**CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)**

# Residential Instantaneous Water Heaters

Measure Number: 2016-RES-DHW1-F

Residential Water Heating

***2016 CALIFORNIA BUILDING ENERGY EFFICIENCY STANDARDS***

California Utilities Statewide Codes and Standards Team

Updated February 2015

*Prepared by: Sarah Schneider, Bijit Kundu, Heidi Hauenstein (Energy Solutions)*



This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

# Note to Readers

The Title 24 Residential Instantaneous Water Heaters (IWH) CASE Report was originally submitted to the California Energy Commission (CEC) by the Statewide Utilities Codes and Standards Enhancement (CASE) Team on September 19, 2014. The February 2015 version of the CASE Report contains additional information on the proposed standards for residential water heating in new construction and additions as requested by CEC staff. The February 2015 version also includes revisions to the proposed code language originally submitted to CEC in September 2014 and a description of the revised additional prescriptive option and associated energy savings and cost-effectiveness results.

# TABLE OF CONTENTS

## List of Tables

## List of Figures

# Document Information

Category: Codes and Standards

Keywords: Statewide CASE, Statewide Codes and Standards Team, Statewide C&S Team, Codes and Standards Enhancements, Title 24, 2016, efficiency, instantaneous water heater, storage water heater, quality insulation inspection, pipe insulation, compact hot water distribution system, domestic hot water system.

# Executive Summary

## Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (CEC) efforts to update California's Building Energy Efficiency Standards (Title 24) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and Southern California Gas Company – and the Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. The report and the code change proposal presented herein is part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

The goal of this CASE Report is to propose revisions to the prescriptive requirements for water heating in new single family buildings, residential additions, and new multi-family buildings with dedicated water heaters for each dwelling unit. The proposed code changes would modify the code requirements by specifying that the applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH) that meets minimum federal efficiency levels. As an alternative, the Applicant can also comply by installing a gas storage water heater that meets federal minimum efficiency levels. If the Applicant chooses to install a gas storage water heater, they will also be required to have a Home Energy Rating System (HERS) verified Quality Insulation Installation (QII), plus one of the following: installation of a compact hot water distribution design, or a HERS verified domestic hot water pipe insulation.

Additionally, the Statewide CASE Team recommends adding a mandatory measure that requires the installation of a drain kit (i.e. isolation valves) as part of the water heating system if a gas IWH is installed. Isolation valves assist in the flushing of the heat exchanger and help prolong the life of gas IWHs.

The report considers market availability and cost effectiveness[1] of gas IWHs and demonstrates that complying with Title 24 by installing a gas IWH is cost effective and feasible in all California climate zones. While the scope of the CASE proposal is limited to evaluating the impacts of compliance using a gas IWH, the Statewide CASE Team notes that the other proposed pathways to compliance are also cost effective. Applicants that comply using the performance approach can comply by deploying a wide variety of measures. The Statewide CASE Team did not evaluate all compliance pathways.

This report contains pertinent information that justifies the proposed code change including:

---

[1] CEC is only legally required to demonstrate that the primary prescriptive path is cost effective and viable given the current availability of products.

- Description of the code change proposal, the measure history, and existing standards (Section 2);
- Market analysis, including a description of the market structure for specific technologies, market availability, and how the proposed standard will impact building owners and occupants, builders, and equipment manufacturers, distributers, and sellers (Section 3);
- Methodology and assumption used in the analyses for energy and electricity demand impacts, cost-effectiveness, and environmental impacts (Section 4);
- Results of energy and electricity demand impacts analysis, Cost-effectiveness Analysis, and environmental impacts analysis (Section 5); and
- Proposed code change language (Section 6).

## Scope of Code Change Proposal

The proposed code change will affect the following code documents listed in Table 1.

**Table 1: Scope of Code Change Proposal**

| Standards Requirements (see note below) | Compliance Option | Appendix | Modeling Algorithms | Simulation Engine | Forms |
|---|---|---|---|---|---|
| M and Ps | No | No | No | No | No |

Note: An (M) indicates mandatory requirements, (Ps) Prescriptive, (Pm) Performance.

## Measure Description

To comply with Title 24 Standards, an applicant must implement all mandatory requirements in the Standards. In addition to implementing the mandatory measures, the applicant must choose to either (1) implement a discrete set of additional measures, as defined in the prescriptive requirements (i.e. prescriptive approach), or (2) confirm that the building's energy performance meets the required energy budget, as modeled using CEC-approved modeling software (i.e. performance approach). Over 90 percent of applicants comply with the Standards using the performance approach, which provides more flexibility. The energy budget that must be achieved if an applicant complies using the performance approach is developed by modeling the building assuming all the prescriptive measures are deployed. A building will be in compliance with Title 24 if the energy budget of the proposed building achieves the same energy budget that it would have achieved if deploying all of the prescriptive measures.

The 2013 Title 24 prescriptive requirements indicate that if natural gas is available,[2] either a gas-fired storage water heater or gas IWH must be used. If gas is not available, the applicant can comply with the standards prescriptively by installing an electric-resistant water heater

[2] The 2013 Title 24 Standards and accompanying manuals (e.g., Residential Compliance Manual and Alternative Compliance Method Reference Manual) are ambiguous in defining "natural gas availability." As such, this measure is also proposing revisions to the definition of gas availability and recommends an improved method of determining gas availability for compliance enforcement.

(either storage or IWH) combined with a solar water heating system that provides a solar fraction of 0.50.

The Residential IWH measure proposes modifications to the prescriptive requirements for domestic water heating systems in single family homes and multi-family buildings with dedicated water heaters for each individual dwelling unit. The goal of the measure is to update the water heating energy budget to help ensure that builders are encouraged to improve the efficiency of hot water systems in residential buildings.

The proposed code changes would modify the code requirements by specifying that the applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH) that meets minimum federal efficiency levels. As an alternative, the applicant can also comply by installing a gas storage water heater that meets federal minimum efficiency levels. If the applicant chooses to install a gas storage water heater, they will also be required to have a Home Energy Rating System (HERS) verified Quality Insulation Installation (QII), plus one of the following:  installation of a compact hot water distribution design or a HERS verified domestic hot water pipe insulation. Each of these options will result in approximately equivalent energy performance on a statewide basis. They were modeled using CEC's approved public domain modeling software program, CBECC-Residential, Version 3 (see Section 5.1for projected savings of proposed prescriptive options).

The proposed prescriptive options are as follows (See Section 6 for proposed code language):

1. Install a single natural gas or propane IWH meeting minimum federal efficiency levels *(used to calculate baseline energy budget for performance approach*); or
2. Install a single gas or propane storage water heater meeting minimum federal efficiency with an input of 105,000 Btu per hour or less in combination with QII requirements (HERS verified) and either:
    a. Compact hot water distribution design that is field verified; or
    b. Hot water pipe insulation requirements (HERS verified).

Since most applicants use the performance approach to comply with the Title 24 Standards, applicants that use the performance approach would still have the option of complying with the Standards by deploying any number of strategies that would allow them to meet the overall energy budget. For example, an applicant could choose to install a storage water heater in conjunction with other efficiency measures, like a higher performing building envelope. An applicant could also choose to install a heat pump water heater (HPWH) in conjunction with another efficiency measure.

The Statewide CASE Team will be recommending revisions to the ACM Reference Manual and Compliance Manual to improve how "gas availability" is defined, and how one determines gas availability.

Finally, the Statewide CASE Team recommends adding a mandatory measure that if a gas IWH is installed, a drain kit (i.e. isolation valves) must be installed as part of the water heating system. Isolation valves assist in the flushing of the heat exchanger and help prolong the life of gas IWHs. Installation of a drain kit has become common practice among installers and plumbers and is recommended by water heater manufacturers. These valves are typically sold separately and not included with the water heater unit.

***Reason for Proposed Code Change***

Water heating accounts for the largest share of natural gas usage in California homes and 90% of California homes use natural gas to heat water (Hoeschele et al. 2012). Although 49% of natural gas usage in homes is for used for heating water (KEMA 2010) ) and that technology advancements have substantially increased the efficiency of water heating equipment, the Title 24 Standards for residential water heating have experienced only gradual increases in energy efficiency over the last couple decades. Given the advancements in the energy efficiency of water heaters, it is an opportune time to update the baseline energy performance of residential water heating to allow for greater energy savings for California. If California is going to achieve zero net energy (ZNE) goals in a cost-effective manner, it is imperative that the water heating energy budget be revised.

This measure builds upon a measure that was added to the Title 24 Standards during the 2013 code change cycle which requires domestic water heating systems in new residential construction (single family and multi-family buildings with dedicated water heaters in individual dwelling units) to be designed to accommodate high-efficiency gas water heaters (e.g., condensing storage and IWHs). By the time the 2016 Title 24 Standards take effect in 2017, builders will be accustomed to designing buildings so they can accommodate gas IWHs.

Section 2 of this report provides detailed information about the code change proposal. Section 2.2 of this report provides a section-by-section description of the proposed changes to the Standards, Alternate Calculation Method (ACM) Reference Manual, and Compliance Manual that will be modified by the proposed code change. See the following tables for an inventory of sections of each document that will be modified:

- Table 6: Scope of Code Change Proposal
- Table 7: Sections of Standards Impacted by Proposed Code Change
- Table 8: Appendices Impacted by Proposed Code Change

Detailed proposed changes to the text of the Building Efficiency Standards, Residential ACM Reference Manual, and the Residential Compliance Manual are given in Section 6 of this report. This section proposes modifications to language with additions identified with <u>underlined</u> text and deletions identified with ~~strikeout~~ text.

The following documents will be modified by the proposed change:

- 2013 Title 24 Standards, Part 6, Subchapter 2 (Section 110.3(c), Subchapter 7 (Section 150.0(n)), Subchapter 8( Section 150.1(c)8), and Subchapter 8 (Section150.2(b)1G
- 2013 Residential ACM Reference Manual, Sections 2.2.10 and 2.10
- 2013 Residential Compliance Manual, Section 5.4.1

## Market Analysis and Regulatory Impact Assessment

The proposed code change is justified given the current and future residential water heating market, as high-efficiency water heaters (including gas IWHs) have widespread availability in California. The incremental cost of high-efficiency water heaters relative to their less efficient counterparts are recovered over time by way of lower utility bills (i.e. higher energy efficiency reduces energy use and thus lowers utility costs to homeowners) and because IWH have longer lifespans than storage water heaters and will need to be replaced less frequently. As a result, the proposed code change is cost effective over the 30-year period of analysis[3] in all California Climate Zones.

The expected impacts of the proposed code change on various stakeholders are summarized below:

- **Impact on builders:** The potential effect of all proposed changes to Title 24 on builders will be small. Assuming that builders pass compliance costs on to consumers, demand for construction could decrease slightly if all other factors remain the same.
- **Impact on building designers:** The proposed code change will have little to no impact on building designers, as the existing Title 24 Standards already require domestic water heating systems in new residential construction to be designed for the installation of gas IWHs.
- **Impact on occupational safety and health:** The proposed code change is not expected to have an impact on occupational safety and health. It does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by California Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code changes is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.
- **Impact on building owners and occupants:** The proposed code change will have a positive overall impact on building owners and occupants. For building owners, the longer lifespan of IWHs results in fewer water heater replacements over time, particularly if routine maintenance is undertaken to prolong the useful life of the water heater. Homeowner-occupants will benefit from a continual supply of hot water and lower utility bills, though the wait time for hot water may increase slightly due to the additional time it takes for hot water to arrive, particularly if the water heating system is designed so that the water heater is located far from the use points. Research and outreach to stakeholders reveals that homeowners are overwhelmingly satisfied with the performance of their IWH.
- **Impact on equipment retailers (including manufacturers and distributors**): The proposed code change will have some impacts on manufacturers, distributors, and retailers. Sales will increase for manufacturers of qualifying water heaters and for retailers and distributors that stock qualifying products.
- **Impact on energy consultants:** There are no anticipated impacts to energy consultants from the proposed code change.
- **Impact on building inspectors:** As compared to the overall code enforcement effort, this measure has negligible impacts on the effort required to enforce the building codes.

[3] A 30-year period of analysis for residential buildings, as required by the CEC Lifecycle Cost Methodology.

- **Statewide employment impacts:** The proposed changes to Title 24 are expected to impact employment. An increase in employment in the water heating sector (e.g., in-state manufacturing, retailers) is expected while a slight employment decrease for installers may result, as IWHs have higher product life expectancies than storage water heaters; the rate of replacement is lower for the former.
- **Impacts on the creation or elimination of businesses in California:** Based on the California Air Resources Board's economic analyses, the proposed Title 24 code changes will encourage the creation of businesses in California.[4]
- **Impacts on the potential advantages or disadvantages to California businesses:** California businesses would benefit from an overall reduction in energy costs due to the decrease in energy demand from the residential sector. This could help California businesses gain competitive advantage over businesses operating in other states or countries and an increase in investment in California, as noted below.
- **Impacts on the potential increase or decrease of investments in California:** Based on the California Air Resources Board's economic analyses, the proposed Title 24 code changes will encourage more investments in California.
- **Impacts on incentives for innovations in products, materials or processes:** Updating Title 24 standards will encourage innovation through the adoption of new technologies to better manage energy usage and achieve energy savings.
- **Impacts on the State General Fund, Special Funds and local government:** The Statewide CASE Team expects positive overall impacts on state and local government revenues due to higher Gross State Production and personal income resulting in higher tax revenues. Higher property valuations due to energy efficiency enhancements may also result in positive local property tax revenues.
- **Cost of enforcement to State Government and local governments:** All revisions to Title 24 will result in changes to Title 24 compliance determinations. Local governments will need to train permitting staff on the revised Title 24 standards. While this re-training is an expense to local governments, it is not a new/additional cost associated with the 2016 code change cycle.
- **Impacts on migrant workers; persons by age group, race, or religion:** This proposal and all measures adopted by CEC into Title 24 Part 6 do not advantage or discriminate in regards to race, religion or age group.
- **Impact on homeowners (including potential first time home owners):** The proposed code change will have a positive overall impact on homeowners. The longer lifespan of IWHs results in fewer water heater replacements over time, particularly if routine maintenance is undertaken to prolong the useful life of the water heater. Homeowner-occupants will benefit from a continual supply of hot water and lower utility bills, though the wait time for hot water may increase slightly due to the additional time it takes for hot

[4] The California Air Resources Board's economic analyses are discussed in detail in Section 3.5 *Economic Impacts* of this CASE Report.

water to arrive, particularly if the water heating system is designed so that the water heater is located far from the use points. Research and outreach to stakeholders reveals that homeowners are overwhelmingly satisfied with the performance of their IWH.

- **Impact on Renters:** This proposal is advantageous to renters as it reduces the cost of utilities which are typically paid by renters. Since the measure saves more energy costs on a monthly basis than the measure costs on the mortgage as experienced by the landlord, the pass-through of added mortgage costs into rental costs is less than the energy cost savings experienced by renters.
- **Impact on Commuters:** This proposal and all measures adopted by CEC into Title 24 Part 6 are not expected to have an impact on commuters.

## Statewide Energy Impacts

Table 2 shows the estimated energy impacts over the first twelve months of implementation of the IWH measure.

**Table 2: Estimated First Year Energy Savings for the IWH Prescriptive Option**

| | Electricity Savings (GWh) | Power Demand Reduction (MW) | Natural Gas Savings (MMtherms) | First Year TDV Energy Savings (Million kBTU) [1] |
|---|---|---|---|---|
| Proposed Measure | -6.16 | -1.34 | 3.17 | 828 |
| TOTAL | -6.16 | -1.34 | 3.17 | 828 |

1. TDV energy savings calculations include electricity and natural gas use.

Section 4.6.1 discusses the methodology and Section 5.1.1 shows the results for the per unit energy impact analysis.

## Cost-effectiveness

Results of the building unit Cost-effectiveness Analyses are presented in Table 3. The Time Dependent Valuation (TDV) Energy Costs Savings are the present valued energy cost savings over the 30-year period of analysis using CEC's TDV methodology. The Total Incremental Cost represents the incremental equipment and maintenance costs of the proposed measure relative to existing conditions (i.e. current minimally compliant construction practices). Costs incurred in the future, such as periodic maintenance costs or replacement costs, are discounted by a 3% real discount rate per CEC's Lifecycle Cost (LCC) Methodology. The Planning Benefit to Cost (B/C) Ratio is the incremental TDV Energy Costs Savings divided by the Total Incremental Costs. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective. For a detailed description of the Cost-effectiveness Methodology see Section 4.7 of this report.

Based on the results of the Cost-effectiveness Analysis for the proposed IWH prescriptive option, the Planning B/C Ratio is greater than 1.0 in every California climate zone. This means that the installation of gas IWHs, per the proposed primary prescriptive requirement, will result in cost savings relative to the existing conditions. While the measure is cost effective in every climate zone, the magnitude of cost-effectiveness varies from a high Planning B/C ratio of 3.40 in climate zone 15 to a low Planning B/C ratio of 3.22 in climate zone 1.

**Table 3: Cost-effectiveness Summary[1] per Building for All Prescriptive Options**

| Climate Zone | Benefit: Total TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | Cost: Total Incremental Cost[3] (2017 PV $) | Change in Lifecycle Cost[4] (2017 PV $) | Benefit to Cost Ratio[5] |
|---|---|---|---|---|
| **Prescriptive Option: Instantaneous Water Heater** | | | | |
| Climate Zone 1 | $2,334 | $725 | ($1,609) | 3.22 |
| Climate Zone 2 | $2,372 | $725 | ($1,647) | 3.27 |
| Climate Zone 3 | $2,370 | $725 | ($1,645) | 3.27 |
| Climate Zone 4 | $2,387 | $725 | ($1,662) | 3.29 |
| Climate Zone 5 | $2,359 | $725 | ($1,634) | 3.25 |
| Climate Zone 6 | $2,398 | $725 | ($1,673) | 3.31 |
| Climate Zone 7 | $2,378 | $725 | ($1,653) | 3.28 |
| Climate Zone 8 | $2,409 | $725 | ($1,684) | 3.32 |
| Climate Zone 9 | $2,414 | $725 | ($1,689) | 3.33 |
| Climate Zone 10 | $2,415 | $725 | ($1,690) | 3.33 |
| Climate Zone 11 | $2,414 | $725 | ($1,689) | 3.33 |
| Climate Zone 12 | $2,395 | $725 | ($1,670) | 3.30 |
| Climate Zone 13 | $2,415 | $725 | ($1,690) | 3.33 |
| Climate Zone 14 | $2,420 | $725 | ($1,695) | 3.34 |
| Climate Zone 15 | $2,467 | $725 | ($1,742) | 3.40 |
| Climate Zone 16 | $2,354 | $725 | ($1,629) | 3.25 |
| **Additional Prescriptive Option: Storage Water Heater and QII & Compact Design** | | | | |
| Climate Zone 1 | $2,296 | $1,182 | ($1,114) | 1.94 |
| Climate Zone 2 | $1,635 | $1,182 | ($453) | 1.38 |
| Climate Zone 3 | $1,333 | $1,182 | ($151) | 1.13 |
| Climate Zone 4 | $1,508 | $1,182 | ($326) | 1.28 |
| Climate Zone 5 | $1,291 | $1,182 | ($109) | 1.09 |
| Climate Zone 6 | $945 | $1,182 | $237 | 0.80 |
| Climate Zone 7 | $611 | $1,182 | $571 | 0.52 |
| Climate Zone 8 | $1,069 | $1,182 | $113 | 0.90 |

| | | | | |
|---|---|---|---|---|
| Climate Zone 9 | $1,454 | $1,182 | ($272) | 1.23 |
| Climate Zone 10 | $1,545 | $1,182 | ($363) | 1.31 |
| Climate Zone 11 | $2,584 | $1,182 | ($1,402) | 2.19 |
| Climate Zone 12 | $2,268 | $1,182 | ($1,086) | 1.92 |
| Climate Zone 13 | $2,489 | $1,182 | ($1,307) | 2.11 |
| Climate Zone 14 | $2,539 | $1,182 | ($1,357) | 2.15 |
| Climate Zone 15 | $2,012 | $1,182 | ($830) | 1.70 |
| Climate Zone 16 | $2,934 | $1,182 | ($1,752) | 2.48 |
| Statewide Average | $1,782 | $1,182 | ($600) | 1.51 |
| **Additional Prescriptive Option: Storage Water Heater and QII & Pipe Insulation** | | | | |
| Climate Zone 1 | $2,192 | $1,131 | ($1,061) | 1.94 |
| Climate Zone 2 | $1,539 | $1,131 | ($408) | 1.36 |
| Climate Zone 3 | $1,237 | $1,131 | ($106) | 1.09 |
| Climate Zone 4 | $1,416 | $1,131 | ($285) | 1.25 |
| Climate Zone 5 | $1,194 | $1,131 | ($63) | 1.06 |
| Climate Zone 6 | $853 | $1,131 | $278 | 0.75 |
| Climate Zone 7 | $521 | $1,131 | $610 | 0.46 |
| Climate Zone 8 | $979 | $1,131 | $152 | 0.87 |
| Climate Zone 9 | $1,365 | $1,131 | ($234) | 1.21 |
| Climate Zone 10 | $1,455 | $1,131 | ($324) | 1.29 |
| Climate Zone 11 | $2,492 | $1,131 | ($1,361) | 2.20 |
| Climate Zone 12 | $2,176 | $1,131 | ($1,045) | 1.92 |
| Climate Zone 13 | $2,399 | $1,131 | ($1,268) | 2.12 |
| Climate Zone 14 | $2,447 | $1,131 | ($1,316) | 2.16 |
| Climate Zone 15 | $1,935 | $1,131 | ($804) | 1.71 |
| Climate Zone 16 | $2,829 | $1,131 | ($1,698) | 2.50 |
| Statewide Average | $1,689 | $1,131 | ($558) | 1.49 |

1. Relative to existing conditions. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.
3. Total cost equals incremental first cost (equipment and installation).
4. Negative values indicate the measure is cost effective. Change in lifecycle cost equals cost minus benefit.
5. The Benefit to Cost ratio is the total benefit divided by the total incremental costs. The measure is cost effective if the B/C ratio is greater than 1.0.

Section 4.7 discusses the methodology and Section 5.2 shows the results of the Cost-Effectiveness Analysis.

# Greenhouse Gas and Water Related Impacts

For a more detailed analysis of the possible environmental impacts from the implementation of the proposed measure, please refer to Section 5.3 of this report.

## Greenhouse Gas Impacts

Table 4 presents the estimated avoided greenhouse gas (GHG) emissions of the proposed code change for the first year the Standards are in effect. Assumptions used in developing the GHG savings are provided in Section 4.8.1 of this report.

The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the Cost-effectiveness Analysis prepared for this report.

**Table 4: Estimated First Year Statewide Greenhouse Gas Emissions Impacts**

| | Avoided GHG Emissions[1] ($MTCO_2e$/yr) |
|---|---|
| Proposed Measure | 14,647 |
| TOTAL | 14,647 |

1. First year savings from buildings built in 2017; assumes 353 $MTCO_2e$/GWh and 5,303 $MTCO_2e$/MMTherms.

Section 4.8.1 discusses the methodology and Section 5.3.1 shows the results of the greenhouse gas emission impacts analysis.

## Water Use Impacts

Potential water use impacts were considered but not factored into the savings calculations for the proposed measure. Section 4.8.2 and Section 5.3.2 discusses the Statewide CASE Team's rationale.

## Field Verification and Diagnostic Testing

There are no field verification and diagnostic testing requirements associated with the proposed code change.

# 1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (CEC) efforts to update California's Building Energy Efficiency Standards (Title 24) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and Southern California Gas Company – and the Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. The report and the code change proposal presented herein is part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

The goal of this CASE Report is to propose revisions to the prescriptive requirements for water heating in new single family buildings, residential additions, and new multi-family buildings with dedicated water heaters for each dwelling unit. The code change proposal would recommend that an applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH) that meets minimum federal efficiency levels. As an alternative, the applicant can also comply by installing a gas storage water heater that meets federal minimum efficiency levels. If the applicant chooses to install a gas storage water heater, they will also be required to have a Home Energy Rating System (HERS) verified Quality Insulation Installation (QII), plus one of the following: installation of a compact hot water distribution design or a HERS verified domestic hot water pipe insulation.

Additionally, the Statewide CASE Team recommends adding a mandatory measure that if a gas IWH is installed, a drain kit (i.e. isolation valves) must be installed as part of the water heating system. Isolation valves assist in the flushing of the heat exchanger and help prolong the life of gas IWHs.

The report considers market availability and cost effectiveness[5] of gas IWHs and demonstrates that complying with Title 24 by installing a gas IWH is cost effective and feasible in all California climate zones. While the scope of the CASE proposal is limited to evaluating the impacts of compliance using a gas IWH, the Statewide CASE Team notes that other pathways to compliance are also cost effective. Applicants that comply using the performance approach can comply by deploying a wide variety of measures. The Statewide CASE Team did not evaluate all compliance pathways.

Section 2 of this CASE Report provides a description of the measure, how the measure came about, and how the measure helps achieve the state's zero net energy (ZNE) goals. This section presents how the Statewide CASE Team envisions the proposed code change would be enforced and the expected compliance rates. This section also summarized key issues that the Statewide CASE Team addressed during the CASE development process, including issues

[5] CEC is legally required to only demonstrate that the primary prescriptive path is cost effective and viable given the current availability of products.

discussed during a public stakeholder meeting that the Statewide CASE Team hosted in May 2014 and a CEC pre-rulemaking meeting in July 2014.

Section 3 presents the market analysis, including a review of the current market structure, a discussion of product availability, and the useful life and persistence of the savings from the proposed measure. This section offers an overview of how the proposed standard will impact various stakeholders including builders, building designers, building occupants, equipment retailers (including manufacturers and distributors), energy consultants, and building inspectors. Finally, this section presents estimates of how the proposed change will impact statewide employment.

Section 4 describes the methodology and approach the Statewide CASE Team used to estimate energy, demand, costs, and environmental impacts. Key assumptions used in the analyses can be also found in Section 4.

Results from the energy, demand, costs, and environmental impacts analysis are presented in Section 5. The Statewide CASE Team calculated energy, demand, and environmental impacts using two metrics: (1) per unit and (2) statewide impacts during the first year buildings complying with the 2016 Title 24 Standards are in operation. Time Dependent Valuation (TDV) energy impacts, which accounts for the higher value of peak savings, are presented for the first year both per unit and statewide. The incremental costs relative to existing conditions are presented as the present value of year TDV energy cost savings and the overall cost impacts over the 30-year period of analysis, as required by CEC.

