections, and sensors that allow the device to be woken up. Although computers and audio-video products generally provide more sophisticated computing and serve very different applications from irrigation controllers in active mode, their functionality and power requirements in sleep mode may be indicative of achievable standby power levels for irrigation controllers.

Sleep mode power draw of ENERGY STAR-qualified desktop computers, in which the computer is powered down, preserving its session in volatile memory and waiting to be reactivated by the network or user, is as low as 0.1 W and averages 1.6 W (Figure 3). Similarly, ENERGY STAR audio-video products average less than 0.5 W in their sleep mode. Both product types can achieve lower power than that measured for irrigation controllers in standby mode (Figure 3). The wide range of standby power measured within the irrigation controller category indicates that these products have not yet been fully optimized for energy efficiency. The Statewide CASE Team proposes additional research to better understand technically achievable standby power levels for irrigation controllers (see below), but this preliminary comparison suggests that significant savings opportunities exist.

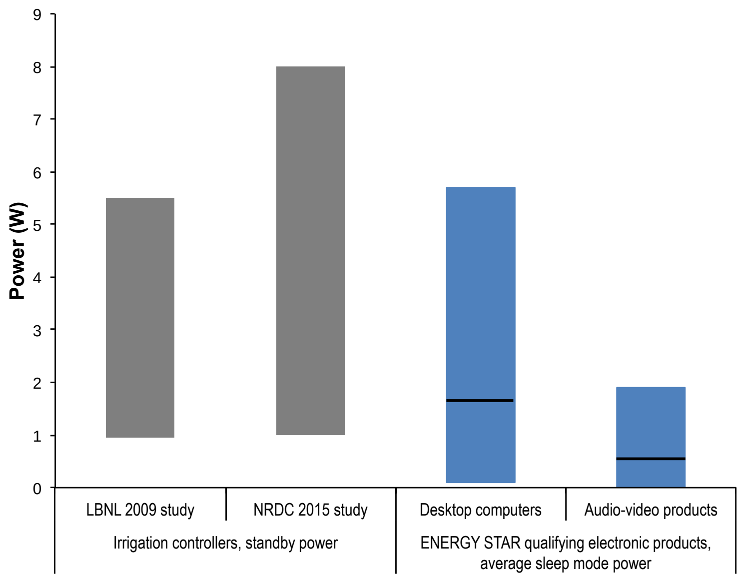

Figure 3: Measured standby power of irrigation controllers compared to sleep power in ENERGY STAR qualified desktops and audio-video products shows significant potential for power reduction. Average sleep mode power for ENERGY STAR computers and A/V products indicated by black lines.

Source: Statewide CASE Team.

Although limiting the energy use of irrigation controllers is technically feasible, data is lacking to support setting a technically feasible irrigation controller-specific energy standard. The Statewide CASE Team proposes the following research activities to support the development of a technically feasible energy efficiency standard for irrigation controllers:

1. Test procedure additions: (1) Develop draft set up instructions for functions, including network connections and sensors, (2) Vet draft instructions with relevant stakeholders, (3) Test the clarity and repeatability of the instructions by coordinating round robin testing of instructions at several test labs, (4) Based on round robin results, revise instructions as necessary.
2. Data collection: Data collection could take place in a single phase that includes traditional, weather-based, and soil moisture-based controllers, or it could be split into multiple phases (e.g., first examine traditional controllers, then weather- and soil moisture-based controllers once the soil moisture sensor-based controller test procedure is finalized). For each type of controller, the Statewide CASE Team proposes the following activities: (1) Characterize as-assembled standby power requirements for a wide range of products that fall under this product category, (2) Identify and measure power draw of the components that deliver low power mode functionality by invasive inspection and testing, and (3) Develop or coordinate development of prototypes to provide proof-of-concept for low power mode improvements.
3. Standards proposal: The Statewide CASE Team could use the information collected to update recommendations on product savings potential, proposed standard framework, identification of technical pathways and analysis of their cost-effectiveness, and proposed standard levels.

5.3.3 Future Market Adoption of Qualifying Products

The Statewide CASE Team anticipates that the proposed standards will steer the California landscape irrigation controller market to more efficient products. The standards may also increase the popularity of rain shut-off sensors due to their low cost and ease of addition to most controllers.

The Statewide CASE Team assumes that without standards, market adoption will remain low. Due to the recent drought, water prices have increased in some areas around the state. However, the Statewide CASE Team does not believe that the drought emergency converted the market for irrigation controllers. Potential market barriers include historical stocking decisions, lack of customer information regarding expected savings, and the lack of any certification process for shut-off devices.

Utility incentive programs that aim to replace basic irrigation timers with more efficient models could increase the shipments of qualifying products. The savings estimates presented in this report assume that irrigation controllers will be replaced at the end of their useful life (11 years). However, utility incentive programs could result in irrigation controllers being replaced more quickly, especially with increased stocking of qualifying products due to new Title 20 Standards. If this happens, stock turnover will occur sooner than presented in this report, and California will realize the full savings potential at an earlier date.

5.4 Statewide Water and Energy Savings

5.4.1 Per Unit Water and Energy Savings Methodology

This section describes the methodology the Statewide CASE Team used to estimate water, energy, and environmental impacts. The Statewide CASE Team calculated the impacts of the proposed code change by comparing non-qualifying products to qualifying products. Table 3 below presents the assumptions used to calculate per unit water and energy savings of the proposed standards.

Table 3: Per Unit Water and Energy Savings Assumptions

Data and Assumptions		
Metric	**Value**	**Notes**
Non-qualifying product average lifetime	11 years	CEC Prop 39 guidelines
Qualifying product average lifetime	11 years	CEC Prop 39 guidelines
Energy and water use		
Time in active mode, base controller	3%	Foster-Porter et al. 2006
Water savings, weather-based controller	15%	WaterSense Supporting Statement; Williams 2014
Water savings, soil moisture sensor-based controller	38%	Williams 2014
Water savings, rain shut-off device	6.7%	Statewide CASE Team analysis
Baseline water use per controller, residential landscape	69,000 gallons/year	DeOreo et al. 2011[17]

[17] The weighted average annual outdoor use was 190 gallons per household per day, or about 69,000 gallons per household per year. This average does not explicitly exclude homes that were not irrigating. For irrigating homes only, the average outdoor water use was 93,600 gallons per household. The lower estimate is used here per controller to account for the fact that some homes with large landscape areas may use more than one controller per home (DeOreo et al. 2011).

Baseline water use per controller, commercial landscape	230,000 gallons/year	Statewide CASE Team estimate[18]
Commercial, industrial, and institutional market share	12.9%	Mayer 2009

5.4.1.1 Per Unit Water Use and Savings Methodology

Baseline water use is based on the market share and individual weighted baseline water use of residential and commercial, industrial and institutional (CI&I) controllers. The residential baseline of 69,000 gallons per year (DeOreo et al. 2011) represents a statewide average, as baseline use can vary between regions and between users.[19] The baseline for CI&I controllers is based on total CI&I water use (DWR 2013) and an assumption that one-third of total CI&I water use is for irrigation.[20] This estimate does not include separately metered large landscapes, such as golf courses, cemeteries, and parks, which are likely to have specialized and closely managed irrigation systems. The market share of residential and CI&I controllers is based on a study which evaluated in incentive programs for weather-based irrigation controllers in California (Mayer et al. 2009).[21]

Outdoor irrigation water use is a function of many different parameters including, but not limited to, landscape size, plant types, plant groupings, geographic location, weather conditions, landscape design, proper equipment installation, operation, and maintenance. Per unit baseline water use is calculated using Equation 1 below.

