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Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Compact Hot Water Distribution – Final Report

Measure Number**:** 2019-RES-DHW1-F

Residential Plumbing

July 2017

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Authors:	Marc Hoeschele and Peter Grant (Davis Energy Group)
Project Management:	California Utilities Statewide Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, SoCalGas®, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District

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EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) 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 SoCalGas®– and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

Measure Description

The Compact Hot Water Distribution proposal is intended to provide builders a compliance option credit for designing residential buildings with hot water use fixtures located close to the water heater, saving both energy and water. A compliance option represents a voluntary measure available to builders to help meet or exceed the performance level defined by the Standard Design. The measure is intended to apply only to single family homes and low-rise multifamily apartments where each dwelling unit is served by a dedicated water heater. As a compliance option, it is a voluntary measure rewarding builders who wish to pursue the credit. The proposed measure is for new construction only.

The Compact Hot Water Distribution measure currently exists in 2016 Title 24, Part 6. The 2016 measure involves a Home Energy Rating System (HERS) verification process to demonstrate that the measured length of the hot water supply line from the water heater to the furthest fixture is less than a maximum specified pipe length, which varies with the conditioned floor area of the dwelling unit. Recent CalCERTS registry data collected over a 16-month period showed that only 0.1 percent of homes used this credit, and feedback from builders indicated the low uptake was due to the credit being not worth the added effort of an extra HERS verification effort. The proposed 2019 update is intended to provide added compliance flexibility to the measure by offering two compact credit options:

1. a Basic Credit option that eliminates any HERS verification requirement, and
2. an Expanded Credit option offering greater energy credits, but does require limited HERS verification.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Standards, References Appendices, and compliance documents that will be modified as a result of the proposed change. The measure will impact new construction only.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document (s)
Compact Hot Water Distribution	Performance Compliance Option	N/A	Residential Appendices RA3.6.5 and RA4.4.16 will need to be modified	Yes. Current compact distribution modeling method will be changed and the Residential Alternative Calculation Method Reference Manual will need to be updated	Existing documents will need to be modified: CF2R-PLB-22H and CF3R-PLB-22H

Market Analysis and Regulatory Impact Assessment

As a proposed compliance option, this measure is voluntary and does not require a cost-effectiveness assessment. The proposal offers value to California consumers by saving water as well as energy, leaving more money available for discretionary and investment purposes.

The proposed changes to Title 24, Part 6 have a negligible impact on the complexity of the standards or the cost of enforcement. When developing this compliance option proposal, the Statewide CASE Team interviewed building officials, Title 24 energy analysts and others involved in the code compliance process to simplify and streamline the compliance and enforcement aspects of this proposal.

Cost-Effectiveness

Determination of cost-effectiveness is not required for compliance option measures.

Statewide Energy Impacts

Table 2 shows the estimated energy and water savings over the first twelve months of implementation of the proposed compliance option. The projected savings are based on the assumption that ten percent of new homes will choose the compliance option. As a compliance option, the Compact Hot Water Distribution System (CHWDS) measure will likely be used to offset other energy impacts associated with the proposed building design, and therefore the projected first-year gas savings are shown as zero. If the measure was used to exceed the standards, first-year gas savings of 0.063 million therms/yr are projected. Water savings of 12.95 million gallons/yr will be realized with this measure and the assumed ten percent market share of new dwellings. See Section 6 for more details.

Table 2: Estimated Statewide First-Year[a] Energy and Water Savings

Measure	First-Year Electricity Savings (GWh/yr)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Water Savings (million gallons/yr)	First-Year Natural Gas Savings (million therms/yr)
New Construction	0.0	0.0	12.95	0.0
Additions	N/A	N/A	N/A	N/A
Alterations	N/A	N/A	N/A	N/A
TOTAL	**0.0**	**0.0**	**12.95**	**0.0**

a. First-year savings from all buildings completed statewide in 2020.

Compliance and Enforcement

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process will have on various market actors. The compliance process is described in Section 2.5. The impacts the proposed measure will have on various market actors is described in Section 3.3 and Appendix C. The key issues related to compliance and enforcement are summarized below:

- Builders and designers pursuing the compact design compliance option would need to evaluate plans for architectural design and water heater location to determine if they would comply with this voluntary compliance option measure.
- Plan checkers would need to review the plans to determine if the project complies with the compact design requirements. This represents a new step in the plan check process, but the Statewide CASE Team finds that the added plan review effort in determining compliance with the compact eligibility criteria is minimal.
- For the proposed Basic Credit, no further verification is needed. If an Expanded Credit with larger savings is desired, a HERS inspection is required to verify fairly simple eligibility criteria are met. To ensure compliance with the eligibility criteria, communication between the design team and the plumber is critical.

Although a needs analysis has been conducted with the affected market actors while developing the code change proposal, the code requirements may change between the time the final CASE Report is submitted and the time the 2019 Standards are adopted. The recommended compliance process and compliance documentation may also evolve with the code language. To effectively implement the adopted code requirements, a plan should be developed that identifies potential barriers to compliance when rolling-out the code change and approaches that should be deployed to minimize the barriers.

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) 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 SoCalGas® and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical information for a proposed compliance option on building energy efficient design practices and technologies. This proposed code change does not require a cost-effectiveness analysis.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

The overall goal of this CASE Report is to propose a code change proposal for Compact Hot Water Distribution Systems (CHWDS) in new single family homes. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshops that the Statewide CASE Team held on October 26, 2016 and March 23, 2017, as well as additional comments from stakeholders during the CASE development process.

Section 2 of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this change is accomplished in the various sections and documents that make up the Title 24, Part 6.

Section 3 presents the market analysis, including a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards such as fire, seismic, and other safety standards and whether technical, compliance, or enforceability challenges exist.

Section 4 presents the per-unit energy, demand, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy, demand, and energy cost savings.

Section 5 normally presents the lifecycle cost and cost-effectiveness analysis, but since this is a compliance option, a cost-effectiveness analysis is not required to implement the proposed code change.

Section 6 presents the statewide energy savings and environmental impacts of the proposed code change for the first-year after the 2019 Standards take effect. This includes the amount of energy that will be saved by California building owners and tenants, and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also considered.

Section 7 concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (additions) language for the Standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.

2. MEASURE DESCRIPTION

2.1 Measure Overview

This proposed measure would modify the CHWDS compliance option that exists under 2016 Title 24, Part 6 to improve acceptance by the building industry. The measure is intended to apply to new single family residential buildings and low-rise multifamily apartments where each dwelling unit is served by a dedicated water heater. The proposed changes to the compact design measure include both changes to the eligibility criteria and to how the potential credit is implemented in the Alternative Calculation Method (ACM). The 2016 version of the CHWDS credit requires a physical measurement by a Home Energy Rating System (HERS) rater confirming that the longest pipe run from the water heater to the furthest hot water end use point in the building is shorter than a maximum length. If compliance was field verified by the HERS Rater, the ACM would assume a reduction in the hot water distribution losses and a resulting compliance credit.

In comparison, the proposed 2019 compliance option would offer two pathways. The Basic Credit would require only plan view measurements and an algebraic calculation to demonstrate that the installed system meets the CHWDS qualification criteria. No HERS verification would be required for the Basic Credit. A second Expanded Credit option would include additional eligibility criteria and a greater compliance credit, but would require a HERS verification element. However, the proposed inspection requirements are designed to be considerably less time consuming than the current inspection criteria. The Expanded Credit compliance impact would increase relative to the Basic Credit, depending on the relative level of plumbing system compactness (how close the water heater is to the fixtures).

2.2 Measure History

Inefficient hot water distribution systems have been recognized as a problem for many years as they result in energy and water waste, and result in long hot water delay times that are the cause of a significant number of complaints by new home buyers. Recirculation systems are a solution to two of the three problems (water and wait time), but the thermal energy impact of different recirculation system options is highly variable and dependent on the recirculation plumbing design.

This distribution system problem exists for a variety of factors including:

- An outdated pipe sizing methodology in the plumbing code that results in oversized hot water distribution systems since the assumed fixture flow rates are much higher than current requirements.
- Municipalities with design recommendations that force plumbers and designers to assume low supply water pressure, resulting in larger distribution piping, which waste more water and energy.
- Increasing California efforts to conserve water has resulted in the realization of water savings due to improvements in showerhead and lavatory maximum flow rates; however, reduced flow rates often result in increased wait times if the hot water distribution system is not designed to accommodate lower flows.
- Increasing popularity of gas instantaneous water heaters, which offer improved operating efficiency, but can result in increased water waste when starting from a “cold start up” situation.

- Inefficient plumbing installations that are not focused on minimizing pipe lengths.

The proposed 2019 measure is a modification of the HERS verified CHWDS credit that was originally developed under the 2013 Title 24, Part 6 update and remained in place for the 2016 code cycle. The fundamental goal of the CHWDS credit is to reward building designs that bring the water heater in closer proximity to the hot water use points, reducing the likelihood of sprawling oversized distribution systems. To qualify for the 2016 credit, a HERS inspector must verify that the measured length of plumbing between the water heater and furthest hot water use point is shorter than a threshold value as shown in Table 3. If compliance is demonstrated, the distribution system performance metric (the distribution system multiplier or DSM) used in residential compliance software calculations is set at 0.7.[1] The DSM impacts only estimated distribution losses within the ACM, which amounts to roughly 15 percent of the annual usage of the prescriptive minimum efficiency instantaneous gas water heater for a typical 2,430 ft^2 California new home.

Table 3: CHWDS Pipe Length Threshold in 2016 ACM

Floor Area Served (ft^2)	Maximum Measured Water Heater to Use Point Distance (ft)
≤1000	28’
1001-1600	43’
1601-2200	53’
2201-2800	62’
> 2800	68’

Uptake of this measure over a recent 16-month time period was found to only be 0.1 percent of residential buildings according to data from the CalCERTS registry.[2] Anecdotal feedback from builders suggests that the credit was not significant enough in magnitude to justify the required HERS verification costs, as well as the uncertainty in knowing in advance if the plumbers’ installation met the maximum length criteria. The proposed 2019 measure is designed to create a simpler path to demonstrating compliance, resulting in increased adoption, and therefore a more easily attainable compliance credit.

The origins of the DSM implementation dates back to the advent of a more detailed hot water modeling methodology in Title 24, Part 6 as originally introduced in the mid-1990’s. Over the years, the modeling of distribution systems, which relies on very detailed and high resolution simulation models (Hoeschele, M.; Weitzel, E. 2012) to accurately model the interactions between hot water draws, plumbing materials, and pipes in different thermal environments, has improved and the impacts have been recognized in updates to the DSMs used in the ACM. The challenge has always been how to reasonably and accurately model distribution system performance within a simulation model environment where complex input parameter specification is beyond the scope of a compliance tool. More details on the water heating methodology can be found in the ACM (California Energy Commission 2015).

Under the 2016 Title 24, Part 6 code, the saturation of gas instantaneous water heaters in new homes is expected to increase with typical installation locations likely on exterior garage walls, resulting in

[1] The DSM compares the proposed distribution system to a “standard” trunk and branch distribution system which has a nominal DSM of 1.0. Better performing distribution systems have DSMs below 1.0 and worse performing would have a DSM greater than 1.0.