This report concludes with specific recommendations for language for the Title 24 Standards, Residential ACM Reference Manual, and Residential Compliance Manual.

# 2. MEASURE DESCRIPTION

## 2.1 Measure Overview

### 2.1.1 Measure Description

To comply with Title 24 Standards, an applicant must implement all mandatory requirements in the Standards. In addition to implementing the mandatory measures, the applicant must choose to either (1) implement a discrete set of additional measures, as defined in the prescriptive requirements (i.e. prescriptive approach), or (2) confirm that the building's energy performance meets the required energy budget, as modeled using CEC-approved modeling software (i.e. performance approach). Over 90 percent of applicants comply with the Standards using the performance approach, which provides more flexibility. The energy budget that must be achieved if an applicant complies using the performance approach is developed by modeling the building assuming all the prescriptive measures are deployed. A building will be in compliance with Title 24 if the energy budget of the proposed building achieves the same energy budget that it would have achieved if deploying all of the prescriptive measures.

The 2013 Title 24 prescriptive requirements indicate that if natural gas is available,[6] either a gas-fired storage water heater or IWH must be used. If gas is not available, the applicant can comply with the standards prescriptively by installing an electric-resistant water heater (either storage or IWH) combined with a solar water heating system that provides a solar fraction of at least 0.50.

The Residential IWH measure proposes modifications to the prescriptive requirements for domestic water heating systems in single family homes and multi-family buildings with dedicated water heaters for each individual dwelling unit. The goal of the measure is to update the water heating energy budget to help ensure that builders are encouraged to improve the efficiency of hot water systems in residential buildings.

The proposed code changes would modify the code requirements by specifying that the applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH) that meets minimum federal efficiency levels. As an alternative, the applicant can also comply by installing a gas storage water heater that meets federal minimum efficiency levels. If the applicant chooses to install a gas storage water heater, they will also be required to have a Home Energy Rating System (HERS) verified Quality Insulation Installation (QII), plus one of the following:  installation of a compact hot water distribution design or a HERS verified domestic hot water pipe insulation. Each of these options will result in approximately equivalent energy performance on a statewide basis; they were modeled using CEC's approved public domain modeling software program, CBECC-Residential, Version 3 (see Section 5.1for projected savings of proposed prescriptive options).

The proposed prescriptive options are as follows (See Section 6 for proposed code language):

1. Install a single natural gas or propane IWH meeting minimum federal efficiency levels *(used to calculate baseline energy budget for performance approach*); or
2. Install a single gas or propane storage water heater meeting minimum federal efficiency level plus with an input of 105,000 Btu per hour or less in combination with QII requirements (HERS verified) and either:
    a. Compact hot water distribution design that is field verified; or
    b. Pipe insulation requirements (HERS verified).

As mentioned, most applicants use the performance approach to comply with the Title 24 Standards. Applicants that use the performance approach would still have the option of complying with the Standards by deploying any number of strategies that would allow them to meet the overall energy budget. For example, an applicant could choose to install a storage water heater in conjunction with other efficiency measures, like a higher performing building

[6] The 2013 Title 24 Standards and accompanying manuals (e.g., Residential Compliance Manual and Alternative Compliance Method Reference Manual) are ambiguous in defining "natural gas availability." As such, this measure is also proposing revisions to the definition of gas availability and recommends an improved method of determining gas availability for compliance enforcement.

envelope. An applicant could also choose to install a heat pump water heater (HPWH) in conjunction with another efficiency measure.

The Statewide CASE Team will be recommending revisions to the ACM Reference Manual and Compliance Manual to improve how "gas availability" is defined, and how one determines "gas availability."

Finally, the Statewide CASE Team recommends adding a mandatory measure that if a gas IWH is installed, a drain kit (i.e. isolation valves) must be installed as part of the water heating system. Isolation valves assist in the flushing of the heat exchanger and help prolong the life of gas IWHs. Installation of a drain kit has become the standard among installers and plumbers and is recommended by water heater manufacturers. These valves are typically not included with the water heater unit.

***Additional Prescriptive Options***

Prior to CEC's November 3, 2014 pre-rulemaking workshop, CEC released draft language that recommended a prescriptive option that would allow an applicant to install a minimally compliant gas storage water heater in combination with HERS verified QII and either 1) HERS pipe insulation requirements, or 2) compact hot water distribution design. The Statewide CASE Team supports this prescriptive option, as QII as a method for improving envelope efficiency is more practical and cost-effective than the option that called for the use of a solar thermal system to provide a fraction of the water heating demand that was proposed in the CASE Report submitted to CEC in September 2014.

This section of the CASE Report provides information about the additional prescriptive option, including the calculated energy impacts and cost-effectiveness. While the additional prescriptive option is cost effective in most climate zones, it is still the CASE Team's understanding that the prescriptive option does not need to be cost effective in every climate zone as long as the measure is cost effective statewide.

*Quality Insulation Inspection (QII)*

Interviews with homebuilders, contractors, and energy program implementers have found that the most commonly used wall insulation in California is fiberglass batt, while loose-fill fiberglass insulation is commonly used in attic insulation. Raised-floors are also commonly filled with fiberglass batts. Requiring QII for batt, blanket or loose-fill insulation would ensure that the majority of insulation installations are properly implemented, increasing the effective U-factor of these envelope assemblies. QII requires verification by a HERS rater to ensure proper installation within the entire thermal envelope.

*Compact Hot Water Distribution System (HWDS) Design*

The goal of a compact HWDS is to reduce the distance between plumbing fixtures and the water heater. There are two elements to a compact HWDS: 1) the intelligent design of a building in terms of appropriately locating bathrooms, kitchen, and laundry nearer each other, and 2) locating the water heater closer to these use points. The latter element will typically result in moving the water heater from the exterior garage wall to a preferred garage location on an interior wall, but could also result in optimally locating the water heater indoors or in an exterior closet. A more compact configuration will result in less hot water distribution piping, which in turn reduces the amount of heat loss (energy loss) and hot water delivery times.

To meet the compact HWD requirement, the longest measured pipe run length between a hot water use point and the water heater serving that use shall be no more than a distance calculated, whereby the maximum radial distance between water heater(s) and all hot water use points are defined. The goal is to move plumbing design towards more efficient layouts that reduce energy and water use.

Table 4.4.5 in Section RA4.4.16 of the Residential Appendix, outlined in Figure 1 below, specifies the maximum pipe length as a function of floor area served, where floor area served is defined as the conditioned floor area divided by the number of installed water heaters. The RA states that a HERS inspection is required in order to obtain the credit.

| **Floor Area Served (sq-ft)** | **Maximum Measured Water Heater to Use Point Distance (ft)** |
|---|---|
| < 1000 | 28’ |
| 1001 – 1600 | 43’ |
| 1601 – 2200 | 53’ |
| 2201 – 2800 | 62’ |
| > 2800 | 68’ |

**Figure 1. HERS-Verified Compact Hot Water Distribution System Requirements**

*Pipe Insulation*

The 2013 Title 24 Standards include mandatory pipe insulation requirements for domestic hot water system in residential buildings (Section 150.0 (j)2). The following piping must be insulated:

- The first 5 feet (1.5 meters) of hot and cold water pipes from the storage tank.
- All piping with a nominal diameter of 3/4 inch (19 millimeter) or larger.
- All piping associated with a domestic hot water recirculation system regardless of the pipe diameter.
- Piping from the heating source to storage tank or between tanks.
- Piping buried below grade.
- All hot water pipes from the heating source to the kitchen fixtures.

In addition to the pipe insulation requirements in the Standards, the Residential Appendix (RA) includes specifications for the Proper Installation of Pipe Insulation (RA4.4.1) and requirements if an applicant wishes to claim the Pipe Insulation Credit (RA4.4.3) or the HERS-Verified Pipe Insulation Credit (RA4.4.14). The Proper Installation of Pipe Insulation does not include requirements beyond those specified in the Standards. The Pipe Insulation Credit requires that, “[a]ll piping in the hot water distribution system must be insulated from the water heater to each fixture or appliance.” The current standards do not require insulation on pipe less than ¾ inch in diameter. The Pipe Insulation Credit would require insulation on all pipe including ½ pipe. The HERS-Verified Pipe Insulation Credit states that a HERS inspection is required to verify pipes are insulated correctly.

As currently written, if the applicant wishes to use pipe insulation as a component of the prescriptive option, they must comply with all relevant sections of the Residential Appendix. In effect, this means that the applicant would need to insulate all pipes in the distribution system, including ½ inch pipes, and a HERS inspection would be required.

Pipe Insulation Requirements in the Uniform Plumbing Code

The Uniform Plumbing Code (UPC) is a model building code developed by the International Association of Plumbing and Mechanical Officials (IAPMO) using the American National Standard Institute (ANSI) consensus development procedures. The purpose of the UPC is to provide consumers with safe and sanitary plumbing systems. The UPC serves as a model code that states can adopt as their own plumbing standards. California has historically used the UPC as a basis for California Plumbing Code (Title 24 Part 5). The Building Standards Commission (BSC) and the Department of Housing and Community Development (HCD) are the regulatory agencies responsible for updating the California Plumbing Code. They have the authority to adopt the full UPC or make California amendments to the UPC.

The pipe insulation requirements in the UPC will be changing in 2015 so that insulation will now be required on all domestic hot water piping regardless of pipe diameter. The full IAPMO technical assembly voted to approve the draft language (see Figure 2) during their September 2014 meeting. The language presented below is almost certainly going to appear in the 2015 UPC, which will be published in early 2015. If adopted by HCD and BSC, the UPC pipe insulation requirements in Part 6 will supersede the mandatory pipe insulation requirements. CEC will maintain the proposed pipe insulation prescriptive option since the pipe insulation installation will be verified by a HERS rater.

**610.14 Pipe Insulation.** Insulation of domestic hot water piping shall be in accordance with Section 610.14.1 and Section 610.14.2.

**610.14.1 Insulation Requirements.** Domestic hot water piping shall be insulated.

**610.14.2. Pipe Insulation Wall Thickness.** Hot water pipe insulation shall have a minimum wall thickness of not less than the diameter of the pipe for a pipe up to 2 inches (50 mm) in diameter. Insulation wall thickness shall be not less than 2 inches (51 mm) for a pipe of 2 inches (50 mm) or more in diameter.

**Exceptions:**

(1) Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration.

(2) Hot water piping between the fixture control valve or supply stop and the fixture or appliance shall not be required to be insulated.

**Figure 2: 2015 UPC Pipe Insulation Requirement (to be published by IAPMO in 2015)**

### 2.1.2 Measure History

For the 2013 Title 24 code change cycle, the Statewide CASE Team submitted a CASE Report to CEC that proposed standards to support building component compatibility with high-efficiency water heaters (HEWHs), such as gas IWHs (CA IOUs 2011a). The purpose of the HEWH measure was to remove infrastructure barriers for adopting forced draft, condensing, and/or gas IWHs, for both new construction and future replacements. The Statewide CASE Team held several discussions on the new proposal ideas with CEC in order to conduct market research and technical analyses to directly address CEC's concerns. The proposed measure was based on application considerations collected from water heater installation guidelines, contractors, and industry experts. Therefore, when the proposal was presented at stakeholder meetings and CEC rulemaking meetings, there were no strong objections or major concerns from either stakeholders or CEC staff and the measure was adopted into the 2013 Standards.

The HEWH requirements, which went into effect July 1, 2014, apply to single family homes and multi-family buildings with a dedicated water heater for each individual dwelling unit. The new mandatory measure requires new construction to include:

1. Accessibility of electrical power supply near the water heater to support draft fans and controls.
2. Vent to accommodate acidic exhaust from high efficiency water heaters, including but not limited to condensing water heaters.
3. Condensate drains must meet local jurisdiction requirements.
4. Gas pipe sizing to support IWHs without any exemptions so that homeowners have the option to install IWHs in the future.

As previously stated, the HEWH requirements were adopted as mandatory requirements for new residential construction and have paved the way for the code change proposal presented in this report.

***Reason for Proposed Code Change***

Water heating accounts for the largest share of natural gas usage in California homes and 90% of California homes use natural gas to heat water (Hoeschele et al. 2012). Although 49% of natural gas usage in homes is for used for heating water (KEMA 2010) ) and that technology advancements have substantially increased the efficiency of water heating equipment, the Title 24 Standards for residential water heating have experienced only gradual increases in energy efficiency over the last couple decades. Given the advancements in the energy efficiency of water heaters, it is an opportune time to update the baseline energy performance of residential water heating to allow for greater energy savings for California. If California is going to achieve zero net energy (ZNE) goals in a cost-effective manner, it is imperative that the water heating energy budget be revised.

This measure builds upon a measure that was added to the Title 24 Standards during the 2013 code change cycle which requires domestic water heating systems in new residential construction (single family and multi-family buildings with dedicated water heaters in individual dwelling units) to be designed to accommodate high-efficiency gas water heaters (e.g., condensing storage and IWHs). By the time the 2016 Title 24 Standards take effect in 2017, builders will be accustomed to designing buildings so they can accommodate gas IWHs.

### 2.1.3 Existing Standards

The 2013 Title 24 prescriptive requirements state that if natural gas is available, a natural gas water heater (either storage or IWH) must be used. If natural gas is not available, the applicant can comply with the standards prescriptively by installing an electric water heater (either storage or IWH) combined with a solar water heating system that provides a solar fraction of 0.50.

In addition to the Title 24 Standards, there are federal energy performance standards for residential water heating equipment for products sold in California. Table 5 displays the federal residential water heater standards that will take effect in April 2015. In addition to energy performance requirements, the federal standards will require gas storage water heaters larger than 55 gallons to be condensing type (ASAP 2014).

The United States Department of Energy (DOE) recently updated the test procedure for residential water heaters (DOE 2014). The new test procedure includes modifications to the test conditions and the hot water draw patterns of the current test procedure. The new test procedure calls for the use of a Uniform Energy Factor (UEF) rating which will replace the current Energy Factor (EF) rating. The UEF rating nomenclature characterizes the efficiency of water heating equipment in the same way as the EF rating. Because the existing and new ratings are determined under different test conditions, DOE adopted a new name to distinguish between the efficiency result under the existing test procedure and the result under the amended test procedure. The change to the test procedure and the rating factor cannot change the stringency of the federal standards. DOE will be developing a mathematical factor for converting EF ratings to UEF ratings. To avoid confusion, the Statewide CASE Team recommends avoiding specifying a required EF or UEF rating in Title 24. Rather, the proposed standards will specify that the water heating products must meet minimum federal efficiency requirements.

As discussed in Section 2.4 of this report, changes to DOE's test procedure may impact how the energy performance of gas IWH systems are evaluated in the Alternative Calculation Method for applicants that comply with the Standards using the performance approach. The previous test procedure resulted in EF ratings for IWH systems that lab and field testing found to be too high (Burch et al. 2008; Hoeschele et al. 2011). As a result, CEC's compliance simulation software discounted the EF ratings for gas IWH by 8% prior to calculating the energy performance of water heating systems that used gas IWHs. CEC may want to evaluate whether discounting the efficiency ratings that are determined using the new test procedure is still necessary.

**Table 5: Federal Water Heater Standards (Effective 2015)**

| Product Class | Rated Storage Volume | Energy Factor (EF) |
|---|---|---|
| Gas Storage Water Heater | ≥ 20 gallons and ≤ 55 gallons | 0.675 – (0.0015*Vs) |
| Gas Storage Water Heater | < 55 gallons and ≤100 gallons | 0.8012 – (0.00078* $V_s$) |
| Gas Instantaneous Water Heater | < 2 gallons | 0.82 – (0.0019*$V_s$) |
| Electric Water Heater | ≥20 gallons and ≤ 55 gallons | 0.960 – (0.0003*$V_s$) |
| Electric Water Heater | < 55 gallons and ≤120 gallons | 2.057 – (0.00113*$V_s$) |
| Oil Water Heater | ≤ 50 gallons | 0.68 – (0.0019*$V_s$) |
| Instantaneous Electric Water Heater | < 2 gallons | 0.93 – (0.00132*$V_s$) |

$V_s$: Rated Storage Volume – the water storage capacity of a water heater (in gallons).

### 2.1.4 Alignment with Zero Net Energy (ZNE) Goals

The Statewide CASE Team and the CEC are committed to achieving the State of California's ZNE goals. Although water heating accounts for nearly 50% of natural gas use in homes, the Standards for residential water heating have experienced only gradual increases in energy efficiency over last couple decades. Given the advancements in water heater technology in recent years that substantially increased the energy efficiency of water heaters, it is an opportune time to update the baseline energy performance of residential water heating to allow for greater energy savings for California. If California is going to achieve ZNE goals in a cost-effective way, it is imperative that the water heating energy budget be revised.

### 2.1.5 Relationship to Other Title 24 Measures

The proposed measure does not overlap with any other Title 24 code change proposals for the 2016 code update.  The September 2014 version of the code change proposal for Residential High Performance Walls and QII included recommendations for QII, however the current version of this code change proposal from February 2015 does not include recommendations for QII.

## 2.2 Summary of Changes to Code Documents

The sections below provide a summary of how each Title 24 document will be modified by the proposed change. See Section 6 of this report for detailed proposed revisions to code language.

### 2.2.1 Catalogue of Proposed Changes

***Scope***

Table 6 identifies the scope of the code change proposal. This measure will impact the following areas (marked by a "Yes").

**Table 6: Scope of Code Change Proposal**

| Mandatory | Prescriptive | Performance | Compliance Option | Trade-Off | Modeling Algorithms | Forms |
|---|---|---|---|---|---|---|
| Yes | Yes | N/A | N/A | N/A | N/A | N/A |

***Standards***

The proposed code change will modify the sections of the California Building Energy Efficiency Standards (Title 24, Part 6) identified in Table 7.

**Table 7: Sections of Standards Impacted by Proposed Code Change**

| Title 24, Part 6 Section Number | Section Title | Mandatory (M) Prescriptive (Ps) Performance (Pm) | Modify Existing (E) New Section (N) |
|---|---|---|---|
| 110.3(c) | Mandatory Requirements For Service Water Heating Systems And Equipment | M | E |
| 150.1(c)8 | Prescriptive Standards/Component Package for Domestic Water Heating Systems | Ps | E |
| 150.2(b)1(G) | Low-rise Residential Buildings, Alterations, Prescriptive approach for Water-Heating Systems | Ps | E |

***Appendices***

The proposed code change will not modify any sections of the reference appendices (see Table 8).

**Table 8: Appendices Impacted by Proposed Code Change**

| APPENDIX NAME | | |
|---|---|---|
| **Section Number** | **Section Title** | **Modify Existing (E) New Section (N)** |
| N/A | N/A | N/A |

***Residential Alternative Calculation Method (ACM) Reference Manual***

The Statewide CASE Team will be proposing changes to the Residential ACM Reference Manual language in a separate deliverable to CEC. The changes will aim to improve the definition of natural gas availability and provide clarification on how one determines gas availability.

***Simulation Engine Adaptations***

The proposed code change can be modeled using the current simulation engine. Changes to the simulation engine are not necessary. As mentioned in Section 2.1.3, CEC's compliance simulation software discounted the EF ratings for gas IWH by 8% prior to calculating the energy performance of water heating systems that used gas IWHs. CEC may want to evaluate whether discounting the efficiency ratings that are determined using the new test procedure is still necessary.

### 2.2.2 Standards Change Summary

The proposed code change will modify Section 110.3(c), Section 150.0(n), and Section 150.1(c)8 of the Standards, as described below. The proposal will impact mandatory and prescriptive requirements for gas domestic water heating systems in single family homes and multi-family buildings with a dedicated water heater for each individual dwelling unit. See Section 6.1 of this report for the detailed proposed revisions to the Standards language.

Note that the proposed code change will not change the scope of the existing Title 24 Standards for residential water heating.

**SECTION 110.3 – MANDATORY REQUIREMENTS FOR SERVICE WATERHEATING SYSTEMS AND EQUIPMENT**

**Subsection 110.3(c):** The proposed measure would modify the mandatory requirements for residential water heating by requiring the installation of drain kits on all gas IWHs to assist with the flushing of the heat exchanger. This measure only applies if the applicant chooses to install a gas IWH.

**SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR NEWLY CONSTRUCTED RESIDENTIAL BUILDINGS**

**Subsection 150.1(c)8:** The proposed measure would modify the prescriptive requirements in Subsection 150.1(c)8 by specifying that the applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH) that meets minimum federal efficiency levels. As an alternative, the applicant can also comply by installing a gas storage water heater that meets federal minimum efficiency levels. If the applicant chooses to install a gas storage water heater, they will also be required to have a Home Energy Rating System (HERS) verified Quality Insulation Installation (QII), plus one of the following: installation of a compact hot water distribution design or a HERS verified domestic hot water pipe insulation

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS IN EXISTING BUILDINGS THAT WILL BE LOW-RISE RESIDENTIAL OCCUPANCIES**

**Subsection 150.2(a)1D (Additions):** There are no proposed changes to this section. The existing language states that if a water heater is installed as part of an addition, the water heater system must meet the prescriptive requirements presented in Section 150.1(c)8. The QII, compact design, and pipe insulation requirements are only intended to apply to the addition, not the entire building. If natural gas is not connected to the building, the water heater can be an electric water heater that meets the minimum efficiency requirements as defined by California's Appliance Efficiency Standards.

**Subsection 150.2(b)1G (Alterations):** The code language will be updated to clarify that the applicant does not need to retrofit the building to comply with QII, compact design, or pipe insulation requirements if a water heater is replaced as part of an alteration.

### 2.2.3 Standards Reference Appendices Change Summary

There are no modifications to the Standards Appendices as a result of the proposed code change.

### 2.2.4 Residential Alternative Calculation Method (ACM) Reference Manual Change Summary

The Statewide CASE Team will be proposing changes to the Residential ACM Reference Manual language in a separate deliverable to CEC.

### 2.2.5 Residential Compliance Manual

This proposal would modify Section 5.2.2 and Section 5.4 of the Residential Compliance Manual to reflect the changes made to the Standards. See Section 6.4 of this report for the detailed proposed revisions to the text of the Residential Compliance Manual.

### 2.2.6 Compliance Forms Change Summary

The proposed code change will not modify the compliance forms.

### 2.2.7 Simulation Engine Adaptations

The proposed code change will not modify the simulation engine that is currently modeled for the proposed measure. Again, as a result of DOE's revised test method, the CEC might consider revising the current methodology that derates the EF or gas IWH by 8% prior to calculating the energy use of water heating systems that use gas IWHs.

### 2.2.8 Other Areas Affected

There are no other areas of the existing standards affected as a result of the proposed code change.

## 2.3 Code Implementation

### 2.3.1 Verifying Code Compliance

There will be no additional requirements for code enforcement entities for determining if a building complies with the proposed code change based on existing Title 24 Standards.

### 2.3.2 Code Implementation

Since domestic water heating systems are already regulated by Title 24, builders are required to install the necessary components (e.g., vent, electrical connection, ¾ inch gas pipe) for the installation of a gas IWH (effective July 1, 2014). With the new high-efficiency water heating ready measure, builders will be accustomed to designing for high-efficiency water heaters by the time the proposed measure takes effect in 2017. Conversations with various stakeholders indicate that builders have already been specifying IWHs in new residential designs on a regular basis. Builders that comply with the Standards using the performance approach will still have the option of installing any water heater that complies with federal appliance standards, as long as the total energy budget requirements are achieved. This flexibility could make it easier for builders to comply with the requirements. As such, the Statewide CASE Team does not anticipate challenges with code implementation.

### 2.3.3 Field Verification and Diagnostic Testing

Though field verification and diagnostic testing are required for many residential measures, they are not needed in order to assure optimum performance of the propose IWH prescriptive requirement. The proposed additional prescriptive option does require HERS verification (i.e. field verification) for QII and insulation on domestic hot water piping.

## 2.4 Issues Addressed During CASE Development Process

The Statewide CASE Team solicited feedback from a variety of stakeholders when developing the code change proposal presented in this report. In addition to personal outreach to key stakeholders, the Statewide CASE Team conducted a public stakeholder meeting to discuss the proposal on May 20, 2014 and presented the proposed measure at a CEC pre-rulemaking Workshop on July 21, 2014. The main issues that were addressed during development of the code change proposal are summarized below.

***Relationship between Proposed Code Change and Federal Preemption***

Stakeholders expressed concern that the code change proposal was a potential violation of federal preemption under the Energy Policy and Conservation Act of 1975 (EPCA). In response, it is important to note that this measure is not proposing a standard level that exceeds the federal minimum energy efficiency level nor is this measure prohibiting the installation of any type of water heater. Instead, the measure would be resetting the total baseline energy budget based on the efficiency level of a gas IWH that meets but does not exceed the efficiency level required by federal regulations. The proposed prescriptive requirements would allow an applicant that has access to natural gas to comply with the Standards in one of three ways: 1) installing a gas IWH that meets minimum federal efficiency standard level, 2) installing a gas storage water heater that is minimally compliant with federal efficiency standards in conjunction with a solar thermal water heating system that achieves a solar fraction of 0.55, or 3) installing a gas storage water heater that meets or exceeds the energy performance of a minimally compliant gas IWH.

CEC staff has indicated that CEC legal staff has evaluated the relationship between this proposed measure and federal preemption and is comfortable that this measure will not violate preemption. CEC staff has indicated they will continue to evaluate preemption concerns.

***DOE Test Procedure Impact on Proposed Code Change***

On July 11, 2014, DOE published a Final Rule for the test procedure for residential and certain commercial water heaters (DOE 2014). The new test procedure is scheduled to take effect on July 13, 2015. Stakeholders had questions about the impact of the new test procedure on this measure and Title 24 water heating standards in general. As required by federal law, changes to test procedures cannot increase the stringency of the efficiency standards. In a separate rulemaking, DOE will develop a mathematical conversion to translate existing EF ratings to the new UEF ratings and to ensure that the revised test procedure does not increase the stringency of the efficiency standards. Once DOE has determined the conversion factors, CEC might determine if it is appropriate to revise the CEC's compliance simulation software which discounts the EF rating of gas IWHs by 8%. The proposed Title 24 code change does not dictate a specific EF or UEF rating for water heaters. Rather, the code change would state that gas IWH be compliant with minimum federal efficiency standards. If the federal standard level changes to the new metric based on the new test procedure, the Title 24 Standards will not need to change.

