

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

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

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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 code change proposal would recommend that if gas is available, as defined, an applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH), a high efficiency gas storage water heater or a less efficient storage water heater in conjunction with a solar thermal system. The Report also recommends revisions to how natural gas availability is determined and offers clarification on which type of water heater should be used in the standard design when natural gas is not available. 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 which helps maintain efficient operation and prolongs the life of a gas IWH.

The report considers market availability and cost effectiveness¹ 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.

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

- Description of the code change proposal, the measure history, and existing standards (Section 2);

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

- 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, distributors, 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 current prescriptive requirements indicate that if natural gas is available,² 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 0.50.

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.

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 measure would modify the prescriptive requirements by specifying that if natural gas is available, the applicant can install one of three natural gas water heating systems: 1) a gas IWH that meets minimum federal efficiency levels, 2) a gas storage water heater that achieves the same or better energy performance as a gas IWH that meets federal minimum efficiency, or 3) a gas storage water heater that meets minimum federal efficiency requirements plus a solar hot water heating system that provides a solar fraction of at least 0.55. Each of these three options will result in approximately equivalent energy performance in every climate zone; they were modeled using CEC's approved public domain modeling software program, CBECC-Residential, Version 3 (see Appendix D for projected savings of proposed prescriptive options). That said, the proposed code change would specify that if gas is available, the water heating energy budget will be calculated assuming a gas IWH will be installed, as this option (primary prescriptive option) is used to calculate the baseline energy use for applicants that wish to comply with the Standards using the performance approach.

The proposed prescriptive options if natural gas is available are (See Section 6 for proposed code language):

1. Install a gas IWH meeting minimum federal efficiency levels (*Primary Path, used to calculate baseline energy budget for performance approach*); or
2. Install a gas storage water heater meeting minimum federal efficiency level plus a solar fraction of 0.55 in Climate Zones 1-14, 16 and solar fraction of 0.70 in Climate Zone 15; or
3. Install a gas storage water heater that performs as well or better than a gas IWH that meets the minimum federal efficiency level.

The proposed code change does not modify the prescriptive requirements if gas is not available. That is, if gas is not available, an applicant can comply with the Standards 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.

The 2013 Residential Alternative Calculation Method (ACM) Reference Manual contains contradicting information about which type of water heating system to use as the standard design case (base case) if natural gas is not available. Section 2.2.10 specifies that propane water heating should be used if natural gas is not available, but Section 2.10 specifies that an electric storage water heater should be used if natural gas is not available. The proposed code change aims to address this ambiguity by clarifying that a propane water heater be used in the standard design case if natural gas is not available.

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

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

In addition to the changes to the prescriptive requirements, the Statewide CASE Team has recommended revisions to how “gas availability” is defined, and how one determines “gas availability” for code compliance (See Section 6).

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.

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
- Table 9: Sections of ACM 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 0 of this report. This section proposes modifications to language with additions identified with underlined 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 analysis³ 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

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

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.
- **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

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

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 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

	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 code change, 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 Summary¹ per Building

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings (2017 PV \$) ¹	Cost: Total Incremental Cost (2017 PV \$)	Change in Lifecycle Cost ² (2017 PV \$)	Benefit to Cost Ratio ³
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.

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 Emissions¹ (MTCO₂e/yr)
Proposed Measure	14,647
TOTAL	14,647

¹. First year savings from buildings built in 2017; assumes 353 MTCO₂e/GWh and 5,303 MTCO₂e/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 if gas is available, as defined, an applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH), a high efficiency gas storage water heater or a less efficient storage water heater in conjunction with a solar thermal system. This CASE Report also recommends revisions to how natural gas availability is determined and offers clarification on which type of water heater should be used in the standard design when natural gas is not available. 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.

The report considers market availability and cost effectiveness⁵ 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 current 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 measure would modify the prescriptive requirements by specifying that if natural gas is available, the applicant can install one of three natural gas water heating systems: 1) a gas IWH that meets minimum federal efficiency levels, 2) a gas storage water heater that achieves the same or better energy performance as a gas IWH that meets federal minimum efficiency, or 3) a gas storage water heater that meets minimum federal efficiency requirements plus a solar hot water heating system that provides a solar fraction of at least 0.55. Each of these three options will result in approximately equivalent energy performance in every climate zone; they were modeled using CEC's approved public domain modeling software program, CBECC-Residential, Version 3 (see Appendix D for projected savings of proposed prescriptive options). That said, the proposed code change would specify that if gas is available, the water heating energy budget will be calculated assuming a gas IWH will be installed, as this option (primary prescriptive option) is used to calculate the baseline energy use for applicants that wish to comply with the Standards using the performance approach.