[2] Data from the registry during the period January 1, 2015 to April 30, 2016.

greater plumbing distances between the water heater and hot water use points. This, combined with instantaneous cold start delays[3] exacerbate water waste and homeowner wait times.

To address concerns with the current compact criteria and to bolster industry uptake of the measure, the Statewide CASE Team is proposing a simplified approach to verifying compliance with the compact credit. The credit aims to motivate builders to locate the water heater in a central location, thereby reducing occupant wait time for hot water, and associated energy use and water waste. The credit could be achieved through locating the water heater on the exterior wall of the house (close to key use points), centrally in the attic, or in a garage location in closer proximity to the fixtures. While these possibilities are available, builders have expressed a strong preference to locate the water heater in the garage. The following analysis generically uses the term "centrally located in the garage" to describe the basic approach of bringing the water heater in close proximity to use points.

The proposal is based on two levels of credit: Basic and Expanded. The Basic Credit would consist of a plan view check without any HERS verification, significantly reducing the effort required to demonstrate compliance. Alternatively, builders can earn an Expanded Credit by meeting more rigorous criteria, including simple HERS verification steps. The magnitude of the Expanded Credit increases savings, depending upon the level of compactness of the plumbing design. The following sections provide an overview of the method for determining compliance with the Basic and Expanded Credit and background information used to develop the approach. A more detailed discussion of the full process and background information can be found in Appendix D.

To secure either the Basic or the Expanded compact design credit, simple plan review calculations based on the construction drawings would be completed that demonstrate that the plumbing design (water heater to fixture proximity) is more compact than a "Qualification Distance" threshold criteria that is defined based on floor area, number of stories, and number of installed water heaters. Compactness is characterized by calculating the "Weighted Distance" from the water heater(s) to the fixtures. Based on stakeholder input presented at the June 1, 2017 pre-rulemaking workshop, the Statewide CASE Team expanded the applicability of the CHWDS measure to include low-rise multifamily dwellings that are served by a dedicated water heater, but not to low-rise multifamily buildings with central water heating systems.

There are no preemption concerns with this voluntary compliance option. Other national efforts at addressing various facets of inefficient hot water distribution systems are discussed in Section 2.4 of this report.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each Title 24, Part 6 document will be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Standards Change Summary

The proposed code change will not modify the standard.

2.3.2 Reference Appendices Change Summary

This proposal will modify the following sections of the standards Appendices as shown below. See Section 7.2 of this report for the detailed proposed revisions to the text of the reference appendices.

[3] As gas instantaneous water heaters initiate operation from a cold start condition, potable water is flowing through the unit while the water heater goes through an initial startup phase and then begins firing and heating of the heat exchanger. This results in a five to twenty second delay before hot water leaves the unit resulting in water waste if the user is waiting for hot water to arrive. Manufacturers are continuing to work on strategies to improve startup time delays.

RESIDENTIAL APPENDICES

RA2 - Table RA2-1 (Summary of Measures Requiring Field Verification and Diagnostic Testing): Language in table to be clarified.

RA3 – Residential Field Verification and Diagnostic Test Protocols: The proposed requirements revise the eligibility criteria and HERS inspection criteria for the compact hot water distribution design Expanded Credit. The compact design Basic Credit will not have any HERS verification requirements. The following sub-sections will be revised:

- RA3.6.5 HERS-Verified Compact Hot Water Distribution System.
- RA4.4.16 HERS-Verified Compact Hot Water Distribution System.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal will modify the following sections of the ACM Reference Manual:

- Appendix B- Water Heating Calculation Method.
- Section B4. Hourly Adjusted Recovery Load.

See Section 7 of this report for the detailed proposed revisions to the text of the ACM Reference Manual. To support the proposed ACM modifications, the Statewide CASE Team has generated a detailed description of the approach and background for the proposed ACM changes, including development of the Qualification Distance and Weighted Distance parameters. This can be found in Appendix D.

2.3.4 Compliance Manual Change Summary

The proposed code change will modify Section 5.6.2.4 HERS-Verified Compact Design of the Title 24, Part 6 Compliance Manual.

2.3.5 Compliance Documents Change Summary

The proposed code change will require modification to the compliance documents related to installer and HERS verification procedures for hot water distribution systems: CF2R-PLB-22-H and CF2R-PLB-23-H.

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

A CHWDS compliance option already exists under Title 24, Part 6. The proposed measure would be a modification of the current compliance option.

2.4.2 Relationship to Other Title 24 Requirements

This measure will have no impact on other measures, beyond slightly reducing the recovery load on the installed water heater. A related code update that impacts all hot water distribution design is the California Plumbing Code (Title 24, Part 5) requirement, which effective January 1, 2017 requires that all domestic hot water piping be insulated with a wall thickness equal to or greater than the pipe diameter. This requirement will likely impact residential plumbing installation practice, although it is not yet clear exactly how. One reasonable outcome is that over time, this insulation requirement will tend to have some influence on residential design and distribution system compactness.

Title 24, Part 11 (CALGreen) contains a voluntary requirement that residential buildings be equipped with a demand recirculation system to conserve water and reduce hot water times. This measure does not necessarily save energy since hot water distribution losses may well be larger, depending upon the distribution system design and patterns of hot water consumption.

2.4.3 Relationship to State or Federal Laws

There are no federal regulatory requirements that address the same topic as this proposed change.

2.4.4 Relationship to Industry Standards

The National Resources Defense Council submitted a code change proposal for the 2018 International Energy Conservation Code (IECC) that included a prescriptive requirement specifying a maximum plan view distance between the water heater and the furthest hot water use point. In addition, it proposed a performance credit for compact designs that were smaller than the prescriptive requirement. The proposal did not ultimately gain approval.

The Environmental Protection Agency's (EPA) WaterSense® program is focused on products that are 20 percent more water efficient than standard products. From that perspective, the WaterSense New Home Specification requires hot water distribution systems to store no more than half a gallon of water between the source of hot water and the furthest fixture. The hot water source is defined as "The container in which water is stored and/or heated, such as a hot water heater or a demand-controlled recirculation loop". Field verification is required to demonstrate compliance. Achieving this level of water efficiency performance without a demand recirculation system is challenging in almost any production home architectural environment. From a water efficiency perspective, the WaterSense requirement will result in water savings, however energy savings are much more uncertain given the recirculation system design and associated heat loss between hot water draw events.

The 2015 International Association of Plumbing and Mechanical Officials (IAPMO) Green Plumbing and Mechanical Code Supplement was developed to promote reliable "green" plumbing and mechanical provisions. Chapter 7 of the supplement addresses distribution system design. In addition to insulation requirements, the supplement includes a mandatory provision stating that "The maximum length of a branch between a source of hot water and the fixture fitting shall not exceed 15 feet or the volume shall not exceed 24 ounces. Water heaters, recirculation loops and electrically heat traced pipe shall be considered sources of hot water." Similar to the WaterSense requirement, it is the judgment of the Statewide CASE Team that although water efficient, this design approach is generally not feasible in typical home designs without a recirculation system, which may well increase energy usage.

2.5 Compliance and Enforcement

The Statewide CASE Team collected input during the stakeholder outreach process on what compliance and enforcement issues may be associated with this measure. This section summarizes how the proposed code change will modify the code compliance process. Appendix C presents a detailed description of how the proposed code changes could impact various market actors. When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced.

This code change proposal will exclusively affect new single family homes that use the performance approach to compliance. The key steps and changes to the compliance process are summarized below:

- **Design Phase**: Compliance with the Basic Credit and the Expanded Credit is based on architectural plan view drawings. For both credits, during design the architect or designer will need to complete a plan-view evaluation of the design to ensure that it meets the criteria. The compliance software would accept a user-defined input that defines the level of distribution system compactness and the software would then internally calculate whether the design meets the maximum threshold distance requirement. The designer would complete the following steps:

- Examine the plans to identify the locations of the water heater and all water use fixtures (with the exception of the laundry room);
- Draw straight lines from the water heater to the center-point of specified key hot water use points and record the scaled distances; and
- Perform an algebraic calculation based on the measured distances from the water heater to specified fixtures is less than the maximum Qualification Distance threshold (the latter defined by floor area and number of stories).

If the designer's goal is to go beyond the Basic Credit and achieve the Expanded Credit, the designer would need to clearly communicate the eligibility critieria to the plumber to ensure that the installed plumbing design will pass the HERS inspection.

One area where the Expanded Credit interacts with the 2015 Uniform Plumbing Code is in regard to the distribution pipe sizing requirements outlined in Chapter 610.4. The Expanded Credit contains eligibility criteria, which limits the length of one-inch pipe to a maximum of eight feet in length. There will be situations where this limitation may pose a challenge given the available supply water pressure at the site and/or the number of fixture units being served by the water heater. Since the Expanded Credit represents an option to the Basic Credit (which does not have this eligibility requirement), the Statewide CASE Team recommends this two-tiered approach. From an energy and water savings perspective, minimizing the length of larger sized piping is a key goal of the CHWDS measure.

- **Permit Application Phase**: The permit application phase would require an additional plan review step. As mentioned above, during the design phase, the architect or Title 24, Part 6 consultant would need to use architectural floor plans to develop straight line vectors from the water heater to designated hot water use points. Ideally the architect or Title 24, Part 6 consultant would provide the calculation documentation directly on the plans to allow the plan checker to easily confirm the distances. The reviewer would then check the diagrams and calculations to ensure that everything was done correctly, and that the design meets the qualification criteria. The compliance software would automatically compute the CHWDS measure qualification criteria based on key characteristics of the floor plan (number of stories, recirculating or non-recirculating distribution system type) for comparison to the plan check measurement.
- **Construction Phase**: There are two proposed compliance credits. One, the Basic Credit, does not require any verification steps beyond the Permit Application Phase plan check review. (This represents a major simplification compared to the existing 2016 HERS-Verified Compact Design credit, where the plumber is responsible in ensuring that the installed plumbing meets the maximum "water heater to furthest fixture" length criteria, since the HERS inspection would require a physical length measurement of the full pipe run length.) The proposed 2019 Expanded Credit would provide greater savings benefit, but does require some HERS verification inspection steps. Communication between the design team and the plumber is critical to ensure that the Expanded Credit eligibility criteria are met.
- **Inspection Phase**: Buildings taking the Basic Credit will not require any inspection. The Expanded Credit is more rigorous, requiring HERS inspection to ensure various eligibility criteria are met, and will require CF-2R and CF-3R documents to be filed.

No major challenges are anticipated in the compliance and enforcement process. Completing point-to-point straight-line measurements between the water heater and three key use points on the plan drawings, and adding a simple algebraic calculation using those measurements would create minimal work on the design side. The plan check verification step would be an added step over current practice, but the level of complexity is on the order of computing the area of a window or door. Required field verification for the Expanded Credit would need to be completed by a HERS Rater, but the proposed revisions are simpler than the verification process that has been in place since the 2013 code cycle implementation of the CHWDS measure.