***Incremental Cost of Gas IWH***

Another concern shared by stakeholders was the incremental cost of a gas storage water heater to a gas IWH, including the installation and maintenance costs. A publicly-available draft version of this CASE Report reported that there are no maintenance costs for a gas storage water heater versus gas IWHs, as research and outreach revealed that routine maintenance was not being undertaken for either type of water heater. Several stakeholders commented that gas IWHs do have higher maintenance costs than gas storage water heaters. As a result of this feedback, the Statewide CASE Team conducted further research and added information about incremental maintenance costs in this version of the CASE Report (See Section 5.2.1).

***Definition of Natural Gas Availability***

Though the course of developing this CASE Report, it has become apparent that the definition of "natural gas availability" is not clear and that a clearer definition is needed. The definitions of gas availability in the Standards, the ACM Reference Manual, and the Compliance Manuals are contradictory. For example, Section 150.1(c)8D of the Standards, which contain the prescriptive requirements for new residential construction, states that, "(f)or systems serving individual dwelling units, an electric-resistance storage or instantaneous water heater may be installed as the main water heating source only if natural gas is unavailable." The ambiguity in this language has led to questions on whether "availability" means a gas line connection to the proposed building or whether the area is serviced by a natural gas utility, and who has the authority to determine whether natural gas is available. As a result, the Statewide CASE Team will be recommending a clear method for determining if natural gas is available by way of revisions to the ACM Reference Manual and Compliance Manual.

Some stakeholders have requested that CEC reconsider the prescriptive requirement that requires applicants to use gas water heating if gas is available. The Statewide CASE Team does not support a change to the prescriptive requirements that would allow the installation of electric water heaters if natural gas is available. Natural gas water heaters are more TDV efficient than electric water heaters, although heat pump water heaters (HPWH) are closing the efficiency gap. If an applicant wants to install an electric water heater, they still have the option of doing so if they comply with the standards through the performance approach.

***Heat Pump Water Heaters as a Prescriptive Option***

On a related note, some stakeholders requested the addition of heat pump water heaters (HPWH) as a prescriptive option for situations when natural gas is not available. The Statewide CASE Team determined that exploring electric water heating options is outside the scope of this particular code change proposal.

***Venting***

Gas-fired water heaters must be properly vented so the products of combustion that are created when fuel is combusted are directed outdoors and away from people. The Statewide CASE Team has received several questions about the assumptions for venting IWHs. During the 2013 Title 24 rulemaking, the Statewide CASE Team recommended that the water heater venting requirements be updated to ensure that high-efficiency water heaters can be installed in new buildings. The High-Efficiency Water Heater Ready CASE Report submitted to CEC by the

Statewide CASE Team in 2011 includes detailed information about venting requirements and the cost associated with vents for high-efficiency water heaters, including gas IWH and condensing gas storage water heaters. The Statewide CASE Team's recommendations on venting have not changed since developing the CASE Report for the 2013 rulemaking.

The High-efficiency Water Heater Ready CASE Report (2011) resulted in a new mandatory requirement in Title 24 that requires systems using gas or propane water heaters to have a Category III or IV vent or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed. This means that buildings already have to install vent systems that are suitable for gas IWHs. The CASE Report submitted in September 2014 does not focus on venting requirements because no changes to Title 24 are needed as a result of the current proposed code change. Similarly, the cost of the appropriate vent is not included in the LCC analysis because new residential buildings already have to be designed to accommodate a gas IWH.

The cost effectiveness analysis presented in the High-Efficiency Water Heater Ready CASE Report (2011) assumes plastic vent piping will be installed. This assumption was made because there are models of high-efficiency water heaters that can use plastic vents, and generally the cost-effectiveness analysis is completed on the basic system design as opposed to an upgraded system design that uses more expensive componentry. The 2011 CASE Report identified the initial cost of plastic vents in a prototype building to be $158 and stainless steel vents to be $482.

The type of vent (e.g., plastic, steel, concentric) is typically specified by the manufacturer of the water heater. While many manufacturers allow plastic vents, several manufacturers of gas IWHs require a stainless steel vent because it can withstand the condensation that is created by the water heater.[7] The installer of the water heater should follow manufacturer specifications to determine the type of vent required for each IWH model.

The following is an excerpt from the 2011 CASE Report regarding appropriate venting for high-efficiency water heaters (CA IOUs 2011a):

> The National Fuel Gas Code (NFGC), ANSI Z223.1[8], divides gas appliances into four categories based on vent operating pressure and the likelihood of condensation occurring in the vent. The four categories, which are used to determine which type of vent is appropriate for a given appliance, are shown in [Figure 3]. Negative pressure systems, also known as non-positive pressure systems, operate at static pressures that are less than the surrounding room pressure. The joints of negative pressure systems do not need to be gas tight. If vent leakage occurs, room air will be sucked into the lower pressure flue stream. On the other hand, positive pressure systems require gas tight seals. If a leak occurs in a positive pressure system, flue gases will escape into the equipment room or, even worse, into the living space causing a potentially fatal buildup of carbon monoxide.
>
> The appliance category does not directly indicate the type of venting material needed. Nearly all residential natural draft water heaters are Category I appliances and use a 3 or 4 inch diameter

7 Rheem, Bosch, Takagi, and Noritz require Category III stainless steel vents for their gas-fired, non-condensing IWHs.

8 National Fire Protection Association, National Fuel Gas Code—2009 Edition. http:// www.nfpa.org

double wall metal type-B vent. There are no Category II gas-fired water heaters. Most residential water heaters with power vent fall into Category III or IV, and they require different venting materials than a standard natural draft water heater. Manufacturers usually provide certified vent materials and installation specifications for their products. Plastic vent pipes, such as PVC, CPVC or ABS pipes, are typically used, although aluminum and stainless steel vents are also used for some models. Size of the vent pipe depends on heat input rating, length of the entire horizontal and vertical pipe sections, and the number of installed elbows. For residential applications, 2-inch diameter pipes are usually used. Some manufacturers require the use of proprietary concentric vent pipes, instead of generic plastic pipes.

There is not a vent product that can be used for all types of water heaters. Some stainless steel vent products, e.g. Z-Flex vents, are certified for Category I through IV applications. When they are used for a Category I natural draft water heater, 3-inch or 4-inch pipes are used. If the water heater is to be upgraded to a power vent water heater, the venting system still might have to be replaced even though it is certified for Category III and IV appliances because the new power vent water heater may only certify the use of a 2-inch diameter pipe vent.

| Appliance Category | Vent Pressure | Condensing |
|---|---|---|
| I | Non-Positive | Non-Condensing |
| II | Non-Positive | Condensing |
| III | Positive | Non-Condensing |
| 'IV | Positive | Condensing |

**Figure 3. National Fuel Gas Code Gas Appliance Category**

# 3. Market Analysis

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The Statewide CASE Team considered how the proposed standard may impact the market in general and individual market players. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach to key stakeholders including statewide CASE program staff, CEC, and a wide range of industry actors who were invited to participate in Statewide CASE Team's public stakeholder meetings held in May 2014 and the pre-rulemaking meeting hosted by CEC in July 2014.

## 3.1 Market Structure

The residential water heater market is comprised of manufacturers, distributors/suppliers, retailers, builders, plumbers/installers, and consumers. The majority of water heaters are sold as replacements to existing water heaters. Approximately 7% of water heaters are sold for new construction (NEEA 2012). In the replacement market, water heaters are typically purchased by homeowners or plumber/installers through brick and mortar and online retailers. Market research reveals that the top water heater retailers are The Home Depot, Lowe's Home

Improvement, and Sears (PG&E 2012). In new construction, water heaters can be purchased directly from the manufacturers by suppliers or distributors who in turn sell them to builders and/or contracted plumber/installers (see Figure 4). Builders and plumbers can also purchase water heaters from retailers, such as the three mentioned above.

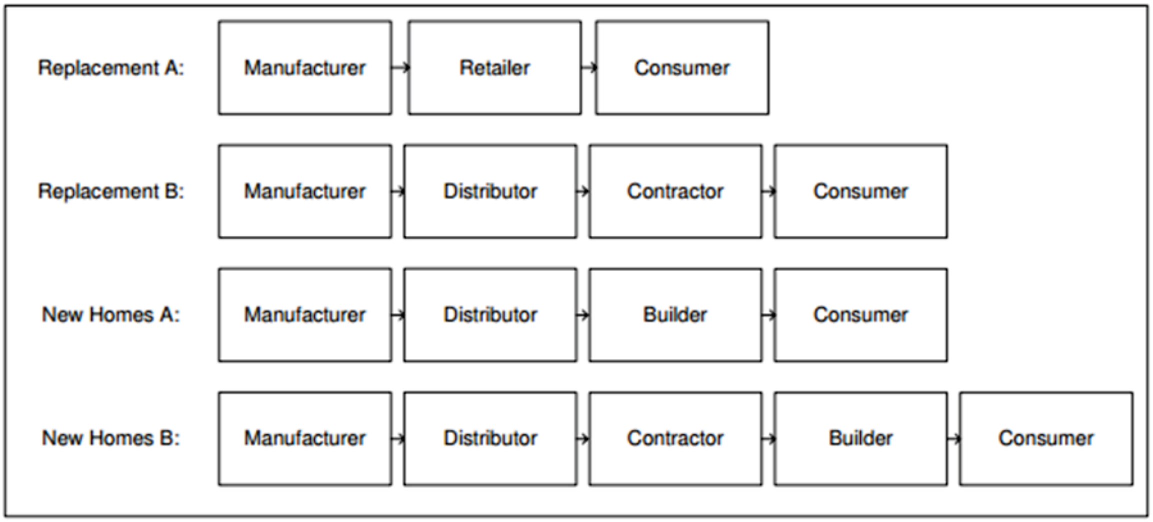


**Figure 4: Residential Water Heater Distribution Channels**

Source: DOE 2010

There are three manufacturers that comprise more than 95% of the residential water heating market in the United States (PG&E 2012). These manufacturers are A.O. Smith, Bradford White Corporation and Rheem and they manufacturer several unique brands of water heaters (see Figure 5 and Table 9). A.O. Smith and Rheem distribute their products through retailer and contractor channels. Bradford White water heaters are available only through contractors. Over 25 manufacturers make up the remaining 5% of the water heater market. Approximately one-third of water heater manufacturers sell gas IWHs in California (CEC Appliance Efficiency Database 2014).

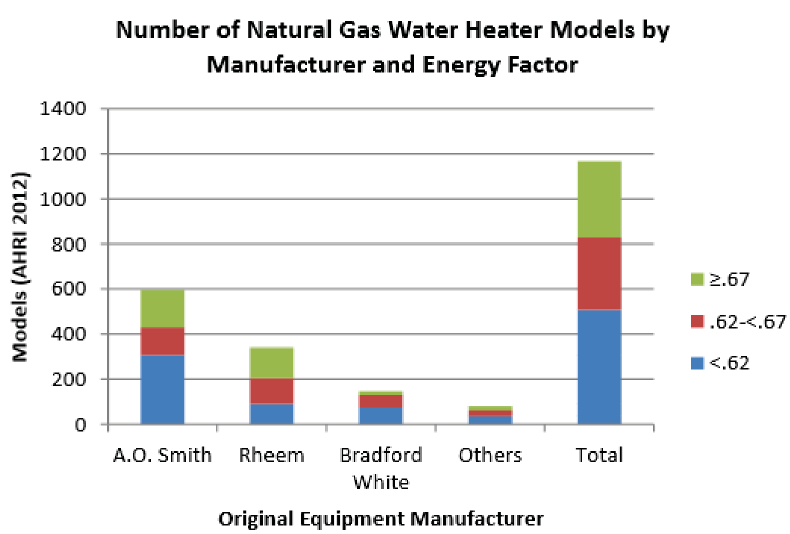

**Figure 5: Natural Gas Water Heater Models by Manufacturer and Energy Factors**

Source: PG&E 2012

## Table 9: Water Heater Manufacturers and Brands

Sources: CEC 2014; Consortium for Energy Efficiency 2014; ENERGY STAR 2014

| Manufacturer | Brand |
|---|---|
| A.O. Smith* | A O Smith Water Products (IWH and Storage)<br>Amercican (IWH)<br>American Water Heater Co. (IWH and Storage)<br>Apollo (Storage)<br>Garrison (Storage)<br>GSW (Storage)<br>Lochinvar Corp. (Storage)<br>Maytag (Storage)<br>Kenmore (IWH)<br>Powerflex (Storage)<br>Reliance (IWH and Storage)<br>Sears Brand (IWH and Storage)<br>State Industries (IWH and Storage)<br>Takagi (IWH)<br>U.S. Craftsmaster (IWH and Storage)<br>Whirlpool (Storage) |
| Rheem* | EcoSense (IWH)<br>General Electric (Storage)<br>Paloma/Waiwela (IWH)<br>Raypack (IWH)<br>Rheem (IWH and Storage)<br>Richmond (IWH and Storage)<br>Ruud (IWH and Storage)<br>Sure Comfort (IWH)<br>Vanguard (Storage) |
| Bradford White Corporation* | Bradford White (IWH and Storage)<br>Lochinvar Corp. (Storage) |
| Rinnai | Giant (IWH)<br>Jaccuzi Luxury Bath - Signature (IWH)<br>Rinnai (IWH) |
| American Standard | Dura-Glass (Storage) |
| Navien | Navien (IWH) |
| Quietside | Quietside (IWH) |
| Bosch Thermotechology Group | Bosch (IWH)<br>Aquastar (IWH) |

| | |
|---|---|
| | Pro Tankless (IWH)<br>Therm (IWH) |
| Giant Factories | Giant Factories (IWH and Storage) |
| Grand Hall | Eternal (IWH) |
| Contractors Supply Club, LLC/DBA Greenworks Unlimited | EcoHot (IWH) |
| Heat Cell Technologies, Inc. / ECO Heating Systems | Hamilton Engineering (IWH)<br>Propak TM (IWH) |
| Noritz America Corp. | Electrolux Home Products (IWH)<br>Noritz America Corp. (IWH) |
| Water Heater Innovations | Marathon (Storage)<br>Sears (Storage) |
| Demand Energy LLC | Insta Heat (IWH) |

* One of the three largest U.S. manufacturers that comprise approximately 95% of the water heating market.

## 3.2 Market Availability and Current Practices

### 3.2.1 Market Availability

There is widespread availability of high efficiency water heaters in California. This CASE Report focuses on the market availability and cost effectiveness of gas IWHs because CEC must show the prescriptive path that is used to establish the building's water heating budget is cost effective and viable given the currently available products. This report demonstrates that complying with Title 24 by installing a gas IWH is cost effective and feasible in all California climate zones. While the scope of the CASE analysis is limited to evaluating the impact of complying using a gas IWH, other compliance paths are likely cost-effective. Applicants that comply using the performance approach can comply by deploying a wide variety of measures. The Statewide CASE Team did not evaluate all compliance pathways.

CEC maintains a database of appliances that can be sold in California (federal and Title 20 compliant). As of September 17, 2014, there are 18 different manufacturers of gas IWHs that comply with the minimum federal efficiency standard of an EF of 0.82 or higher listed in the database (0.82 EF will become the minimum energy efficiency level when the federal standards go into effect in April 2015). Among these manufacturers, there are 41 unique brands. In total, there are 1,475 unique gas IWH models (EF range of 0.82 to 0.99) in the database. Products that meet the federal minimum efficiency of 0.82 EF comprises approximately 47% of the total products listed (CEC 2014). In sum, the market for gas IWHs appears to be more than sufficient to provide builders with many options to comply with the proposed standard using gas IWHs.

On a national level, sales and shipment data provide evidence that IWHs are growing in market share. For example, ENERGY STAR® certified gas IWHs[9] have seen a 15% increase in the number of units shipped in recent years: there were 337,186 shipments in 2011 (ENERGY STAR 2012) and 397,000 shipments in 2013 (ENERGY STAR 2014).

In the new construction market, IWHs sales have been as high as 18 to 21% (NEEA 2011; PG&E 2012). In other words, the current U.S. market for IWHs is three times as large as the forecast for low rise new construction in California in 2017 (108,032 single family and 27,784 multifamily dwelling units). Thus, manufacturing capacity or equipment availability is not considered to be a constraint.

According to PG&E’s Emerging Technology Program, the market potential for gas IWHs is significant, with an estimated potential market of about 250,000 (~25% of the market) units per year in California (137,000 new construction, 113,000 retrofit) (PG&E 2007).

The widespread availability of IWHs can be attributed to numerous factors, including growing consumer interest. According to Kema’s (2010) IOU energy efficiency program evaluation study that evaluated programs that were in effect in 2006-08, as well as industry predictions, the water heater and residential retrofit markets are embracing IWHs. A survey of retailers and manufacturers that the Northwest Energy Efficiency Alliance (NEEA) conducted indicated that 1) energy efficiency and 2) IWHs are perceived to be the two most significant market trends in the water heating industry. Results of the survey are presented in Figure 6. NEEA also reported a 61% increase in Internet search traffic for “tankless water heater” between January 2004 and January 2011 (NEEA 2012). Furthermore, a large water heater and plumbing company that installs IWHs in existing buildings across California reports that 25-30% (roughly 600 per year) of their water heater installations are gas IWHs, and that the regions where more IWHs are installed are Los Angeles, Orange, Ventura, and San Diego Counties (personal communication on August 7, 2014). This certainly reflects growing consumer interest in IWHs.

[9] The minimum EF rating for ENERGY STAR Qualified IWHs is 0.82.

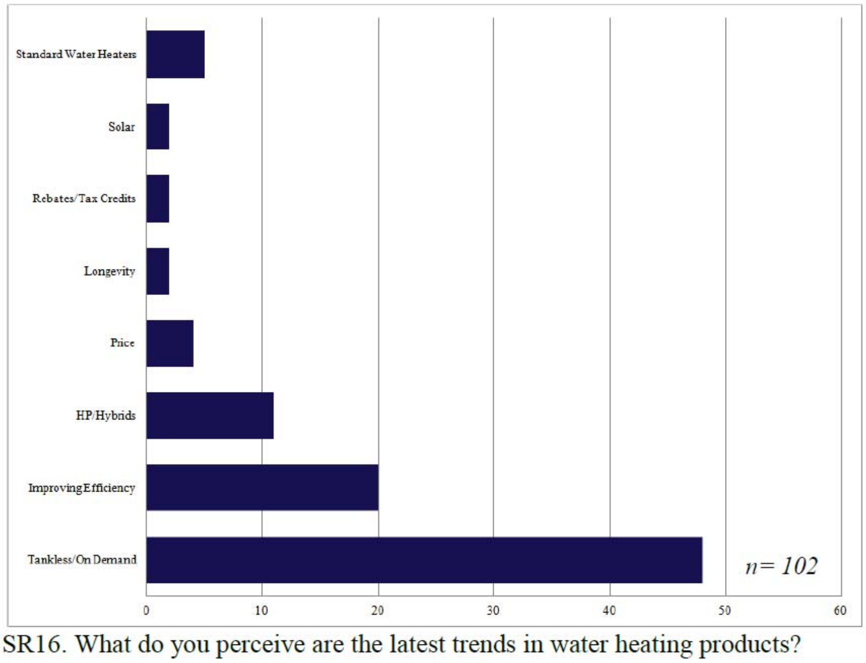


**Figure 6: Key Market Trends in Water Heating Industry**

Source: NEEA 2012

The interest in IWHs can be attributed to their benefits, such as compact size, longer product lifespan, and higher energy efficiency, as well as the frequently marketed benefits such as an endless supply of hot water and lower utility bills. Rodgers and O'Donnell (2008) assert that bringing consumer attention to these other benefits may be changing the dynamic of the water heater market as a whole.

State and federal water heating standards will influence the market trend toward higher-efficiency water heating, including IWHs. The 2013 Title 24 Standards, effective July 2014, require new residential construction to be designed so they can accommodate high efficiency water heaters. While the 2013 Title 24 Standards do not require that the high-efficiency water heater be installed, it is anticipated that since buildings have to be designed to accommodate higher efficiency water heaters, some builders will opt to install more efficient water heaters voluntarily. The higher efficiency water heaters could be gas IWH or condensing storage.

Finally, the market penetration of gas IWHs has grown due to the success of reach codes and incentive programs, such as ENERGY STAR and utility rebate programs, such as the one offered by Southern California Gas. Industry projections indicate a future annual growth rate of more than 10% per year (CA IOUs 2011a). The growth in market share of IWHs will result in decreasing installed product costs, which is another factor driving the trend toward instantaneous water heating.

### 3.2.2 Current Practice

Historically, storage water heaters have dominated the water heater market both in California and nationally. In recent years, however, builders have frequently been offering gas IWHs in addition to gas storage water heaters in the designs on new single family construction, (personal communication with plan checker on May 8, 2014; personal communication with national home builder on July 30, 2014). In fact, IWHs are now more commonly included in the design plans for new homes in Southern California, based on our discussions with various stakeholders. Other high-efficiency water heater technologies are also gaining popularity, such as heat pump water heaters and condensing gas storage water heaters.

## 3.3 Useful Life and Maintenance

### 3.3.1 Useful Life

The estimated useful life (EUL) of water heaters is variable and depends largely on usage patterns, water quality, and maintenance. Table 10 lists the EUL of water heaters as reported by numerous reputable sources. As can be seen in Table 10, IWHs are commonly cited as having a useful life of 20 years with storage water heaters ranging between 5 and 13 years.

Manufacturer warranties can also be used as a data point for estimating the EUL of a product. Table 11 lists the warranties of various water heater heaters. Generally, a manufacturer will warranty its products for a portion of their useful life and not for the full life since that would not be cost-effective for the manufacturer. As such, it can be assumed that if a company warranties a product for 15 years, as do a number of IWH manufacturers, then the product will last longer than 15 years if properly installed and maintained.

Based on the range of EULs for IWHs and storage water heaters, it is evident that IWHs are expected to have a longer useful life than their storage counterparts. The useful life depends on how the water heater is maintained. See Section 3.3.2 below for more information about proper water heater maintenance.

The Statewide CASE Team used DOE’s estimates of useful life in the Life-cycle Cost (LCC) analysis (13 years for storage water heaters and 20 years for IWHs). DOE’s estimates of useful life were developed through a rigorous public process with participation and input from the major players within the water heating industry. As such, the Statewide CASE Team used DOE’s estimates because they were vetted through a diligent public process that involved industry experts.

**Table 10: Product Life Ranges**

| Source | Lifespan (years) | | Reference |
|---|---|---|---|
| | Storage | IWH | |
| U.S. Department of Energy (2010) | 13 | 20 | http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0005 |
| American Council for an Energy-Efficient Economy (2012) | 13 | 13 | http://www.aceee.org/consumer/water-heating |
| Northwest Energy Efficiency Alliance (2006) | 12.9 | -- | http://neea.org/docs/reports/2011waterheatermarketupdatea273dbb87ca3.pdf |
| Southern California Gas Company Application Tables (2013-2014) | 11 | 20 | http://www.socalgas.com/regulatory/documents/A-12-07-003/SCG%20Appendix%20E%20Application%20Tables.pdf |
| Database for Energy Efficiency Resources (2014) | 11 | 20 | http://www.deeresources.com/ |
| Super Efficient Gas Water Heating Appliance Initiative (2008) | 13 | -- | http://www.energy.ca.gov/2007publications/CEC-500-2007-105/C EC-500-2007-105.PDF |
| National Association of Home Builders/Bank of America Home Equity (2007) | 10 | 20+ | https://www.nahb.org/fileUpload_details.aspx?contentID=99359 |
| Center for Energy and Environment (2012) | 10-12 | 15-20 | Schoenbauer, B., D. Bohac and M. Hewett. "Tankless Water Heaters - Do They Really Work?" In ACEEE Summer Study Proceedings, 2012. Paper 193. Pacific Grove, CA, 2012. |
| Builders Websource (2012) | -- | 15-20 | http://www.builderswebsource.com/techbriefs/tankless.htm |
| A National Home Builder | 5-10 | -- | Personal Communication on July 30, 2014 |
| A statewide professional plumbing company | 10 | 20 | Personal Communication on August 7, 2014 |

**Table 11: Water Heater Warranties**

| Source | Warranty (years) | | Reference |
|---|---|---|---|
| | Storage | IWH | |
| A.O. Smith | 6 (tank)<br>6 (parts) | 15 (heat exchanger)<br>5 (parts) | http://www.americanwaterheater.com/products/resGas.aspx<br>http://www.americanwaterheater.com/products/onDemand.aspx |
| Bradford White | 10 (tank)<br>6 (parts) | 12 (heat exchanger)<br>5 (parts) | http://www.bradfordwhite.com/sites/default/files/product_literature/39699ZAD.pdf<br>https://www.plumbersstock.com/product/67453/bradford-white-tg-150e-n-nat-gas-tankless-water-heater/?gclid=CIKx6cD6wMACFSsSMwod8hEAIg |
| Noritz | -- | 12 (heat exchanger)<br>5 (parts) | http://www.noritz.com/residential-products/nr71-sv/<br>http://www.noritz.com/residential-products/nr66/<br>http://www.noritz.com/residential-products/nr50/ |
| Rheem | 9 - 12 (tank and parts) | 12 (heat exchanger)<br>5 (parts) | http://cdn.globalimageserver.com/fetchdocument-rh.aspx?name=performance-platinum-atmospheric-performance-platinum-atmospheric |
| Lochinvar | 6 - 10 (tank)<br>2 - 6 (parts) | -- | http://www.lochinvar.com/products/default.aspx?type=productline&lineid=45 |
| State | 6 (tank)<br>6 (parts) | 15 (heat exchanger)<br>5 (parts) | http://www.statewaterheaters.com/lit/warranty/res-gas.html<br>http://www.statewaterheaters.com/lit/warranty/tankless.html |
| Rinnai | -- | 12 (heat exchanger)<br>5 (parts) | http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCAQFjAA&url=http%3A%2F%2Fwww.rinnai.us%2Fdocumentation%2Fdownloads%2FRinnai_Value_Series_Tankless_Water_Heater_Warranty.pdf&ei=i_2BVJ6SM4XToATi-YLQAQ&usg=AFQjCNFdXU7FHePug2JqI7-_0-a1n2Y1Rg&bvm=bv.81177339,d.cGU |
| American Water Heaters | 6 – 12 (tank)<br>6 - 12 (parts) | 5 – 15 (heat exchanger)<br>5 (parts) | http://www.americanwaterheater.com/products/resGas.aspx<br>http://www.americanwaterheater.com/products/onDemand.aspx |
| Bosch | -- | 15 (heat exchanger)<br>5 (parts) | http://www.bosch-climate.us/support-center/product-warranty.html |

### 3.3.2 Maintenance

Water heaters should be maintained according to manufacturer recommendations to ensure proper water heater performance, prolonged useful life, and warranty coverage. If water heaters are not maintained, the useful life can be shortened and failures may not be covered under the warranty. Table 12 lists the primary maintenance activities for storage water heaters and IWH based on manufacturer and plumber recommendations. Some manufacturers recommend additional maintenance activities than those listed in Table 12. For example, a leading water heater manufacturer recommends draining one gallon of water from the bottom of storage water heaters on a monthly basis to remove sediment in the tank. As noted in Table 12, both storage water heaters and IWHs have recommended regular maintenance procedures.