Equation 1: Average Baseline Per Unit Annual Water Use Calculation

$$\begin{aligned}\textit{Annual Water Use} \\ &= \text{water use (residential controller) x market share} \\ &+ \text{water use (CI\&I controller) x market share}\end{aligned}$$

The standards case water use is based on assumed market share with standards in place for each controller technology and the assumed water savings for each technology compared to the baseline.

Equation 2: Per Unit Annual Water Use Calculation with Standards

$$\begin{aligned}\textit{Annual Water Use} \\ &= \text{water use (weather based controller) x market share} \\ &+ \text{water use (soil moisture sensor based controller) x market share}\end{aligned}$$

The Statewide CASE Team estimated potential 15 percent water savings from weather-based controllers based on the WaterSense estimate of 15 percent (U.S. EPA 2011b) and an LBNL estimate of 15 percent, which was based on a survey of numerous studies (Williams 2014). Actual savings will vary based on many

[18] Estimate based on assumption that one third of commercial, industrial and institutional (CII) water use is outdoors, and the assumption that all commercial landscape irrigation is controlled with an automatic controller. This water use was then divided by the estimated commercial controller stock to yield this estimate. This estimate does not include water use of large landscapes with dedicated meters.

[19] For example, an average home in Las Virgenes, CA uses approximately 230 kilogallons annually for outdoor irrigation. On the other hand, an average home in Lompoc, CA uses only a fraction of this – about 40 kilogallons annually – for outdoor irrigation (DeOreo et al. 2011).

[20] Per Pacific Institute 2003 Figure 4-6 (p.83), 35 percent of total CI&I water use is attributable to landscaping. Per the footnote on Figure 2 (page 2) of PPIC 2016, their estimate of commercial and institutional outdoor use includes official estimates for "… a third of the total estimate for commercial and institutional demand."

[21] Changes, such as the MWELO revisions updated on July 15, 2015, may lead to longer-term landscape irrigation efficiency for new landscapes. Because MWELO applies only to new landscapes, only a subset of controllers will be affected. However, replacement units are subject to Title 20.

factors, such as local weather and proper installation. One prior study conducted in California (Mayer 2009) estimated lower savings, while other studies have found significantly higher water savings from properly programmed and installed units.

The Statewide CASE Team estimated potential 38 percent water savings for soil moisture sensor-based controllers based on the LBNL study estimate (Williams 2014). This estimate may be revised after the release of results of soil moisture sensor-based controller testing that is currently ongoing (to support the development of the ASABE test protocol).

The Statewide CASE Team also prepared an estimate of rain shut-off savings to revise an estimate in the 2009 CASE Report to account for rainfall events that will not trigger a rain shut-off device. This more recent analysis determined that sufficient precipitate to activate a rain sensor shut-off will occur 6.7 percent of days.

The Statewide CASE team found that rain shut-off device will stop irrigation after 0.13-0.14 in of precipitation (approximately 3.4 mm) has occurred.[22] In addition, the Statewide CASE Team analyzed over 32,000 days of precipitation data from 2,000-2,015 from the California Irrigation Management Information System covering six major regions of California to determine the percentage of days with precipitation exceeding this level.[23] Each region was given equal weight when calculating statewide savings estimates for simplicity.[24]

The mean frequency of days with precipitation sufficient to activate a rain-sensor shut-off (i.e., 0.14 in or greater) is 6.7 percent as shown below in Table 4. The estimate is significantly more conservative than other national estimates of potential water savings from rain shut-off sensors (Williams 2014).

Table 4: Rainfall Distribution by City and Region

Percent of dates, October 2000 - September 2015							
Precipitation (in)	U.C. Riverside	Castroville	Davis	Petaluma East	Fresno State	Concord	Mean
	Los Angeles Basin	Monterey Bay	Sacramento Valley	North Coast Valleys	San Joaquin Valley	San Francisco Bay	
0.13 or less	96.1%	93.4%	92.0%	91.3%	94.3%	92.6%	93.3%
0.14 or greater	3.9%	6.6%	8.0%	8.7%	5.7%	7.4%	6.7%

Source: CMIS 2015, Statewide CASE Team analysis.

5.4.1.2 Per Unit Energy Use and Savings Methodology

This section describes the methodology the Statewide CASE Team used to estimate direct controller energy based on energy use for different operating modes, as well as energy used to activate solenoids.

[22] The Statewide CASE Team based this estimate an average of several multi-year studies of various models (Meeks 2012; Table 2). The study includes multiple trials of the Hunter Mini-Clik, each of which was weighted equally with trials for other products, because the Mini-Clik is a very common product.

[23] This information is available at http://www.cimis.water.ca.gov/.

[24] The Statewide CASE Team recognizes that the Los Angeles (LA) Basin has greater population, but consumers and installers may generally prefer weather-based controllers in drier regions. Therefore, the Statewide CASE Team did not assign extra weight to the results for the LA Basin.

Landscape irrigation controllers affect on-site energy usage (typically household current) in several ways. First, controllers consume electricity in both standby and active mode. Second, they use electricity to control a solenoid that allows irrigation to occur.

Equation 3: Product Annual Energy Use Calculation

$$Annual\ Energy\ Use\ (kWh\ per\ Year) \\ = \text{standby mode power x hours in standby mode} \\ + \text{active mode power x hours in active mode}$$

Annual per unit energy use is calculated based on the weighted average of standby and active mode energy usage for each product, including power supplied to a solenoid in active mode (see Equation 4 below). The calculation is repeated for both the baseline and standards case, with the net difference representing the per unit savings.

Controller Operating Modes

Standby power consumption is a large contributor to annual energy consumption of an irrigation controller, because a typical irrigation controller is connected to the grid continuously throughout the year and spends about 97 percent of the time in standby mode (i.e., not activating a solenoid) (Foster-Porter et al. 2006), which is equal to about two hours of active mode, three days a week during a hypothetical 42-week watering season.

Controller Energy Use in Each Mode

The amount of time in active mode can vary between a basic and qualified product, due to water savings and expected shorter run-times for products with water savings features. Standby energy usage is similarly adjusted for the standards case and the expected small increase in standby mode due to shorter run times.

Equation 4: Product Energy Use Calculation

$$Active\ Mode\ Energy\ Use\ (kWh) \\ = \text{active mode controller electricity use} + \text{solenoid electricity use}$$

Energy consumption for the standards case could be calculated based on the base energy standard and any energy adders for equipment with add-on sensors or networking capabilities. Energy savings were not calculated for the amount of time a device is in active mode following customer use or network activity (for networked units) due to a lack of baseline data. Because the regulation would cap the amount of time before a product enters standby mode, the energy use estimates are likely conservative.

The Statewide CASE Team reviewed three independent sources of baseline direct energy consumption data. The most detailed study of standby power for irrigation controllers was conducted in 2009 by LBNL. In this study, the energy use of both conventional and smart irrigation controllers was directly measured (Brown 2009). The study's findings showed that a basic residential controller uses about 2.1 W in standby mode. The standby power of basic controllers measured by LBNL ranged from just under one W to approximately three W. Smart controllers had a higher power draw in standby mode, with an average standby power of 4.2 W with a range from approximately 3 W to approximately 5.6 W.