If this compliance option proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 3 and Appendix C be used to develop a plan that identifies a process to develop compliance documentation and how to minimize barriers to compliance.

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 actors. Normally, the Statewide CASE Team would gather information about the incremental cost of the proposed measure, but since this is a compliance option that step is unnecessary. Estimates of measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in utility-sponsored stakeholder meetings held on October 26, 2016 and March 23, 2017.

3.1 Market Structure

The residential new construction plumbing market in California is dominated by the use of cross-linked polyethylene (PEX) plastic piping in most of the state. This transition has occurred over the last 15 years as the industry has moved away from costlier copper piping to cheaper PEX. PEX comes in large spools and can be fairly rapidly deployed with minimal connections (another advantage over copper). There are still areas where copper piping is more common, but the vast majority of potable hot and cold water piping installed in new residential construction in the state is PEX (Kosar, D; Glanville, P.; and H. Vadnal 2015). Chlorinated polyvinyl chloride (CPVC) pipe also has a niche market share in California. The major PEX pipe manufacturers include Uponor, Viega, Nibco, Zurn, IPEX, and Dow Chemical.

PEX plumbing offers advantages in ease of installation and requires less skill to install, but at the same time it is a product that can be installed more haphazardly due to the ease of installation. This has led to plumbing installations that are inefficient, resulting in excessive piping length (and pipe volume) in many of the lines between the water heater and the end use points. For the builder this leads to decreased homeowner satisfaction as hot water wait times increase, and increased interest in recirculation strategies, which certainly save water and reduce hot water waiting times, but are not reliable energy saving devices (Henderson and Wade 2014, Nones M.; Gutierrez, E. 2015, Weitzel, E.; Hoeschele, M. 2014).

A compact distribution plumbing strategy is not a central element to mainstream production home design, although several plumbing designers interviewed indicated that they currently attempt to implement CHWDS in their designs, in situations where the builder is receptive. In these cases, the solutions being proposed include water heater relocation (including central attic locations) and running hot water piping between floors in multi-story homes (avoiding the common practice of running piping to the attic in two-story house for simplicity and then dropping down to first floor use points). The level of builder interest to these strategies appears inconsistent, but at least there is a dialog underway to educate the building industry on alternative practices.

This measure would constitute a change in plumbing design practice for some plumbers, but does not require the use of any new products.

3.2 Technical Feasibility, Market Availability, and Current Practices

There are no issues with the market being able to achieve the compact criteria. As a compliance option, it will be entirely voluntary for the builder to pursue. For the Basic Credit, the entire compliance process hinges on the building design and a plan view check that the design is compliant. For the Basic Credit, no HERS inspection is required. This represents a major simplification from the 2016 code and is intended to promote increased builder and designer interest in CHWDS design.

For the Expanded Credit, the challenge will be in translating a cohesive design vision from the architect and plumbing designer (if there is one) to the plumber in the field. The designer and plumber must be aware of any local water supply pressure issues in which the plumbing code would dictate pipe sizing that would potentially not meet the eligibility criteria. In that case, the Basic Credit would still be available, but the larger credits available with the Expanded Credit could not be realized since the eligibility criteria may conflict with the Uniform Plumbing Code. HERS inspection requirements for the Expanded Credit involve verifying pipe location and maximum diameter of installed hot water piping. These tasks are still expected to be a much simpler inspection process than the current compact credit, which requires a point-to-point pipe length measurement of the longest pipe run from the water heater.

The most noticeable impact of this compliance measure will be to increase visibility of design practices that direct more attention to water heater location relative to the hot water use points. The measure focuses on how far the water heater is from the hot water fixtures, so either locating the water heater in alternative locations or shrinking the plumbing design footprint will be required. It is anticipated that most builders will move the water heater without changing the architectural layout, although some architectural designs may well require both modifications to meet the requirements to claim the compliance credit. At the other extreme are the homes or multifamily apartments that are either designed, or through happenstance, are compact to begin with.

A related code update that impacts all hot water distribution design is the California Plumbing Code (Title 24, Part 5) requirement, which effective January 1, 2017 requires that all domestic hot water piping be insulated with a wall thickness equal to or greater than the pipe diameter. This requirement will likely impact residential plumbing layouts, although it is not yet clear exactly how. One reasonable outcome is that over time, this insulation requirement will tend to have some influence on residential design and distribution system compactness.

One design concept some plumbing design engineers are presenting to interested builders is the idea of locating the water heater in the attic. This strategy has some logical benefits in not only improving the ability to centralize the water heater location, but it can piggyback on other common infrastructure that is typically installed nearby with the furnace, air handler, and cooling coil (gas line, electrical source, and condensate disposal). While one plumbing designer expressed builder client receptiveness to this strategy, there is certainly resistance in terms of having a potential leak source above conditioned space, as well as a concern over reduced homeowner maintenance follow-up (“out of sight, out of mind”).

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all of the proposed changes to Title 24, Part 6. Builders could be impacted for change in demand for new buildings and by construction costs. Demand for new buildings is driven more by factors such as the overall health of the economy and population growth than the cost of construction. The cost of complying with Title 24, Part 6 requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on demand for new buildings or the builders' profits. As shown in Figure 1, California home prices have increased by about $300,000 in the last 20 years. In the six years between the peak of the market bubble in 2006 and the bottom of the crashing in 2012, the median home price dropped by $250,000. The current median price is about $500,000 per single family home. The combination of all single family measures for the 2016 Title 24, Part 6 Standards was around $2,700 (California Energy Commission 2015). This is a cost impact of approximately half of one percent of the home value. The cost impact is negligible as compared to other variables that impact the home value.

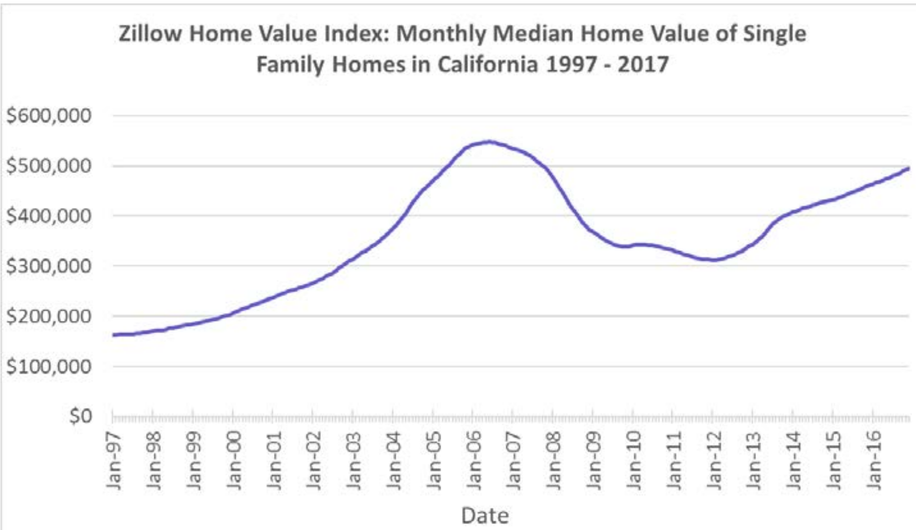

Figure 1: California median home values 1997 to 2017

Source: (Zilllow 2017)

Market actors will need to invest in training and education to ensure the workforce, including designers and those working in construction trades, know how to comply with the proposed Expanded Credit requirements. Workforce training is not unique to the building industry, and is common in many fields associated with the production of goods and services. Costs associated with workforce training are typically accounted for in long-term financial planning and spread out across the unit price of many units as to avoid price spikes when changes in designs and/or processes are implemented.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials and ASHRAE 90.1) are typically updated on a three-year revision cycles. As discussed in Section 3.3.1, all market actors, including building designers and energy consultants, should (and do) plan for training and education that may be required to adjust design practices to accommodate compliance with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2019 code cycle aim to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility in requirements can be met.

The architect and plumbing designer is responsible for understanding the design requirements, ensuring that all subcontractors are aware of these requirements, and ultimately ensuring that all requirements are implemented per the design intent. Limited additional time may be required for these processes.

Energy consultants are also not expected to be significantly impacted by this measure. They will continue to serve as the primary resource for designers and builders for Title 24, Part 6 compliance information. With their detailed knowledge of the Title 24, Part 6 compliance software, the energy consultant will work closely with the builder in determining whether the compact compliance option makes sense for the particular project and whether the Basic or Expanded Credit is desired, depending on the design, project location, and construction team comfort level with the methods.

3.3.3 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 Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants, or those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)

Building owners and occupants will benefit from lower energy bills. For example, the Energy Commission estimates that on average the 2016 Title 24, Part 6 Standards will increase the construction cost by $2,700 per single family home, but the standards will also result in a savings of $7,400 in energy and maintenance cost savings over 30 years. This is roughly equivalent to an $11 per month increase in payments for a 30-year mortgage and a monthly energy cost savings of $31 per month. Overall, the 2016 Title 24, Part 6 Standards are expected to save homeowners about $240 per year relative to homeowners whose single family homes are minimally compliant with the 2013 Title 24, Part 6 requirements (California Energy Commission 2015). As discussed in Section 3.4.1, when homeowners or building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without food or medical care to save money for energy bills (Association, National Energy Assistance Directors 2011).

The main anticipated impact on building occupants is reduced wait times for hot water, and a resulting increase in their satisfaction. In addition to the projected energy savings, water savings will also be realized as less water needs to be discharged from the lines prior to the arrival of hot water.

No maintenance or health/safety impacts are expected.

3.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

Impacts on manufacturers and distributors are generally expected to be negligible. There are small variations in piping materials anticipated as a CHWDS may require less length (and weight) of PEX piping, which also impact the need for pipe insulation. One potential impact of the measure is that if builders pursue water heater relocation as a part of achieving the compact criteria, it may push more builders using gas water heaters to install condensing gas instantaneous water heaters rather than non-condensing water heaters.[4] This may occur as venting costs for condensing units are lower due to the ability to use plastic PVC pipe. Therefore, a potential impact is that condensing gas instantaneous water heater sales will increase (at the expense of non-condensing) as builders see that the total incremental cost is small and that the additional Title 24, Part 6 compliance benefit from higher efficiency water heaters warrant the switch.

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[4] The example refers to gas instantaneous water heaters solely since they are the prescriptive standard case where natural gas is available and also the most commonly installed water heater in new California homes. Other water heater types such as storage gas and electric heat pump water heater are also valid solutions under Title 24, Part 6.

3.3.6 Impact on Building Inspectors

This measure will slightly increase the effort for the plans examiners. They will be responsible for ensuring that the required plan view calculation meets the compliance criteria. Our expectation is that building designers will provide the distances and calculations directly on the plans, making the plan verification step trivial.

Changes to HERS verification will vary depending on which form of the credit is taken by the builder. If they take the Basic Credit, no HERS verification is required. This is a simplification from the current version of the credit, which does require HERS verification of maximum pipe length. For the Expanded Credit, HERS inspection will be required to verify where distribution piping is located, and whether an excessive length of larger diameter pipe has been installed. Both of these visual inspections are much more streamlined than the current requirement involving physical measurement of the longest pipe run, with an expectation that the proposed verifications and should be completed in five or ten minutes.