The proposed prescriptive options if natural gas is available are (See Section 6 for proposed code language):

1. Install a gas IWH meeting minimum federal efficiency levels (*Primary Path, used to calculate baseline energy budget for performance approach*); or
2. Install a gas storage water heater meeting minimum federal efficiency level plus a solar fraction of 0.55 in Climate Zones 1-14, 16 and solar fraction of 0.70 in Climate Zone 15; or
3. Install a gas storage water heater that performs as well or better than a gas IWH that meets the minimum federal efficiency level.

The proposed code change does not modify the prescriptive requirements if gas is not available. That is, if gas is not available, an applicant can comply with the Standards 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.

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.

The 2013 Residential Alternative Calculation Method (ACM) Reference Manual contains contradicting information about which type of water heating system to use as the standard design case (basecase) if natural gas is not available. Section 2.2.10 specifies that propane water heating should be used if natural gas is not available, but Section 2.10 specifies that an electric storage water heater should be used if natural gas is not available. The proposed code change aims to address this ambiguity by clarifying that a propane water heater be used in the standard design case if natural gas is not available.

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

In addition to the changes to the prescriptive requirements, the Statewide CASE Team has recommended revisions to how “gas availability” is defined, and how one determines “gas availability” for code compliance (See Section 6).

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.

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 2011). 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 current 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) has 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	$0.675 - (0.0015 * V_s)$
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.

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 0 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 proposed code change will modify Sections 2.2.10 and 2.10 of the Residential ACM Reference Manual (see Table 9).

Table 9: Sections of ACM Impacted by Proposed Code Change

Residential Alternative Calculation Method Reference		
Section Number	Section Title	Modify Existing (E) New Section (N)
2.2.10	Natural Gas Availability	E
2.10	Domestic Hot Water (DHW), <i>Standard Design</i>	E

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 if natural gas is available, the applicant can install one of three gas water heaters: 1) a gas IWH that meets minimum federal efficiency levels, 2) a gas storage water heater that meets federal efficiency

requirements in conjunction with a solar hot water heating system that provides a solar fraction of 0.55 (Climate Zones 1-14, 16) and 0.70 (Climate Zone 15), or 3) a gas storage water heater that achieves the same or better energy performance than a gas IWH. The proposed code change does not modify the prescriptive requirements if natural gas is not available. In other words, if gas is not available, an applicant can still comply with the Standards 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.

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

Subsection 150.2(b)1G: The code language will be updated to clarify that natural gas availability is determined by the natural gas utility, and to clarify that a solar water heating system does not need to be installed 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

This proposal will modify Sections 2.2.10 and 2.10 of the Residential ACM Reference Manual. See Section 6.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

Section 2.2.10 – Natural Gas Availability: The language in Section 2.2.10 would be revised to clarify how “natural gas availability” is determined.

Section 2.10 - Domestic Hot Water (DHW): The proposed code change would revise the standard design requirement described in the Residential ACM Reference Manual to ensure that when natural gas is available, a gas IWH that complies with the minimum federal efficiency requirements will be used to establish the baseline water heating energy budget.

This CASE Report does not include recommendations for the CEC to modify the calculation methods in response to changes to DOE’s test procedure. However, the CEC might consider revising sections of Appendix E to the Residential ACM Reference Manual that describe 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.

2.2.5 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. No changes to the compliance forms for domestic water heating are needed as a result of this proposed code change. Since there are no changes to compliance determination, the Statewide CASE Team anticipates that verifying code compliance will be relatively easy.

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 measure, as the proposed code change pertains to the water heater unit and not the water heating system design. Furthermore, the proposed measure does not need Home Energy Rating System (HERS) verification, which does require field verification.

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 has recommended a clear method for determining if natural gas is available (see Section 6).

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 Alternative

On a related note, some stakeholders requested the addition of heat pump water heaters (HPWH) as a prescriptive alternative 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.

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 1). Builders and plumbers can also purchase water heaters from retailers, such as the three mentioned above.