More recent data are available based on voluntary listings of smart irrigation controllers in manufacturer product literature. Table 5 below lists three weather-based controllers that are currently available on the market. One is a local controller, and the other two are connected controllers. The standalone controller has a higher standby power draw at 7.2 W, while the connected controller consumes 2.5 W.

Table 5: Per Unit Standby Energy Use for Sample Weather-Based Controllers

Smart Controller	Active Mode Power (watts)	Standby Mode Power (watts)	Non-Volatile Memory?
Standalone locally controlled unit	21.6	7.2	Yes
Connected unit #1	48	2.5	Yes
Connected unit #2	70	2.5	Yes
Average	46	4.1	N/A

Source: Data from manufacturer literature. The literature did not indicate the test procedure used or if the data represent rated consumption or measured energy consumption.

A third source of baseline irrigation controller data is a May 2015 issue paper from the Natural Resources Defense Council (NRDC) on home idle load (Delforge 2015). The paper included results from an audit of idle loads for ten San Francisco Bay Area homes. Irrigation systems were installed in seven of the ten homes audited (some homes had more than one controller installed), with standby power consumption ranging from one W to eight W. The controllers measured were existing systems, and the age of these systems and type of features were not listed in this report.

The standby power draw for irrigation controllers from all data sources range from one W to eight W. Standalone smart controllers may consume more energy in standby mode because of the need to collect, store, and process data on site (see Table 5). Connected controllers may require less energy than controllers with local analytical capability, because the processing capabilities are delegated to the cloud. Conventional controllers may consume the least amount of energy in standby mode because they are largely dormant when not in active irrigation mode.

<u>Solenoids</u>

Solenoid valve operation is another source of energy use related to landscape irrigation controllers. Solenoids typically use about 14 W per solenoid in active mode (Rain Bird 2015c, 78). The Statewide CASE Team assumes one solenoid valve per station in the analysis presented in this report, though some systems have two (Rain Bird 2015c, 78). Total solenoid energy consumption is likely less than the energy consumed by the controller due to the standby energy consumption of the controller.

5.4.1.3 Peak Demand Methodology

Peak demand was calculated by multiplying daily electricity use by an assumed load factor. A load factor is the ratio of average annual load to coincident peak load. The Statewide CASE Team obtained end-use load factors through consultations with the Energy Commission. The load factors used in this report were developed by the Energy Commission using an Hourly Energy and Load Model (Koomey and Brown 2002) on 2013 utility-level energy demand data. A complete table of updated values for several end-uses is included in Appendix B: Load Factors.

5.4.1.4 Annual Per Unit Embedded Electricity Use Methodology

Energy is required for water supply (e.g., pumping), conveyance, treatment, and distribution of potable water. The Statewide CASE Team assumes that every million gallons of water used for an outdoor application in California results in 3,565 kilowatt-hours (kWh) of electricity use. This value was derived from a California Public Utilities Commission (CPUC) cost-effectiveness analysis of water and energy prepared by Navigant Consulting, Inc. (CPUC 2015). See Appendix D: Embedded Electricity Usage Methodology for further discussion on the methodology used to develop the embedded energy factor. While some landscapes are irrigated using recycled water or on-site collection of rainwater or shower & laundry drains, etc., this fraction is considered small and excluded from the methodology described in the Appendix.

5.4.2 Summary of Per Unit Energy Use Impacts

Annual per unit energy impacts are not presented in this report, as the level of annual energy savings depends on the proposed level of the energy standard. Once a technically feasible energy standard is proposed as a result of the ongoing research activities in Section 5.3.2, the Statewide CASE Team will provide an estimate of per unit energy impacts for qualifying products. As previously described, non-qualifying products are those which *do not* meet the proposed standard; qualifying products are products which *do* meet the proposed standards. The methodology used to calculate these estimates is presented above.

5.4.3 Stock

The Statewide CASE Team estimated a stock of approximately 3.3 million irrigation controllers in operation in single family homes in California in 2015. This is based on the annual sales estimate of 300,000 units per year as discussed below and a 11-year estimated useful life of the controller (CEC 2014). The Statewide CASE Team also estimated a stock of about 490,000 units for multifamily, commercial, and other nonresidential buildings using the same methodology. Therefore, the total estimate for irrigation controller stock in California in 2015 was about 3.8 million units. Assuming an annual growth rate, Table 6 presents the estimated landscape irrigation controllers sales and stock in years 2019 through 2030.

The Energy Information Agency (EIA) found 3.8 million California homes have landscape irrigation controllers based on 2005 residential surveys (EIA 2005, Berry 2015).[25] The survey asks whether homes have an automatic irrigation system, but the survey does not differentiate between controllers addressed by this proposed standard, and hose-end timers, which are excluded from the analysis and the proposed standard in this report.

In a previous 2009 report, the Statewide CASE Team estimate of landscape irrigation controller stock was based on a California Urban Water Conservation Council (CUWCC) estimate that 61 percent of single family homes in California irrigate lawns and gardens using an automatic sprinkler/irrigation system and controller (CUWCC 2007).[26] Based on the estimated number of single family homes in California, and the 11-year expected useful life of irrigation controllers, this would translate to approximately 500,000 systems. The Statewide CASE Team notes that the difference between the 2009 CASE Report estimate and the lower estimate in this report is at least partially attributable to the exclusion of hose-end timers in the current CASE Report.[27]

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[25] According to the EIA and industry input, California has a larger share of the irrigation market than California's share of the national population. The original survey question can be viewed at: http://www.eia.gov/survey/form/eia_457/2005%20RECS%20457-A%20Household%20Survey.pdf.

[26] According to the statewide survey, 68 percent of single family homes use an automatic sprinkler. Of these homes, 89 percent of them have a timer that controls the irrigation schedule (CUWCC 2007). From this, the Statewide CASE Team estimates approximately 61 percent (68 percent x 89 percent) of single family homes throughout the state have an automatic irrigation system that uses an irrigation controller/timer.

[27] Note that these estimates include controller sales for both retrofits and new construction. New construction sales represent a relatively small fraction at stock turnover. For new construction, the latest California MWELO requires automatic irrigation controllers that utilize either

Table 6: California Stock and Sales

Year	Annual Sales (units)	Stock (units)
2019	348,000	3,970,000
2020	348,000	4,000,000
2021	349,000	4,040,000
2022	350,000	4,070,000
2023	351,000	4,110,000
2024	351,000	4,150,000
2025	352,000	4,180,000
2026	353,000	4,220,000
2027	354,000	4,260,000
2028	354,000	4,300,000
2029	355,000	4,340,000
2030	356,000	4,380,000

Source: Estimated based on industry interviews, EIA 2005, and Mayer 2009.

5.4.4 Shipments

The Statewide CASE Team estimates annual California sales of about 300,000 units per year for the residential sector and 45,000 units per year for the commercial sector. This residential estimate relies on interviews with industry experts, and the commercial estimate is based on the estimated commercial market share compared to the residential market (Mayer 2009). We note that this estimate is lower than the 2009 CASE Report estimate of 500,000 annual sales due to the lower estimate of total stock.