**Table 12: Key Maintenance Activities for Water Heaters**

| Type | Activity | Frequency | Source |
|---|---|---|---|
| IWH | Draining and flushing heat exchanger | Every 2-4 years1 | Statewide plumbing company |
| | Inspection of burner, temperature & pressure relief valve, air intake filter, water filter, and venting system | Annually | Rheem<br>Bradford White<br>A.O. Smith<br>American Standard<br>Takagi |
| Storage | Draining and flushing storage tank | Every 6 months to annually | Bradford White<br>Statewide plumbing company<br>Lochinvar<br>US Craftsmaster<br>GSW |
| | Inspection of burner, thermostat (operation of), venting system, temperature & pressure relief valve | Every 3 months to annually | Bradford White<br>American Standard<br>Lochinvar<br>State<br>GSW<br>American Standard |
| | Inspection of the anode rod | Every 1- 2 years, or more frequently in areas with soft water | Bradford White<br>Lochinvar<br>GSW<br>Pacific Northwest National Laboratory |

[1] In areas with hard water, flushing is typically recommended every 2 years. In areas with soft water (naturally occurring or conditioned), flushing is recommended every 3-4 years.

With proper maintenance of any water heater, the useful life of the product will be extended. However, the need to replace an IWH will not be as frequent as a storage water heater if maintenance is routinely carried out. According to one national home builder that installs IWHs and storage water heaters in single family homes, storage water heaters typically fail between 5 and 10 years without routine maintenance (the lifetime used in the LCC analysis is 13 years). Failure of a storage water heater (e.g., leaking a large volume of water) requires a full replacement of the unit. Failure of an IWH, on the other hand, oftentimes does not necessitate a replacement of the water heater itself but a repair to or replacement of the damaged part (typically the heat exchanger) (personal communication with home builder on July 30, 2014 and professional plumbing company on August 14, 2014). According to a statewide professional plumbing company, the cost to replace a storage tank is substantially higher than repairing an IWH (personal communication August 14, 2014).

Though water heaters require regular maintenance to prolong their useful life, it is uncertain whether people are maintaining their water heaters as recommended by manufacturers. Anecdotal evidence from conversations with homeowners in areas with varying levels of water quality, various household sizes, and who have had a gas IWH installed in their homes between 2 and 10 years reveals that maintenance is not being performed. None of the homeowners with IWHs claimed they have needed to repair or replace their water heaters in spite of not ever maintaining them. Homeowners with storage water heaters also claimed that were not maintaining their water heaters as recommended.

Section 4.7.1 of this report discusses the maintenance cost assumptions used in the LCC analysis.

***Maintenance of Gas IWHs***

The primary maintenance activities for an IWH are flushing the heat exchanger to remove scale buildup and inspecting and cleaning the inlet water filter screen which helps minimize the amount of debris or sediment that enters the water heater.

Some manufacturers recommend a maintenance schedule, but the maintenance schedule homeowners deploy will vary based largely on water quality. For example, in areas with hard water, professional plumbers the Statewide CASE Team spoke with recommended more frequent maintenance (every 2 years). In areas where the water quality is relatively good, plumbers recommend servicing the water heater every 3 - 4 years (personal communication with professional plumbers on August 8, 2014 and on August 21, 2014). Frequent inspection of the inlet water filter screen will enable a homeowner to monitor the amount of sediment entering the water heater. If the filter tends to fill with sediment regularly, then more frequent flushing may be required. Homeowners can also reference local water quality data to determine the level of water quality in their area to help guide maintenance schedules.

To assist in flushing the heat exchanger, manufacturers and plumbers recommend the installation of a drain kit (i.e. isolation valves). As shown in Figure 7, the drain kit consists of a cold-in and hot-out multiple function valves. The drain kit allows the IWH to be isolated from both the inlet cold water and the outlet hot water lines. Integral to the kit are hose bibs that allow the flushing hoses to be attached.

Though recommended, the drain kit is not required by manufacturers.[10] However, the installation of a drain kit has become standard practice among plumbers and homebuilders, as it simplifies the activity of flushing the heat exchanger. Therefore, the Statewide CASE Team proposes to add a mandatory measure to Title 24 that would require the installation of drain kits when installing gas IWHs. See Section 4.7.1 for cost information on drain kits.

Manufacturers recommend that a licensed professional flush the heat exchanger to avoid potentially damaging the water heater, though some manufacturers sell flush kits so that homeowners can conduct their own maintenance activities on the water heater. Flush kits are comprised of a submersible pump, two short hoses, hose connections, and a 5-gallon bucket. These components can be purchased separately or as a pre-assembled kit. A solution of white vinegar is widely recommended for flushing the heat exchanger as it is food grade and very effective at removing scale.

In addition to flushing the heat exchanger, manufacturers recommend periodically inspecting and cleaning the inlet water filter screen, which helps minimize the amount of debris or

[10] Rheem's installation guide for 17 unique IWH models state that valve kits may be purchased and installed as optional items (Rheem 2009). Noritz also states that the drain kit/isolation valves are optional (Noritz 2009).

sediment that enters the water heater. This can be done by running the filter screen under hot water and using a brush to remove debris (Noritz 2005; Rheem 2009; Bradford White 2011). Replacement of the inlet water filter screen is not necessary unless it is damaged (personal communication with water heater manufacturer on August 27, 2014).


**Figure 7: Drain Kit Components**

Source: http://www.brasscraft.com/products.aspx?id=266

***Maintenance of Gas Storage Water Heaters***

For a storage water heater, maintenance largely consists of draining the tank, inspecting the anode rod, and replacing the anode rod if necessary. The recommended frequency of regular maintenance varies by manufacturer. Like IWHs, the frequency of maintenance depends on water quality. Most manufacturers recommend draining the tank every six months to once per year in order to remove sediment that has accumulated in the bottom of the tank. As previously noted, one manufacturer recommends draining a gallon of water from the tank every month to remove the sediment that builds up during operation. Some manufacturers also recommend that yearly inspections of the burners, venting system, and temperature and pressure relief valves be conducted by a qualified service technician (see Figure 8). [11] Others recommend visual inspections as frequently as every three to six months.

[11] Bradford White storage water heater operation manuals were reviewed for the following models: M-2-XR75S6BN, M-I-30T6FBN, M-I-0S6FBN, M-I-303T6FBN, M-I-40T6FBN, M-I-403S6FBN, M-I-404T6FBN, M-I-5036FBN, M-I-50L6FBN, M-I-504S6FBN, M-I-60T6FBN.

**IMPORTANT**

**The water heater should be inspected at a minimum annually by a qualified service technician for damaged components and/or joints not sealed. DO NOT operate this water heater if any part is found damaged or if any joint is found not sealed.**

**Figure 8: Storage Water Heater Maintenance Recommendation**

Source: Bradford White 2012

Manufacturers typically recommend inspecting the anode rod every two years and to replace it when necessary to prolong tank life, but the frequency of inspection is dependent on local water conditions. With the use of a water softener, more frequent inspection of the anode is needed (Bradford White 2007). According to a statewide professional plumbing company, homeowners do not typically request replacement of the anode rod, as the cost can be high for this service if the setup of the water heater obstructs access to the anode. If the setup of the water heater prevents an easy removal of the 3-foot anode rod, then it might be necessary to completely remove the tank from its location to replace the anode rod. Moving the tank can triple the cost of replacing the anode rod (personal communication with a professional plumber on August 14, 2014). (See Section 4.7.1 for cost information). However, if the anode rod is not periodically replaced it can lead to corrosion of the water heater storage tank, which in turn could lead to the tank leaking water and the need to replace the entire unit.

### 3.3.3 Water Heater Efficiency Degradation

The Statewide CASE Team was asked by CEC to investigate how efficiency degrades over time for both storage water heaters and IWHs. A 2010 study conducted by the Battelle Memorial Institute, the administrator of several national laboratories, evaluated the impact of scale formation on equipment efficiency for electric storage, gas storage, and gas IWHs using an accelerating testing approach. During the test period, the water heaters were not maintained according to manufacturer recommendations.[12] The researchers evaluated 10 of each type of water heater: five water heaters were connected to water that had been treated with a water softener and contained 0.55 grains per gallon (gpg) of water hardness and five were connected to un-softened well water that contained 26.2 gpg. It should be noted that water hardness of 26 gpg is very hard. For reference, San Diego has a water hardness of about 15 gpg and Anaheim has a water hardness of about 18 gpg. Both cities have some of the hardest water in the state. As described in Section 3.3.2 of the CASE Report, hard water can cause scale buildup which can reduce the efficiency and useful life of IWHs. The Batelle study reported that hard water also reduces the efficiency of storage water heaters. Soft water (e.g., 0.55 gpg) may also have detrimental effects, such as increasing risk of corrosion to the storage tank.

[12] The Battelle study assumed a daily hot water use of 50 gallons per household per day; the study did not replicate draw patterns but simulated total hot water use without evaluating when water was used. Though the study did not use the same temperatures setpoints for all types of water heaters, it did account for the difference in temperature setpoints when conducting the analysis of test results.

The efficiency degradation of gas IWHs can be managed by flushing the heat exchanger. To maintain efficiency, gas IWHs should be flushed more frequently in areas with harder water and as hot water use increases. The Battelle study's analysis assumed that IWHs will be flushed after efficiency degrades by about 8 percent, but water heaters can be flushed more frequently if higher efficiency is desired. Similarly, the efficiency of gas storage water heaters will also degrade overtime, with the rate of degradation increasing as water hardness and water use increases. The study did not identify any maintenance practices that would allow efficiency of storage water heaters to be maintained.

The Battelle study concluded that, "none of the electric or gas storage water heaters or the instantaneous gas water heaters on the un-softened water made it through the entire testing period because the outlet piping system consisting of one-half inch copper pipe, a needle valve, and a solenoid valve became clogged with scale buildup." They found that for storage water heaters, hard water decreased the thermal efficiency of the equipment from 70 percent to 67 percent over the equivalent of two years of field service; a three percent degradation in efficiency. For the gas IWH used in the study, hard water decreased the efficiency from 80 percent to 72 percent over 1.6 years, after which the IWH ceased proper operation because of sediment buildup prevented the controls from functioning properly. However, after the IWH heat exchanger was flushed, the efficiency of the gas IWH returned to 77 percent. This study indicates that the efficiency of both gas storage water heaters and gas IWHs degrades over time and that regular maintenance is important to maintain efficiency, especially when water is hard.

In addition, the Battelle study extrapolated the test data out over a period of years in order to model efficiency degradation over time as a function of water hardness and hot water usage. Table 13 and Table 14 present the results of the extrapolation for gas IWHs and gas storage water heaters, respectively. As can be seen, the efficiencies of gas IWHs and storage water heaters degrade with time due to scale buildup and increased hot water usage. As can be seen in Table 13, at a daily hot water use of 50 gallons, IWHs are projected to require a flushing (i.e. deliming) at roughly two years in areas with *very* hard water (>20 gpg) and at four years in areas with hard water (>10 gpg). These results are similar to the recommended maintenance schedules provided by the professional plumbers that were interviewed as part of the CASE analysis with one exception: the study projects that IWHs will need to be flushed at approximately eight years in areas with soft water, rather than at four years as estimated by plumbing professionals.

A 2013 Pacific Northwest National Laboratory (PNNL) study also confirmed the results of the Battelle study that scale buildup will impact the efficiencies of both storage water heaters and IWHs and can lead to decreased equipment life.

**Table 13: Predicted Efficiencies of Instantaneous Water Heaters as a Function of Water Hardness and Hot Water Usage**

Source: Battelle Memorial Institute 2010

| | 50 Gallons Per Day of Hot Water Usage | | | | | | | 100 Gallons Per Day of Hot Water Usage | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Water Hardness in Grains Per Gallon | | | | | | | Water Hardness in Grains Per Gallon | | | | | | |
| (Years) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| 0.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 |
| 0.2 | 80.0 | 79.8 | 79.6 | 79.4 | 79.2 | 79.0 | 78.8 | 80.0 | 79.6 | 79.2 | 78.8 | 78.4 | 78.0 | 77.6 |
| 0.4 | 80.0 | 79.6 | 79.2 | 78.8 | 78.4 | 78.0 | 77.6 | 80.0 | 79.2 | 78.4 | 77.6 | 76.9 | 76.1 | 75.3 |
| 0.6 | 80.0 | 79.4 | 78.8 | 78.2 | 77.6 | 77.1 | 76.5 | 80.0 | 78.8 | 77.6 | 76.5 | 75.3 | 74.1 | 72.9 |
| 0.8 | 80.0 | 79.2 | 78.4 | 77.6 | 76.9 | 76.1 | 75.3 | 80.0 | 78.4 | 76.9 | 75.3 | 73.7 | 72.2 | Delime |
| 1.0 | 80.0 | 79.0 | 78.0 | 77.1 | 76.1 | 75.1 | 74.1 | 80.0 | 78.0 | 76.1 | 74.1 | 72.2 | Delime | |
| 1.2 | 80.0 | 78.8 | 77.6 | 76.5 | 75.3 | 74.1 | 72.9 | 80.0 | 77.6 | 75.3 | 72.9 | Delime | | |
| 1.4 | 80.0 | 78.6 | 77.3 | 75.9 | 74.5 | 73.1 | Delime | 80.0 | 77.3 | 74.5 | Delime | | | |
| 1.6 | 80.0 | 78.4 | 76.9 | 75.3 | 73.7 | 72.2 | | 80.0 | 76.9 | 73.7 | | | | |
| 1.8 | 80.0 | 78.2 | 76.5 | 74.7 | 72.9 | Delime | | 80.0 | 76.5 | 72.9 | | | | |
| 2.0 | 80.0 | 78.0 | 76.1 | 74.1 | 72.2 | | | 80.0 | 76.1 | 72.2 | | | | |
| 2.2 | 80.0 | 77.8 | 75.7 | 73.5 | Delime | | | 80.0 | 75.7 | Delime | | | | |
| 2.4 | 80.0 | 77.6 | 75.3 | 72.9 | | | | 80.0 | 75.3 | | | | | |
| 2.6 | 80.0 | 77.4 | 74.9 | 72.3 | | | | 80.0 | 74.9 | | | | | |
| 2.8 | 80.0 | 77.3 | 74.5 | Delime | | | | 80.0 | 74.5 | | | | | |
| 3.0 | 80.0 | 77.1 | 74.1 | | | | | 80.0 | 74.1 | | | | | |
| 3.2 | 80.0 | 76.9 | 73.7 | | | | | 80.0 | 73.7 | | | | | |
| 3.4 | 80.0 | 76.7 | 73.3 | | | | | 80.0 | 73.3 | | | | | |
| 3.6 | 80.0 | 76.5 | 72.9 | | | | | 80.0 | 72.9 | | | | | |
| 3.8 | 80.0 | 76.3 | 72.5 | | | | | 80.0 | 72.5 | | | | | |
| 4.0 | 80.0 | 76.1 | 72.2 | | | | | 80.0 | 72.2 | | | | | |
| 4.2 | 80.0 | 75.9 | 71.8 | | | | | 80.0 | Delime | | | | | |
| 4.4 | 80.0 | 75.7 | Delime | | | | | 80.0 | | | | | | |
| 4.6 | 80.0 | 75.5 | | | | | | 80.0 | | | | | | |
| 4.8 | 80.0 | 75.3 | | | | | | 80.0 | | | | | | |
| 5.0 | 80.0 | 75.1 | | | | | | 80.0 | | | | | | |
| 5.2 | 80.0 | 74.9 | | | | | | 80.0 | | | | | | |
| 5.4 | 80.0 | 74.7 | | | | | | 80.0 | | | | | | |
| 5.6 | 80.0 | 74.5 | | | | | | 80.0 | | | | | | |
| 5.8 | 80.0 | 74.3 | | | | | | 80.0 | | | | | | |
| 6.0 | 80.0 | 74.1 | | | | | | 80.0 | | | | | | |
| 6.2 | 80.0 | 73.9 | | | | | | 80.0 | | | | | | |
| 6.4 | 80.0 | 73.7 | | | | | | 80.0 | | | | | | |
| 6.6 | 80.0 | 73.5 | | | | | | 80.0 | | | | | | |
| 6.8 | 80.0 | 73.3 | | | | | | 80.0 | | | | | | |
| 7.0 | 80.0 | 73.1 | | | | | | 80.0 | | | | | | |
| 7.2 | 80.0 | 72.9 | | | | | | 80.0 | | | | | | |
| 7.4 | 80.0 | 72.7 | | | | | | 80.0 | | | | | | |
| 7.6 | 80.0 | 72.5 | | | | | | 80.0 | | | | | | |
| 7.8 | 80.0 | 72.3 | | | | | | 80.0 | | | | | | |
| 8.0 | 80.0 | 72.2 | | | | | | 80.0 | | | | | | |
| 8.2 | 80.0 | 72.0 | | | | | | 80.0 | | | | | | |
| 8.4 | 80.0 | Delime | | | | | | 80.0 | | | | | | |

## Table 14: Predicted Efficiencies of Gas Storage Water Heaters as a Function of Water Hardness and Hot Water Usage

Source: Battelle Memorial Institute 2010

| Time | 50 Gallons Per Day of Hot Water Usage | | | | | | | 100 Gallons Per Day of Hot Water Usage | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water Hardness in Grains Per Gallon | | | | | | | Water Hardness in Grains Per Gallon | | | | | | |
| (Years) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| 0.00 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 |
| 0.25 | 70.4 | 70.3 | 70.3 | 70.2 | 70.1 | 70.0 | 70.0 | 70.4 | 70.3 | 70.1 | 70.0 | 69.8 | 69.7 | 69.5 |
| 0.50 | 70.4 | 70.3 | 70.1 | 70.0 | 69.8 | 69.7 | 69.5 | 70.4 | 70.1 | 69.8 | 69.5 | 69.3 | 69.0 | 68.7 |
| 0.75 | 70.4 | 70.2 | 70.0 | 69.8 | 69.5 | 69.3 | 69.1 | 70.4 | 70.0 | 69.5 | 69.1 | 68.7 | 68.3 | 67.8 |
| 1.00 | 70.4 | 70.1 | 69.8 | 69.5 | 69.3 | 69.0 | 68.7 | 70.4 | 69.8 | 69.3 | 68.7 | 68.1 | 67.6 | 67.0 |
| 1.25 | 70.4 | 70.0 | 69.7 | 69.3 | 69.0 | 68.6 | 68.3 | 70.4 | 69.7 | 69.0 | 68.3 | 67.6 | 66.9 | 66.1 |
| 1.50 | 70.4 | 70.0 | 69.5 | 69.1 | 68.7 | 68.3 | 67.8 | 70.4 | 69.5 | 68.7 | 67.8 | 67.0 | 66.1 | 65.3 |
| 1.75 | 70.4 | 69.9 | 69.4 | 68.9 | 68.4 | 67.9 | 67.4 | 70.4 | 69.4 | 68.4 | 67.4 | 66.4 | 65.4 | 64.4 |
| 2.00 | 70.4 | 69.8 | 69.3 | 68.7 | 68.1 | 67.6 | 67.0 | 70.4 | 69.3 | 68.1 | 67.0 | 65.9 | 64.7 | 63.6 |
| 2.25 | 70.4 | 69.8 | 69.1 | 68.5 | 67.8 | 67.2 | 66.6 | 70.4 | 69.1 | 67.8 | 66.6 | 65.3 | 64.0 | 62.7 |
| 2.50 | 70.4 | 69.7 | 69.0 | 68.3 | 67.6 | 66.9 | 66.1 | 70.4 | 69.0 | 67.6 | 66.1 | 64.7 | 63.3 | 61.9 |
| 2.75 | 70.4 | 69.6 | 68.8 | 68.1 | 67.3 | 66.5 | 65.7 | 70.4 | 68.8 | 67.3 | 65.7 | 64.2 | 62.6 | 61.0 |
| 3.00 | 70.4 | 69.5 | 68.7 | 67.8 | 67.0 | 66.1 | 65.3 | 70.4 | 68.7 | 67.0 | 65.3 | 63.6 | 61.9 | 60.2 |
| 3.25 | 70.4 | 69.5 | 68.6 | 67.6 | 66.7 | 65.8 | 64.9 | 70.4 | 68.6 | 66.7 | 64.9 | 63.0 | 61.2 | 59.3 |
| 3.50 | 70.4 | 69.4 | 68.4 | 67.4 | 66.4 | 65.4 | 64.4 | 70.4 | 68.4 | 66.4 | 64.4 | 62.5 | 60.5 | 58.5 |
| 3.75 | 70.4 | 69.3 | 68.3 | 67.2 | 66.1 | 65.1 | 64.0 | 70.4 | 68.3 | 66.1 | 64.0 | 61.9 | 59.8 | 57.6 |
| 4.00 | 70.4 | 69.3 | 68.1 | 67.0 | 65.9 | 64.7 | 63.6 | 70.4 | 68.1 | 65.9 | 63.6 | 61.3 | 59.1 | 56.8 |
| 4.25 | 70.4 | 69.2 | 68.0 | 66.8 | 65.6 | 64.4 | 63.2 | 70.4 | 68.0 | 65.6 | 63.2 | 60.8 | 58.4 | 55.9 |
| 4.50 | 70.4 | 69.1 | 67.8 | 66.6 | 65.3 | 64.0 | 62.7 | 70.4 | 67.8 | 65.3 | 62.7 | 60.2 | 57.6 | 55.1 |
| 4.75 | 70.4 | 69.1 | 67.7 | 66.4 | 65.0 | 63.7 | 62.3 | 70.4 | 67.7 | 65.0 | 62.3 | 59.6 | 56.9 | 54.2 |
| 5.00 | 70.4 | 69.0 | 67.6 | 66.1 | 64.7 | 63.3 | 61.9 | 70.4 | 67.6 | 64.7 | 61.9 | 59.1 | 56.2 | 53.4 |
| 5.25 | 70.4 | 68.9 | 67.4 | 65.9 | 64.4 | 63.0 | 61.5 | 70.4 | 67.4 | 64.4 | 61.5 | 58.5 | 55.5 | 52.5 |
| 5.50 | 70.4 | 68.8 | 67.3 | 65.7 | 64.2 | 62.6 | 61.0 | 70.4 | 67.3 | 64.2 | 61.0 | 57.9 | 54.8 | 51.7 |
| 5.75 | 70.4 | 68.8 | 67.1 | 65.5 | 63.9 | 62.3 | 60.6 | 70.4 | 67.1 | 63.9 | 60.6 | 57.4 | 54.1 | 50.8 |
| 6.00 | 70.4 | 68.7 | 67.0 | 65.3 | 63.6 | 61.9 | 60.2 | 70.4 | 67.0 | 63.6 | 60.2 | 56.8 | 53.4 | 50.0 |
| 6.25 | 70.4 | 68.6 | 66.9 | 65.1 | 63.3 | 61.5 | 59.8 | 70.4 | 66.9 | 63.3 | 59.8 | 56.2 | 52.7 | 49.1 |
| 6.50 | 70.4 | 68.6 | 66.7 | 64.9 | 63.0 | 61.2 | 59.3 | 70.4 | 66.7 | 63.0 | 59.3 | 55.7 | 52.0 | 48.3 |
| 6.75 | 70.4 | 68.5 | 66.6 | 64.7 | 62.7 | 60.8 | 58.9 | 70.4 | 66.6 | 62.7 | 58.9 | 55.1 | 51.3 | 47.4 |
| 7.00 | 70.4 | 68.4 | 66.4 | 64.4 | 62.5 | 60.5 | 58.5 | 70.4 | 66.4 | 62.5 | 58.5 | 54.5 | 50.6 | 46.6 |
| 7.25 | 70.4 | 68.3 | 66.3 | 64.2 | 62.2 | 60.1 | 58.1 | 70.4 | 66.3 | 62.2 | 58.1 | 54.0 | 49.9 | 45.7 |
| 7.50 | 70.4 | 68.3 | 66.1 | 64.0 | 61.9 | 59.8 | 57.6 | 70.4 | 66.1 | 61.9 | 57.6 | 53.4 | 49.1 | 44.9 |
| 7.75 | 70.4 | 68.2 | 66.0 | 63.8 | 61.6 | 59.4 | 57.2 | 70.4 | 66.0 | 61.6 | 57.2 | 52.8 | 48.4 | 44.0 |
| 8.00 | 70.4 | 68.1 | 65.9 | 63.6 | 61.3 | 59.1 | 56.8 | 70.4 | 65.9 | 61.3 | 56.8 | 52.3 | 47.7 | 43.2 |
| 8.25 | 70.4 | 68.1 | 65.7 | 63.4 | 61.0 | 58.7 | 56.4 | 70.4 | 65.7 | 61.0 | 56.4 | 51.7 | 47.0 | 42.3 |
| 8.50 | 70.4 | 68.0 | 65.6 | 63.2 | 60.8 | 58.4 | 55.9 | 70.4 | 65.6 | 60.8 | 55.9 | 51.1 | 46.3 | 41.5 |
| 8.75 | 70.4 | 67.9 | 65.4 | 63.0 | 60.5 | 58.0 | 55.5 | 70.4 | 65.4 | 60.5 | 55.5 | 50.6 | 45.6 | 40.6 |
| 9.00 | 70.4 | 67.8 | 65.3 | 62.7 | 60.2 | 57.6 | 55.1 | 70.4 | 65.3 | 60.2 | 55.1 | 50.0 | 44.9 | 39.8 |
| 9.25 | 70.4 | 67.8 | 65.2 | 62.5 | 59.9 | 57.3 | 54.7 | 70.4 | 65.2 | 59.9 | 54.7 | 49.4 | 44.2 | 38.9 |
| 9.50 | 70.4 | 67.7 | 65.0 | 62.3 | 59.6 | 56.9 | 54.2 | 70.4 | 65.0 | 59.6 | 54.2 | 48.9 | 43.5 | 38.1 |
| 9.75 | 70.4 | 67.6 | 64.9 | 62.1 | 59.3 | 56.6 | 53.8 | 70.4 | 64.9 | 59.3 | 53.8 | 48.3 | 42.8 | 37.2 |
| 10.00 | 70.4 | 67.6 | 64.7 | 61.9 | 59.1 | 56.2 | 53.4 | 70.4 | 64.7 | 59.1 | 53.4 | 47.7 | 42.1 | 36.4 |

## 3.4 Market Impacts and Economic Assessments

### 3.4.1 Impact on Builders

This particular proposed code change will have a minor impact on builders. Since the 2013 Title 24 Standards already require the installation of system components that are compatible with gas IWHs, there are no additional installation costs to builders. In addition, the large volume of instantaneous units installed in new construction may result in decreasing costs, as contractors may be able to reduce costs over a large number of installations (Schoenbauer, Bohac & Hewett 2012). Furthermore, builders will still have the option of taking the performance approach and can install other types of water heaters as long as the energy budget for the building not exceeded, as well as the other prescriptive options.