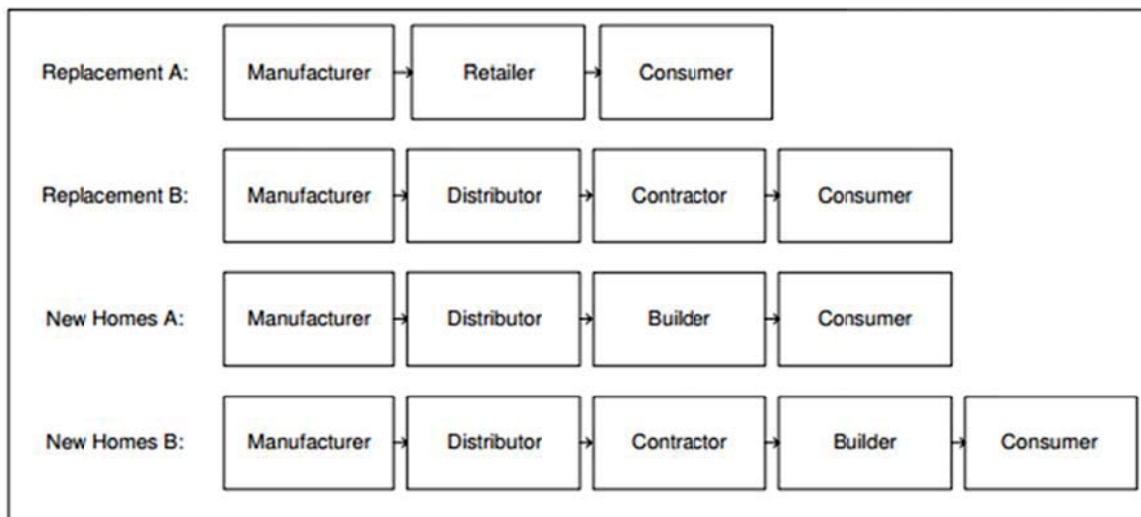


Figure 1: Residential Water Heater Distribution Channels

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 manufacture several unique brands of water heaters (see Figure 2 and Table 10). 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).

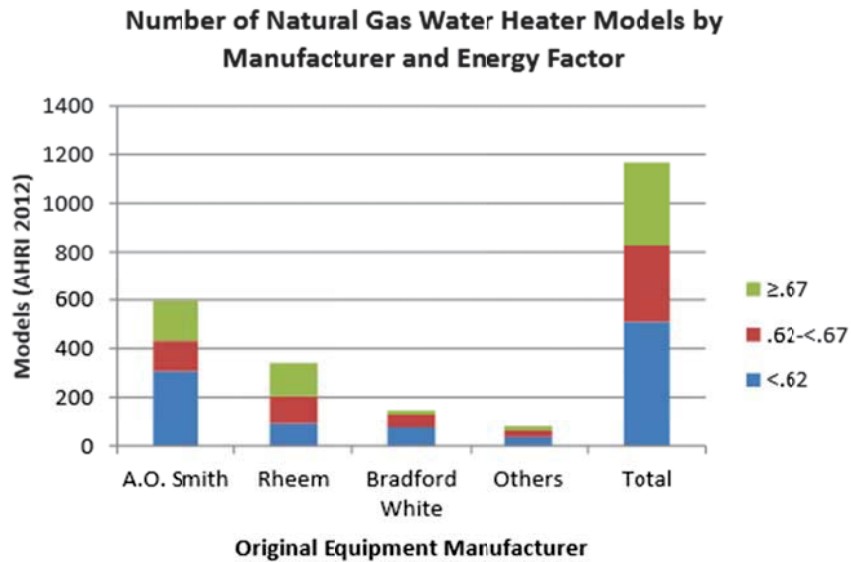


Figure 2: Natural Gas Water Heater Models by Manufacturer and Energy Factors

Source: PG&E 2012

Table 10: 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) Americana (IWH) American Water Heater Co. (IWH and Storage) Apollo (Storage) Garrison (Storage) GSW (Storage) Lochinvar Corp. (Storage) Maytag (Storage) Kenmore (IWH) Powerflex (Storage) Reliance (IWH and Storage) Sears Brand (IWH and Storage) State Industries (IWH and Storage) Takagi (IWH) U.S. Craftsman (IWH and Storage) Whirlpool (Storage)
Rheem*	EcoSense (IWH) General Electric (Storage) Paloma/Waiwela (IWH) Raypack (IWH) Rheem (IWH and Storage)

	Richmond (IWH and Storage) Ruud (IWH and Storage) Sure Comfort (IWH) Vanguard (Storage)
Bradford White Corporation*	Bradford White (IWH and Storage) Lochinvar Corp. (Storage)
Rinnai	Giant (IWH) Jacuzzi Luxury Bath - Signature (IWH) Rinnai (IWH)
American Standard	Dura-Glass (Storage)
Navien	Navien (IWH)
Quietside	Quietside (IWH)
Bosch Thermotechnology Group	Bosch (IWH) Aquastar (IWH) Pro Tankless (IWH) 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) Propak TM (IWH)
Noritz America Corp.	Electrolux Home Products (IWH) Noritz America Corp. (IWH)
Water Heater Innovations	Marathon (Storage) 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 primary prescriptive path 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.