5.4.5 Current and Future Shipments

5.4.5.1 Current Market Share of Qualifying products

The Statewide CASE Team assumed that the market share of qualifying irrigation controllers (those which account for environmental data when scheduling irrigation) is about 20 percent in California. This estimate is also supported by U.S. EPA's estimate that, on a national level, less than ten percent of installed irrigation controllers are weather-based (U.S. EPA 2011b). Given existing California mandates for installation of these units (such as in the MWELO for new landscapes), the Statewide CASE Team believes that ten percent is a reasonable estimate for the California market share of weather-based controllers. The Statewide CASE Team also estimates a similar market share of at most ten percent for other qualifying units, such as those with soil moisture sensors as informed by interviews with several industry experts.

Market data related to the standby power consumption of landscape irrigation controllers currently offered for sale are not widely available. However, the Statewide CASE Team reviewed data showing that existing basic controllers consume between one and three W in standby mode and weather-based controllers consume between three and eight W in standby mode (Brown 2009; Delforge 2015). When more product test data is available to substantiate the energy use claims for a variety of irrigation controllers, the Statewide CASE Team will have additional information about the market share of controllers that meet the proposed energy standard.

evapotranspiration or soil moisture sensor data, and that utilize a rain sensor, but the standards proposed here are not the same as MWELO, because MWELO lacks performance standards for these devices.

5.5 Environmental Impacts/Benefits

5.5.1 Greenhouse Gases

Annual and stock greenhouse gas (GHG) savings are expected for the energy efficiency standard. The anticipated level of GHG savings depends on the level of the energy standard, which is dependent on the completion of additional product testing. The Statewide CASE Team calculates the avoided GHG emissions from the adoption of a proposed standard assuming a 2020 emissions factors of 353 metric tons of carbon dioxide equivalent ($MTCO_2e$) per Gigawatt-hour (GWh) of electricity savings (CARB 2010).

The Statewide CASE Team also uses California Air Resources Board (CARB) data to determine an avoided carbon dioxide emission factor. CARB prepared an analysis of increasing California's Renewable Electricity Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020 with different future electricity demand scenarios.[28] The emissions factor used is intended to provide a benchmark of emissions reductions attributable to energy efficiency measures that would help achieve the low load scenario. The emissions factor is calculated by dividing the difference between California emissions in the high and low generation forecasts by the difference between total electricity generated in those two scenarios. While emission rates may change over time, 2020 is a representative year for this measure.

5.5.2 Water Resources

Water is essential to supporting and sustaining the environmental, economic, and public health needs of the state. The continuing risk of severe future droughts, shifts in regional climate patterns, and the state's population growth are leading to concerns about the sustainability of ever-growing demands on a limited (and shrinking) water supply. Since water security is critically important to the state, improving water efficiency is a well-established statewide policy goal. For instance, legislation enacted in 2009 (SB X7-7, 2009) established the goal of achieving a 20 percent reduction in urban per capita water use in California by 2020.

Establishing more stringent water-efficiency standards is a cost-effective intervention for reducing California's water demand, especially compared to other costly solutions that aim to increase and maintain reliable water supplies. For instance, projects, such as ocean water desalination, dams, or new water conveyance cost billions of dollars.[29] The water-efficiency standards presented in this document, on the other hand, will reduce Californians' expenditures on water bills and reduce demand on water supplies at a much lower cost than developing new sources.

In addition, more efficient qualifying products may reduce runoff as well as releases of pesticides, fertilizers, and sediment into streams, rivers, lakes, and oceans, either directly through flows into surface waters or storm sewers or as residuals from treated wastewater.

5.5.3 Indoor or Outdoor Air Quality

This measure will have no direct effect on air quality. The measure will reduce embedded energy and thereby indirectly reduce air pollution.

[28] CARB calculated GHG emissions for two scenarios: (1) a high load scenario in which load continues at the same rate, and (2) a low load rate that assumes the state will successfully implement energy efficiency strategies outlined in the AB32 (Global Warming Solutions Act) scoping plan, which would reduce overall electricity load in the state (CARB 2010). The Statewide CASE Team calculated the emissions factors of the incremental electricity savings between the low and high load scenarios.

[29] Though it can produce a reliable source of water, desalination is a very expensive and energy-intensive technology. It also has an impact on the local aquatic environment (Pacific Institute 2013). Further, upgrading infrastructure for water conveyance and storage can cost tens of billions of dollars.

5.5.4 Hazardous Materials

The Statewide CASE Team did not identify any direct impacts on hazardous materials from this measure.

5.6 Impact on California's Economy

5.6.1 Impacts to Businesses and Disadvantaged Communities

The Statewide CASE Team does not believe that proposed standards would negatively affect California businesses, including small businesses, for several reasons.

First, the Statewide CASE Team is not aware of any comments that Title 20 Standards would adversely affect California businesses, including small businesses, during the adoption of California legislation requiring these standards. Second, total U.S. revenues for landscaping services are estimated at $83 billion, including a variety of installation and maintenance services.[30] Irrigation consists of a relatively small share of overall revenue and even less so for the smallest businesses (see Table 7 below), so any costs that they cannot recover should be a small share of total revenue. Third, the Statewide CASE Team does not anticipate any significant reduction in consumer spending for this market, even if costs are passed onto consumers, due to the relatively low cost of compliance compared to the overall cost of installing a landscape.

Table 7: Revenue by Market Segment and Company Size

	Sales Under $200k	Sales of $200k or More
Lawn mowing/maintenance	59%	34%
Design/build	13%	27%
Lawn care	10%	17%
Tree and ornamental	7%	5%
Irrigation	3%	8%
Other	9%	9%

Source: Lawn and Landscape 2014.

Note: The Statewide CASE Team calculated market segments without the ice and snow removal category that was included in the national survey.

The Statewide CASE Team does not anticipate any negative impacts on disadvantaged communities. These communities will likely benefit from these products in the same way that other consumers will benefit.

5.6.2 Incremental Cost

Given the wide array of irrigation controller features offered by models that are currently on the market, there can be significant variation in the current cost of an irrigation controller.

Table 8 below provides an example of the range of retail prices for irrigation controllers that are currently on the market. One primary driver in the price is the number of stations or zones the device can control. Price is also affected by the complexity of the features the device offers. The average price of non-qualifying landscape irrigation controllers on the market is lower than that of qualifying products, which is likely attributable to the fewer number of features offered in a typical non-qualifying product.

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[30] See https://www.ibisworld.com/industry-trends/market-research-reports/administration-business-support-waste-management-services/administrative/landscaping-services.html.

Based on retail price data, the Statewide CASE Team estimates that the cost of a simple weather-based controller (excluding potential cost for energy efficiency standard compliance) is approximately $100 more than the cost of a basic traditional controller. Comparatively, a basic traditional controller can be purchased for approximately $50.