3.3.7 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to Title 24, Part 6.

3.4 Economic Impacts

The estimated impacts that the proposed code change will have on California's economy are discussed below.

3.4.1 Creation or Elimination of Jobs

In 2015, California's building energy efficiency industry employed more than 321,000 workers who worked at least part time or a fraction of their time on activities related to building efficiency. Employment in the building energy efficiency industry grew six percent between 2014 and 2015 while the overall statewide employment grew three percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's report *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth* (2010) provides details on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes.

Building codes that reduce energy consumption provide jobs through *direct employment*, *indirect employment*, and *induced employment*.[5] Title 24, Part 6 creates jobs in all three categories with a significant amount attributed to induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., nonindustry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. For example, as mentioned in Section 3.3.4, the 2016 Standards are expected to save single family homeowners about $240 per year. Money saved from hundreds of

[5] The definitions of direct, indirect, and induced jobs vary widely by study. Wei et al (2010) describes the definitions and usage of these categories as follows: "*Direct employment* includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. *Indirect employment* refers to the ''supplier effect'' of upstream and downstream suppliers. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. *Induced employment* accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees, e.g. non-industry jobs created such as teachers, grocery store clerks, and postal workers."

thousands of homeowners over the entire life of the building will be reinvested in local businesses. Wei, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years[6] per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced.

This compliance option measure, which may be used to offset other prescriptive requirements, is not anticipated to have a significant impact on labor needs in the California housing industry.

3.4.2 Creation or Elimination of Businesses in California

There are approximately 43,000 businesses that play a role in California's advanced energy economy (BW Research Partnership 2016). California's clean economy grew ten times more than the total state economy between 2002 and 2012 (20 percent compared to two percent). The energy efficiency industry, which is driven in part by recurrent updates to the building code, is the largest component of the core clean economy (Ettenson and Heavey 2015). Adopting cost-effective code changes for the 2019 Title 24, Part 6 code cycle will help maintain the energy efficiency industry.

Table 4 lists industries that will likely benefit from the proposed code change classified by their North American Industry Classification System (NAICS) Code.

Since no new products or materials are required for this measure, no significant impacts are anticipated.

Table 4: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Residential Building Construction	2361
Plumbing, Heating, and Air-Conditioning Contractors	23822
Boiler and Pipe Insulation Installation	23829
Manufacturing	32412
Engineering Services	541330
Building Inspection Services	541350

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

In 2014, California's electricity statewide costs were 1.7 percent of the state's gross domestic product (GPD) while electricity costs in the rest of the United States (U.S.) were 2.4 percent of GDP (Thornberg, Chong and Fowler 2016). As a result of spending a smaller portion of overall GDP on electricity relative to other states, Californians and California businesses save billions of dollars in energy costs per year relative to businesses located elsewhere. Money saved on energy costs can be otherwise invested, which provides California businesses with an advantage that will only be strengthened by the adoption of the proposed code changes that impact nonresidential buildings.

No impacts on the competitiveness of homebuilders in California are anticipated. To the extent the Compact measure is successfully implemented in the residential building sector, it should improve customer satisfaction and reduce potential warranty calls.

3.4.4 Increase or Decrease of Investments in the State of California

The proposed changes to the building code are not expected to impact investments in California on a macroeconomic scale, nor are they expected to affect investments by individual firms. The allocation of resources for the production of goods in California is not expected to change as a result of this code change proposal.

[6] One job-year (or ''full-time equivalent'' FTE job) is full time employment for one person for a duration of one year.

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

The proposed code changes are not expected to have a significant impact on the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are: personal income taxes, corporation taxes, sales and use taxes, and property taxes. The proposed changes for the 2019 Title 24, Part 6 Standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected to change. As discussed, reductions in energy expenditures are expected to increase discretionary income. State and local sales tax revenues may increase if homeowners spend their additional discretionary income on taxable items. Although logic indicates there may be changes to sales tax revenue, the impacts that are directly related to revisions to Title 24, Part 6 have not been quantified. Finally, revenue generated from property taxes is directly linked to the value of the property, which is usually linked to the purchase price of the property. The proposed changes will increase construction costs. As discussed in Section 3.3.1, however, there is no statistical evidence that Title 24, Part 6 drives construction costs or that construction costs have a significant impact on home price. Since compliance with Title 24, Part 6 does not have a clear impact on purchase price, it can follow that Title 24, Part 6 cannot be shown to impact revenues from property taxes.

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, 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, Part 6 will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 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, including tools, training and resources provided by the Investor Owned Utility codes and standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix C, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters, or persons by age, race or religion. Given construction costs are not well correlated with home prices, the proposed code changes are not expected to have an impact on financing costs for business or home-buyers. Some financial institutions have progressive policies that recognize the financial implications associated with occupants of energy efficient homes saving on energy bills and therefore have more discretionary income.[7]

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 some of the net savings depending on if and how landlords account for energy cost when determining rent prices.

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 (Association, National Energy Assistance Directors 2011). Thus, low-income families are likely to disproportionately benefit from Title 24, Part 6 Standards that reduce residential energy costs.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relied on the CBECC-Res software to estimate energy use for single family homes. Simulations were conducted using the 2016.2.0+ (864) version of the software and the 2016.2.0+ (626) version of the BEM Compliance Manager.

The 2016 California Plumbing Code (CA BSC 2016b) includes requirements that all hot water pipes be insulated. The next expected release of the CBECC-Res compliance software during summer 2017 is expected to incorporate this requirement but the current release does not. The Standard Design and the Proposed Design have been adjusted to include the presence of pipe insulation for the evaluations. This effectively reduces the simulated base case distribution loss by 10-15 percent relative to the prior Title 24, Part 6 requirement (Section 150.0(j)2.A), which only required insulation on the largest heat loss distribution piping including:

- All recirculation system piping;
- First five feet of hot and cold water piping connected to a storage tank water heater;
- All piping greater than or equal to ¾ inches in diameter;
- All piping feeding the kitchen hot water use points.

The CHWDS Basic Credit savings calculation is based on the CHWDS DSM currently available in the 2016 ACM. This savings estimation approach was chosen given the complexities of hot water distribution system modeling and the required need for very short simulation time steps (on the order of seconds) to provide proper resolution of distribution system heat transfer and water waste effects, rather than the longer interval time steps utilized in the CBECC-Res compliance software. In addition, the inability to precisely characterize the distribution system layout (length, diameter, and location of all piping runs, and hot water use points), as well as the lack of availability of very high resolution hot water draw schedules (as defined by discrete use points in the dwelling), severely complicates this type of modeling in a compliance environment.[8]

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[7] For example, see the U.S. EPA's ENERGY STAR® website for examples: http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=CA.

[8] CBECC-Res does have discrete hot water use profiles defined by end use type (shower, sink, etc), but does not specifically assign those draws to a specific bathroom or use point location.

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared current design practices to compact design practices that will comply with the proposed Basic Credit requirements. As noted in Section 4.1, the CBECC-Res evaluations were completed assuming the pipe insulation credit available under the 2016 Title 24, Part 6 Standards was in place in the base system design. Domestic hot water system performance for the prescriptively assumed gas instantaneous water heater (when natural gas is available) is independent of the construction characteristics of the home. Water heating performance in the ACM is dependent on the floor area and number of bedrooms in the dwelling unit. Floor area impacts the assumed distribution losses and number of bedrooms impact the hot water draw schedule and magnitude of average daily hot water consumption. Since these are the parameters that impact distribution losses and total water heating energy usage, the Statewide CASE Team evaluated performance for a range of dwelling sizes (varying from 500 to 4,000 square feet) and associated number of bedrooms to assess the savings potential of the proposed compact Basic Credit. Table 5 summarizes this information.

Table 5: Floor Area and Bedroom Assumptions

Floor Area Modeled (ft^2)	Number of Bedrooms
500	1
800	2
1,200	3
1,600	3
2,000	3
2,100	3
2,500	4
2,700	4
3,000	4
4,000	5

Hot water distribution losses are not strongly climate dependent in terms of the fraction of energy lost by the distribution system relative to the total annual water heater energy consumed. Energy savings, energy cost savings, and peak demand reductions were calculate using a time dependent valuation) (TDV) methodology.

4.3 Per-Unit Energy Impacts Results

Projected Basic Credit compact design energy savings impacts when using a minimum efficiency gas instantaneous water heater (primary prescriptive path) are presented for a 2,430 square foot home in Table 6.[9] The per-unit energy savings estimates do not take naturally occurring market adoption or compliance rates into account. With the assumption of the predominant gas water heater type installed in California residences, only natural gas savings are shown here; CHWDS savings impacts for other water heater types such as heat pump water heaters would also be calculated in the ACM. Although the savings vary by climate zone with milder zones showing less savings and colder zones showing higher savings, the savings fraction of total water heater annual consumption remains fairly constant by climate zone.

[9] Most 2019 CASE Reports for residential measures present results for the 2,430 square feet blended prototype which is based on 45 percent weighting of the 2,100 square feet one-story prototype and 55 percent weighting of the 2,700 square feet two-story prototype. Since this is a recognized results reporting example, it is used here as well.

Table 6: First-Year Energy Impacts Per 2,430 Square Feet Single Family Weighted Average Prototype – New Construction

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0	0	6.0	1,205
2	0	0	5.4	1,079
3	0	0	5.4	1,080
4	0	0	5.1	1,028
5	0	0	5.5	1,107
6	0	0	4.9	982
7	0	0	4.8	948
8	0	0	4.6	938
9	0	0	4.6	938
10	0	0	4.6	932
11	0	0	4.7	954
12	0	0	5.0	1,002
13	0	0	4.6	934
14	0	0	4.8	972
15	0	0	3.3	686
16	0	0	6.0	1,213

Figure 2 plots the sensitivity of the project Basic Credit compact savings with floor area on a statewide average basis. Since water heating loads in the ACM are dependent on number of bedrooms, smaller dwelling units are projected to have lower savings potential. For most multifamily apartments, projected savings are approximately one-third of the savings for a typical single family home.