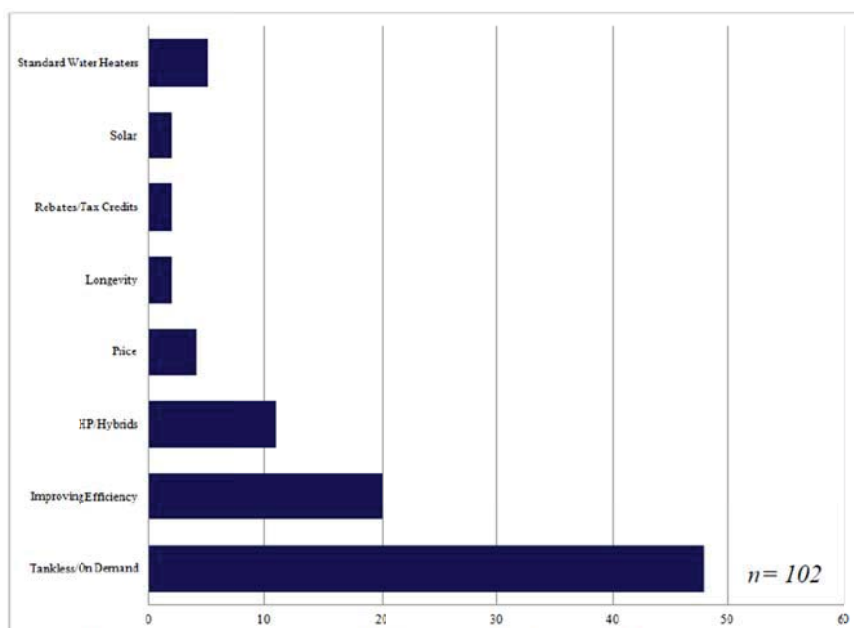
On a national level, sales and shipment data provide evidence that IWHs are growing in market share. For example, ENERGY STAR[®] certified gas IWHs⁷ have seen a 15% increase in the number of units shipped in recent years: there were 337,186 shipments in 2011 (ENERGY STAR 2012) and 397,000 shipments in 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 3. 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.

⁷ The minimum EF rating for ENERGY STAR Qualified IWHs is 0.82.



SR16. What do you perceive are the latest trends in water heating products?

Figure 3: 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 2011). 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

Table 11 lists the expected useful life of storage water heaters and IWHs as reported by numerous reputable sources. IWHs are commonly cited as having a useful life of 20 years. The lifespan of storage water heaters ranges between 5 and 13 years according to the same sources. Based on the range of product lifetimes for IWH 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 3.2.2 for water heater maintenance.

The Statewide CASE Team used DOE's estimates of useful life in the LCC analysis (13 years for storage water heaters and 20 years for IWH). 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. Therefore, the Statewide CASE Team used DOE's estimates since they were vetted through DOE's diligent process.

Table 11: 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

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 1 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	Flushing heat exchanger	Every 2-4 years ¹	Statewide plumbing company
	Inspection of burner, relief valve, air intake filter, water filter, and venting system	Annually	Rheem; Bradford White; A.O. Smith
Storage	Draining storage tank	1-2 times per year	Bradford White; Statewide plumbing company
	Inspection of the anode rode every two years	Every two years, or more frequently in areas with soft water	Bradford White; 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 4, 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.⁸ 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 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).

⁸ 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).



Figure 4: 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 annually. As previously noted, one manufacturer recommends draining a gallon of water from the tank every month to remove sediment that may build up during operation. Another manufacturer recommends draining the whole tank every 6 months and others recommend doing so on an annual basis. Some manufacturers also recommend that yearly inspections be conducted by a qualified service technician (see Figure 5).⁹

⁹ 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.



Figure 5: 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 the 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. The anode rod is a straight 3-foot piece of piping and could require a complete removal of the tank from its location in order to reinstall a new anode rod. This procedure would triple the cost if the water heater is not set up to enable easy access to the anode (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 causing the need for a replacement of the entire unit.

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.¹⁰ 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),¹¹ 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

¹⁰ 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.