Table 8: Example Prices of Irrigation Controllers for Residential/Light Commercial Use

Models	Retail Price (2015 $)
Traditional Controller/Timer	
Orbit Easy Set Logic, 4-Station Indoor/Outdoor	$39.97
K Rain RPS 46, 4-Station Indoor	$49.99
Rain Bird SST, 4-Zone Indoor	$49.99
Hunter X-Core, 4-Station Indoor	$55.98
Irritrol KwikDial, 4-Station Indoor	$78.67
Rain Bird ESP-ME, 4-Station Indoor	$75.11
Toro Evolution, 4-Station Indoor	$105.20
Weather-Based Controller with Connected/Integrated Features	
Rain Bird ESP-SMTE, 4-Station Indoor	$158.05
Rachio IRO, 8-Station Indoor	$249.00
SkyDrop, 8-Station	$199.00
Orbit B-hyve Wi-fi Controller, 6-Station Indoor	$100.00
Hunter HC-600i Hydrawise Wi-fi Controller, 6-Station Indoor	$149.00
Weather-Based Controller with Included Sensor	
Raindrip WeatherSmart Pro, 6-Station Indoor	$35.99
Add-on Weather Sensor Only	
Hunter Solar Sync	$69.52
Hunter Solar Sync Wireless	$122.47
Irritrol Climate Logic Wireless	$120.00
Toro EVO-WS ET Weather Sensor	$56.43
Add-on Rain Shut-Off Sensor Only – Wireless	
Hunter WR-Clik	$52.36
Rain Bird WR2RC	$55.24
Irritrol RS1000	$45.15
Toro TWRS	$57.40
Add-on Rain Shut-Off Sensor Only – Wired	
Hunter Rain-Clik	$17.99
Rain Bird RSDBEX	$18.17

Toro TRS	$22.39
Irritrol RS500	$20.23
K Rain R 200	$26.68
Add-on Soil Moisture Sensor Only	
Hunter Soil-Clik	$82.36
Rain Bird SMRT-Y Kit	$143.08
Toro Precision Soil Sensor Kit	$129.90
Irrometer WaterSwitch	$121.00
Acclima TDT Soil Moisture Sensor	$169.00
Baseline WaterTec	$170.00

Source: Statewide CASE Team Research.

In addition to the incremental equipment cost, some weather-based controllers with signals have monthly subscription fees unlike other signal based controllers that rely solely on historical pre-programmed data and/or on-site sensors. The Statewide CASE Team did not factor these additional fees into the analysis because controllers without subscription fees are widely available, and it is up to the user whether they enroll in a subscription.

Additionally, many weather-based smart controllers can involve fairly time-intensive programming to input factors such as plant/soil type, slope conditions, sun/shade conditions, or other site-specific variables when they are installed (DOI 2007). Accordingly, the Statewide CASE Team assumed incremental installation costs of $50 for qualifying controllers with water savings features to account for the additional time an irrigation contractor would need to collect and program the data for each station into the irrigation controller. In addition, a number of manufacturers recommend some periodic maintenance (e.g., wiping the sensors clean every 30 days). However, the Statewide CASE Team did not include this cost in the analysis since we have not attempted to monetize the benefits that smart controllers provide over an irrigation controller in terms of greater convenience (i.e., fewer manual adjustments).

There are no direct studies of incremental cost for meeting a proposed standby power (standby-passive and standby-active) standard. The cost for meeting this standard will depend somewhat on the technical pathways by which controller energy use can be reduced. These technical pathways could be identified during the proposed research activities to support the development of an energy efficiency standard.

5.6.3 Design Life

The analysis presented in this report assumes that irrigation controllers have a lifetime of 11 years (CEC 2014). This lifetime estimate is approximate, as there is evidence that irrigation controllers could last for longer. For example, WaterSense (2011) and Hanak and Davis (2006) assume that a weather-based irrigation controller has a 15-year product lifetime, and other sources state that the lifespan of smart irrigation controllers is ten years or 10-15 years (Mayer 2009, CA ILG 2012).

5.6.4 Costs and Benefits

The Statewide CASE Team expects that the proposed standards will be cost effective, with benefits exceeding lifecycle costs. The precise level of expected benefits depends on the level and cost of the energy efficiency standard and the level of water savings achievable by soil moisture sensor-based controllers. Once ongoing and proposed product testing is completed, more information on the costs and benefits of the proposed standard will be available. With new data, the Statewide CASE Team could estimate the per unit and statewide cost, benefits, and cost-effectiveness of the proposed standard.

Cost savings are driven primarily by the reduction in water use, which may increase over time due to water price increases as a result of scarcity, spreading fixed water supply infrastructure costs over a diminishing quantity of water supply from existing resources, and the potential development of new, more costly supply options.

Cost-effectiveness estimates may understate total benefits of the standards, due to the likelihood that technology costs will continue to decrease over time due to development of technology, improved manufacturing processes from "learning by doing," and economies of scale due to larger manufacturing scale with the new Title 20 Standards.

5.7 Consumer Utility/Acceptance

Qualifying products will provide consumers with energy and water savings, which will contribute to consumer acceptance. Qualifying irrigation controllers are typically installed in the same manner as non-qualifying controllers, but they may require placement of sensors or additional programming upon installation. However, since they can automatically adjust irrigation schedules based on environmental conditions, they may be more convenient for consumers who will not have to worry about changing irrigation schedules often to keep up with weather or seasonal changes. Energy efficiency standards will help mitigate the potential increase in energy use due to "smart" irrigation controller features, reducing energy cost increases for consumers.

Proper programming is essential in ensuring savings from irrigation controllers, as the existing conditions and optimal irrigation strategies will vary by landscape. Consumer and contractor education may help facilitate savings from qualifying products (Haley 2007). The information needed to properly install and configure landscape irrigation controllers should be included with all products sold in California, which would also help educate homeowners who self-install retrofit controllers.

For instance, rain shut-off devices could be packaged with clear instructions for proper siting and use, such as avoiding installation within the spray path of sprinklers, under tree canopies, or under gutters (Meeks 2012). Rain shut-off devices utilizing an expanding disk should also contain instructions and a recommended maintenance interval. Similarly, soil moisture sensors should be packaged with instructions detailing the optimal placement of these devices.

One opportunity to provide additional education and outreach regarding these products is MWELO implementation. DWR added requirements for landscape irrigation controller configuration to the MWELO (23 CCR Division 2 Section 492.12) as recommended in comments submitted by the Statewide CASE Team on July 26, 2015. The revised MWELO requires configuration of irrigation controllers with irrigation application rate, soil types, plant factors, slope, exposure, and any other factors necessary for accurate programming. Any education for MWELO implementation should also spill over into retrofit applications of these products in landscapes not subject to MWELO. The Statewide CASE Team also recommends considering other opportunities for education and outreach in coordination with DWR and other key stakeholders.

5.8 Manufacturer Structure & Supply Chain Timelines

5.8.1 Market Structure

The three largest manufacturers of landscape irrigation equipment in the California market are Rain Bird, Hunter, and Toro. All three companies offer base model irrigation controllers as well as models with a range of water saving products and features. They also manufacture add-on devices, such as rain shut-off devices, weather sensors, and soil-moisture sensors. Weather-based irrigation controllers are offered by a variety of additional manufacturers including: Cyber-Rain, ETWater, HydroPoint, Rachio, Signature, Raindrip, Rainmaster, and Weathermatic. Soil moisture sensor-based controllers are a more specialized product often offered by niche manufacturers in addition to the major ones. Soil moisture sensor-based controller manufacturers include Acclima, Baseline, Decagon, Irrometer, and UgMo.

The number of landscape irrigation controller models with water-saving features has expanded significantly since weather-based products entered the market in the early 2000s. As of 2015, the U.S. Department of Interior's (DOI) Bureau of Reclamation report "Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices, Technical Review Report – 5th Edition" provided summaries of products for approximately 18 weather-based controller manufacturers as well as nine soil moisture-based controller manufacturers compared to only seven in 2004. Furthermore, a WaterSense specification for weather-based irrigation controllers was released in 2011. Over time, the number of WaterSense labeled irrigation controllers has steadily increased, from 67 in 2012, to 153 in 2013, to over 400 and growing in 2017.