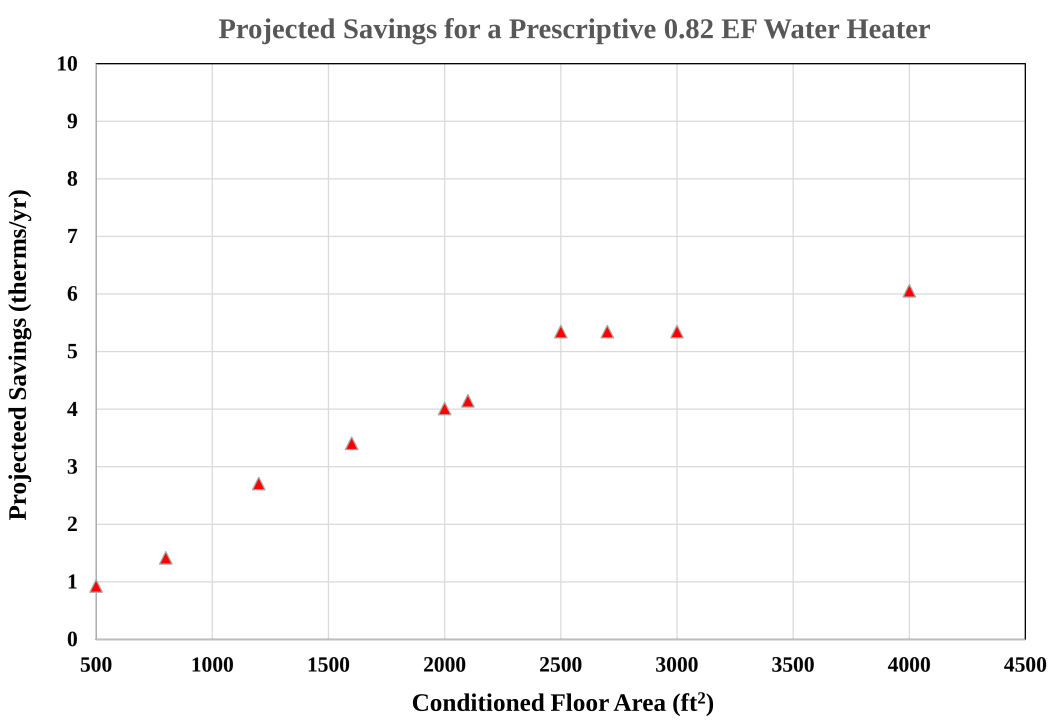


Figure 2: Statewide average projected basic CHWDS credit annual savings

5. Lifecycle Cost and Cost-Effectiveness

5.1 Energy Cost Savings Methodology

Time Dependent Valuation (TDV) energy is a normalized format for comparing electricity and natural gas cost savings that takes into account the cost of electricity and natural gas consumed during each hour of the 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 30 years. The TDV cost impacts are presented in 2020 present value (PV) dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of “TDV kBtu”. The Energy Commission derived the 2020 TDV values that were used in the analyses for this report (Energy + Environmental Economics 2016).

The proposed compliance option is limited to single and multifamily new construction cases where the dwelling unit is served by individual water heaters, therefore excluding multifamily central water heating systems.

5.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings over the 30-year period of analysis are presented in Table 7 for the single family new construction case based on the 2,430 square foot blended prototype. All TDV savings for the CHWDS compliance option measure are attributable to a reduction in gas use. Alternative water heater types such as gas storage or heat pump water heaters would demonstrate differing impacts.

Table 7: TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Single Family Dwelling Unit (2,430 square feet) – New Construction

Climate Zone	30-Year TDV Electricity Cost Savings (2020PV $)	30-Year TDV Natural Gas Cost Savings (2020PV $)	Total 30-Year TDV Energy Cost Savings (2020PV $)
1	$0	$207	$207
2	$0	$187	$187
3	$0	$185	$185
4	$0	$177	$177
5	$0	$191	$191
6	$0	$169	$169
7	$0	$163	$163
8	$0	$161	$161
9	$0	$161	$161
10	$0	$160	$160
11	$0	$164	$164
12	$0	$172	$172
13	$0	$160	$160
14	$0	$166	$166
15	$0	$119	$119
16	$0	$208	$208

5.3 Incremental First Cost

This measure recommends revisions to an existing 2016 Title 24, Part 6 compliance option. As a compliance option, it is not necessary to demonstrate that the measure is cost-effective, because builders will have discretion on whether to implement the CHWDS measure. As a result, this CASE Report does not present incremental costs or a lifecycle cost-effectiveness analysis. Builders will make a determination on using this measure based on their house designs, plumbing practices, and costs associated with any necessary design modifications. In general, the Statewide CASE Team expects that potential cost differences relative to standard practice will be:

- Reduced cost of PEX due to less material installed.
- Reduced cost of pipe insulation due to smaller plumbing layout.
- Reduced or no change in labor hours for plumber.
- Increased water heater venting costs, if water heater is centrally relocated.
- Increased venting labor costs, if the water heater is relocated from an exterior garage wall location to an interior garage, indoor, or attic location.

5.4 Lifetime Incremental Maintenance Costs

No changes in maintenance costs are anticipated.

5.5 Lifecycle Cost-Effectiveness

This measure proposes a compliance option and therefore does not require cost-effectiveness evaluations.

6. First-Year Statewide Impacts

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings for the 2,430 square foot weighted average prototype, which are presented in Section 4.3, by the statewide new construction forecast for 2020, which is presented in more detail in Appendix A. The first-year energy impacts assume ten percent uptake of the CHWDS Basic Credit for residential buildings completed in 2020. This penetration rate assumption represents the Statewide CASE Team's best assessment of initial 2020 market uptake. The lifecycle energy cost savings represents the energy cost savings over the entire 30-year analysis period. Results are presented in Table 8 for new construction with the ten percent assumption applied uniformly to construction estimates in each climate zone. For the ten percent penetration rate assumption, the projected 0.063 million therm/yr savings (and 2.18 million dollar discounted 30-year energy cost savings) represent an upper limit on the CHWDS impacts given that compliance option credits are frequently traded off as part of the performance method. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 8: Statewide Energy and Energy Cost Impacts –New Construction

Climate Zone	Statewide New Single Family Construction in 2020 (Units)	Statewide New Multifamily Construction in 2020 (Units)	First-Year[a] Natural Gas Savings (million therms)	Lifecycle[b] PV Energy Cost Savings (PV$ million)
1	46	11	3.0×10^{-4}	$ 0.01
2	309	158	1.9×10^{-3}	$ 0.06
3	1,150	843	7.3×10^{-3}	$ 0.25
4	743	385	4.3×10^{-3}	$ 0.15
5	144	75	9.0×10^{-3}	$ 0.03
6	645	338	3.5×10^{-3}	$ 0.12
7	578	394	3.2×10^{-3}	$ 0.11
8	995	515	5.2×10^{-3}	$ 0.18
9	1,229	1,035	6.9×10^{-3}	$ 0.24
10	1,840	419	8.9×10^{-3}	$ 0.31
11	395	75	1.9×10^{-3}	$ 0.07
12	1,941	602	1.0×10^{-3}	$ 0.36
13	703	138	3.4×10^{-3}	$ 0.12
14	348	76	1.7×10^{-3}	$ 0.06
15	320	45	1.1×10^{-3}	$ 0.04
16	319	144	2.1×10^{-3}	$ 0.07
TOTAL	11,707	5,253	$\mathbf{6.3 \times 10^{-2}}$	**$ 2.18**

a. First-year savings assume ten percent of all buildings completed statewide in 2020.

b. Energy cost savings assumes ten percent of all buildings completed statewide in 2020 accrued during 30-year period of analysis.

6.2 Statewide Water Use Impacts

Estimated impacts on water use are presented in Table 9. Water use savings estimates are challenging given that hot water usage behaviors among individuals and households are highly variable and can depend strongly on the demographics of the household (Parker, D.; Fairey, P.; and Lutz, J.; 2015). In addition, the proposed compliance option approach ensures that compliant hot water distribution systems will be smaller than a conventional non-compact system, but cannot precisely specify the design and configuration and hence the impacts on water waste. To provide a best approximation of water savings impacts, the Statewide CASE Team relied on detailed distribution simulation study completed under the U.S. Department of Energy's Building America program (Weitzel, E.; Hoeschele, M. 2014). A validated transient system simulation tool (TRNSYS) model was used to evaluate the performance of various distribution options including standard plumbing layouts, compact layouts, and insulated and uninsulated distribution systems. For the four national climate locations simulated in that study, the Statewide CASE Team selected the two warmer climates (Phoenix and Atlanta) for the water savings estimate, although the variations between climates were small. On average, for a three-person household, the average annual water savings for a three person single family household was estimated at 962 gallons per year. (Water savings for multifamily apartments are approximated at one-third the level of the single family homes.) If ten percent of projected 2020 single family housing starts are assumed to pursue the CHWDS compliance option credit, an estimated 11,707 homes and 5,253 apartment units per year would be impacted.

It was assumed that all water savings occurred indoors, and the embedded electricity value was 4,848 kWh/million gallons of water. The embedded electricity estimate was derived from a 2015 California Public Utilities Commission study that quantified the embedded electricity savings from IOU programs that save both water and energy (California Public Utilities Commission 2015a). See 0 additional information on the embedded electricity savings estimates.

Table 9: Impacts on Water Use

	On-Site Indoor Water Savings (gal/yr)	On-Site Outdoor Water Savings (gal/yr)	Embedded Electricity Savings[a] (kWh/yr)
Per Dwelling Unit Impacts (single family)	962	0	4.7
Per Dwelling Unit Impacts (multifamily)	321	0	1.6
First-Year[b] Statewide Impacts	12,947,000	0	62,765

a. Assumes embedded energy factor of 4,848 kWh per million gallons of water (CPUC 2015).

b. First-year savings from ten percent of all single family homes and multifamily apartments completed statewide in 2020.

6.3 Statewide Material Impacts

It is anticipated that many builders who pursue the CHWDS compliance option credit will do so by moving the water heater to a more central location. In the case of a single family home this may involve relocating the water heater from exterior of the garage wall to a central location in the garage (or attic) to shorten the piping runs. An assessment of the impact of a water heater relocation in a typical single family home is outlined below:

- Quantity of PEX plumbing is expected to decrease, because the water heater will be closer to the fixtures.
- The relocation of the water heater will likely require a longer run of larger diameter natural gas as the water heater moves further from the gas meter, increasing steel use.
- The length of vent pipe will increase as it must reach across the garage instead of directly through the wall.
- Builders will consider moving from the “typical” non-condensing instantaneous gas water heater to condensing instantaneous water heaters, because condensing units can use cheaper PVC vent pipe rather than more expensive metal pipe. This switch would result in a more expensive water heater, but an increased compliance credit due to the higher efficiency of the condensing units.

These changes will impact material use based on the different lengths and diameters of the piping or vent material used. The following assumptions were used when calculating the estimates reported in Table 10:

- The average length of one inch diameter PEX tubing in the house will not change,
- The average observed length of ¾ inch diameter PEX tubing in Californian houses is 51 feet (see Appendix D in (Lutz, J.D. 2008));
- Based on the Statewide CASE Team’s analysis of 60 floor plans, the average Weighted Distance of centrally located water heaters is 67 percent of the average Weighted Distance of external garage wall-mounted water heaters. 67 percent of 51 feet is 34.2 feet, resulting in an estimated savings of 16.8 feet of ¾ inch PEX tubing per house;
- Gas piping in California homes is typically steel pipe with the main gas line from the meter typically delivering gas to the water heater, then to the rest of the house;
- The gas line entering the house/garage from the gas meter is typically 1.25-inch diameter before the water heater, and one inch in diameter after;
- Relocating the water heater will result in an average increase in vent length from two feet to 15.7 feet;

- A non-condensing gas instantaneous water heater uses a three-inch diameter, 1/16 inch wall thickness stainless steel vent and five-inch diameter, 1/8 inch wall thickness PVC air intake; and
- A condensing gas instantaneous water heater uses a three-inch diameter 1/8 inch wall thickness PVC vent, and a five-inch diameter, 1/8 inch wall thickness PVC air intake.