¹¹ GSP is the sum of all value added by industries within the state plus taxes on production and imports.

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 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 13 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).¹² 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.

¹² 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 13: 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 retraining 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.¹³

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

¹³ 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 primary prescriptive path (prescriptive baseline), which is used to calculate the energy budget if natural gas is available, 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 0 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 14 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 14. 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 14: 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 3.¹⁴ 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.)

¹⁴ 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° 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 15 lists the key inputs used in calculating the per unit energy impact of the proposed measure.

Table 15: Key Assumptions for Per Unit Energy Impacts Analysis

Parameter	Assumption	Source
Conditioned Floor Area of Prototype Building (percent weighted)	<ul style="list-style-type: none"> 2,100 square feet (45%) 2,700 square feet (55%) 	CEC
Daily hot water use	<ul style="list-style-type: none"> 35.7 gallons (2,100 SF) 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)	<ul style="list-style-type: none"> 40-gallon volume Federal minimum efficiency level in 2015 (0.62 EF) Input Rating 40,000 Btu/hr Recovery Efficiency 70% 	AHRI 2014 2013 Residential ACM Reference Manual, Appendix E
Gas IWH (measure case)	<ul style="list-style-type: none"> 0-gallon volume Federal minimum efficiency level in 2015 (0.82 EF) Input Rating: 190,000 Btu/hr Annual electricity use: 57 kWh/yr 	2013 Residential ACM Reference Manual, Appendix E 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 16.

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 17. 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 apply 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 16: Translation from Forecast Climate Zones to Building Climate Zones

Source: CEC Demand Analysis Office

		Building Standards Climate Zones (BCZ)																Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Forecast Climate Zones (FCZ)	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%	13.04%	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 17: Projected New Residential Construction in 2017 by Climate Zone¹

Building Climate Zone	Single Family Starts	Multifamily Starts²
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

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:

- 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 the gas water heater in the 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 IWH 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 18 below.

Table 18: 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 19.

Table 19: 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	
<i>Subtotal</i>	<i>\$946</i>		
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 11 in this report.
Number of Replacements Installations Over 30 Years	2		Based on Equipment Useful Life. Replacements occur in years 13 and 26.
<i>Subtotal</i>	<i>\$1,150</i>		Replacements costs over 30-year period of analysis.
Maintenance Cost			
Per Event Maintenance Cost	\$144	Interviews with California Plumbers	Average cost to drain water heater provided by three California plumbing companies (See Table 20)

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 11 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 Equipment Cost ¹	\$655	United States Department of Energy 2010 Final Rule: Chapter 8	Inflation adjusted to 2014 dollars.

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 20 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 20: Maintenance and Repair Costs

	Activity	Cost Range ¹	Recommended Frequency
Storage	Draining tank by professional plumber	\$189 \$127 \$120	Yearly Yearly Yearly
	Draining tank by homeowner	\$0	Manufacturer recommendations range between monthly and yearly.
	Replacing anode rod by professional plumber	\$200 - \$600	As needed --
IWH	Flushing heat exchanger and cleaning filter by professional plumber	\$185 \$200 \$225	Yearly 1.5 – 2 years 3-4 years (good water quality)
	Flush kit for flushing of heat exchanger by homeowner	\$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 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.

4.7.2 Cost Savings Methodology

Energy Cost Savings Methodology

The present value of the energy savings was calculated using the method described in the LCC Methodology (CEC 2011). In summation, 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.

4.7.3 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 (MTCO₂e) 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 MTCO₂e/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 21. 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 21: First Year¹ Energy Impacts per Building

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.

5.1.2 Statewide Energy Impacts Results

First Year Statewide Energy Impacts

The statewide energy impacts of the proposed measure are presented in Table 22. 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 22: First Year¹ Statewide Energy Impacts

	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.

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 23. 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 23: Incremental Cost of Proposed Measure¹

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; ΔCI_C .

^{3.} Initial construction cost using estimated prices after adoption; ΔCI_{PA} .

^{4.} Present value of maintenance costs over 30 year period of analysis; ΔCM .

^{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 IWH 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 cost 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 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.

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 24. 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 24: TDV Energy Cost Savings Over 30-Year Period of Analysis - Per Building

Climate Zone	Total TDV Energy Cost Savings (2017 PV \$)
Climate Zone 1	\$1,259
Climate Zone 2	\$1,297
Climate Zone 3	\$1,296
Climate Zone 4	\$1,312
Climate Zone 5	\$1,285
Climate Zone 6	\$1,324
Climate Zone 7	\$1,304
Climate Zone 8	\$1,335
Climate Zone 9	\$1,339
Climate Zone 10	\$1,341
Climate Zone 11	\$1,339
Climate Zone 12	\$1,321
Climate Zone 13	\$1,341
Climate Zone 14	\$1,345
Climate Zone 15	\$1,392
Climate Zone 16	\$1,279

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.