Landscape irrigation controllers are distributed through several outlets, including direct sales (e.g., manufacturers sell directly to homebuilders or other volume purchasers), sales from irrigation product distributors, and retail sales (e.g., Home Depot, Lowes, or online retailers). Retail sales are common for do-it-yourself irrigation projects. Large retail stores and online retailers, such as Amazon.com, Sprinkler Warehouse and Sprinkler Supply Store, process many of the retail sales. These retailers have a significant influence on which products reach the mainstream market. Price, performance, features, and ease of use and installation play a role in which products retailers choose to stock. In addition to large manufacturers and distributors, small irrigation contractor businesses also play a role in the market, as these companies often provide the product to end-use consumers.

Most manufacturers recommend professional installation and programming of controllers that have advanced water saving features (although some irrigation controllers can be installed and programmed by do-it-yourself homeowners) (DOI 2015). Irrigation product distributors process many of the sales to professional installers. Some manufacturers have localized distribution channels that utilize wholesale distributors to deliver a tailored distribution strategy for different regions. Wholesale distributors may work with builders, contractors, water utilities, or retail stores. The wholesaler distribution option is most common for larger manufacturers that offer a wide variety of products. Sales representatives from the wholesaler can offer personalized messaging to interested customers. Wholesalers also tend to target markets with high sales or markets that have an appetite for the specialty products they carry.

5.8.2 Proposed Timeline

As discussed in Section 4.3.2, new test procedures are under development for weather-based irrigation controllers and soil moisture sensor-based controllers. These procedures will take time to complete and once completed, product testing will be required to certify products under a standard. In the case that manufacturers must change products to comply with new requirements, additional time may be required, as irrigation controllers with water saving features are complex products with specialized programming. Additionally, irrigation manufacturers may have to modify devices to comply with energy efficiency requirements. Therefore, the Statewide CASE Team proposes a compliance date of twenty-four months after adoption in order to allow for adequate time for manufacturers to meet new requirements after new test procedures are completed.

5.9 Stakeholder Positions

The Statewide CASE Team conducted extensive stakeholder outreach to inform the proposed standards and the analyses presented in this report. For instance, the Statewide CASE Team held several discussions with IA staff regarding IA test methods and other research and based the rain sensor shut-off test method on the IA protocol. The Statewide CASE Team also contacted product development and customer support staff for major manufacturers to obtain product technology and market data, understand the market structure, and request review of the proposed test protocol. In addition, the Statewide CASE Team interviewed several smaller manufacturers, including several with WaterSense certified products that rely on off-site data collection to optimize irrigation scheduling.

These interviews informed the recommendations in this report, including technical details of the Statewide CASE Team's proposed test method for rain shut-off devices. The Statewide CASE Team also found that manufacturers have made significant investments in water efficient products and several staff expressed support for statewide standards for water efficient controllers.

In addition, the Statewide CASE Team interviewed WaterSense staff to discuss coordination between the proposed Title 20 Standards and WaterSense specifications and coordinated with DWR staff who led revisions to the MWELO. The Statewide CASE Team also reached out to the Metropolitan Water District of Southern California and interviewed staff at Fresno State University's Center for Irrigation Technology (CIT). Based on feedback from CIT staff, the Statewide CASE Team revised the rain shut-off savings estimate to account for rainfall events that are not significant enough to trigger irrigation shut-off.

5.10 Other Regulatory Considerations

5.10.1 Federal Regulatory Background

See Section 4.2.1 for a discussion on federal regulatory concerns.

5.10.2 California Regulatory Background

See Section 4.2.2 for a discussion on California regulatory background.

5.10.3 Utility and Other Incentive Programs

Many water utilities and cities provide rebates for water efficient irrigation controllers designed for single family landscapes as well as for multi-family and commercial landscapes. Per a summary by Rain Bird, in California there are at least 129 rebate programs for weather-based controllers, 13 programs for rain shut-off devices, and ten programs for soil moisture sensors (Rain Bird 2015a, Rain Bird 2015b). Rebates can be issued either per controller or per station, and they are sometimes bundled with broader programs. In at least some cases, the programs are intended to replace older existing units since they are not subject to water or energy efficiency standards. We note that these incentive programs can complement the proposed Title 20 Standards by encouraging early replacement of inefficient products with equipment that meets the proposed standards. In addition, an incentive program that promotes installation of both a weather-based controller and a rain shut-off device may maximize savings.

5.10.4 Model Codes and Voluntary Standards

Many government and non-government entities have made substantial progress establishing model building codes and voluntary standards that address water efficiency. Many of these existing codes and standards have been developed through rigorous public vetting processes that included participation by key industry stakeholders. Table 9 below lists various model codes and standards related to landscape irrigation.

Table 9: Model Codes and Standards for Landscape Irrigation Controllers

Model Code	Requirements

WaterSense[31] (effective November 3, 2011)	Weather-based controllers can qualify for WaterSense certification if they are tested to achieve water application between 80 and 105 percent of the theoretical optimal rate by using the IA's Smart Water Application Technologies protocol (as modified by WaterSense). They must also have the following supplemental capabilities in both smart mode and standard mode.
	• The controller shall be capable of preserving the contents of the irrigation program settings when the power source is lost and without relying on an external battery backup.
	• The controller shall either be capable of independent, zone-specific programming or storing a minimum of three different programs to allow for separate schedules for zones with differing water needs.
	• The controller shall be capable of indicating to the user when it is not receiving a signal or local sensor input and is not adjusting irrigation based on current weather conditions.
	• The controller shall be capable of interfacing with a rainfall device.
	• The controller shall be capable of accommodating watering restrictions as follows:
	  ○ Operation on a prescribed day(s)-of-week schedule (e.g., Monday-Wednesday-Friday, Tuesday-Thursday-Saturday; any two days; any single day, etc.).
	  ○ Either even day or odd day scheduling or any day interval scheduling between two and seven days.
	  ○ The ability to set irrigation runtimes to avoid watering during a prohibited time of day (e.g., between 9:00 a.m. and 9:00 p.m.).
	  ○ Complete shutoff (e.g., on/off switch) to accommodate outdoor irrigation prohibition restrictions.
	• The controller shall include a percent adjust (water budget) feature.
	• If the primary source of weather information is lost, the controller shall be capable of reverting to either a proxy of historical weather data or a percent adjust (water budget) feature.
	• The controller shall be capable of allowing for a manual operation troubleshooting test cycle and shall automatically return to smart mode within some period of time as designated by the manufacturer, even if the switch is still positioned for manual operation.

[31] WaterSense has also issued a notice of intent to consider a specification for soil moisture sensor-based controllers once the test procedure under development is completed.