### 3.4.2 Impact on Building Designers

Title 24 is updated on a three-year revision cycle, so acclimating to changes in Title 24 Standards is routine practice for building designers; adjusting design practices to comply with changing code practices is within the normal practices of building designers. This particular revision to the Title 24 water heating standards will not require a departure from standard or common design practices for building designers.

Though water heating design changes are not required, designing for a gas IWH may encourage building designers to explore compact hot water distribution, which is an efficient and effective strategy for increasing energy and water savings as well as user utility. The energy and water savings associated with compact distribution are not accounted for in this report.

As a whole, the measures being considered for the 2016 code change cycle aim to provide designers with options on how to comply with the building efficiency standards. The proposed standards do not aim to limit building aesthetics or any particular type of building equipment.

### 3.4.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Department of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have any impact on the safety or health of occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

### 3.4.4 Impact on Building Owners and Occupants

The proposed code change will have an impact on building owners and occupants. For building owners, the longer lifespan of IWHs results in fewer water heater replacements over time, particularly if routine maintenance is undertaken to prolong the useful life of the water heater. Homeowner-occupants will benefit from a continual supply of hot water and lower utility bills, though the wait time for hot water may increase slightly due to the additional time it takes for hot water to arrive, particularly if the water heating system is designed so that the water heater is located far from the use points. Research and outreach to stakeholders reveals that homeowners are overwhelmingly satisfied with the performance of their IWH.

### 3.4.5 Impact on Retailers (including manufacturers and distributors)

The proposed code change will have some impacts on manufacturers, distributors, and retailers. Sales will increase for manufacturers of qualifying IWHs and for retailers and distributors that stock qualifying products. DOE projections indicate roughly a 43% market penetration of IWHs in 2015 in the absence of the recently adopted federal standards (DOE 2010). This implies that product availability and adoption will grow at a steady rate each year, thus reducing the likelihood for a lack of available products.

### 3.4.6 Impact on Energy Consultants

As discussed in Section. 3.5.2 of this report, the changes made to Title 24 may have a positive impact on job growth in the state. Energy consultants may benefit from being able to offer their builder clients compliance alternatives.

### 3.4.7 Impact on Building Inspectors

There are no anticipated impacts to building inspectors from the proposed code change. Inspectors will not be required to complete any tasks that they are not already conducting to verify compliance with the 2013 Title 24 Standards.

### 3.4.8 Impact on Statewide Employment

The proposed changes to Title 24 may impact employment. An increase in employment in the water heating sector is expected while a slight employment decrease for installers may result, as IWHs have higher product life expectancies than storage water heaters; the rate of replacement is lower for the former. More impacts to employment are noted below in Section 3.5.

### 3.4.9 Impact on Homeowners (including potential first time home owners)

The proposed code change will have an impact on homeowners. The longer lifespan of IWHs results in fewer water heater replacements over time, particularly if routine maintenance is undertaken to prolong the useful life of the water heater. Homeowner-occupants will benefit from a continual supply of hot water and lower utility bills, though the wait time for hot water may increase slightly due to the additional time it takes for hot water to arrive, particularly if the water heating system is designed so that the water heater is located far from the use points. Research and outreach to stakeholders reveals that homeowners are overwhelmingly satisfied with the performance of their IWH.

### 3.4.10 Impact on Renters

This proposal is advantageous to renters as it reduces the cost of utilities which are typically paid by renters. Since the measure saves more energy costs on a monthly basis than the measure costs on the mortgage as experienced by the landlord, the pass-through of added mortgage costs into rental costs is less than the energy cost savings experienced by renters.

## 3.5 Economic Impacts

The proposed Title 24 code changes, including this measure, are expected to increase job creation, income, and investment in California. As a result of the proposed code changes, it is anticipated that less money will be sent out of state to fund energy imports, and local spending is expected to increase due to higher disposable incomes due to reduced energy costs.[13] For instance, the statewide life cycle net present value of this measure is $204 million over the 30 year period of analysis. In other words, utility customers will have $204 million to spend elsewhere in the economy. In addition, more dollars will be spent in state on improving the energy efficient of new buildings.

These economic impacts of energy efficiency are documented in several resources including the California Air Resources Board's (CARB) Updated Economic Analysis of California's Climate Change Scoping Plan, which compares the economic impacts of several scenario cases (CARB, 2010b). CARB include one case (Case 1) with a 33% renewable portfolio standard (RPS) and higher levels of energy efficiency compared to an alternative case (Case 4) with a 20 % RPS and lower levels of energy efficiency. Gross state production (GSP),14 personal income, and labor demand were between 0.6% and 1.1% higher in the case with the higher RPS and more energy efficiency (CARB 2010b, Table 26). While CARB's analysis does not report the benefits of energy efficiency and the RPS separately, we expect that the benefits of the package of measures are primarily due to energy efficiency. Energy efficiency measures are expected to reduce costs by $2,133 million annually (CARB 2008, pC-117) whereas the RPS implementation is expected to cost $1,782 million annually, not including the benefits of GHG and air pollution reduction (CARB 2008, pC-130).

Macro-economic analysis of past energy efficiency programs and forward-looking analysis of energy efficiency policies and investments similarly show the benefits to California's economy of investments in energy efficiency (Roland-Holst 2008; UC Berkeley 2011).

### 3.5.1 Creation or Elimination of Jobs

CARB's economic analysis of higher levels of energy efficiency and 33% RPS implementation estimates that this scenario would result in a 1.1% increase in statewide labor demand in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b, Tables 26 and 27). CARB's economic analysis also estimates a 1.3% increase in small business employment levels in 2020 (CARB 2010b, Table 32).

### 3.5.2 Creation or Elimination of Businesses within California

CARB's economic analysis of higher levels of energy efficiency and 33% RPS implementation (as described above) estimates that this scenario would result in 0.6% additional GSP in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b, Table ES-2). We

---

[13] Energy efficiency measures may result in reduced power plant construction, both in-state and out-of-state. These plants tend to be highly capital-intensive and often rely on equipment produced out of state, thus we expect that displaced power plant spending will be more than off-set from job growth in other sectors in California.

[14] GSP is the sum of all value added by industries within the state plus taxes on production and imports.

expect that higher GSP will drive additional business creation in California. In particular, local small businesses that spend a much larger proportion of revenue on energy than other businesses (CARB 2010b, Figures 13 and 14) should disproportionately benefit from lower energy costs due to energy efficiency standards. Increased labor demand, as noted earlier, is another indication of business creation.

Table 15 shows California industries that are expected to receive the economic benefit of the proposed Title 24 code changes. It is anticipated that these industries will expand due to an increase in funding as a result of energy efficiency improvements. The list of industries is based on the industries that the University of California, Berkeley identified as being impacted by energy efficiency programs (UC Berkeley 2011 Table 3.8).[15] The list provided below is not specific to one individual code change proposal, but is an approximation of the industries that may receive benefit from the 2016 Title 24 code changes. A table listing total expected job creation by industry that is expected in 2015 and 2020 from all investments in California energy efficiency and renewable energy is presented in the Appendix B of this CASE Report.

[15] Table 3.8 of the UC Berkeley report includes industries that will receive benefits of a wide variety of efficiency interventions, including Title 24 standards and efficiency programs. The authors of the UC Berkeley report did not know in 2011 which Title 24 measures would be considered for the 2016 adoption cycle, so the UC Berkeley report was likely conservative in their approximations of industries impacted by Title 24. The Statewide CASE Team believes that industries impacted by utilities efficiency programs is a more realistic and reasonable proxy for industries potentially affected by upcoming Title 24 standards. Therefore, the table provided in this CASE Report includes the industries that are listed as benefiting from Title 24 and utility energy efficiency programs.

**Table 15: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code**

| Industry | NAICS Code |
|---|---|
| Residential Building Construction | 2361 |
| Nonresidential Building Construction | 2362 |
| Roofing Contractors | 238160 |
| Electrical Contractors | 23821 |
| Plumbing, Heating, and Air-Conditioning Contractors | 23822 |
| Boiler and Pipe Insulation Installation | 23829 |
| Insulation Contractors | 23831 |
| Window and Door Installation | 23835 |
| Asphalt Paving, Roofing, and Saturated Materials | 32412 |
| Manufacturing | 32412 |
| Other Nonmetallic Mineral Product Manufacturing | 3279 |
| Industrial Machinery Manufacturing | 3332 |
| Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equipment Manufacturing | 3334 |
| Computer and Peripheral Equipment Manufacturing | 3341 |
| Communications Equipment Manufacturing | 3342 |
| Electric Lighting Equipment Manufacturing | 3351 |
| Household Appliance Manufacturing | 3352 |
| Other Major Household Appliance Manufacturing | 335228 |
| Used Household and Office Goods Moving | 484210 |
| Engineering Services | 541330 |
| Building Inspection Services | 541350 |
| Environmental Consulting Services | 541620 |
| Other Scientific and Technical Consulting Services | 541690 |
| Advertising and Related Services | 5418 |
| Corporate, Subsidiary, and Regional Managing Offices | 551114 |
| Office Administrative Services | 5611 |
| Commercial & Industrial Machinery & Equip. (exc. Auto. & Electronic) Repair & Maintenance | 811310 |

### 3.5.3 Competitive Advantages or Disadvantages for Businesses within California

California businesses would benefit from an overall reduction in energy costs. This could help California businesses gain competitive advantage over businesses operating in other states or countries and an increase in investment in California, as noted below.

### 3.5.4 Increase or Decrease of Investments in the State of California

CARB's economic analysis indicate that higher levels of energy efficiency and 33% RPS will increase investment in California by about 3% in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b Figures 7a and 10a).

### 3.5.5 Incentives for Innovation in Products, Materials, or Processes

Updating Title 24 standards will encourage innovation through the adoption of new technologies to better manage energy usage and achieve energy savings.

### 3.5.6 Effects on the State General Fund, State Special Funds and Local Governments

The Statewide CASE Team expects positive overall impacts on state and local government revenues due to higher GSP and personal income resulting in higher tax revenues, as noted earlier. Higher property valuations due to energy efficiency enhancements may also result in positive local property tax revenues. The Statewide CASE Team has not obtained specific data to quantify potential revenue benefits for this measure.

#### *3.5.6.1 Cost of Enforcement*

**Cost to the State**

State government already has the budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24 standards, including updating education and compliance materials and responding to questions about the revised standards, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals.

**Cost to Local Governments**

All revisions to Title 24 will result in changes to Title 24 compliance determinations. Local governments will need to train permitting staff on the revised Title 24 standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2016 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining. For example, the California utilities offer compliance training such as “Decoding” talks to provide training and materials to local permitting departments. As noted earlier, though retraining is a cost of the revised standards, Title 24 energy efficiency standards are expected to increase economic growth and income with positive impacts on local revenue.

The proposed prescriptive standard would revise an existing measure without significantly affecting the complexity of this measure. Therefore, on-going costs are not expected to change significantly.

#### *3.5.6.2 Impacts on Specific Persons*

The proposed changes to Title 24 are not expected to have a differential impact on any of the following groups relative to the state population as a whole:

- Migrant Workers
- Persons by age
- Persons by race
- Persons by religion
- Commuters

We expect that the proposed code changes for the 2016 Title 24 code change cycle will reduce energy costs and could put potential first-time homeowners in a better position to afford mortgage payments. On the other hand, homeowners may experience higher first costs to the extent that builders pass through the increased costs of Title 24 compliance to home buyers. Some financial institutions have progressive policies that recognize that home buyers can better afford energy efficiency homes (even with a higher first cost) due to lower energy costs.[16]

Renters will typically benefit from lower energy bills if they pay energy bills directly. These savings should more than offset any capital costs passed-through from landlords. Renters who do not pay directly for energy costs may see more of less of the net savings based on how much landlords pass the energy cost savings on to renters.

On average, low-income families spend less on energy than higher income families, however lower income families spend a much larger portion of their incomes on energy (Roland-Holst 2008). Thus it seems reasonable that low-income families would disproportionately benefit from Title 24 standards that reduce residential energy costs.

# 4. METHODOLOGY

This section describes the methodology and approach the Statewide CASE Team used to estimate energy, demand, costs, and environmental impacts. The Statewide CASE Team calculated the impacts of the proposed code change by comparing existing conditions to the proposed if the code change is adopted. This section of the CASE Report goes into more detail on the assumptions about the existing and proposed conditions, prototype buildings, and the methodology used to estimate energy, demand, cost, and environmental impacts.

To assess the energy, demand, costs, and environmental impacts of the proposed measure, the Statewide CASE Team compared current design practices to design practices that would comply with the proposed requirements. Since the existing Title 24 Standards cover domestic water heating systems, including water heaters, the existing conditions assume the base case is a building that complies with the 2013 Title 24 Standards.

## 4.1 Existing Conditions

To assess the energy, demand, costs, and environmental impacts, the Statewide CASE Team compared current design practices to design practices that would comply with the proposed requirements. Since the existing Title 24 Standards cover the domestic hot water system in residential buildings, the existing conditions assume a building complies with the 2013 Title 24 Standards.

As described in Section 2, the existing Title 24 Standards include requirements for domestic gas water heating systems for newly constructed and existing single-family and multi-family buildings. The current prescriptive Standards for residential new construction allow for the

[16] Refer to the ENERGY STAR website for examples.

installation of a gas storage water heater (75,000 BTU or less), a gas IWH (200,000 BTU or less), or an electric storage or electric IWH as part of a solar hot water system in new residential construction (including multi-family buildings with dedicated water heaters for each individual dwelling unit). The IWH prescriptive path (prescriptive baseline), which is used to calculate the energy budget, assumes a 40-gallon gas storage water heater that meets federal minimum efficiency requirements. Though the 2013 ACM Reference Manual uses a 50-gallon storage water heater as the baseline equipment, the Statewide CASE Team assumed a 40-gallon volume because it is more commonly installed in new construction according to builders, plumbers, and manufacturers. The 2015 federal residential water heater minimum efficiency level (EF of 0.62) was used as the baseline for energy savings estimates since it will be in effect starting April 2015, well in advance of the 2016 Title 24 effective date (January 1, 2017).

## 4.2 Proposed Conditions

The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change will change the prescriptive baseline from a 50-gallon gas storage water heater to a gas IWH (meeting federal minimum standards). The proposed conditions assume a gas IWH with an EF of 0.82 will be installed. In other words, compliance via the performance path will be based on meeting the building's total energy budget that is set using the energy performance of a gas IWH that meets the federal minimum standard. See Section 2 and Section 6 of this report regarding the proposed code language. The Statewide CASE Team used IWHs for savings estimates in our analyses.

## 4.3 Prototype Building

CEC provided guidance on the type of prototype building that should be modeled in the 2013 Residential ACM Reference Manual. As such, the prototypical single family residential building used in this analysis is a 2,100 square-foot single-story building and a 2,700 square-foot two-story building. Table 16 summarizes the prototype buildings used in the analysis that were used to reflect the most recent updates to the Residential ACM. Based on direction from the CEC, the energy impacts, savings, and cost effectiveness results are reported as a weighted average of the two prototype building sizes in this CASE Report. The weighting between the two prototype buildings is shown in Table 16. Appendix C contains the results for each prototype building.

Since hot water usage patterns in multi-family and single-family buildings is similar, the energy savings for single-family residential prototype buildings can be used as a reasonable estimate for the savings that are likely in multi-family buildings. Multi-family buildings with central water heating systems are outside the scope of this proposal, and therefore, were not modeled.

**Table 16: Prototype Single Family Residential Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis**

| | Occupancy Type (Residential, Retail, Office, etc.) | Area (Square Feet) | Number of Stories | Relative Weight to Statewide Estimates |
|---|---|---|---|---|
| Prototype 1 | Residential | 2,100 | 1 | 45% |
| Prototype 2 | Residential | 2,700 | 2 | 55% |

## 4.4 Climate Dependent

The Statewide CASE Team modeled energy and cost savings in each California climate zone using statewide Time Dependent Valuation factors. Additionally, for each climate zone the cold water inlet temperatures were calculated from ground temperatures based on an hourly basis and air temperatures were based on the average of the last 31 days. This assumption is to reflect the calculations outlined in the Residential ACM Reference Manual, Appendix E.

## 4.5 Time Dependent Valuation (TDV)

The TDV (Time Dependent Valuation) of savings is a normalized format for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during different times of the day and year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDV kBTUs" so that the savings are evaluated in terms of energy units and measures with different periods of analysis can be combined into a single value.

CEC derived the 2016 TDV values that were used in the analyses for this report (CEC 2014). The TDV energy impacts are presented in Section 5.1 of this report, and the statewide TDV cost impacts are presented in Section 5.2.

## 4.6 Energy Impacts Methodology

The Statewide CASE Team calculated per unit impacts and statewide impacts associated with all new construction, alterations, and additions during the first year buildings complying with the 2016 Title 24 Standards are in operation.

The Statewide CASE Team calculated the TDV savings for the proposed measure using the outputs from CEC's public domain simulation program known as CBECC-Residential, Version 3.[17] This software is used for Title 24 compliance and is required for permit applications. (See Section 4.6.1 for a discussion on the inputs and assumptions used for the energy analyses.)

[17] CEC 2014

### 4.6.1 Per Unit Energy Impacts Methodology

The Statewide CASE Team estimated the natural gas savings and electricity use associated with the proposed code change. Gas IWHs consume electrical energy both in standby mode and in firing mode. Electricity use was included in the energy impacts calculations.

The energy impacts were calculated on a per single family dwelling basis. Annual energy use (natural gas and electricity use) was calculated according to the guidelines presented in Section E6 (*Energy Use of Individual Water Heaters*) in Appendix E of the 2013 Residential ACM Reference Manual.

***Analysis Tools***

To calculate TDV energy impacts, the Statewide CASE Team simulated the existing conditions and proposed conditions using version 3 of the Residential California Building Energy Code Compliance modeling software (CBECC-Res). Version 3 was approved by CEC on August 27, 2014.

***Key Assumptions***

The Statewide CASE Team used the following assumptions in the energy analysis. Based on CEC guidance, the prototype buildings for a single family home are 2,100 square foot (SF) of conditioned floor area for a single-story and 2,700 SF of conditioned floor area for a two-story home. The daily hot water demand was based on hourly water heating schedules on weekdays and weekends as displayed in Table RE-1 of the 2013 Residential ACM Reference Manual Appendix E. The daily hot water usage is 35.7 gallons for a 2,100 SF building and 39.7 gallons for a 2,700 SF building. Standard distribution loss multipliers, based on conditioned floor areas, were also used to calculate the hourly hot water consumption as outlined in the 2013 Residential ACM Reference Manual, Appendix E. The calculated values are 1.33 for a 2,100 SF building and 1.38 for a 2,700 SF building. Using the approach to calculate useful hot water consumption as outlined in 2013 Residential ACM Reference Manual, Appendix E is comparable to field studies on hot water use in California households (Hoeschele et al. 2011).

To estimate the electricity use associated with the proposed code change, the Statewide CASE Team used electricity consumption estimates from a 2007 PG&E study conducted by the Davis Energy Group (PG&E 2007). The 2007 study noted a gas IWH installed in an average California household consumes approximately 57 kWh per year. For comparison, the 2010 DOE Final Rule modeled the annual electricity consumption of a gas IWH to be 29 kWh per year (DOE 2010). For this CASE proposal we used the value that would result in more conservative energy savings and assumed an electricity consumption of 57 kWh per year per the 2007 PG&E report.

According to the 2013 Residential ACM Reference Manual, Appendix E, the cold water inlet temperatures is assumed to vary on a daily basis with ground temperature and air temperature for each climate zone, and the hot water supply temperature is assumed to be 124$^{o}$ F. Hourly hot water draw is determined using the hot water draw schedule defined by CEC in Table RE-1 in Appendix E.

The present values of hot water heating energy use were calculated using the residential 30-year natural gas 2016 TDV values and corresponding conversion factors.

To determine energy savings between the baseline and measure cases, the Statewide CASE Team used the 2015 federal minimum standard EF ratings for a gas storage water heater (40-gallon) and gas IWH. As discussed in Section 2.1.3 results of a PIER study indicate that the current DOE test procedure underestimates the impact of small volume hot water draws and heat exchanger cycling on annual system performance. Based on these findings, the Title 24 Standards applied a 0.92 derating factor on the nominal EF of all gas IWHs. This derating approach was validated by further PIER field research completed in 2011(Hoeschele et al. 2011). The analysis presented in this CASE Report multiplied the EF rating for gas IWHs by 92% to reflect the impacts of performance under the current DOE test procedure as outlined by the Residential ACM Reference Manual, Appendix E.

Table 17 lists the key inputs used in calculating the per unit energy impact of the proposed measure.

**Table 17: Key Assumptions for Per Unit Energy Impacts Analysis**

| Parameter | Assumption | Source |
|---|---|---|
| Conditioned Floor Area of Prototype Building (percent weighted) | ▪ 2,100 square feet (45%)<br>▪ 2,700 square feet (55%) | CEC |
| Daily hot water use | ▪ 35.7 gallons (2,100 SF)<br>▪ 39.7 gallons (2,700 SF) | 2013 Residential ACM Reference Manual, Appendix E |
| Hot water supply temperature | 124° F | 2013 Residential ACM Reference Manual, Appendix E |
| Cold water inlet temperature | Ground and Air Temperature (by climate zone) | 2013 Residential ACM Reference Manual, Appendix E |
| Gas storage water heater (base case) | ▪ 40-gallon volume<br>▪ Federal minimum efficiency level in 2015 (0.62 EF)<br>▪ Input Rating 40,000 Btu/hr<br>▪ Recovery Efficiency 70% | AHRI 2014<br><br>2013 Residential ACM Reference Manual, Appendix E |
| Gas IWH (measure case) | ▪ 0-gallon volume<br>▪ Federal minimum efficiency level in 2015 (0.82 EF)<br>▪ Input Rating: 190,000 Btu/hr<br>▪ Annual electricity use: 57 kWh/yr | 2013 Residential ACM Reference Manual, Appendix E<br><br>PG&E 2007 |
| IWH efficiency adjustment factor | 92% | 2013 Residential ACM Reference Manual, Appendix E |

### 4.6.2 Statewide Energy Impacts Methodology

***First Year Statewide Impacts***

The Statewide CASE Team estimated statewide impacts for the first year that new dwellings comply with the 2016 Title 24 Standards by multiplying per unit savings estimates by statewide construction forecasts.

The CEC Demand Analysis office provided the projected annual residential dwelling starts for the single family and multi-family sectors. CEC provided three projections: low, mid and high estimates with each case broken out by Forecast Climate Zones (FCZ). The Statewide CASE Team translated this data to Building Climate Zones (BCZ) using the same weighting of FCZ to BCZ as the previous code update cycle (2013), as presented in in Table 18.

The Statewide CASE Team used the mid scenario of forecasted residential new construction for statewide savings estimates. The estimates are for dwellings that are not apartments. The projected new residential construction forecast, presented by BCZ is listed in Table 19.The proposed code change applies to newly-constructed single-family buildings, newly constructed multi-family buildings with dedicated water heaters for every dwelling unit, and additions to these types of buildings if the addition includes the installation of a new water heater. The statewide energy savings conservatively include only the savings from new single-family construction. Data on the percentage of low-rise multi-family dwellings with dedicated water heaters is not readily available, so the energy savings from multi-family buildings with dedicated water heaters were not included in the statewide savings estimates. While the measure does applies to additions if a new water heater is installed as part of the addition. In practice, installing a water heater to serve the addition is not common. Because energy savings from additions will be limited, the statewide savings analysis does not include savings from additions.

**Table 18: Translation from Forecast Climate Zones to Building Climate Zones**

Source: CEC Demand Analysis Office

| | Building Standards Climate Zones (BCZ) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forecast Climate Zones (FCZ) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Grand Total |
| 1 | 22.51% | 20.62% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 9.80% | 33.14% | 0.16% | 0.00% | 0.00% | 13.77% | 100.00% |
| 2 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 22.00% | 75.70% | 0.00% | 0.00% | 0.00% | 2.30% | 100.00% |
| 3 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 20.95% | 22.76% | 54.50% | 0.00% | 0.00% | 1.79% | 100.00% |
| 4 | 0.15% | 13.73% | 8.36% | 46.03% | 8.94% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 22.81% | 0.00% | 0.00% | 0.00% | 0.00% | 100.02% |
| 5 | 0.00% | 4.23% | 89.13% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 6.64% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 6 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 7 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 75.80% | 7.08% | 0.00% | 17.12% | 100.00% |
| 8 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 40.37% | 0.00% | 51.08% | 8.09% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.46% | 100.00% |
| 9 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 6.97% | 0.00% | 24.54% | 57.85% | 0.00% | 0.00% | 0.00% | 0.00% | 6.68% | 0.00% | 3.95% | 99.99% |
| 10 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 74.90% | 0.00% | 0.00% | 0.00% | 12.27% | 7.90% | 4.93% | 100.00% |
| 11 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 33.04% | 0.00% | 24.75% | 42.21% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 12 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.92% | 0.00% | 20.20% | 75.19% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 3.69% | 100.00% |
| 13 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 69.55% | 0.00% | 0.00% | 28.77% | 0.00% | 0.00% | 0.00% | 1.56% | 0.09% | 0.00% | 99.97% |
| 14 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 15 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.12% | 99.88% | 0.00% | 100.00% |
| 16 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 17 | 2.95% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 97.05% | 100.00% |

**Table 19: Projected New Residential Construction in 2017 by Climate Zone[1]**

| Building Climate Zone | Single Family Starts | Multifamily Starts[2] |
|---|---|---|
| Climate Zone 1 | 695 | 47 |
| Climate Zone 2 | 2,602 | 507 |
| Climate Zone 3 | 5,217 | 3,420 |
| Climate Zone 4 | 5,992 | 1,053 |
| Climate Zone 5 | 1,164 | 205 |
| Climate Zone 6 | 4,142 | 2,151 |
| Climate Zone 7 | 6,527 | 2,687 |
| Climate Zone 8 | 7,110 | 3,903 |
| Climate Zone 9 | 8,259 | 8,023 |
| Climate Zone 10 | 16,620 | 1,868 |
| Climate Zone 11 | 5,970 | 217 |
| Climate Zone 12 | 19,465 | 1,498 |
| Climate Zone 13 | 13,912 | 770 |
| Climate Zone 14 | 3,338 | 492 |
| Climate Zone 15 | 3,885 | 433 |
| Climate Zone 16 | 3,135 | 508 |
| **Total** | **108,032** | **27,784** |

1. CEC provided a low, middle, and high forecast. The Statewide CASE Team used the middle forecast for the statewide savings estimates. Statewide savings estimates do not include savings from mobile homes for multi-family buildings.
2. Includes high-rise and low-rise multi-family construction. The statewide savings analysis does not include savings from multi-family buildings.