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.

The results of the per building Cost-effectiveness Analysis are presented in Table 25. 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.

Table 25: Cost-effectiveness Summary per Building¹

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
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.

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.

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 26 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 MTCO₂e.

Table 26: First Year Statewide Greenhouse Gas Emissions Impacts

	Avoided GHG Emissions¹ (MTCO₂e/yr)
Proposed Measure	14,647
TOTAL	14,647

^{1.} First year savings from buildings built in 2017; assumes 353 MTCO₂e/GWh and 5,303 MTCO₂e/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).¹⁵ 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

¹⁵ $2.09/1.40 \times (1-0.23) = 1.15$

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).¹⁶

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 27).

¹⁶ 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 27: Impacts of Water Use and Water Quality

	On-Site Water Savings¹ (gallons/yr)	Embedded Energy Savings² (kWh/yr)	Impact on Water Quality 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 ~~striketroughs~~ 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

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:

... {Code language that does not pertain to the proposed measure omitted} ...

8. Domestic Water-Heating Systems. Water-heating systems shall meet the requirements of either A, B, ~~or C, 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 150.0(j) 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 unit, the water heating system shall meet the requirements of either i, ii, or iii:

- 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 75,000 Btu per hour or less, and that meets the tank insulation requirements of Section 150.0(j) and the requirements of Sections 110.1 and 110.3 may be installed as the main water heating source only if the water heater is located within the building envelope, a solar water-heating system meeting the installation criteria specified in the Reference Residential Appendix RA4 and with a minimum solar savings fraction of 0.55 for Climate Zones 1-14 and 16 is installed. A minimum solar savings fraction of 0.70 is required for Climate Zone 15. The solar savings fraction shall be determined using a calculation method approved by the Commission.

- iii. A single gas or propane storage type water heater with an input of 75,000 Btu per hour or less, that meets the tank insulation requirements of Section 150.0j, and meets or exceeds the minimum federal efficiency level stated in 75 FR 20112 for a non-condensing gas instantaneous water heater shall be installed.

€ 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.

- Đ. C. 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 as determined by the natural gas utility, 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 approved by the Commission. Recirculation pumps shall not be used.

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

... {Code language that does not pertain to the proposed measure omitted} ...

(b) Alterations

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

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. For storage type water heaters the capacity shall not exceed 60 gallons. A natural gas or propane water heating system that meets the requirements of 150.1(e)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): 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

Chapter 2 of the Residential ACM Reference Manual will need to be revised. See proposed changes below.

Section 2.2.10 Natural Gas Availability

The natural gas utility is responsible for determining if natural gas is available at the site. If the natural gas utility has determined that extension of natural gas service is impractical and that natural gas is not available at the site, the user can specify whether natural

gas is not available at the site. This is used to establish the TDV values from Reference Appendices JA3 used by the compliance software in determining standard and proposed design energy use.

PROPOSED DESIGN

The user specifies whether natural gas is available at the site. User can only specify that natural gas is not available if the natural gas utility has made the initial determination.

STANDARD DESIGN

The standard design has natural gas space and water heating if natural gas is available at the site; otherwise it is propane.

VERIFICATION AND REPORTING

Whether natural gas is or is not available is reported on the CF1R.

Section 2.10 Domestic Hot Water (DHW)

STANDARD DESIGN

Individual dwelling units: The standard design is based on §150.1c)8. For single-family dwellings or dwelling units served by a dedicated water heating system, each dwelling unit has one ~~small storage < 75000 Btu), 50-gallon gas storage~~ instantaneous water heater, meeting minimum federal ~~energy efficiency as stated in 75 FR 20112 Energy Factor standards 0.575 in 2014, 0.60 in 2015)~~ Energy Factor standards 0.904 in 2014, (0.945 in 2015) if natural gas is not available, as determined by natural gas utility. The distribution type is either standard or, if a recirculating system is shown in the proposed design, a recirculating system with manual controls.

6.4 Compliance Manuals

Chapter 5 of the Residential Compliance Manual will need to be revised. See proposed changes below.

5.2.2 Mandatory Requirements for Water Heaters

§110.3(c)

Instantaneous water heaters with an input rating more 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.