Table 10: Impacts of Material Use

	Impact on Material Use (lb)			
	PEX	**Stainless Steel**	**PVC**	**Steel**
Impact (I, D, or NC)[a]	D	D	I	I
Per-Unit Impacts	1.11	1.34	8.3	11.7
First-Year[b] Statewide Impacts	12.994	15,690	97,170	136,970

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. First-year savings from ten percent of all single family homes completed statewide in 2020.

6.4 Other Non-Energy Impacts

A more compact hot water distribution system design will result in improved occupant comfort and higher satisfaction with their hot water system.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

There are no proposed changes to the standards.

7.2 Reference Appendices

Table RA2-1 (Summary of Measures Requiring Field Verification and Diagnostic Testing)

Language to be updated as shown below.

Measure Title	Description	Procedure(s)
Verified Compact Hot Water Distribution System Expanded Credit (CHWDS-H-EX)	Field verification to insure that the eligibility criteria ~~longest pipe run from any use point to the water heater serving that use point does not exceed a maximum length as~~ specified in RA3.6.5 are met.	RA3.6.5

RA3.6.5 HERS-Verified Compact Hot Water Distribution System Expanded Credit (CHWDS-H-EX)

To meet the Compact ~~HWDS~~ hot water distribution system Expanded Credit eligibility requirements, the following HERS field verifications are required:

- No hot water piping >1" diameter piping is allowed,
- Length of 1" diameter piping is limited to 8 ft or less,
- Two and three story dwelling units cannot have hot water distribution piping in the attic, unless the water heater is also located in the attic and,
- Eligible recirculating systems must be HERS-Verified Demand Recirculation: Manual Control conforming to RA4.4.17.

~~measurements shall verify that the longest measured pipe run length between a hot water use point and the water heater serving that use be no more than the distance specified in Table 3.6.4. Table 3.6.4 specifies the maximum pipe length as a function of Floor Area Served, where Floor Area Served is defined as the conditioned floor area divided by the number of installed water heaters.~~

~~TABLE 3.6.5~~

~~Floor Area Served (ft2)~~	~~Maximum Measured Water Heater To Use Point Distance (ft)~~
~~< 1000~~	~~28'~~
~~1001 – 1600~~	~~43'~~
~~1601 – 2200~~	~~53'~~
~~2201 – 2800~~	~~62'~~
~~>2800~~	~~68'~~

~~Verification shall include:~~

~~(a) Verify that floor area (ft2) of the building matches the conditioned floor area that was used in compliance documentation. (Note: Floor Areas Served equals the conditioned floor area divided by the number of installed water heaters).~~

~~(b) Measure length from water heater to the use point furthest from the water heater and determine if that value is equal to or less than listed in Table 3.6.4. Measurements shall be made to the nearest half foot.~~

~~(c) The hot water distribution system piping from the water heater(s) to the fixtures and appliances must take the most direct path. For example, in a house with more than 1-story and the water heater in the garage, this requirement would exclude running hot water supply piping from the manifold to the attic, and then running the line back down to a first floor point of use.~~

~~(d) The HERS inspector shall also verify that hot water piping is insulated to a level that meets the requirements of §150.0(j) and is installed in accordance with Proper Installation of Pipe Insulation as specified inRA3.6.2.2~~

RA4.4.16 ~~HERS-Verified~~ Compact Hot Water Distribution System (CHWDS-H)

~~requirement, the longest measured pipe run length between a hot water use point and the water heater serving that use shall be no more than the distance specified in Table 4.4.5. This table specifies the maximum pipe length as a function of Floor Area Served, where Floor Area Served is defined as the conditioned floor area divided by the number of installed water heaters.~~

~~Table 5-10: Compact Distribution System~~

~~Floor Area Served (ft2)~~	~~Maximum Water Heater To Use Point Distance (ft)~~
~~< 1000~~	~~28'~~
~~1001 – 1600~~	~~43'~~
~~1601 – 2200~~	~~53'~~
~~2201 – 2800~~	~~62'~~
~~>2800~~	~~68'~~

~~Requirements include that:~~

~~(a) The floor area (ft^2) of the building matches the conditioned floor area that was used in compliance documentation. (Note: Floor Areas Served equals the conditioned floor area divided by the number of installed water heaters).~~

~~(b) The length from the water heater to the furthest use point it serves shall be equal to or less than listed in Table 4.4.5. Measurements shall be made to the nearest half foot.~~

~~(c) The hot water distribution system piping from the water heater(s) to the fixtures and appliances must take the most direct path. For example, in a house with more than 1-story and the water heater in the garage, this requirement would exclude running hot water supply piping from the manifold to the attic, and then running the line back down to a first floor point of use.~~

~~(d) Hot water piping shall be insulated to a level that meets the requirements of §150.0(j) and be installed in accordance with Proper Installation of Pipe Insulation R4.4.1.~~

To receive the Compact Hot Water Distribution System credit (available for single family homes and multifamily dwellings served by individual water heaters), plan calculations must be completed that demonstrate that the water heater to fixture proximity is more compact than a threshold criteria that is defined based on the dwelling unit conditioned floor area, distribution system type, and number of stories. Compactness is characterized by calculating the "Weighted Distance" from the water heater to key fixtures, and the threshold criteria is identified by the "Qualification Distance".[10]

[10] The Qualification Distance is automatically calculated by the ACM.

Determination of the Weighted Distance for a particular floor plan is also dependent on whether it is a non-recirculating or a recirculating distribution system, with the recirculation option only available for single family homes. In each case the basis of the calculation is the plan-view, straight line distance from the water heater to the center of the furthest use point fixture in three locations of the dwelling unit, two of which are the master bathroom and the kitchen. It is calculated using the following equation:

Weighted_Distance = x * d_MasterBath + y * d_Kitchen + z * d_FurthestThird

where,

- x, y, and z = Weighted Distance coefficients (unitless), see Table.
- d_MasterBath = The plan view, straight line distance from the water heater to the furthest fixture in the master bathroom (feet).
- d_Kitchen = The plan view, straight line distance from the water heater to the furthest fixture in the kitchen (feet).
- d_FurthestThird = The plan view, straight line distance from the water heater to the furthest fixture in the furthest room[11] in the dwelling unit (feet).

Table 17: Weighted Distance Coefficients

Distribution System	x	y	z
Non-Recirculating	0.4	0.4	0.2
Recirculating	0.0	0.0	1.0

Note that the calculations are only based on horizontal plan view distance measurements from the center of the water heater to the center of the use point in the designated location.[12] Vertical pipe run lengths (for example, the vertical distance from the first to second floor) are neglected in the calculations. Use points that are located on floors different than the water heater would have their location translated to the floor where the water heater is located.

In houses with multiple water heaters, the Weighted Distance “z term” calculation is performed for each water heater to arrive at a FurthestThird term averaged over each of the “n” water heaters installed. For a non-recirculating distribution system, the resulting Weighted Distance calculation would include the Master Bath, the Kitchen and an average of the FurthestThird term for each of the installed water heaters. (For recirculating systems, similarly the FurthestThird term would represent an average across the “n” water heaters.)

The Qualification Distance is a function of conditioned floor area (CFA), number of stories, and number of installed water heaters. The Qualification Distance for systems with multiple water heaters is identified by using the equation for the appropriate distribution system (recirculation or non-recirculation), and dividing by the number of water heaters installed as shown in the equation below:

Qualification Distance = (a + b * CFA) / n

where

a, b = Qualification distance coefficients (unitless), see Table 20below,

CFA = Conditioned floor area of the dwelling unit (ft^2), and

[11] Because the Master Bath and Kitchen represent unique defined use points, the d_FurthestThird fixture must not be located in either of these rooms. The laundry room is excluded, and should not be used as the furthest third room. In some multifamily cases, there may not be another qualifying use point, in which case the d_FurthestThird term equals zero.

[12] For example, a shower/tub combination would take the measurement from the center of the shower/tub, while a two sink lavatory in the master bath would take the measurement from the center of the lavatory furthest from the water heater.

n = Number of water heaters in the dwelling unit (unitless).

Table 18: Coefficients for the Qualification Distance Calculation

	Coefficient a		Coefficient b	
Building Type	Non-Recirculating	Recirculating	Non-Recirculating	Recirculating
Single Family				
One story	10	22.7	0.0095	0.0099
Two story	15	11.5	0.0048	0.0095
Three story	10	0.5	0.0030	0.0014
Multi-Family				
One story	7.5	n/a	0.0080	n/a
Two or more story	7.5	n/a	0.0050	n/a

7.3 ACM Reference Manual

The following changes are proposed for Appendix B- Water Heating Calculation Method.

B4. Hourly Adjusted Recovery Load

The hourly adjusted recovery load for the kth water heating system is calculated as follows:

$$HARL_k = HSEU_k + HRDL_k + \sum_{1}^{NL_k} HJL_l \qquad \textit{Equation 3}$$

where

$HSEU_k$ = Hourly standard end use at all use point (Btu), see *Equation 4*.

$HRDL_k$ = Hourly recirculation distribution loss (Btu), see Equation 11. ~~$HDRL_k$~~ $HRDL_k$ is non-zero only for multi-family central water heating systems.

NL_k = Number of unfired or indirectly-fired storage tanks in the k^{th} system.

HJL_l = Tank surface losses of the l^{th} unfired tank of the k^{th} system (Btu), see *Equation 40*.

Equation 4 calculates the hourly standard end use (HSEU). The heat content of the water delivered at the fixture is the draw volume in gallons (GPH) times the temperature rise ΔT (difference between the cold water inlet temperature and the hot water supply temperature) times the heat required to elevate a gallon of 1°F (the 8.345 constant).

$$HSEU_k = 8.345 * GPH_k * (T_S - T_{inlet}) \qquad \textit{Equation 4}$$

where

$HSEU_k$ = Hourly standard end use (Btu).

GPH_k = Hourly hot water consumption (Gallons) from Equation 2.

Equation 5 calculates the distribution loss multiplier (DLM) which combines ~~two~~ three terms: the standard distribution loss multiplier (SDLM), which depends on the floor area of the dwelling unit, ~~and~~

the distribution system multiplier (DSM) listed in Table B-1, and the Compactness Factor (CF) which is calculated according to Section 5.6.2.4 of the Residential Compliance Manual.

$$DLM_k = 1 + (SDLM_k - 1) * DSM_k * \text{CF} \qquad \textit{Equation 5}$$

where

DLM_k = Distribution loss multiplier (unitless)

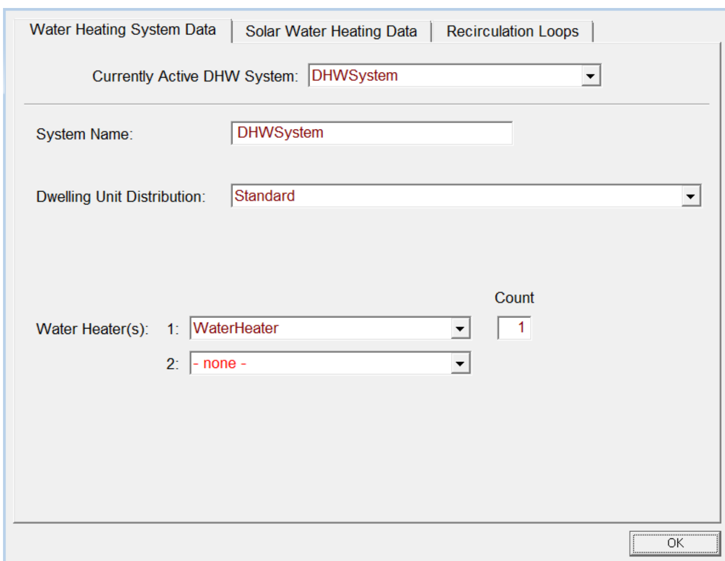
$SDLM_k$ = Standard distribution loss multiplier (unitless), see Equation 6.