## 4.7 Cost-effectiveness Methodology

This measure proposes a modification to the prescriptive requirement for domestic water heating in residential new construction. As such, a lifecycle cost (LCC) analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

CEC's procedures for calculating lifecycle cost-effectiveness are documented in the LCC Methodology (CEC 2011). The Statewide CASE Team followed these guidelines when developing the Cost-effectiveness Analysis for this measure. CEC's guidance dictated which costs were included in the analysis: incremental equipment and maintenance costs over the 30-year period of analysis. TDV energy cost savings from natural gas savings were also considered. Each of these components is discussed in more detail below.

Design costs and the incremental cost of verification were not included in the Cost-effectiveness Analysis as there are none associated with the proposed code change.

### 4.7.1 Incremental Cost Methodology – Gas IWH

***Incremental Construction/Installation Cost Methodology***

The 2013 Title 24 Standards for residential water heating require new homes to be equipped with components for the installation of high-efficiency water heaters, such as gas IWHs.

Section 150.0(n) of 2013 the Title 24 Standards already requires the following components for water heaters using gas or propane in newly-constructed low-rise residential buildings (see Section 2.4 for discussion on venting requirements):

- A 120V electrical receptacle that is within 3 feet from the water heater and accessible to the water heater with no obstructions; and
- A Category III or IV vent, or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed; and
- A condensate drain that is no more than 2 inches higher than the base of the installed water heater, and allows natural draining without pump assistance, and
- A gas supply line with a capacity of at least 200,000 Btu/hr.

The installation costs for implementing measures that are already required in the Title 24 Standards were not included in the incremental installation/construction cost for the proposed measure. The installation costs considered in this analysis were the labor costs involved in (1) purchasing and installing a gas water heater in a new dwelling and (2) replacement of the equipment after its useful life. Research the Statewide CASE Team conducted indicates that when excluding the components that are already required in the Standards, there is no difference in the cost of installing a gas storage water heater and a gas IWH. The labor costs for a single installation or replacement were assumed to be the same for the base and measure cases.

Based on the assumptions for the useful life of storage and IWHs described in Section 3.3.1, over the 30-year period of analysis, it was assumed that a storage water heater will be replaced twice, and an IWH will be replaced once.

***Incremental Equipment Cost Methodology***

To determine the incremental equipment Statewide CASE Team compared price points of gas storage water heaters (EF 0.62) to a gas IWH (EF 0.82) from a number of reputable sources. The incremental equipment costs were adjusted for inflation to 2014 dollars and summarized in Table 20 below.

**Table 20: Incremental Equipment Costs of Gas IWH versus Gas Storage Water Heater**

| Source | Incremental Equipment Cost (2014$) |
|---|---|
| DOE Technical Support Document, Chapter 8 (2010) | $655* |
| Presentation from William Hoover (2011) | $635 |
| CBIA/ConSol (2011) | $610 |
| 2013 Title 24 High-Efficiency Water Heater Ready CASE Report (2011) | $520 |

* Cost estimate used by the Statewide CASE Team for the analysis.

The incremental equipment cost between a gas storage water heater and a gas IWH ranges between $520 and $655. For the analysis, the Statewide CASE Team used the incremental equipment cost used by DOE in the establishment of the federal residential water heating standards (DOE Technical Support Document, Chapter 8 2010). This estimate represents the worst-case scenario regarding incremental cost since it is the highest cost value among the four data points provided by stakeholders. DOE conducted extensive studies of costs for water heaters and its methodologies and findings were published as supporting rulemaking documents that were thoroughly vetted by national stakeholders, including water heater manufacturers and homebuilder associations. These documents represent the most comprehensive data source for residential water heater costs (DOE Technical Support Document, Chapter 8 2010).

The analysis presented in this CASE Report assumed the average lifespan of a gas storage water heater as 13 years and gas IWH as 20 years, based on manufacturer claims (including warranties), DOE's assumptions used to develop the federal water heater standards, and the estimates provided by the National Home Builders Association and Database for Energy Efficient Resources (DEER). Based on these values, the Statewide CASE Team factored in 2.3 times the storage water heater equipment costs and 1.5 times the IWH equipment costs for the 30-year LCC analysis.

Key assumptions used to derive costs (both first cost and maintenance costs) are presented in Table 21.

**Table 21: Key Assumptions for Per Unit Incremental Cost**

| Parameter | Assumption | Source | Notes |
|---|---|---|---|
| **STORAGE WATER HEATER** | | | |
| **First Cost** | | | |
| Equipment Cost | $518 | DOE 2010 | Inflation adjusted to 2014 dollars. |
| Installation Cost (new construction) | $428 | DOE 2010 | |
| ***Subtotal*** | ***$946*** | | |
| **Equipment Replacement Cost** | | | |
| Replacement Water Heater | $518 | | Cost of water heater in year 1. Assumes a 3% annual discount rate for replacements. |
| Replacement Labor Cost | $487 | DOE 2010 | Cost of water heater in year 1. Analysis assumes a 3% annual discount rate. |
| Equipment Life | 13 years | United States Department of Energy 2010 Final Rule: Chapter 8; National Home Builders Association; Database for Energy Efficient Resources | See Table 10 in this report. |
| Number of Replacements Installations Over 30 Years | 2 | | Based on Equipment Useful Life. Replacements occur in years 13 and 26. |
| ***Subtotal*** | ***$1,150*** | | Replacements costs over 30-year period of analysis. |
| **Maintenance Cost** | | | |
| Per Event | $144 | Interviews with California | Average cost to drain water heater provided by three California |

| | | | |
|---|---|---|---|
| Maintenance Cost | | Plumbers | plumbing companies (See Table 22) |
| Maintenance Frequency (years) | 1 | Manufacturer and professional plumber recommendations | |
| ***Subtotal*** | ***$2,822*** | | Maintenance Cost over 30-year Period of Analysis. |
| **INSTANTANEOUS WATER HEATER** | | | |
| **First Cost** | | | |
| Equipment Cost | $1,173 | DOE 2010 | Inflation adjusted to 2014 dollars. |
| Water Heater Installation Cost (new construction) | $428 | DOE 2010 | |
| Drain Kit (Isolation Valves) | $70 | Internet | |
| ***Subtotal*** | ***$1,671*** | | |
| **Equipment Replacement Cost** | | | |
| Equipment Cost | $1,173 | | Cost of water heater in year 1. Assumes a 3% annual discount rate for replacements. |
| Replacement Labor Cost | $487 | DOE 2010 | |
| Equipment Life | 20 years | United States Department of Energy 2010 Final Rule: Chapter 8; National Home Builders Association; Database for Energy Efficient Resources | See Table 10 in this report. |
| Number of Replacement Installations Over 30 Years | 1 | | Based on Equipment Useful Life. Replacements occur in years 20. |
| ***Subtotal*** | ***$919*** | | Replacements costs over 30-year period of analysis. |
| **Maintenance Cost** | | | |
| Per Event Maintenance Cost | $205 | Interviews with Plumbing Companies | Average cost to flush heat exchanger provided by three California plumbing companies |
| Maintenance Frequency (years) | 2 | Manufacturer and professional plumber recommendations | |
| ***Subtotal*** | ***$1,979*** | | Maintenance Cost over 30-year Period of Analysis. |
| **INCREMENTAL COSTS** | | | |
| Incremental First | $655 | United States Department of | Inflation adjusted to 2014 dollars. |

| | | | |
|---|---|---|---|
| Equipment Cost [1] | | Energy 2010 Final Rule: Chapter 8 | |
| Total Incremental First Cost | $725 | | Includes cost of water heater and IWH drain kit (i.e. isolation valves) |
| Incremental Equipment Replacement Cost | ($231) | | Negative value indicates that over the 30-year period of analysis, replacing a storage water heater is more expensive than replacing an IWH. |
| Incremental Maintenance Cost | ($843) | | Negative value indicates that over the 30-year period of analysis, the incremental cost of maintaining a storage water heater is higher than it is for an IWH. |

[1] Incremental equipment cost is calculated by subtracting the equipment cost for a storage water heater ($518) from the equipment cost for an IWH ($1,173). The value was also adjusted for inflation from 2008 cost data provided by DOE (2010) to 2014 dollars.

### *Incremental Maintenance Cost Methodology*

The Statewide CASE Team gathered estimates of maintenance costs for both storage water heaters and IWHs based on conversations with professional plumbing companies across California. Table 22 lists the maintenance prices that were gathered. The price points are provided to show the range of expected maintenance costs for both storage water heaters and IWHs. As shown, there are costs associated with maintaining both storage water heaters and IWHs.

**Table 22: Maintenance and Repair Costs**

| | Activity | Cost Range[1] | Recommended Frequency |
|---|---|---|---|
| Storage | Draining tank by professional plumber | $189<br>$127<br>$120 | Yearly<br>Yearly<br>Yearly |
| | Draining tank by homeowner | $0 | Manufacturer recommendations range between monthly and yearly. |
| | Replacing anode rod by professional plumber | $200 - $600 | As needed<br>-- |
| IWH | Flushing heat exchanger and cleaning filter by professional plumber | $185<br>$200<br>$225 | Yearly<br>1.5 – 2 years<br>3-4 years (good water quality) |
| | Flush kit for flushing of heat exchanger by home owner | $85* | |
| | White vinegar (solution used for flushing) | $10 | Every 2 years |

1. Cost data were provided by professional plumbing services. Sources are not included to for confidentiality purposes.

* One time upfront cost for the flush kit.

The cost analysis presented in this CASE Report assumes that homeowners will follow the recommendations of manufacturers and hire a professional plumber to conduct routine maintenance of their IWH (e.g., flushing the heat exchanger) or storage water heater (e.g., draining the tank). Based on the cost data provided by professional plumbers around California, the Statewide CASE Team assumed the average cost a plumber charges for draining a storage water heater is $144 and the average cost for a plumber to flush the heat exchanger of an IWH is average $205. Taking net present value into account, the total maintenance costs for an IWH and a storage water heater over the 30-year period is $1,979 and $2,822, respectively. This is based on the manufacturer and professional plumber recommended maintenance schedules of every 2 years for IWHs and every year for storage water heaters. See Section 3.3.2 of this report for a discussion on the frequency of maintenance.

*Impact of Isolation Valves on Maintenance Costs of IWHs*

After submitting the CASE Report to CEC in September 2014, the Statewide CASE Team was asked by CEC staff whether the presence of isolation valves impacts the maintenance cost for IWHs. Isolation valves (i.e. drain kits) assist in the flushing of the heat exchanger. To help ensure IWHs can be maintained with minimal nuisance, this code change proposal recommends a requirement that IWHs must be installed with isolation valves. The LCC analysis presented in this report assumes that a plumber will flush the IWH heat exchanger on a regular basis. The maintenance cost presented in the report also assumes that the isolation valves are already installed on the IWH. Plumbers have indicated that if there are no isolation valves on an existing IWH, they will charge an additional fee to install the isolation valves. The cost to install a set of valves on an existing IWH can range from $225 to $290 (labor and equipment) with the bulk of the price being labor. The plumbers we spoke with also install new IWHs and they include the installation of isolation valves at no additional labor cost when installing new IWHs (personal communication on August 28, 2014). The cost of the isolation valves is included in the initial incremental cost of the IWH measure (see Section 4.7). In sum, the proposed mandatory standard requiring the installation of isolation valves on IWHS in new construction does not impose additional maintenance costs.

### 4.7.2 Incremental Cost Methodology – Additional Prescriptive Compliance Option

Table 23 presents the cost assumptions used for evaluating the cost-effectiveness of the proposed additional prescriptive option. All three components of the additional option (QII, compact hot water distribution systems, and pipe insulation) have been evaluated in other CASE Reports that the Statewide CASE Team has developed for the 2016 (Residential High Performance Walls and QII CASE Report, September 2014 version) and 2013 (High Efficiency Water Heater Ready CASE Report) Title 24 code change cycles. See the relevant CASE Reports for more information about cost assumptions for each component of the additional prescriptive option.

**Table 23: Key Assumptions for per unit Incremental Construction Cost for Additional Prescriptive Option**

| Parameter | Assumption | Source | Notes |
|---|---|---|---|
| QII | $890 | California Building Industry Association, Statewide CASE Team 2014 | CBIA estimate of $843 for the incremental cost of QII was provided during the 2013 Title 24 Standards rulemaking. CBIA cost data from 2011, so cost estimate was adjusted to reflect $2014. |
| Compact Hot Water Distribution Systems (HWDS) | $292 | CA IOUs 2011b, Figure 12 | CASE Report for 2013 code Cycle cost estimate of $277 was weighted average for 1-story 2010 sq-ft (45%) and 2-story 2811 sq-ft (55%) prototypes. Cost assumption was adjusted to reflect $2014. |
| Pipe Insulation on ¾ inch or larger pipe | $241 | CA IOUs 2011b, Figure 8 | CASE Report cost estimate of $228 was weighted average for 1-story 2010 sq-ft (45%) and 2-story 2811 sq-ft (55%) prototypes. Cost assumption was adjusted to reflect $2014. |

### 4.7.3 Cost Savings Methodology

***Energy Cost Savings Methodology***

The present value of the energy savings associated with the proposed IWH prescriptive requirement was calculated using the method described in the LCC Methodology (CEC 2011). In summary, the hourly energy savings estimates for the first year of building operation were multiplied by TDV cost values to arrive at the present value of the cost savings over the period of analysis. This measure is climate sensitive, so the energy cost savings were calculated in each climate zone using TDV values for each unique climate zone.

### 4.7.4 Cost-effectiveness Methodology

The Statewide CASE Team calculated cost-effectiveness using the LCC Methodology. According to CEC's definition, a measure is cost effective if it reduces overall lifecycle cost from the current base case (existing conditions). The LCC Methodology clarifies that absolute lifecycle cost of the proposed measure does not need to be calculated. Rather, it is necessary to calculate the change in lifecycle cost from the existing conditions to the proposed conditions.

If the change in lifecycle cost is negative then the measure is cost effective, meaning that the present value of TDV energy savings is greater than the cost premium. In other words, the proposed measure would reduce the total lifecycle cost as compared to the existing conditions. Propane TDV costs were not used in the evaluation of this measure.

The Planning Benefit to Cost (B/C) Ratio is another metric that can be used to evaluate cost-effectiveness. The B/C Ratio is calculated by dividing the total present value TDV energy cost savings (the benefit) by the present value of the total incremental cost (the cost). If the B/C

Ratio is greater than 1.0 (i.e. the present valued benefits are greater than the present valued costs over the period of analysis), then the measure is cost effective.

## 4.8 Environmental Impacts Methodology

### 4.8.1 Greenhouse Gas Emissions Impacts Methodology

***Greenhouse Gas Emissions Impacts Methodology***

The Statewide CASE Team calculated avoided greenhouse gas (GHG) emissions assuming an emission factor of 353 metric tons of carbon dioxide equivalent ($MTCO_2e$) per Gigawatt-hours (GWh) of electricity savings. As described in more detail in Appendix A: Environmental Impacts Methodology, the electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard (RPS) goal of 33% renewable electricity generation by 2020. Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

### 4.8.2 Water Use Impacts Methodology

The Statewide CASE Team reviewed several studies to determine whether IWHs result in increases hot water use due to the continual supply of hot water and the longer hot water delivery times from a cold water start up. Based on the findings of field studies conducted by the Davis Energy Group (Hoeschele et al. 2011) and the Minnesota Center for Energy and Environment (Schoenberger & Bohac 2013), we have determined that the potential water use impacts of the proposed measure are not significant enough to include in the savings analyses. (See Section 5.3.2 for discussion.)

### 4.8.3 Material Impacts Methodology

The Statewide CASE Team did not develop estimates of material impacts.

### 4.8.4 Other Impacts Methodology

There are no other impacts from the proposed code change.

# 5. ANALYSIS AND RESULTS

Results from the energy, demand, cost, and environmental impacts analyses are presented in this section.

## 5.1 Energy Impacts Results

### 5.1.1 Per Building (Unit) Energy Savings Results

Per building (unit) energy and demand impacts of the proposed measure by climate zone are presented in Table 24. The average natural gas savings for the first year the proposed Standards are in effect are projected to be in the range of 29 to 35 therms per prototype building per year, depending on the climate zone. Since the analysis included the electricity use of gas IWHs to operate combustion fans and controls, whereas the tank type water heater does not use any electricity, the average per unit electricity consumption increase would be 57 kWh/year and a 0.13 kW increase in power demand for each prototype building.

Since the EF rating for IWHs includes site energy consumption from both gas and electricity use and the TDV calculations factor in the EF rating, the TDV savings calculations presented accounts for both the electricity and natural gas consumption of IWHs.

It is estimated that the average per unit net TDV savings (natural gas and electricity) over the 30-year period of analysis will be in the range of 7,300 to 8,000 kBTU depending on the climate zone.

**Table 24: First Year[1] Energy Impacts per Building for the IWH Prescriptive Option (Option 1)**

| Climate Zone | Electricity Savings[2] (kWh/yr) | Demand Savings (kW) | Natural Gas Savings (Therms/yr) | Total TDV Savings (kBTU) [3] |
|---|---|---|---|---|
| Climate Zone 1 | -57 | -0.13 | 35 | 7,271 |
| Climate Zone 2 | -57 | -0.13 | 31 | 7,490 |
| Climate Zone 3 | -57 | -0.13 | 32 | 7,480 |
| Climate Zone 4 | -57 | -0.13 | 30 | 7,578 |
| Climate Zone 5 | -57 | -0.13 | 32 | 7,417 |
| Climate Zone 6 | -57 | -0.13 | 29 | 7,645 |
| Climate Zone 7 | -57 | -0.13 | 29 | 7,529 |
| Climate Zone 8 | -57 | -0.13 | 29 | 7,709 |
| Climate Zone 9 | -57 | -0.13 | 29 | 7,733 |
| Climate Zone 10 | -57 | -0.13 | 29 | 7,742 |
| Climate Zone 11 | -57 | -0.13 | 29 | 7,733 |
| Climate Zone 12 | -57 | -0.13 | 30 | 7,626 |
| Climate Zone 13 | -57 | -0.13 | 29 | 7,742 |
| Climate Zone 14 | -57 | -0.13 | 29 | 7,767 |
| Climate Zone 15 | -57 | -0.13 | 23 | 8,039 |
| Climate Zone 16 | -57 | -0.13 | 34 | 7,387 |

1. Savings from one prototype building for the first year the building is in operation.
2. Site electricity savings.
3. TDV energy savings for one prototype building for the first year the building is in operation. Calculated using CEC's 2016 TDV factors and methodology. TDV energy savings calculations include electricity and natural gas use.

Table 25 presents the first year per prototype building energy savings for the prescriptive options. The methodology for the energy savings impacts analysis is described in Section 4 of the CASE Report. The assumptions for existing conditions (baseline building) are the same for all three scenarios. For the additional prescriptive option, it is assumed that the QII, compact distribution, and pipe insulation requirements specified in the Residential Appendix will be implemented. The analysis was completed using version 3 of CBECC-Res.

**Table 25: First Year[1] Energy Impacts per Building for All Prescriptive Options**

| Climate Zone | Total TDV Energy Savings (kBTU)[1] | | |
|---|---|---|---|
| | Option 1: Instantaneous Water Heater (kBTU | Option 2a: Storage Water Heater with QII & Compact Design (kBTU) | Option 2b: Storage Water Heater with QII & Pipe Insulation (kBTU) |
| Climate Zone 1 | 7,271 | 13,258 | 12,656 |
| Climate Zone 2 | 7,490 | 9,441 | 8,887 |
| Climate Zone 3 | 7,480 | 7,696 | 7,143 |
| Climate Zone 4 | 7,578 | 8,708 | 8,178 |
| Climate Zone 5 | 7,417 | 7,455 | 6,892 |
| Climate Zone 6 | 7,645 | 5,455 | 4,926 |
| Climate Zone 7 | 7,529 | 3,526 | 3,006 |
| Climate Zone 8 | 7,709 | 6,174 | 5,654 |
| Climate Zone 9 | 7,733 | 8,393 | 7,879 |
| Climate Zone 10 | 7,742 | 8,918 | 8,398 |
| Climate Zone 11 | 7,733 | 14,918 | 14,388 |
| Climate Zone 12 | 7,626 | 13,095 | 12,566 |
| Climate Zone 13 | 7,742 | 14,373 | 13,854 |
| Climate Zone 14 | 7,767 | 14,657 | 14,128 |
| Climate Zone 15 | 8,039 | 11,619 | 11,173 |
| Climate Zone 16 | 7,387 | 16,938 | 16,336 |

1. TDV energy savings for one prototype building for the first year the building is in operation. Calculated using CEC's 2016 TDV factors and methodology.

### 5.1.2 Statewide Energy Impacts Results

***First Year Statewide Energy Impacts***

The statewide energy impacts of the proposed IWH prescriptive option are presented in Table 26. Though this measure slightly increases statewide electricity consumption and electrical demand, the proposed measure is expected to reduce natural gas use by approximately 3.17 million therms (MMtherms) during the first year the 2016 Title 24 Standards are in effect (2017).

In addition, it is estimated that the statewide net TDV savings (natural gas and electricity) over the 30-year period of analysis will be approximately 828 million kBTU.

All assumptions and calculations used to derive per unit and statewide energy and demand savings are presented in Section 4 of this report.

**Table 26: First Year[1] Statewide Energy Impacts for the IWH Prescriptive Option (Option 1)**

| | Electricity Savings[2] (GWh) | Power Demand Reduction (MW) | Natural Gas Savings (MMtherms) | TDV Energy Savings[2] (Million kBTU) |
|---|---|---|---|---|
| Proposed Measure | -6.16 | -1.34 | 3.17 | 828 |
| TOTAL | -6.16 | -1.34 | 3.17 | 828 |

1. First year savings from all buildings built statewide during the first year the 2016 Standards are in effect.
2. Site electricity savings.
3. First year TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect. Calculated using CEC's 2016 TDV factors and methodology. TDV energy savings calculations include electricity and natural gas use.

The first year statewide energy impacts of the prescriptive options are presented in Table 27. The methodology used to calculate statewide savings estimates are presented in Section 4 of the CASE Report. The results in Table 27 assume that all buildings will comply using the identified approach. For example, the statewide savings estimate of 838 million TDV kBTU for the IWH prescriptive option assumes that all buildings built in 2017 will comply by installing a gas IWH. If all buildings complied using the QII + Compact Design option, the statewide savings would be 1,133 million TDV kBTU. Though users can comply with Title 24 by implementing any of the prescriptive options, based on historical trends, the majority of users will likely comply using the performance approach. The IWH prescriptive option (option 1) establishes the baseline energy budget for the performance approach.

**Table 27: First Year[1] Statewide Energy Impacts of All Prescriptive Options (2017)**

| Prescriptive Approach | TDV Energy Savings[2] (Million kBTU) |
|---|---|
| Option 1: Instantaneous Water Heater | 828 |
| Option 2a: Baseline Storage Water Heater with QII & Compact Design | 1,133 |
| Option 2b: Baseline Storage Water Heater with QII & Pipe Insulation | 1,076 |

1. First year savings from all residential buildings built statewide during the first year the 2016 Standards are in effect (2017). 2017 construction forecast published by CEC's Demand Analysis Office.
2. First year TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect (2017). Calculated using CEC's 2016 TDV factors and methodology. TDV energy savings calculations include electricity and natural gas use.

## 5.2 Cost-effectiveness Results

### 5.2.1 Incremental Cost Results

The incremental cost of the proposed measure, relative to existing conditions, is presented in Table 28. The total incremental cost includes the incremental cost during initial installation, the replacement costs of the equipment, and the present value of the incremental maintenance cost over the 30-year period of analysis. Based on assumed lifespans of each water heater type, storage equipment is expected to be replaced twice and IWHs are expected to be replaced once in 30 years. Each of the incremental cost components (installation, equipment, and maintenance) is discussed below.

**Table 28: Incremental Cost for the IWH Prescriptive Option[1]**

| Condition | Equipment Cost[2] | | Present Value of Maintenance Cost[5] | Total Cost[6] |
|---|---|---|---|---|
| | Current[3] | Post Adoption[4] | | |
| Existing Conditions | $2,096 | $2,096 | $2,822 | $4,918 |
| Proposed Conditions | $2,590 | $2,590 | $1,979 | $4,569 |
| Incremental[1] | ($494) | ($494) | $843 | $349 |

1. Incremental costs equal the difference between existing conditions and proposed conditions.
2. Equipment cost includes cost of the water heater and IWH drain kit plus the installation cost for original equipment and all replacements that are installed within 30-year period of analysis. Initial construction cost using current prices; $\Delta CI_C$.
3. Initial construction cost using estimated prices after adoption; $\Delta CI_{PA}$.
4. Present value of maintenance costs over 30 year period of analysis; $\Delta CM$.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs; $\Delta CI_{PA} + \Delta CM$.