5. Isolation Valves

§150.0(n)

Instantaneous water heaters with an input rating more than 6.8 kBTU/hr (2 kW) shall meet the requirements of §110.3(c).

5.4 Prescriptive Water Heater and Distribution System Requirements

5.4.1 Single Dwelling Units

150.1c) 8

The ~~conventional~~ approach ~~to~~ for meeting the prescriptive requirements of ~~Package option Ai~~ for systems serving individual dwelling units, ~~is that the system would be designed to use either a small storage or a gas instantaneous gas water heater as~~ prescribed in the water heater Section 5.1. The distribution type options for a complying system would include either a conventional trunk and branch system or an on-demand recirculation system with manual controls. Both distribution systems must meet all of the mandatory requirements previously mentioned in this chapter. Other distribution system types do not meet the prescriptive requirement.

The other option under the prescriptive compliance method is to use the performance method for water heating only as defined in §150.1b)1 and which is discussed in full in the performance compliance section later in this chapter. This path requires inputting the building square footage and detailing the water heater and distribution system information into the building performance compliance tool.

§150.1c) 8

With the changes in the ~~2013~~ 2016 standards there are actually ~~three~~ four prescriptive options for domestic hot water heating in single family residences depending upon whether natural gas service is available at the site.

~~1. A system with a single gas or propane storage type water heater must have:~~

~~a) A gas input rating $< 75,000$ Btu/h,~~

~~b) If the water heater's efficiency only meets the minimum federal efficiency standards, the tank must be wrapped with an R-12 water heating blanket [a mandatory requirement in §150.0j)1].~~

~~c) If the system uses a trunk and branch distribution system then all pipes from the water heater to the kitchen must be insulated and all pipe with a diameter equal to or greater than $\frac{3}{4}$ of an inch must be insulated.~~

~~d) If this system has a recirculation pump then the control must be demand based with manual controls pump only runs upon user direct activation until water temperature equals temperature setpoint). All portions of the distribution system that recirculate water must be insulated.~~

~~e) All applicable mandatory requirements in Section 110.3 and 150.0j,n) must be met~~

2-1. A system with a single gas or propane instantaneous water heater without a storage tank must have:

- a) A gas input rating < 200,000 Btu/h,
- b) No supplemental storage tank is installed,
- c) Uses a trunk and branch distribution system then all pipes from the water heater to the kitchen must be insulated and all pipes with a diameter equal to or greater than $\frac{3}{4}$ of an inch must be insulated.
- d) All applicable mandatory requirements in Section 110.3 and 150.0j,n) must be met
- e) If this system has a recirculation pump then the control must be demand based with manual controls pump only runs upon user direct activation until water temperature equals temperature setpoint). All portions of the distribution system that recirculate water must be insulated.

3-2. A system with a single gas or propane storage type water heater must have:

- a) A gas input rating < 75,000 Btu/h,
- b) If the water heater's efficiency only meets the minimum federal efficiency standards, the tank must be wrapped with an R-12 water heating blanket [a mandatory requirement in §150.0j)1].
- c) If the system uses a trunk and branch distribution system then all pipes from the water heater to the kitchen must be insulated and all pipe with a diameter equal to or greater than $\frac{3}{4}$ of an inch must be insulated.
- d) If this system has a recirculation pump then the control must be demand based with manual controls pump only runs upon user direct activation until water temperature equals temperature setpoint). All portions of the distribution system that recirculate water must be insulated.
- e) All applicable mandatory requirements in Section 110.3 and 150.0j,n) must be met
- f) Must be installed with a solar water heating system at a solar savings fraction of
 - i. 0.55 for Climate Zones 1-14, and 16, and
 - ii. 0.70 for Climate Zone 15

and installed as specified in the Reference Residential Appendix RA4. The details of the solar water heating prescriptive requirements are in described in more detail in Section 5.6.1 later on in this chapter.