DSM_k = Distribution system multiplier (unitless), see Section 3.2

CF = Compactness factor (unitless), default value = 1.0.

The following information is provided to the compliance software vendors:

An example of the current CBECC-Res interface is shown below.



There are two new proposed user inputs to the existing CBECC-Res interface.

1. Above the Dwelling Unit Distribution pull down, another pull down will be added. It will be called Distribution System Compactness and will include three options:
   a. Non-compact,
   b. Compact - Basic, and
   c. Compact - Expanded.

   Non-compact will be the default case.
2. If either Compact – Basic, or Compact – Expanded are selected, a box with the text "Weighted Distance (ft)" will appear to the right of the Distribution System Compactness pull-down menu. The user will need to input the Weighted Distance (calculated as outlined in the Residential Manual).

Qualification Distance will be calculated as shown below:

Qualification_Distance = (a + b * CFA) / n

where

a, b = Qualification distance coefficients, see Table B-1,

CFA = Conditioned floor area of the dwelling unit (ft^2), and

n = Number of water heaters in the dwelling unit (unitless).

Table 20 presents the values of the coefficients depending on the number of stories and whether the distribution system incorporates a recirculation pump.

Table B-1: Coefficients for the Qualification Distance Calculation

	Coefficient a		Coefficient b	
Building Type	Non-Recirculating	Recirculating	Non-Recirculating	Recirculating
Single Family				
One story	10	22.7	0.0095	0.0099
Two story	15	11.5	0.0048	0.0095
Three story	10	0.5	0.0030	0.0014
Multi-Family				
One story	7.5	n/a	0.0080	n/a
Two or more story	7.5	n/a	0.0050	n/a

The Residential Manual provides the Weighted Distance calculations. CF varies as shown below.

If Weighted Distance <= Qualification Distance AND Compact Basic Credit is chosen, then CF = 0.7,

If Weighted Distance <= Qualification Distance AND Compact Expanded Credit is chosen, then

CF = 0.3 + 0.4 * (Weighted Distance) / (Qualification Distance)

7.4 Compliance Manuals

Chapter 5.6.2.4 of the Residential Compliance Manual will need to be revised.

5.6.2.4 ~~HERS-Verified~~ Compact Design (Basic and Expanded Credit Options)

~~A compact distribution system design means that all the hot water use points in a non- recirculating distribution system are within a specified length of piping to the water heater that serves those fixtures.~~

The intent of a compact hot water distribution system design is to reduce the size of the plumbing layout by bringing the water heater in much closer proximity to hot water use points than is typical in standard homes. Through this process, energy and water will be saved, and homeowners will experience reduced hot water waiting times. This compliance option is only applicable to new single family residential buildings and low-rise multifamily apartments where each dwelling unit is served by a dedicated water heater.

~~If the user is complying with the Energy Standards using the prescriptive approach, there is the option of using compact hot water distribution design in combination with a propane or natural gas storage water~~

~~heater (and Quality Insulation Installation, if installing a gas storage water heater that is 55 gallons or less). Compact hot water distribution design can also be used to help achieve the required energy budget (in other words, as a compliance credit) if the user is complying with the Energy Standards using the performance approach. To use the compact hot water distribution design to comply with the Energy Standards, the design and installation must be HERS-verified and meet the Reference Appendix RA4.4.16 requirements~~.

~~Table 5-10 below specifies the maximum pipe run length that meets the compact design criteria based on floor area served (floor area served = building conditioned floor area divided by the number of water heaters), which recognizes that multiple water heaters may be beneficial in achieving a more compact distribution system.~~

~~Typical~~ Installed hot water distribution systems are often ~~designed to be~~ much larger than needed in terms of excessive pipe length and oversized pipe diameter. A design consideration that often is overlooked is the location of the water heater relative to hot water use points. Figure 5-11 below shows a common production home layout with the water heater located in the corner of the garage and hot water use points in each corner of the house.

A more effective hot water distribution system design is shown in Figure 5-12. In the figure, the location of the water heater is near the kitchen and bathrooms and laundry area. The location of hot water use points plays an integral role in achieving the benefits associated with a compact distribution system design.

Eligible compact hot water distribution designs can generate a compliance credit using the performance approach. There are two versions of the Compact Design credit: the Basic Credit and the Expanded Credit. Qualification for both credits is based on using a plan view, straight-line measurement to calculate a “Weighted Distance” to key hot water use points including the master bath, kitchen, and remaining furthest hot water fixture from the water heater. (In some multifamily situations, there may not be another use point beyond the master bath and kitchen, resulting in the third term being ignored.) If this resulting Weighted Distance is less than a Qualification Distance (dependent on floor area, number of stories in the dwelling unit, and number of water heaters), then the plan is eligible for the Basic Credit. The Basic Credit does not require any further verification steps to secure the compliance credit. If the builder chooses to pursue an Expanded Credit, additional energy savings will be recognized under the performance method, however there are several HERS-verification requirements that must be met.

Figure 5-11: "Common" Production Home House Layout

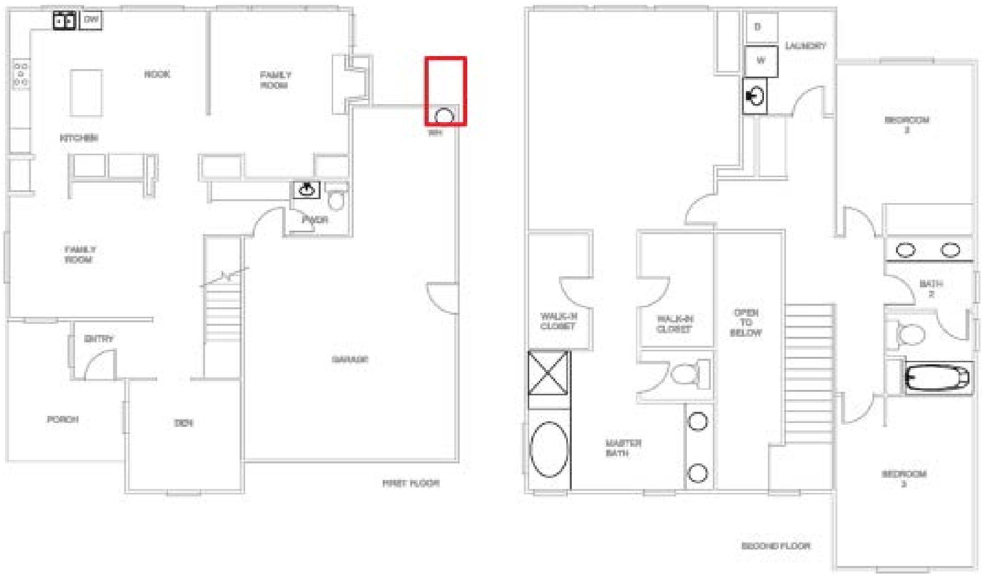


Figure 5-12: Compact Design Distribution System

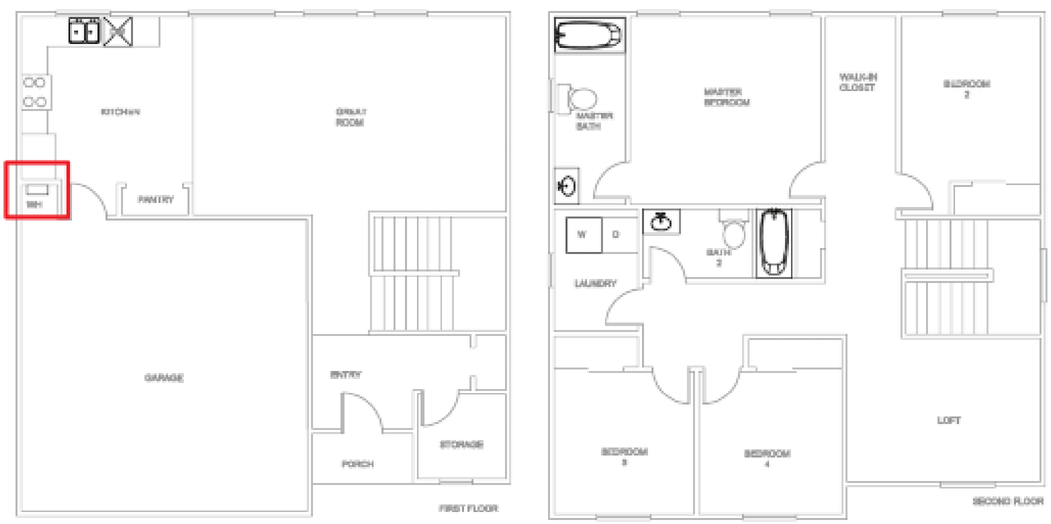


Table 5-10: Compact Distribution System

Floor Area Served (ft2)	*Maximum Water Heater To Use Point Distance (ft)*
< 1000	28’
1001 – 1600	43’
1601 – 2200	53’
2201 – 2800	62’
>2800	68’

5.6.2.4.1 Weighted Distance Calculation Method

The proposal is based on two different Weighted Distance calculations depending on whether it is a standard non-recirculating distribution system or a house with a recirculation distribution system.

The basis of the calculation is a plan-view, straight line measurement from the water heater to the center of the use point fixture in three rooms of the house. It is calculated using the following equation.

$$Weighted\_Distance = x * d\_MasterBath + y * d\_Kitchen + z * d\_FurthestThird$$

where,

- x, y, and z = Weighted Distance coefficients (unitless), see Table 11.
- d_MasterBath = The plan view, straight line distance from the water heater to the furthest fixture in the master bathroom (feet).
- d_Kitchen = The plan view, straight line distance from the water heater to the furthest fixture in the kitchen (feet).
- d_FurthestThird = The plan view, straight line distance from the water heater to the furthest fixture in the furthest room[13] in the house (feet).

Table 11 shows the values for the coefficients depending on the type of distribution system.

Table 11: Weighted Distance Coefficients

Distribution System	x	y	z
Non-Recirculating	0.4	0.4	0.2
Recirculating	0.0	0.0	1.0

Note that the calculations are based on horizontal plan view distance measurements from the center of the water heater to the center of the use point in the designated location. Vertical length (For example, the vertical distance from the first to second floor) is neglected in the calculations. Use points that are located on floors different than the water heater would have their location translated to the appropriate floor.