ASHRAE SS189.1 Standard for High Performance Buildings (2014)	6.3.1.2 Irrigation System Design. Hydrozoning of automatic irrigation systems to water different plant materials, such as turfgrass versus shrubs is required. 6.3.1.3. Controls. Any irrigation system for the project site shall be controlled by a qualifying smart controller that uses ET and weather data to adjust irrigation schedules and that complies with the minimum requirements or an on-site rain or moisture sensor that automatically shuts the system off after a predetermined amount of rainfall or sensed moisture in the soil. Qualifying smart controllers shall meet the minimum requirements as listed below when tested in accordance with IA's Smart Water Application Technologies "Climatological Based Controllers: 8th Draft Testing Protocol." Smart controllers that use ET shall use the following inputs for calculating appropriate irrigation amounts: a. Irrigation adequacy – 80 percent minimum ET_c. b. Irrigation excess – not to exceed 10 percent. Exception: A temporary irrigation system used exclusively for the establishment of a new landscape shall be exempt from this requirement. Temporary irrigation systems shall be removed or permanently disabled at such time as the landscape establishment period has expired.
ASHRAE S191P Standard for Water Efficiency (2012, public review draft v.1)	4.3.3 Irrigation System Design. If a permanent irrigation system is required on the site, all irrigation systems shall meet the IA's Best Management Practices "Turf and Landscape Irrigation Best Management Practices" Section 2, 3, and Appendix B. 4.3.4 Controls. Any irrigation system for the project site shall be controlled by a WaterSense labeled irrigation controller. All such control systems shall also incorporate a properly installed on-site rain or moisture sensor that automatically shuts the system off after a predetermined amount of rainfall or sensed moisture in the soil.
IAPMO Green Plumbing & Mechanical Code Supplement (2012)	413.4 Irrigation Control Systems. Where installed as part of a landscape irrigation system, irrigation control systems shall: 413.4.1 Automatically adjust the irrigation schedule to respond to plant water needs determined by weather or soil moisture conditions. 413.4.2 Utilize sensors to suspend irrigation during a rainfall. 413.4.3 Utilize sensors to suspend irrigation when adequate soil moisture is present for plant growth. 413.4.4 Have the capability to program multiple and different run times for each irrigation zone to enable cycling of water applications and durations to mitigate water flowing off of the intended irrigation zone. 413.4.5 The site specific settings of the irrigation control system affecting the irrigation shall be posted at the control system location. The posted data, where applicable to the settings of the controller, shall include: (1) Precipitation rate for each zone. (2) Plant ET coefficients for each zone. (3) Soil absorption rate for each zone. (4) Rain sensor settings. (5) Soil moisture setting. (6) Peak demand schedule, including run times for each zone and the number of cycles to mitigate runoff and monthly adjustments or percentage.
International Green Construction Code (IgCC) (2012)	404.1.2.3 Where an irrigation control system is used, the system shall be one that regulates irrigation based on weather, climatological, or soil moisture status data. The controller shall have integrated or separate sensors to suspend irrigation events during rainfall.

Additionally, in the state of Florida, rain shut-off devices have been required for new systems since 2010 with the requirement that "a licensed contractor who installs or performs work on an automatic landscape irrigation system must test for the correct operation of each inhibiting or interrupting device or switch on that system."[32]

5.10.5 Compliance

Compliance with the proposed standards for irrigation controllers could be facilitated by cooperation with the WaterSense program. For instance, the Energy Commission could harmonize the weather-based controller option with the WaterSense Weather-Based Irrigation Controller Specification and harmonize the future soil moisture sensor compliance option with any future WaterSense specification. Any manufacturer with products that have not been tested can do so through a well-established testing process. In this case, the Statewide CASE Team anticipates that the compliance process will be relatively straightforward for manufacturers and retailers.

Additional manufacturer outreach may be appropriate to ensure that all manufacturers are aware of the proposed requirements and test methods.

6. Conclusion

Landscape irrigation is the single largest use of potable water in the residential sector and accounts for approximately half of all urban water usage, further highlighting the importance of standards for this product category (PPIC 2015). Residential and commercial landscape irrigation alone uses over one trillion gallons per year, which is associated with over three terawatt-hours of embedded electricity per year required for water supply, conveyance, potable water treatment, and distribution.

This report provides a code change proposal with technical information supporting water and energy efficiency standards for landscape irrigation controllers. These proposed standards will complement existing MWELO and CALGreen standards that address newly installed landscapes by addressing all product sales, including replacement units. In summary, the Statewide CASE Team estimates positive benefits from the implementation of proposed standards, including water savings, direct energy savings, and embedded energy savings.

[32] Florida Statutes Title XXVIII Chapter 373 Section 62.

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Appendix A: Electricity Rates

The electricity rates used in the Statewide CASE Team analysis were derived from projected future prices for residential, commercial, and industrial sectors in the Energy Commission's "Mid-case" projection of the 2017-2027 Demand Forecast (CEC 2017), which used a three percent discount rate and provided prices in 2015 dollars. The sales weighted average of the five largest utilities in California was converted to 2017 dollars using an inflation adjustment factor of 1.04 percent (DOL 2017). See the rates by year below in Table 10.

Table 10: Statewide Sales Weighted Average Residential Electricity Rates 2017 – 2027 (PG&E, SCE, SDG&E, LADWP and SMUD - 5 largest Utilities) in 2017 cents/kWh

Year	Residential Electricity Rate (2017 cents/kWh)
2017	17.94
2018	18.08
2019	18.49
2020	18.84
2021	19.03
2022	19.02
2023	19.03
2024	19.20
2025	19.27
2026	19.38
2027	19.48
2028	19.58

Appendix B: Load Factors

Table 11: 2013 Electricity Consumption and Peak Demand for the Top 5 California Utilities[a]

Sector & End-Use	Coincident Load		Annual Energy		Load Factor[b]
	MW	% of Total	GWh	% of Total	
Residential					
Cooking	581.4	1%	2833.1	1%	56%
Clothes Dryer	759.4	1%	4419.5	2%	66%
Dishwasher	211.1	0%	2237	1%	121%
Freezer	302.4	1%	2132.1	1%	80%
Miscellaneous	2849.3	5%	23139.9	9%	93%
Multi-Family Water Heater	114.2	0%	1189.4	0%	119%
Pool Heater	33.0	0%	155.6	0%	54%
Pool Pump	769.3	1%	3689.7	1%	55%
Refrigerator	1736.4	3%	13996.2	5%	92%
Solar Water Heat - Back-up	0.0	0%	0.2	0%	63%
Solar Water Heat - Pump	0.8	0%	2.3	0%	31%
Spa Heater	64.9	0%	247.6	0%	44%
Spa Pump	261.5	0%	990.4	0%	43%
Single Family Water Heater	196.5	0%	1709.6	1%	99%
Television	807.2	1%	6003	2%	85%
Waterbed Heater	737.0	1%	12003.7	5%	186%
Clothes Washer	122.2	0%	824.6	0%	77%
Air Conditioning	15739.6	28%	8378.51	3%	6%
Space Heating	0.0	0%	3441.46	1%	0%
Commercial					
Other	3344.8	6%	23762.2	9%	81%
Domestic Hot Water	144.5	0%	675.7	0%	53%
Cooking	94.5	0%	721.9	0%	87%
Office Equipment	263.3	0%	1699.2	1%	74%
Refrigeration	888.4	2%	7872.6	3%	101%
Exterior Lighting	40.9	0%	5909.2	2%	1649%
Interior Lighting	4856.2	9%	30686.2	12%	72%
Ventilation	1787.3	3%	10366.1	4%	66%
Air Conditioning	7714.7	14%	15724.95	6%	23%
Space Heating	0.0	0%	2702.77	1%	0%
Subtotal	19134.6	34%	100120.82	38%	60%

Source: CEC Demand Analysis Office (Tian 2016).

[a] The Top 5 California Utilities are Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison Company (SCE), Sacramento Municipal Utility District (SMUD), and Los Angeles Department of Water and Power (LADWP).

[b] Load Factor is the ratio of average annual load to coincident peak load. The load factors for commercial exterior lighting and residential waterbed heaters are very high, because their consumption is mainly off-peak.