***Incremental Construction Cost Results***

The 2013 Title 24 Standards for domestic water heating requires new single family homes and multi-family buildings with dedicated water heaters for each individual dwelling unit to be equipped with the components to accommodate the installation of IWHs. Research the Statewide CASE Team conducted indicates that when excluding the components that are already required in the Standards, there is no difference in the cost of installing a gas storage water heater and a gas IWH. The labor costs for a single installation or replacement were assumed to be the same for the baseline and measure cases.

The differences in initial cost are attributed to the difference in equipment costs and the inclusion of drain kits for IWHs.

***Incremental Maintenance Cost Results***

As stated in Section 4.7.1, the Statewide CASE Team assumed that the incremental maintenance cost between the base and measure case for the IWH prescriptive option is -$843. That is, the cost of maintaining an IWH over the 30-year period of analysis is $843 less than the maintenance cost for a storage water heater. See Section 4.7.1 for methodology.

The incremental costs of all the prescriptive option are presented in Table 29.

**Table 29: Incremental Cost of All Prescriptive Options[1]**

| Prescriptive Option | Equipment Cost[2] | | Present Value of Maintenance Cost[4] | Total Cost[5] |
|---|---|---|---|---|
| | Current Post Adoption[3] | Post Adoption[3] | | |
| Option1: IWH | $494 | $494 | ($843) | $349 |
| Option 2a. Baseline Storage Water Heater with QII & Compact HWDS | $1,182 | $1,182 | $ - | $1,182 |
| Option 2b. Baseline Storage Water Heater with QII & Pipe Insulation | $1,131 | $1,131 | $ - | $1,131 |

1. Incremental costs are the difference between existing conditions and proposed conditions when compared to a federal minimally compliant gas-fired storage water heater (i.e. existing condition).
2. Equipment cost includes the materials and installation cost. Initial construction cost using current prices.
3. Initial construction cost uses estimated prices after adoption.
4. Present value of maintenance costs over 30 year period of analysis. There are no maintenance costs assumed for QII + compact design and QII + pipe insulation over the 30-year period of analysis.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs.

### 5.2.2 Cost Savings Results

***Energy Cost Savings Results***

The per unit TDV energy cost savings over the 30-year period of analysis are presented in Table 30. The analysis shows the per household gas savings for each climate zone. The proposed measure results in positive cost savings in every climate zone.

**Table 30: TDV Energy Cost Savings Over 30-Year Period of Analysis - Per Building for All Prescriptive Options[1]**

| Climate Zone | Total TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | | |
|---|---|---|---|
| | Option 1: Instantaneous Water Heater | Option 2a: Storage Water Heater with QII & Compact Design | Option 2b: Storage Water Heater with QII & Pipe Insulation |
| Climate Zone 1 | $2,334 | $2,296 | $2,192 |
| Climate Zone 2 | $2,372 | $1,635 | $1,539 |
| Climate Zone 3 | $2,370 | $1,333 | $1,237 |
| Climate Zone 4 | $2,387 | $1,508 | $1,416 |
| Climate Zone 5 | $2,359 | $1,291 | $1,194 |
| Climate Zone 6 | $2,398 | $945 | $853 |
| Climate Zone 7 | $2,378 | $611 | $521 |
| Climate Zone 8 | $2,409 | $ 1,069 | $979 |
| Climate Zone 9 | $2,414 | $1,454 | $1,365 |
| Climate Zone 10 | $2,415 | $ 1,545 | $1,455 |
| Climate Zone 11 | $2,414 | $2,584 | $2,492 |
| Climate Zone 12 | $2,395 | $2,268 | $2,176 |
| Climate Zone 13 | $2,415 | $2,489 | $2,399 |
| Climate Zone 14 | $2,420 | $2,539 | $2,447 |
| Climate Zone 15 | $2,467 | $2,012 | $1,935 |
| Climate Zone 16 | $2,354 | $ 2,934 | $2,829 |
| Statewide Average | $2,394 | $1,782 | $1,689 |

1. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values. TDV energy savings calculations include electricity and natural gas use.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.

### 5.2.3 Cost-effectiveness Results

The proposed measure results in cost savings over the 30-year period of analysis relative to the existing conditions due to the longer life of IWHs and their lower gas usage (i.e. lower utility bills). In sum, the proposed code change is cost effective in every California climate zone. Prescriptive options 2a and 2b are cost effective in all climate zones except climate zones 6, 7, and 8. As previously stated, the additional prescriptive option does not need to be cost-effective in every climate zone as long as it is cost-effective on a statewide level.

The results of the per-building Cost-effectiveness Analysis are presented in Table 31 - Table 33. The negative values in the "Change in Lifecycle Cost" column indicate that the proposed measure is cost effective in every climate zone, as do the B/C ratio values in the last column. Given the 2017 construction forecast published by CEC's Demand Analysis Office, the

Statewide CASE Team estimates that the average LCC savings (30-year) of all buildings built during the first year that the 2016 Title 24 Standards are effective will be approximately $143 million for the IWH prescriptive option.

**Table 31: Cost-effectiveness Summary per Building, Option 1 (IWH)[1]**

| Climate Zone | Benefit: Total TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | Cost: Total Incremental Cost[3] (2017 PV $) | Change in Lifecycle Cost[4] (2017 PV $) | Benefit to Cost Ratio[5] |
|---|---|---|---|---|
| **Option 1: Instantaneous Water Heater** | | | | |
| Climate Zone 1 | $2,334 | $725 | ($1,609) | 3.22 |
| Climate Zone 2 | $2,372 | $725 | ($1,647) | 3.27 |
| Climate Zone 3 | $2,370 | $725 | ($1,645) | 3.27 |
| Climate Zone 4 | $2,387 | $725 | ($1,662) | 3.29 |
| Climate Zone 5 | $2,359 | $725 | ($1,634) | 3.25 |
| Climate Zone 6 | $2,398 | $725 | ($1,673) | 3.31 |
| Climate Zone 7 | $2,378 | $725 | ($1,653) | 3.28 |
| Climate Zone 8 | $2,409 | $725 | ($1,684) | 3.32 |
| Climate Zone 9 | $2,414 | $725 | ($1,689) | 3.33 |
| Climate Zone 10 | $2,415 | $725 | ($1,690) | 3.33 |
| Climate Zone 11 | $2,414 | $725 | ($1,689) | 3.33 |
| Climate Zone 12 | $2,395 | $725 | ($1,670) | 3.30 |
| Climate Zone 13 | $2,415 | $725 | ($1,690) | 3.33 |
| Climate Zone 14 | $2,420 | $725 | ($1,695) | 3.34 |
| Climate Zone 15 | $2,467 | $725 | ($1,742) | 3.40 |
| Climate Zone 16 | $2,354 | $725 | ($1,629) | 3.25 |

1. Relative to existing conditions. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.
3. Total cost equals incremental first cost (equipment and installation).
4. Negative values indicate the measure is cost effective. Change in lifecycle cost equals cost minus benefit.
5. The Benefit to Cost ratio is the total benefit divided by the total incremental costs. The measure is cost effective if the B/C ratio is greater than 1.0.

**Table 32: Cost-effectiveness Summary per Building, Option 2a (Storage Water Heater with QII & Compact Design)[1]**

| Climate Zone | Benefit: Total TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | Cost: Total Incremental Cost[3] (2017 PV $) | Change in Lifecycle Cost[4] (2017 PV $) | Benefit to Cost Ratio[5] |
|---|---|---|---|---|
| **Option 2a: Storage Water Heater with QII & Compact Design** | | | | |
| Climate Zone 1 | $2,296 | $1,182 | ($1,114) | 1.94 |
| Climate Zone 2 | $1,635 | $1,182 | ($453) | 1.38 |
| Climate Zone 3 | $1,333 | $1,182 | ($151) | 1.13 |
| Climate Zone 4 | $1,508 | $1,182 | ($326) | 1.28 |
| Climate Zone 5 | $1,291 | $1,182 | ($109) | 1.09 |
| Climate Zone 6 | $945 | $1,182 | $237 | 0.80 |
| Climate Zone 7 | $611 | $1,182 | $571 | 0.52 |
| Climate Zone 8 | $1,069 | $1,182 | $113 | 0.90 |
| Climate Zone 9 | $1,454 | $1,182 | ($272) | 1.23 |
| Climate Zone 10 | $1,545 | $1,182 | ($363) | 1.31 |
| Climate Zone 11 | $2,584 | $1,182 | ($1,402) | 2.19 |
| Climate Zone 12 | $2,268 | $1,182 | ($1,086) | 1.92 |
| Climate Zone 13 | $2,489 | $1,182 | ($1,307) | 2.11 |
| Climate Zone 14 | $2,539 | $1,182 | ($1,357) | 2.15 |
| Climate Zone 15 | $2,012 | $1,182 | ($830) | 1.70 |
| Climate Zone 16 | $2,934 | $1,182 | ($1,752) | 2.48 |
| Statewide Average | $1,782 | $1,182 | ($600) | 1.51 |

1. Relative to existing conditions. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.
3. Total cost equals incremental first cost (equipment and installation).
4. Negative values indicate the measure is cost effective. Change in lifecycle cost equals cost minus benefit.
5. The Benefit to Cost ratio is the total benefit divided by the total incremental cost. The measure is cost effective if the B/C ratio is greater than 1.0.

**Table 33: Cost-effectiveness Summary per Building, Option 2b (Storage Water Heater with QII & Pipe Insulation)[1]**

| Climate Zone | Benefit: Total TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | Cost: Total Incremental Cost[3] (2017 PV $) | Change in Lifecycle Cost[4] (2017 PV $) | Benefit to Cost Ratio[5] |
|---|---|---|---|---|
| **Option 2b: QII & Pipe Insulation** | | | | |
| Climate Zone 1 | $2,192 | $1,131 | ($1,061) | 1.94 |
| Climate Zone 2 | $1,539 | $1,131 | ($408) | 1.36 |
| Climate Zone 3 | $1,237 | $1,131 | ($106) | 1.09 |
| Climate Zone 4 | $1,416 | $1,131 | ($285) | 1.25 |
| Climate Zone 5 | $1,194 | $1,131 | ($63) | 1.06 |
| Climate Zone 6 | $853 | $1,131 | $278 | 0.75 |
| Climate Zone 7 | $521 | $1,131 | $610 | 0.46 |
| Climate Zone 8 | $979 | $1,131 | $152 | 0.87 |
| Climate Zone 9 | $1,365 | $1,131 | ($234) | 1.21 |
| Climate Zone 10 | $1,455 | $1,131 | ($324) | 1.29 |
| Climate Zone 11 | $2,492 | $1,131 | ($1,361) | 2.20 |
| Climate Zone 12 | $2,176 | $1,131 | ($1,045) | 1.92 |
| Climate Zone 13 | $2,399 | $1,131 | ($1,268) | 2.12 |
| Climate Zone 14 | $2,447 | $1,131 | ($1,316) | 2.16 |
| Climate Zone 15 | $1,935 | $1,131 | ($804) | 1.71 |
| Climate Zone 16 | $2,829 | $1,131 | ($1,698) | 2.50 |
| Statewide Average | $1,689 | $1,131 | ($558) | 1.49 |

1. Relative to existing conditions. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.
3. Total cost equals incremental first cost (equipment and installation).
4. Negative values indicate the measure is cost effective. Change in lifecycle cost equals cost minus benefit.
5. The Benefit to Cost ratio is the total benefit divided by the total incremental costs. The measure is cost effective if the B/C ratio is greater than 1.0.

## 5.3 Environmental Impacts Results

The greatest environmental impact of the proposed measure is the expected emissions reduction due to reduced natural gas use for water heating.

### 5.3.1 Greenhouse Gas Emissions Results

Table 34 presents the estimated first year avoided GHG emissions of the proposed code change. During the first year the 2016 Title 24 Standards are in effect the proposed measure will result in avoided GHG emissions of 28,476 $MTCO_2e$.

**Table 34: First Year Statewide Greenhouse Gas Emissions Impacts**

| | **Avoided GHG Emissions[1] ($MTCO_2e/yr$)** |
|---|---|
| Proposed Measure | 14,647 |
| TOTAL | 14,647 |

1. First year savings from buildings built in 2017; assumes 353 $MTCO_2e/GWh$ and 5,303 $MTCO_2e/MMTherms$.

### 5.3.2 Water Use Impacts

The Statewide CASE Team considered the potential water use impacts associated with the proposed measure, such as the potential increase in hot water usage from the continual and endless supply of hot water and longer hot water delivery times from a cold start up.

Since hot water usage is largely a function of behavior and is unique to each household, it is challenging to determine if hot water use will increase in a household will use more hot water if there is an IWH as opposed to a storage water heater. Several studies have evaluated this question and have found that despite the “endless supply of water” that IWHs provide hot water usage did not significantly increase after an IWH was installed at the study sites. For example, a study conducted by the Davis Energy Group (2011) that looked at the associated water use of high-efficiency water heaters installed in 18 California single family homes found that IWHs increased hot water consumption by about 15%. The sites retrofitted with IWHs showed an increase in average hot water draw volume from 1.40 to 2.09 gallons per draw, which was counteracted by an average 23% reduction in the daily number of draws (Hoeschele et al. 2011; Hoeschele et al. 2012).[18] In other words, people were using the hot water tap less frequently which cancelled out the longer draws. As such, there was a slight increase in the hot water load after installing an IWH but the results were within the statistical error of the study.

Further, a study by the Minnesota Center for Energy and Environment provided an in-depth look at storage and IWHs in Minnesota homes. The report addressed the impact of the water heater on the amount of hot water used and any behavioral impacts from switching from a storage water heater to IWH. Based on the data collected from each monitoring site, the study determined that there was no statistical difference in hot water usage with the storage water

[18] 2.09/1.40 x (1-0.23) = 1.15

heater and the IWH. The study also found that replacing a storage water heater with an IWH resulted in a 37% savings in water heating energy per household, as well as acceptable service at a reduced monthly cost without increasing total hot water consumption (Schoenbauer & Bohac 2013).

In terms of the time it takes for hot water to arrive at the tap, respondents in both studies reported an increase in wait time ranging from 5 to 60 seconds for hot water. These studies evaluated retrofitting existing buildings with IWS. While hot water wait time in retrofits is an important factor to consider, the proposed measure will only impact new construction (and additions if the addition includes adding a new water heater). Methods to address hot water delivery time in new construction are addressed in the following paragraphs. As noted earlier, there was no statistical difference in the amount of hot water used with a storage water heater over IWH. Moreover, 80% of study respondents were satisfied overall with their IWH, particularly with the consistent hot water temperatures during each draw, and many of the respondents adjusted their behavior to account for the wait time, including not using hot water for shorter tasks (Hoeschele 2011; Schoenbauer & Bohac 2013). Conversations with water heater installers, plumbers, and home builders also reveal consumer satisfaction with IWHs. This is particularly true when the homeowner is informed of the possible delay in hot water and the "cold water sandwich" effect that is common with IWHs (personal communication on July 30, 2014 and August 7, 2014). [19]

Hot water delivery time is a function of several variables, including length and pipe, pipe diameter, fixture flow rate, inlet and outlet water temperatures, and type of water heater.

An effective way to reduce hot water delivery time is to design the hot water distribution system in a manner that minimizes pipe length. Placing the water heater closer to the points of use will help reduce heat loss and decrease the amount of time it takes hot water to reach the tap. Several studies investigating hot water distribution systems have revealed that new homes have increased in size over the past few decades and that the common architecture of homes has resulted in distribution systems that locate the water heater quite a distance from use points. Designing homes with a more compact hot water system would minimize wait times and energy losses in the pipes. Though outside the scope of this proposal, the Statewide CASE Team encourages CEC to consider future measures aimed at more compact hot water distribution systems.

Pipe insulation is another factor to consider in hot water distribution systems. Insulating hot water pipes can reduce wait times for hot water. The 2013 Title 24 water heating standards now require pipe insulation in new residential construction. This mandatory requirement will help reduce the amount of heat loss as the hot water travels from the water heater to the tap.

The Statewide CASE Team concluded that the measure will have a not significant impact on water use or water quality (see Table 35).

[19] A "cold water sandwich" occurs when cold water is introduced into the hot water supply line during frequent on/off operation of an IWH. The effect appears as a momentary drop in temperature as the cold water is discharged from a hot water supply outlet (e.g., shower, tub, or faucet) (Rinnai 2014).

**Table 35: Impacts of Water Use and Water Quality**

| | On-Site Water Savings[1] (gallons/yr) | Embedded Energy Savings[2] (kWh/yr) | Impact on Water Quality<br>Material Increase (I), Decrease (D), or No Change (NC) compared to existing conditions | | | |
|---|---|---|---|---|---|---|
| | | | **Mineralization (calcium, boron, and salts)** | **Algae or Bacterial Buildup** | **Corrosives as a Result of PH Change** | **Others** |
| Impact (I, D, or NC) | NC | NC | NC | NC | NC | NC |
| Per Unit Impacts[3] | n/a | n/a | n/a | n/a | n/a | n/a |
| Statewide Impacts (first year) | n/a | n/a | n/a | n/a | n/a | n/a |
| Comment on reasons for your impact assessment | n/a | n/a | n/a | n/a | n/a | n/a |

1. Does not include water savings at power plant
2. Assumes embedded energy factor of 10,045 kWh per million gallons of water.

### 5.3.3 Material Impacts Results (Optional)

The material impacts of the proposed code change on material use were not evaluated.

### 5.3.4 Other Impacts Results

There are no other impacts of the proposed code change.

# 6. Proposed Language

The proposed changes to the 2013 Title 24 Standards, Residential ACM Reference Manual, and Compliance Manual are provided below. Changes to the 2013 documents are marked with underlining new language) and ~~strikethroughs~~ deletions).

## 6.1 Standards

**SECTION 110.3 – MANDATORY REQUIREMENTS FOR SERVICE WATERHEATING SYSTEMS AND EQUIPMENT**

**(c) Installation.**

7. **Isolation valves.** Instantaneous water heaters with an input rating greater than 6.8 kBTU/hr (2 kW) shall have isolation valves on both the cold water supply and the hot water pipe leaving the water heater and hose bibs or other fittings on both the cold water supply and leaving hot water piping for flushing the water heater when isolation valves are closed.

**SUBCHAPTER 7**
**LOW-RISE RESIDENTIAL BUILDINGS – MANDATORY FEATURES AND DEVICES**

**SECTION 150.0 – MANDATORY FEATURES AND DEVICES**

Any newly constructed low-rise residential building shall meet the requirements of this Section

(n) **Water Heating System**.

1. Systems using gas or propane water heaters to serve individual dwelling units shall include the following components:

   A. A 120V electrical receptacle that is within 3 feet from the water heater and accessible to the water heater with no obstructions; and

   B. A Category III or IV vent, or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed; and

   C. A condensate drain that is no more than 2 inches higher than the base of the installed water heater, and allows natural draining without pump assistance, and

   D. A gas supply line with a capacity of at least 200,000 Btu/hr.

2. Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 110.3(c)5.

3. Solar water-heating systems and collectors shall be certified and rated by the Solar Rating and Certification Corporation (SRCC) or by a testing agency approved by the Executive Director.

4. Instantaneous water heaters with an input rating greater than 6.8 kBTU/hr (2 kW) shall comply with Section 110.3(c) 7.

## SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR NEWLY CONSTRUCTED RESIDENTIAL BUILDINGS

*{Content that does not pertain to proposed standard omitted}*

c) **Prescriptive Standards/Component Package.** Buildings that comply with the prescriptive standards shall be designed, constructed, and equipped to meet all of the requirements for the appropriate Climate Zone shown in TABLE 150.1-A. In TABLE 150.1-A, a NA not allowed) means that feature is not permitted in a particular Climate Zone and a NR no requirement) means that there is no prescriptive requirement for that feature in a particular Climate Zone. Installed components shall meet the following requirements:

*{Content that does not pertain to proposed standard omitted}*

8. **Domestic Water-Heating Systems.** Water-heating systems shall meet the requirements of either A~~,~~ or B~~, C, or D~~.

~~A. For systems serving individual dwelling units, a single gas or propane storage type water heater with an input of 75,000 Btu per hour or less, and that meets the tank insulation requirements of Section 150.0j) and the requirements of Sections 110.1 and 110.3 shall be installed. For recirculation distribution systems, only Demand Recirculation Systems with manual control pumps shall be used.~~

~~B.~~ A. For systems serving individual dwelling units, the water heating system shall meet the requirements of either i or ii:

i. ~~a~~ A single gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no storage tank, and that meets the requirements of Sections 110.1 and 110.3 shall be installed. For recirculation distribution systems, only Demand Recirculation Systems with manual control pumps shall be used.

ii. A single gas or propane storage type water heater with an input of 105,000 Btu per hour or less, and that meets the requirements of Sections 110.1 and 110.3. For recirculation distribution systems, only Demand Recirculation Systems with manual control pumps shall be used. The dwelling unit shall meet all of the requirements for Quality Insulation Installation (QII) as specified in the Reference Appendix RA3.5, and in addition do either a or b:

a. A compact hot water distribution system that is field verified as specified in the Reference Appendix RA4.4.16; or

b. All domestic hot water piping shall be insulated and field verified as specified in the Reference Appendix RA4.4.1, RA4.4.3 and RA4.4.14.

~~C~~ B. For systems serving multiple dwelling units, a central water-heating system that includes the following components shall be installed:

i. Gas or propane water heaters, boilers or other water heating equipment that meet the minimum efficiency requirements of Sections 110.1 and 110.3; and

ii. A water heating recirculation loop that meets the requirements of Sections 110.3c)2 and 110.3c)5 and is equipped with an automatic control system that controls the recirculation pump operation based on measurement of hot water demand and hot water return temperature and has two recirculation loops each serving half of the building; and

**EXCEPTION to Section 150.1c)8Cii:** Buildings with eight or fewer dwelling units are exempt from the requirement for two recirculation loops.

iii. A solar water-heating system meeting the installation criteria specified in Reference Residential Appendix RA4 and with a minimum solar savings fraction of 0.20 in Climate Zones 1 through 9 or a minimum solar savings fraction of 0.35 in Climate Zones 10 through 16. The solar savings fraction shall be determined using a calculation method approved by the Commission.

~~D. For systems serving individual dwelling units, an electric-resistance storage or instantaneous water heater may be installed as the main water heating source only if natural gas is unavailable, the water heater is located within the building envelope, and a solar water-heating system meeting the installation criteria specified in the Reference Residential Appendix RA4 and with a minimum solar savings fraction of 0.50 is installed. The solar savings fraction shall be determined using a calculation method~~

# SUBCHAPTER 9

## LOW-RISE RESIDENTIAL BUILDINGS - ADDITIONS AND ALTERATIONS IN EXISTING LOW-RISE RESIDENTIAL BUILDINGS

## SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS IN EXISTING BUILDINGS THAT WILL BE LOW-RISE RESIDENTIAL OCCUPANCIES

*{Content that does not pertain to proposed standard omitted}*

**(b) Alterations.** Alterations to existing residential buildings or alterations in conjunction with a change in building occupancy to a low-rise residential occupancy shall meet either Item 1 or 2 below

1. **Prescriptive approach**. The altered component and any newly installed equipment serving the alteration shall meet the applicable requirements of Sections 110.0 through 110.9 and all applicable requirements of Section 150.0(a) through (q); and

*{Content that does not pertain to proposed standard omitted}*

**G. Water-Heating System.** Replacement service water-heating systems or components shall:

Meet the requirements of Section 150.0(j)2 and either be:

i. If natural gas is connected to the building, a natural gas water heater that meets the requirements of the Appliance Efficiency Regulations ~~A natural gas or propane water-heating system that meets the requirements of 150.1(c)8. No recirculation system shall be installed~~; or

ii. If no natural gas is connected to the building, an electric water heater that ~~has an energy factor equal to or greater than required under~~ meets the requirements of the Appliance Efficiency Regulations. For storage type water heaters the capacity shall not exceed 60 gallons. No recirculation system shall be installed; or

iii. A water-heating system determined by the Executive Director to use no more energy than the one specified in Item 1 above; or if no natural gas is connected to the building, a water-heating system determined by the Executive Director to use no more energy than the one specified in Item 2 above; or

iv. Using the existing building plus addition compliance approach as defined in Section 150.2(b)2 demonstrate that the proposed water heating system uses no more energy than the system defined in item 1 above regardless of the type or number of water heaters installed

**EXCEPTION to Section 150.2(b)1G:** Existing inaccessible piping shall not require insulation as defined under 150.0(j)2A iii.

## 6.2 Reference Appendices

There are no proposed changes to the Reference Appendices.

## 6.3 ACM Reference Manual

The Statewide CASE Team will be providing recommended changes to the ACM Reference Manual at a future date.

## 6.4 Compliance Manuals

The following sections of the Residential Compliance Manual will need to be revised:

- Section 5.2.2 – Mandatory Requirements for Water Heaters
- Section 5.4 – Prescriptive Water Hating and Distribution System Requirements

The Statewide CASE Team will recommend changes to the Residential Compliance Manual Specific in a separate deliverable to CEC.

# 7. References and Other Research


[AHRI] The Air-Conditioning, Heating, and Refrigeration Institute. 2014. 2016 Title 24 CEC Pre-Rulemaking Comment Letter by Frank Stanonik, July 18, 2014. http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/prerulemaking_comments/AHRI_Comments_for_the_July_21_2014_Staff_Workshop_2014-07-18_TN-73438.pdf.

A.O. Smith. 2014. "On-Demand Water Heater Installation Manual and Owner's Guide." http://www.hotwater.com/lit/im/res_gas/60z101.pdf.

[ASAP] Appliance Standards Awareness Project. 2014. *Water Heaters*. http://www.appliance-standards.org/product/water-heaters.

Battelle Memorial Institute. 2010. "Final Report: Study on Benefits of Removal of Water Hardness (Calcium and Magnesium Ions) From a Water Supply.". http://www.saltinstitute.org/wp-content/uploads/2013/10/Battelle_Final_Report-on-Water-Softening-1.pdf .

Bradford White Corp. 2007. "Water Heater Installation and Operation Instruction Manual." http://www.bradfordwhite.com/sites/default/files/product_literature/238_44219_00G.pdf.

__. 2011. "Bradford White EverHot Tankless Gas Water Heater For Interior Installation: Installation and Operation Instruction Manual." http://site.theenergyconscious.com/pdf/bradford-tg-150e-operation-guide.pdf

__. 2012. "Water Heater Installation and Operation Instruction Manual." http://www.bradfordwhite.com/sites/default/files/product_literature/238-45637-00L.pdf.

http://www.bradfordwhite.com/sites/default/files/product_literature/238-44219-00K.pdf.