3. A system with a single gas or propane storage type water heater must have:

- a) A gas input rating < 75,000 Btu/h.
- b) Meet or exceed the minimum federal efficiency standard of a non-condensing gas instantaneous water heater as stated in 75 FR 20112.
- c) If the system uses a trunk and branch distribution system then all pipes from the water heater to the kitchen must be insulated and all pipe with a diameter equal to or greater than ¾ of an inch must be insulated.
- d) If this system has a recirculation pump then the control must be demand based with manual controls pump only runs upon user direct activation until water temperature equals temperature setpoint). All portions of the distribution system that recirculate water must be insulated.
- g) All applicable mandatory requirements in Section 110.3 and 150.0j,n) must be met

~~3.~~ 4. An electric resistance storage or instantaneous water heater can be used if all of the following conditions are met:

- a) Natural gas is unavailable at the site, as determined by the natural gas utility
- b) The water heater is located within the building envelope
- c) For storage electric and instantaneous a trunk and branch distribution system must have all pipes from the water heater to the kitchen and must be insulated and all pipes with a diameter equal to or greater than ¾ of an inch must be insulated.
- d) All applicable mandatory requirements in Section 110.3 and 150.0 must be met
- e) A solar water heater is installed which is designed to provide a solar fraction of 50% (provides 50% of the heating load) and is installed as specified in the Reference Residential Appendix RA4. The details of the solar water heating prescriptive requirements are in described in more detail in Section 5.6.1 later on in this chapter.
- e) No supplemental storage tank is installed
- g) No recirculation system can be installed with electric instantaneous water heaters.

If a water heater is installed in combination with a booster heater used to either eliminate cold surges when an instantaneous water heater is the primary system, or used to reheat water in a portion of the system the booster heater must be included in compliance. All booster heaters must be treated as separate electric instantaneous water heaters. To comply, performance compliance must be used to demonstrate the installed system uses no more energy than what is allowed under the standards.

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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 (MTCO₂e) 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.¹⁷

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 MTCO₂e/million therms (U.S. EPA 2011).

¹⁷ 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 28 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 28: 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. 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 15.

Table 29: First Year¹ 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 30: First Year¹ 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 31: 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 32: 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 33: 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 34: 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 35: 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 36: Cost-effectiveness Summary¹ for Prototype Building 1 (CFA=2,100 SF)

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings² (2017 PV \$)	Cost: Total Incremental Cost³ (2017 PV \$)	Change in Lifecycle Cost⁴ (2017 PV \$)	Benefit to Cost Ratio⁵
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 37: Cost-effectiveness Summary¹ for Prototype Building 2 (CFA=2,700 SF)

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings² (2017 PV \$)	Cost: Total Incremental Cost³ (2017 PV \$)	Change in Lifecycle Cost⁴ (2017 PV \$)	Benefit to Cost Ratio⁵
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: PROJECTED PER UNIT TDV ENERGY SAVINGS FOR PRESCRIPTIVE PRIMARY AND ALTERNATIVE OPTIONS

Table 38 below lists the projected TDV energy savings for the proposed primary prescriptive option, which is a gas IWH that meets the minimum federal energy efficiency level, and the proposed alternative prescriptive option, which is the installation of a gas storage water heater that meets the minimum federal energy efficiency level and a solar hot water system with a solar savings fraction of 0.55 in climates zones 1-14 and 16, and 0.70 in climate zone 15. The prescriptive alternative option was selected based on energy performance (TDV results) using CEC's approved public domain modeling software program for Title 24 compliance, CBECC-Residential, Version 3.

The projected savings for prescriptive alternative option two, which allows the installation of a gas storage water heater that meets or exceeds the energy performance of a gas IWH that meets the minimum federal efficiency level, are not included in this table because the projected savings would be similar to the energy savings estimates for the primary prescriptive option.

Table 38: Projected Per Unit TDV Energy Savings for the Primary Prescriptive and Alternative Prescriptive Options for Weighted Average of 2,100 SF and 2,700 SF Prototype Buildings

Climate Zone	Per Unit TDV Energy Savings of Primary Prescriptive (Gas IWH) (kTDV)	Per Unit TDV Energy Savings of Prescriptive Alternative Option One (Minimally Compliant Storage + Solar Savings Fraction of 0.55) (kTDV)
Climate Zone 1	7,271	9,320
Climate Zone 2	7,490	8,699
Climate Zone 3	7,480	8,714
Climate Zone 4	7,578	8,486
Climate Zone 5	7,417	8,845
Climate Zone 6	7,645	8,258
Climate Zone 7	7,529	8,035
Climate Zone 8	7,709	8,035
Climate Zone 9	7,733	8,060
Climate Zone 10	7,742	8,011
Climate Zone 11	7,733	8,132
Climate Zone 12	7,626	8,346
Climate Zone 13	7,742	8,011
Climate Zone 14	7,767	8,239
Climate Zone 15 ¹	8,039	8,458
Climate Zone 16	7,387	9,403

¹ A solar savings fraction of 0.70 would be required for climate zone 15 if a minimally compliant gas storage water heater is installed in residential new construction or additions.

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.