Appendix C: Potable Water and Wastewater Rates

The 2017 potable water rates used in the analysis are based on residential water rate data from a Black & Veatch study that includes the eight largest cities in California (Black & Veatch 2016).[33] This data was weighted by the number of single-family homes in each city based on data from the California Department of Finance. About 30 percent of Californians live in one of these eight cities, and the Statewide CASE Team assumed that rates for these cities are representative of rates throughout the state. The Statewide CASE Team assumes that a typical customer with irrigation uses 11,000 gallons per month as a baseline (Aquacraft 2011b) and the 7,500–15,000 gallons per month rate tier would apply to water saved by this measure. The estimate only considers the variable portion of the residential potable water bill and does not include fixed charges that occur regardless of the amount of water consumption. See Table 12 for the estimated water costs to consumers in each city and the number of single family houses in each city in 2016 dollars. Costs in 2016 were escalated to 2017 rates using Black & Veatch annual increases.

To determine the statewide average wastewater rates, the Statewide CASE Team calculated average volumetric residential wastewater rates of $3.63 per 1000 gallons based on the data for the four California cities that were listed with volumetric (volume-related) wastewater (Black & Veatch 2016). Thirty percent of California residents pay a volumetric wastewater rate, which is typically linked to the potable water meter (Chesnutt 2011). The CASE Team multiplied the average wastewater rate in cities with volumetric rates (assuming the same baseline water usage noted above) by 0.30 to resulting in an average state-wide volumetric wastewater cost of $1.46 for 2017.[34]

Future potable water and wastewater rates were projected based on the Black & Veatch reported annual increases and then discounted to 2017 dollars using a three percent annual discount rate (U.S. Department of Labor 2012). See the rates by year in Table 13.[35]

Table 12: Residential Water and Wastewater Costs

	Fresno	Long Beach	Los Angeles	Oakland	Sacramento	San Diego	San Francisco	San Jose
Number of single family detached homes	105,031	74,394	557,495	73,991	113,494	237,084	65,783	175,614
Incremental Res Water Cost ($/1000gal)	$1.81	$4.84	$7.48	$6.92	$0.00	$9.01	$11.76	$2.24
Incremental Res Wastewater Cost ($/1000gal)	$0.00	$0.53	$5.05	$0.00	$0.53	$5.08	$14.80	$0.00

[33] The eight largest cities in California are Fresno, Long Beach, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, and San Jose.

[34] Wasted irrigation water, about 50 percent of flow rate for spray sprinkler bodies (AWE 2016), may be lost to runoff to sanitary sewers, storm sewers, surface water, or deep percolation. The Statewide CASE Team has not quantified the cost avoided from reduced runoff to sanitary sewers and, stormwater collection systems or surface waters as the Energy Commission determines cost-effectiveness from a consumer cost perspective.

[35] 5.8% annual increase for water and 5.9% for wastewater.

Table 13: Statewide Average Residential Potable Water and Wastewater Rates 2017-2030 (in $2017)[36]

Year	Res Water ($/1,000 gallons)	Res Wastewater ($/1,000 gallons)	Total Water ($/1,000 gallons)
2017	$6.08	$1.46	$7.54
2018	$6.25	$1.50	$7.75
2019	$6.43	$1.59	$8.02
2020	$6.61	$1.62	$8.23
2021	$6.79	$1.65	$8.45
2022	$6.98	$1.69	$8.67
2023	$7.18	$1.72	$8.90
2024	$7.38	$1.75	$9.13
2025	$7.59	$1.79	$9.37
2026	$7.80	$1.82	$9.62
2027	$8.02	$1.85	$9.87
2028	$8.24	$1.89	$10.13
2029	$8.47	$1.92	$10.39
2030	$8.71	$1.95	$10.66

[36] Note that total may vary slightly due to rounding.

Appendix D: Embedded Electricity Usage Methodology

The Statewide CASE Team assumed the following embedded electricity in water values: 4,848 kWh/million gallons of water (MG) for indoor water use and 3,565 kWh/MG for outdoor water use. Embedded electricity use for indoor water use includes electricity used for water extraction, conveyance, treatment to potable quality, water distribution, wastewater collection, and wastewater treatment. Embedded electricity for outdoor water use includes all energy uses upstream of the customer; it does not include wastewater collection or wastewater treatment. The embedded electricity values do not include on-site energy uses for water, such as on-site pumping. On-site energy impacts are accounted for in the energy savings estimates presented in this report.

These embedded electricity values were derived from research conducted for CPUC Rulemaking 13-12-011 (CPUC 2013). The CPUC study aimed to quantify the embedded electricity savings associated with IOU incentive programs that result in water savings, and the findings represent the most up-to-date research by CPUC on embedded energy in water throughout California (CPUC 2015a, 2015b). The CPUC analysis was limited to evaluating the embedded electricity in water and does not include embedded natural gas in water. Since accurate estimates of the embedded natural gas in water were not available at the time of writing, this CASE Report does not include estimates of embedded natural gas savings associated with water reductions.

The CPUC embedded electricity values used in the CASE Report are shown in Table 14. These values represent the average energy intensity by hydrologic region, which are based on the historical supply mix for each region regardless of who supplied the electricity (IOU supplied and non-IOU supplied). The CPUC calculated the energy intensity of marginal supply, but recommended using the average IOU and non-IOU energy intensity to estimate total statewide average embedded electricity of water use in California.

Table 14: Embedded Electricity in Water by California Department of Water Resources Hydrologic Region (kWh per acre foot)

Table 16. Total (IOU + Non-IOU) Energy Intensity (KWh/AF)

Region	Extraction, Conveyance, and Treatment	Distribution	Wastewater Collection + Treatment	Outdoor (Upstream of Customer)	Indoor (All Components)
NC	235	163	418	398	816
SF	375	318	418	693	1,111
CC	513	163	418	677	1,095
SC	1,774	163	418	1,937	2,355
SR	238	18	418	255	674
SJ	279	18	418	297	715
TL	381	18	418	399	817
NL	285	18	418	303	721
SL	837	163	418	1,000	1,418
CR	278	18	418	296	714

Hydrologic Region Abbreviations:
NC = North Coast, SF = San Francisco Bay, CC = Central Coast, SC = South Coast, SR = Sacramento River, SJ = San Joaquin River, TL = Tulare Lake, NL = North Lahontan, SL = South Lahontan, CR = Colorado River
Source: Navigant team analysis

Source: CPUC 2015b.

The Statewide CASE Team used CPUC outdoor embedded electricity estimates by hydrologic region and population data from the U.S. Census Bureau (separated by hydrologic region) to calculate the statewide population-weighted average outdoor embedded electricity values that were used in the CASE Report (see Table 15). The energy intensity values presented in Table 14 were converted from kWh per acre foot to kWh per million gallons to harmonize with the units used in the CASE Report. There are 3.07 acre feet per million gallons.

Table 15: Statewide Population-weighted Average Embedded Electricity in Water

Hydrologic Region	Outdoor Water Use [a] (kWh/MG)	Percent of California Population [b]
North Coast	1,221	2.1
San Francisco	2,127	18.2
Central Coast	2,078	3.8
South Coast	5,944	44.8
Sacramento River	783	8.1
San Joaquin River	911	4.7
Tulare Lake	1,224	6.3
North Lahontan	930	0.1
South Lahontan	3,069	5.5
Colorado River	908	6.5
Statewide Population-weighted Average	**3,565**	

Sources: [a] CPUC 2015b; [b] U.S. Census Bureau 2014 and California Department of Conservation 2007.