Builders Websource. 2012. *Tankless Water Heaters*. http://www.builderswebsource.com/techbriefs/tankless.htm

Burch, J. et al. 2008. "Preliminary Modeling, Testing, and Analysis of a Gas Tankless Water Heater." National Renewable Energy Laboratory. http://www.buildingscience.com/documents/confpapers/cp-1002-preliminary-modeling-testing-analysis-gas-tankless-water-heater.

[CA IOUs] California Utilities Statewide Codes and Standards Team. 2011a. "Codes and Standards Enhancement (CASE) Report for the 2013 California Building Efficiency Standards: High-Efficiency Water Heater Ready" http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_WH2.WH5_WaterHeaterReady-10.28.2011.pdf.

___. 2011b. "Codes and Standards Enhancement (CASE) Report for the 2013 California Building Efficiency Standards: Single Family Water Heating Distribution System Improvements."

http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_R_SEMPRA_Single_Family_DHW_%20Sept_2011.pdf.

____.2014. "Codes and Standards Enhancement (CASE) Report for the 2016 California Building Efficiency Standards: Residential High Performance Walls and QII." http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-21_workshop/final_case_reports/2016_T24_CASE_Report-High_Perf_Walls-Sep2014.pdf.

[CARB] California Air Resources Board. 2008. "Climate Change Scoping Plan Appendices, Volume I." http://www.arb.ca.gov/cc/scopingplan/document/appendices_volume1.pdf.

__. 2010a. "Proposed Regulation for a California Renewable Electricity Standard Staff Report: Initial Statement of Reasons Appendix D." http://www.arb.ca.gov/regact/2010/res2010/res10d.pdf.

__. 2010b. "Updated Economic Analysis of California's Climate Change Scoping Plan: Staff Report to the Air Resources Board." http://www.arb.ca.gov/cc/scopingplan/economics-sp/updated-analysis/updated_sp_analysis.pdf.

__. 2011a. "Appendix C: Cost Effectiveness Calculation Methodology." http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/appc_3_10_11.pdf.

__. 2011b. "Emission Reduction Offsets Transaction Cost Summary Report for 2011." http://www.arb.ca.gov/nsr/erco/erco.htm.

__. 2012. "Emission Reduction Offsets Transaction Cost Summary Report for 2012." http://www.arb.ca.gov/nsr/erco/erco.htm.

__. 2013a. "Mail-Out #MSC 13-09." http://www.arb.ca.gov/msprog/mailouts/msc1309/msc1309.pdf.

__. 2013b. "California Air Resources Board Quarterly Auction 3, May 2013 – Summary Results Report." http://www.arb.ca.gov/cc/capandtrade/auction/may-2013/results.pdf.

[CEC] California Energy Commission. 2008. "Nonresidential Alternative Calculation (ACM) Approval Manual for the 2008 Building Energy Efficiency Standards." December 2008.

__. 2011. "Lifecycle Cost Methodology: 2013 California Building Energy Efficiency Standards. July 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf.

__. 2013. California Energy Commission. "Residential Appendices." http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/final_rulemaking_documents/44_Final_Express_Terms/2013_RA_FINAL.pdf

__. 2014. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2016 Time Dependent Valuation (TDV) Data Sources and Inputs." July 2014. http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-09_workshop/2017_TDV_Documents/Title24_2016_TDV_Methodology_Report%20v3.docx. Accessed July 2014.

__. 2014. "Appliance Efficiency Database." http://www.appliances.energy.ca.gov/QuickSearch1024.aspx.

__. 2014. “2013 Approved Computer Compliance Programs.” http://www.energy.ca.gov/title24/2013standards/2013_computer_prog_list.html.

Consortium for Energy Efficiency. 2014. Residential Natural Gas Water Heaters (Storage) Qualifying Product List http://library.cee1.org/content/natural-gas-residential-water-heaters-storage-qualifying-products-list/.

__. 2014. Residential Natural Gas Water Heaters (Tankless) Qualifying Product List http://library.cee1.org/content/natural-gas-residential-water-heaters-tankless-qualifying-products-list.

[DEER] Database for Energy Efficient Resources. 2014. “DEER 2014 EUL Update.: http://www.deeresources.com/.

ENERGY STAR. 2012. “ENERGY STAR Appliance & Water Heater Highlights.” http://www.energystar.gov/ia/partners/downloads/U.S._EPA-Ryan_and_Stephens-Booker.pdf.

__. 2014. “ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2013 Summary.” https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data.

__. 2014. *New Homes Partners in California.* http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=CA.

__. 2014. ENERGY STAR Qualified Products. https://www.energystar.gov/index.cfm?fuseaction=find_a_product.

Hoeschele et al. 2011. “California Field Performance of Advanced Residential Gas Water Heating Technologies.” Davis Energy Group.

Hoeschele et al. 2012. “Water Heating Design Guide.” Prepared for California Energy Commission by Davis Energy Group and Gas Technology Institute.

http://www.energy.ca.gov/2013publications/CEC-500-2013-126/CEC-500-2013-126.pdf.

Hoover, W. 2011. “The Most Ignored Residential Appliance.” https://www.aceee.org/files/pdf/conferences/hwf/2011/2A%20-%20Bill%20Hoover.pdf.

KEMA. 2010. “2009 California Residential Appliance Saturation Study.” Prepared for CEC. http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-ES.PDF

__. 2010. “Residential New Construction Programs: Impact Evaluation – Volume I. California Investor-Owned Utilities’ Residential New Construction Program Evaluation for Program Years 2006-2008.” Prepared for California Public Utilities Commission – Energy Division. http://www.calmac.org/publications/RNC_Final_Evaluation_Report.pdf.

[LBNL] Lawrence Berkeley National Laboratory. 2008. “Water Heaters and Hot Water Distribution Systems.” Public Interest Energy Research Program. Prepared for California Energy Commission. http://eetd.lbl.gov/sites/all/files/water_heaters_and_hot_water_distribution_systems.pdf.

National Association of Home Builders/Bank of America Home Equity. 2007. "Study of Life Expectancy of Home Components." https://www.nahb.org/fileUpload_details.aspx?contentID=99359

[NEEA] Northwest Energy Efficiency Alliance. 2006. "Residential Water Heater Market." Prepared by KEMA.

http://neea.org/docs/reports/assessmentoftheresidentialwaterheatermarketingnwc6f59c4d2eeb.pdf.

__. 2012. "2011 Water Heater Update." Prepared by Verinnovation Inc. http://neea.org/docs/reports/2011waterheatermarketupdatea273dbb87ca3.pdf.

Noritz. 2005. "Owners Guide and Installation Manual." http://support.noritz.com/download.php?file=Literature%20Page/Owners%20Guide/N063S+N069M%20OG%20IM.pdf&field=OwnersGuide

__. 2009. "Installation Manual: Tankless Gas Water Heater." http://www.noritz.com/commercial/files/manuals/Installation_Manual-_NC380-SV-ASME.pdf

[PG&E] Pacific Gas and Electric Company. 2007. "Residential Feasibility Assessment of Gas Tankless Water Heaters in PG&E Service Territory." http://www.etcc-ca.com/sites/default/files/OLD/images/stories/tanklesswh20et20report_020707_final1.pdf.

__. 2012. "Market-Focused Program Design to Accelerate Penetration of ENERGY STAR Water Heaters." Prepared by Navitas Partners. http://www.etcc-ca.com/sites/default/files/reports/PGE%20Water%20Heater%20ET%20Final%20Report%20-%20FINAL.pdf.

[PNNL] Pacific Northwest National Laboratory. 2013. "Impacts of Water Quality on Residential Water Heating Equipment." http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22921.pdf

Rheem. 2009. "Use & Care Manual with Installation Instructions for the Installer." http://www.homedepot.com/catalog/pdfImages/fd/fd8944c5-1421-49af-9852-c9eddfe95956.pdf

Rinnai. 2014. Frequently Asked Questions: "What is the 'cold water sandwich' effect?" http://www.rinnai.us/customer-care/support-faq#tankless-water-heater-q1.

Rodgers, K. & J. O'Donnell. 2009. "A Market Transformation Strategy for Gas-Fired Domestic Hot Water Heaters." Consortium for Energy Efficiency. http://aceee.org/files/proceedings/2008/data/papers/9_248.pdf.

Roland-Holst, David. "Energy Efficiency, Innovation, and Job Creation in California." October 2008. http://are.berkeley.edu/~dwrh/CERES_Web/Docs/UCB%20Energy%20Innovation%20and%20Job%20Creation%2010-20-08.pdf.

Schoenberger, B., D. Bohac & M. Hewett. 2012. "Tankless Water Heaters: Do They Really Save Energy?" Minnesota Center for Energy and Environment. http://www.mncee.org/getattachment/1ef50130-fd3a-4a5c-beb9-1ea806c26785/.

Schoenberger, B. & D. Bohac. 2013. "Actual Savings and Performance of Natural Gas Tankless Water Heaters." http://mncee.org/Innovation-Exchange/Projects/Past/Actual-Savings-and-Performance-of-Natural-Gas-Tank/.

[UC Berkeley] 2011. University of California Berkeley Donald Vial Center on Employment in the Green Economy. "California Workforce Education and Training Needs Assessment for Energy Efficiency, Distributed Generation, and Demand Response." http://www.irle.berkeley.edu/vial/publications/WET_Part1.pdf.

[U.S. DOE] United States Department of Energy. 2010. "Final Rule: Standards, Federal Register, 75 FR 20112 April 16, 2010)." http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27.

__.2010. Technical Support Document, Chapter 3. "Market and Technology Assessment." http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0170.

__.2010. Technical Support Document, Chapter 8 "Life Cycle Cost and Payback Analysis." http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0170.

[U.S. EPA] United States Environmental Protection Agency. 2011. "Emission Factors for Greenhouse Gas Inventories." http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

Valley Energy Efficiency Corporation. 2008. "Super Efficient Gas Water Heating Appliance Initiative." CEC-500-2007-105. http://www.energy.ca.gov/2007publications/CEC-500-2007-105/CEC-500-2007-105.PDF

# Appendix A: Environmental Impacts Methodology

### *Greenhouse Gas Emissions Impacts Methodology*

The avoided GHG emissions were calculated assuming an emission factor of 353 metric tons of carbon dioxide equivalents $MTCO_2e$) per GWh of electricity savings. The Statewide CASE Team calculated air quality impacts associated with the electricity savings from the proposed measure using emission factors that indicate emissions per GWh of electricity generated.[20] When evaluating the impact of increasing the Renewable Portfolio Standard RPS) from 20% renewables by 2020 to 33% renewables by 2020, California Air Resources Board CARB) published data on expected air pollution emissions for various future electricity generation scenarios CARB 2010). The Statewide CASE Team used data from CARB's analysis to inform the air quality analysis presented in this report.

The GHG emissions factor is a projection for 2020 assuming the state will meet the 33% RPS goal. CARB calculated the 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 scoping plan thereby reducing overall electricity load in the state.

To be conservative, the Statewide CASE Team calculated the emissions factors of the incremental electricity between the low and high load scenarios. These emission factors are intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario. The incremental emissions were 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 was considered a representative year for this measure.

Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

[20] California power plants are subject to a GHG cap and trade program and linked offset programs until 2020 and potentially beyond.

# Appendix B: Job Creation by Industry

Table 36 shows total job creation by industry that is expected from all investments in California energy efficiency and renewable energy (UC Berkeley 2011, Appendix D). While it is not specific to codes and standards, this data indicates the industries that generally will receive the greatest job growth from energy efficiency programs.

**Table 36: Job Creation by Industry**

| NAICS | Industry Description | Direct Jobs | |
|---|---|---|---|
| | | 2015 | 2020 |
| 23822 | Plumbing, Heating, and Air-Conditioning Contractors | 8,695 | 13,243 |
| 2361 | Residential Building Construction | 5,072 | 7,104 |
| 2362 | Nonresidential Building Construction | 5,345 | 6,922 |
| 5611 | Office Administrative Services | 2,848 | 4,785 |
| 23821 | Electrical Contractors | 3,375 | 4,705 |
| 551114 | Corporate, Subsidiary, and Regional Managing Offices | 1,794 | 3,014 |
| 54133 | Engineering Services | 1,644 | 2,825 |
| 5418 | Advertising and Related Services | 1,232 | 2,070 |
| 334413 | Semiconductor and Related Device Manufacturing | 1,598 | 1,598 |
| 541690 | Other Scientific and Technical Consulting Services | 796 | 1,382 |
| 23831 | Drywall and Insulation Contractors | 943 | 1,331 |
| 3334 | Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equipment Manufacturing | 453 | 792 |
| 3351 | Electric Lighting Equipment Manufacturing | 351 | 613 |
| 926130 | Regulation and Administration of Communications, Electric, Gas, Other Utilities | 322 | 319 |
| 23816 | Roofing Contractors | 275 | 277 |
| 54162 | Environmental Consulting Services | 151 | 261 |
| 484210 | Used Household and Office Goods Moving | 137 | 239 |
| 23835 | Finish Carpentry Contractors | 120 | 120 |
| 23829 | Other Building Equipment Contractors | 119 | 113 |
| 3352 | Household Appliance Manufacturing | 63 | 110 |
| Other | Other | 454 | 547 |
| | **Total** | **35,788** | **52,369** |

# APPENDIX C: ENERGY IMPACTS, ESTIMATED FIRST YEAR ENERGY SAVINGS, AND COST EFFECTIVENESS RESULTS FOR EACH PROTOTYPE BUILDING

The tables below present the per unit energy and cost impacts for each of the two prototype buildings used in the energy savings analysis for the IWH prescriptive option (Option 1). As discussed in Section 4.3 of the report, the results presented in the body of the report represent the weighted average savings of the two prototype buildings. Key assumptions about the prototype buildings and the relative weight assigned to each prototype in the savings analysis are presented in Table 17.

**Table 37: First Year[1] Energy Impacts for Prototype Building 1 (conditioned floor area (CFA)= 2,100 SF)**

| Climate Zone | Electricity Savings[2] (kWh/yr) | Demand Savings (kW) | Natural Gas Savings (Therms/yr) | Total TDV Savings (kBTU)[3] |
|---|---|---|---|---|
| Climate Zone 1 | -57 | -0.13 | 32 | 7,413 |
| Climate Zone 2 | -57 | -0.13 | 29 | 7,602 |
| Climate Zone 3 | -57 | -0.13 | 29 | 7,581 |
| Climate Zone 4 | -57 | -0.13 | 28 | 7,665 |
| Climate Zone 5 | -57 | -0.13 | 30 | 7,539 |
| Climate Zone 6 | -57 | -0.13 | 27 | 7,749 |
| Climate Zone 7 | -57 | -0.13 | 27 | 7,623 |
| Climate Zone 8 | -57 | -0.13 | 26 | 7,791 |
| Climate Zone 9 | -57 | -0.13 | 26 | 7,812 |
| Climate Zone 10 | -57 | -0.13 | 26 | 7,833 |
| Climate Zone 11 | -57 | -0.13 | 26 | 7,812 |
| Climate Zone 12 | -57 | -0.13 | 28 | 7,707 |
| Climate Zone 13 | -57 | -0.13 | 26 | 7,833 |
| Climate Zone 14 | -57 | -0.13 | 26 | 7,854 |
| Climate Zone 15 | -57 | -0.13 | 21 | 8,064 |
| Climate Zone 16 | -57 | -0.13 | 31 | 7,539 |

1. Savings from one prototype building for the first year the building is in operation.
2. Site electricity savings.
3. TDV energy savings for one prototype building for the first year the building is in operation. Calculated using CEC's 2016 TDV factors and methodology. Includes savings from electricity and natural gas.

## Table 38: First Year[1] Energy Impacts for Prototype Building 2 (CFA = 2,700 SF)

| Climate Zone | Electricity Savings[2] (kWh/yr) | Demand Savings (kW) | Natural Gas Savings (Therms/yr) | Total TDV Savings[3] (kBTU) |
|---|---|---|---|---|
| Climate Zone 1 | -57 | -0.13 | 37 | 7,155 |
| Climate Zone 2 | -57 | -0.13 | 33 | 7,398 |
| Climate Zone 3 | -57 | -0.13 | 34 | 7,398 |
| Climate Zone 4 | -57 | -0.13 | 32 | 7,506 |
| Climate Zone 5 | -57 | -0.13 | 34 | 7,317 |
| Climate Zone 6 | -57 | -0.13 | 31 | 7,560 |
| Climate Zone 7 | -57 | -0.13 | 31 | 7,452 |
| Climate Zone 8 | -57 | -0.13 | 31 | 7,641 |
| Climate Zone 9 | -57 | -0.13 | 31 | 7,668 |
| Climate Zone 10 | -57 | -0.13 | 31 | 7,668 |
| Climate Zone 11 | -57 | -0.13 | 31 | 7,668 |
| Climate Zone 12 | -57 | -0.13 | 32 | 7,560 |
| Climate Zone 13 | -57 | -0.13 | 31 | 7,668 |
| Climate Zone 14 | -57 | -0.13 | 31 | 7,695 |
| Climate Zone 15 | -57 | -0.13 | 25 | 8,019 |
| Climate Zone 16 | -57 | -0.13 | 36 | 7,263 |

1. Savings from one prototype building for the first year the building is in operation.
2. Site electricity savings.
3. TDV energy savings for one prototype building for the first year the building is in operation. Calculated using CEC's 2016 TDV factors and methodology. Includes savings from electricity and natural gas.

## Table 39: Statewide Energy Impacts (CFA=2,100 SF)

| | First Year Statewide Savings[1] | | | TDV Savings[2] |
|---|---|---|---|---|
| | Electricity Savings[3] (GWh) | Power Demand Reduction (MW) | Natural Gas Savings (MMtherms) | TDV Energy Savings (Million kBTU) |
| Proposed Measure | -6.16 | -1.34 | 2.90 | 838 |
| TOTAL | -6.16 | -1.34 | 2.90 | 838 |

1. First year savings from all buildings built statewide during the first year the 2016 Standards are in effect.
2. TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect. Calculated using CEC's 2016TDV factors and methodology.
3. Site electricity savings.

### Table 40: Statewide Energy Impacts (CFA=2,700 SF)

| | First Year Statewide Savings[1] | | | TDV Savings[2] |
|---|---|---|---|---|
| | Electricity Savings[3] (GWh) | Power Demand Reduction (MW) | Natural Gas Savings (MMtherms) | TDV Energy Savings (Million kBTU) |
| Proposed Measure | -6.16 | -1.34 | 3.40 | 821 |
| TOTAL | -6.16 | -1.34 | 3.40 | 821 |

1. First year savings from all buildings built statewide during the first year the 2016 Standards are in effect.
2. First year TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect. Calculated using CEC's 2016TDV factors and methodology.
3. Site electricity savings.

### Table 41: Estimated First Year Energy Savings

| | Electricity Savings (GWh) | | Power Demand Reduction (MW) | Natural Gas Savings (MMtherms) | | First Year TDV Energy Savings (Million kBTU) | |
|---|---|---|---|---|---|---|---|
| | CFA = 2,100 SF | CFA = 2,700 SF | | CFA = 2,100 SF | CFA = 2,700 SF | CFA = 2,100 SF | CFA = 2,700 SF |
| Proposed Measure | -6.16 | -6.16 | -1.34 | 2.90 | 3.40 | 838 | 821 |
| TOTAL | -6.16 | -6.16 | -1.34 | 2.90 | 3.40 | 838 | 821 |

**Table 42: TDV Energy Cost Savings Over 30-Year Period of Analysis - Per Prototype Building 1 (CFA=2,100 SF)**

| Climate Zone | Total TDV Energy Cost Savings (2017 PV $) |
|---|---:|
| Climate Zone 1 | $1,284 |
| Climate Zone 2 | $1,317 |
| Climate Zone 3 | $1,313 |
| Climate Zone 4 | $1,328 |
| Climate Zone 5 | $1,306 |
| Climate Zone 6 | $1,342 |
| Climate Zone 7 | $1,320 |
| Climate Zone 8 | $1,349 |
| Climate Zone 9 | $1,353 |
| Climate Zone 10 | $1,357 |
| Climate Zone 11 | $1,353 |
| Climate Zone 12 | $1,335 |
| Climate Zone 13 | $1,357 |
| Climate Zone 14 | $1,360 |
| Climate Zone 15 | $1,397 |
| Climate Zone 16 | $1,306 |

All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.

**Table 43: TDV Energy Cost Savings Over 30-Year Period of Analysis - Per Prototype Building 2 (CFA=2,700 SF)**

| Climate Zone | Total TDV Energy Cost Savings (2017 PV $) |
|---|---:|
| Climate Zone 1 | $1,239 |
| Climate Zone 2 | $1,281 |
| Climate Zone 3 | $1,281 |
| Climate Zone 4 | $1,300 |
| Climate Zone 5 | $1,267 |
| Climate Zone 6 | $1,309 |
| Climate Zone 7 | $1,291 |
| Climate Zone 8 | $1,323 |
| Climate Zone 9 | $1,328 |
| Climate Zone 10 | $1,328 |
| Climate Zone 11 | $1,328 |
| Climate Zone 12 | $1,309 |
| Climate Zone 13 | $1,328 |
| Climate Zone 14 | $1,333 |
| Climate Zone 15 | $1,389 |
| Climate Zone 16 | $1,258 |

All cost values presented in 2017 dollars. Cost savings are calculated

**Table 44: Cost-effectiveness Summary[1] for Prototype Building 1 (CFA=2,100 SF)**

| Climate Zone | Benefit: TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | Cost: Total Incremental Cost[3] (2017 PV $) | Change in Lifecycle Cost[4] (2017 PV $) | Benefit to Cost Ratio[5] |
|---|---:|---:|---:|---:|
| Climate Zone 1 | $2,358 | $725 | ($1,609) | 3.22 |
| Climate Zone 2 | $2,391 | $725 | ($1,647) | 3.27 |
| Climate Zone 3 | $2,387 | $725 | ($1,645) | 3.27 |
| Climate Zone 4 | $2,402 | $725 | ($1,662) | 3.29 |
| Climate Zone 5 | $2,380 | $725 | ($1,634) | 3.25 |
| Climate Zone 6 | $2,417 | $725 | ($1,673) | 3.31 |
| Climate Zone 7 | $2,395 | $725 | ($1,653) | 3.28 |
| Climate Zone 8 | $2,424 | $725 | ($1,684) | 3.32 |
| Climate Zone 9 | $2,427 | $725 | ($1,689) | 3.33 |
| Climate Zone 10 | $2,431 | $725 | ($1,690) | 3.33 |
| Climate Zone 11 | $2,427 | $725 | ($1,689) | 3.33 |
| Climate Zone 12 | $2,409 | $725 | ($1,670) | 3.30 |
| Climate Zone 13 | $2,431 | $725 | ($1,690) | 3.33 |
| Climate Zone 14 | $2,435 | $725 | ($1,695) | 3.34 |
| Climate Zone 15 | $2,471 | $725 | ($1,742) | 3.40 |
| Climate Zone 16 | $2,380 | $725 | ($1,629) | 3.25 |

1. Relative to existing conditions. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.
3. Total cost equals incremental first cost (equipment and installation).
4. Negative values indicate the measure is cost effective. Change in lifecycle cost equals cost minus benefit.
5. The Benefit to Cost ratio is the total benefit divided by the total incremental costs. The measure is cost effective if the B/C ratio is greater than 1.0.

**Table 45: Cost-effectiveness Summary[1] for Prototype Building 2 (CFA=2,700 SF)**

| Climate Zone | Benefit: TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $) | Cost: Total Incremental Cost[3] (2017 PV $) | Change in Lifecycle Cost[4] (2017 PV $) | Benefit to Cost Ratio[5] |
|---|---|---|---|---|
| Climate Zone 1 | $2,314 | $725 | ($1,589) | 3.19 |
| Climate Zone 2 | $2,356 | $725 | ($1,631) | 3.25 |
| Climate Zone 3 | $2,356 | $725 | ($1,631) | 3.25 |
| Climate Zone 4 | $2,374 | $725 | ($1,649) | 3.28 |
| Climate Zone 5 | $2,342 | $725 | ($1,617) | 3.23 |
| Climate Zone 6 | $2,384 | $725 | ($1,659) | 3.29 |
| Climate Zone 7 | $2,365 | $725 | ($1,640) | 3.26 |
| Climate Zone 8 | $2,398 | $725 | ($1,673) | 3.31 |
| Climate Zone 9 | $2,402 | $725 | ($1,677) | 3.31 |
| Climate Zone 10 | $2,402 | $725 | ($1,677) | 3.31 |
| Climate Zone 11 | $2,402 | $725 | ($1,677) | 3.31 |
| Climate Zone 12 | $2,384 | $725 | ($1,659) | 3.29 |
| Climate Zone 13 | $2,402 | $725 | ($1,677) | 3.31 |
| Climate Zone 14 | $2,407 | $725 | ($1,682) | 3.32 |
| Climate Zone 15 | $2,463 | $725 | ($1,738) | 3.40 |
| Climate Zone 16 | $2,332 | $725 | ($1,607) | 3.22 |

1. Relative to existing conditions. All cost values presented in 2017 dollars. Cost savings are calculated using 2016 TDV values.
2. Total benefit includes TDV energy cost savings, cost savings from equipment replacements, and incremental maintenance cost savings.
3. Total cost equals incremental first cost (equipment and installation).
4. Negative values indicate the measure is cost effective. Change in lifecycle cost equals cost minus benefit.
5. The Benefit to Cost ratio is the total benefit divided by the total incremental costs. The measure is cost effective if the B/C ratio is greater than 1.0.

# APPENDIX D: *INTENTIONALLY OMITTED*

# APPENDIX E: INSTRUCTIONS FOR USING THE LIFECYCLE COST ANALYSIS SPREADSHEET

The Microsoft Excel file used to perform the lifecycle cost (LCC) analysis that was based on model runs using CBECC-res version 3 software was submitted to CEC along with this CASE Report and entitled, "Residential IWH-LCC Spreadsheet-Appendix E or CASE Report.xlsx." The original CBECC data and assumptions for the LCC analysis are contained in this Excel file. On the "Inputs" worksheet users may modify certain assumptions on the equipment useful life, maintenance frequencies, and maintenance costs that were used in the CASE analysis to understand the impact of these factors on the LCC analysis. Any assumptions that users choose when modifying the LCC analysis should be reasonable and supported by data.