In houses with multiple water heaters, the Weighted Distance “z term” calculation is performed for each water heater to arrive at a FurthestThird term averaged over each of the “n” water heaters installed. For a non-recirculating distribution system, the resulting Weighted Distance calculation would include the Master Bath, the Kitchen and an average of the FurthestThird term for each of the installed water heaters. (For recirculating systems, similarly the FurthestThird term would represent an average across the “n” water heaters.)

The calculated Weighted Distance input cell would be activated in the compliance software if the user selected either the Basic CHWDS Credit or the Expanded Credit.

Figure 5-13 shows an example weighted distance calculation for an 1,814 square foot two-story house with a standard non-recirculating distribution system. The design locates the water heater on the exterior wall, as shown by the red oval. The dotted blue lines and ovals represent translating the fixtures on the second floor to the first floor, neglecting the vertical distance. The red lines and listed distances represent the distance from the water heater to each fixture used in the calculation. The Weighted Distance calculation for this example is shown below Figure 5-13. Figure 5-14 shows a similar calculation for a centrally located water heater.

[13] Because the Master Bath and Kitchen represent unique defined use points, the d_FurthestThird fixture must not be located in either of these rooms. The laundry room is excluded, and should not be used as the furthest third room. In some multifamily cases, there may not be another qualifying use point, in which case the d_FurthestThird term equals zero.

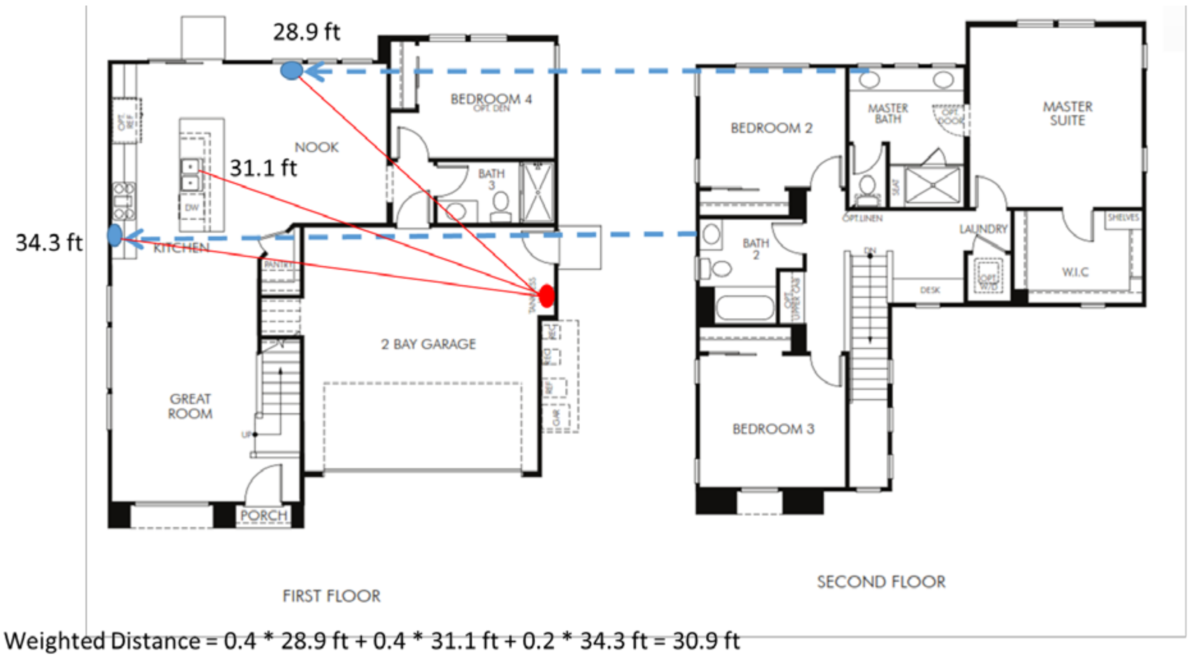


Figure 5-13: Weighted Distance Calculation for the 1,814 Plan with a Conventionally Located Water Heater

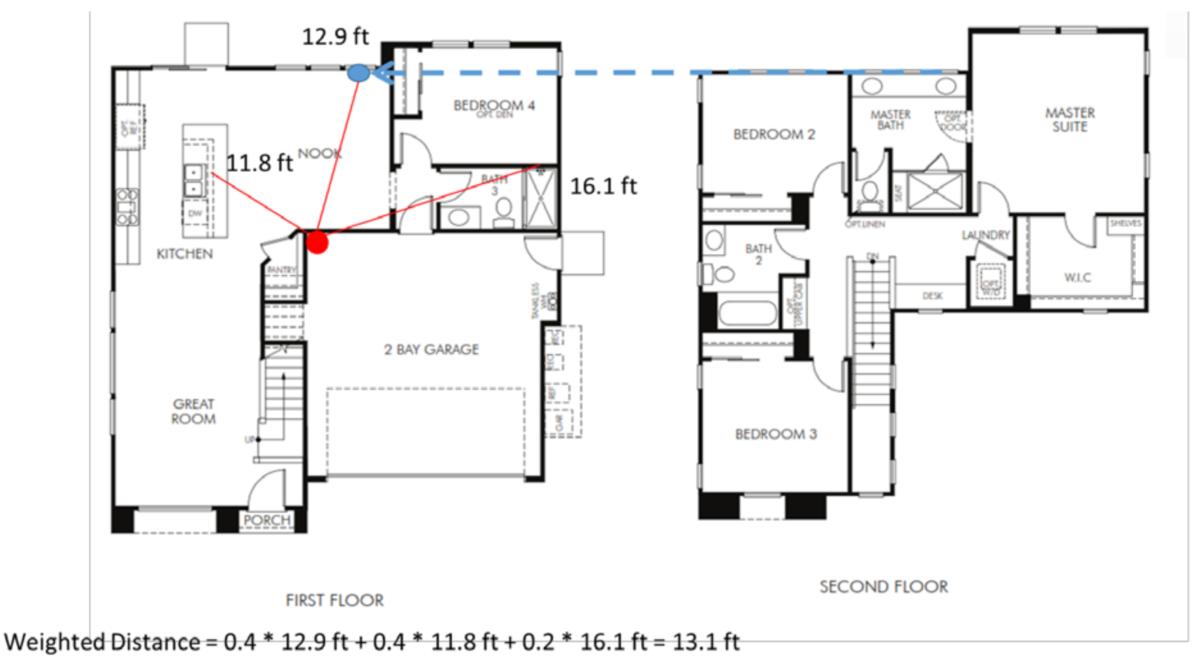


Figure 5-14: Weighted Distance Calculation for the 1,814 Plan with a Centrally Located Water Heater

7.5 Compliance Documents

Forms CF2R-PLB-22-H and CF3R-PLB-22-H will need to be revised to reflect the change in compact design requirements and HERS verification elements.

Proposed modifications to the CF2R-PLB-22-H form are shown below.

H. HERS-Verified Expanded Credit Compact Hot Water Distribution System Requirements Systems that utilize this distribution type shall comply with these requirements		
01	Total Conditioned Floor Area (ft^2):	
02	No hot water piping greater than 1” diameter is allowed ~~Maximum allowed pipe run length from the water heater to the furthest point of use~~ ~~For the floor area served (feet):~~	
03	Length of 1” diameter piping is limited to 8 ft or less ~~The pipe run length from each water heater to the furthest fitting served by that water heater must be no greater than the maximum pipe run length above~~.	
04	Two and three story buildings cannot have hot water distribution piping in the attic, unless the water heater is also located in the attic.	
05	Any recirculating systems installed with the Compact Expanded Credit must be HERS-Verified Demand Recirculation: Manual Control conforming to RA4.4.17	

Proposed modifications to the CF3R-PLB-23-H form are shown below.

H. HERS-Verified Expanded Credit Compact Hot Water Distribution System Requirements Systems that utilize this distribution type shall comply with these requirements		
01	Total Conditioned Floor Area (ft^2):	
02	No hot water piping greater than 1” diameter is allowed ~~Maximum allowed pipe run length from the water heater to the furthest point of use~~ ~~For the floor area served (feet):~~	
03	Length of 1” diameter piping is limited to 8 ft or less ~~The pipe run length from each water heater to the furthest fitting served by that water heater must be no greater than the maximum pipe run length above~~.	
04	Two and three story buildings cannot have hot water distribution piping in the attic, unless the water heater is also located in the attic.	
05	Any recirculating systems installed with the Compact Expanded Credit must be HERS-Verified Demand Recirculation: Manual Control conforming to RA4.4.17	

8. BIBLIOGRAPHY

Association, National Energy Assistance Directors. 2011. "2011 National Energy Assistance Survey Final Report." Accessed February 2, 2017. http://www.appriseinc.org/reports/Final%20NEADA%202011%20Report.pdf.

BW Research Partnership. 2016. *Advanced Energy Jobs in California: Results of the 2016 California Advanced Energy.* Advanced Energy Economy Institute.

CA DWR (California Department of Water Resources). 2016. "California Counties by Hydrologic Regions." Accessed April 3, 2016. http://www.water.ca.gov/landwateruse/images/maps/California-County.pdf.

California Energy Commission. 2015. "2016 Building Energy Efficiency Standards: Frequently Asked Questions." Accessed February 2, 2017. http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/2016_Building_Energy_Efficiency_Standards_FAQ.pdf.

California Energy Commission. 2015. "ACM." http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV2.pdf.

California Public Utilities Commission. 2015a. "Water/Energy Cost-Effectiveness Analysis: Errata to the Revised Final Report." Prepared by Navigant Consulting, Inc. . http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5350.

—. 2015b. "Water/Energy Cost-Effectiveness Analysis: Revised Final Report." Prepared by Navigant Consulting, Inc. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5360.

Energy + Environmental Economics. 2016. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2019 Time Dependent Valuation (TDV) Data Sources and Inputs." Prepared for the California Energy Commission. July. http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf.

Ettenson, Lara , and Christa Heavey. 2015. *California's Golden Energy Efficiency Opportunity: Ramping Up Success to Save Billions and Meet Climate Goals.* Natural Resources Defense Council & Environmental Entrepreneurs (E2).

Goldman, Charles, Merrian C. Fuller, Elizabeth Stuart, Jane S Peters, Marjorie McRay, Nathaniel Albers, Susan Lutzenhiser, and Mersiha Spahic. 2010. *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth.* Lawrence Berkeley National Laboratory.

Henderson, H., and J. Wade. 2014. *Disaggregating Hot Water Use and Predicting Hot Water Waste in Five Test Homes.* U.S. DOE Building America Program. http://www.nrel.gov/docs/fy14osti/61441.pdf.

Hoeschele, M.; Weitzel, E. 2012. *Hot Water Distribution System Model Enhancements.* U.S. DOE Building America Program. http://www.nrel.gov/docs/fy13osti/55203.pdf.

Kosar, D; Glanville, P.; and H. Vadnal. 2015. *Facilitating the Market Transformation to Higher Efficiency Gas-Fired Water Heating.* California Energy Commission. http://www.energy.ca.gov/2013publications/CEC-500-2013-060/CEC-500-2013-060.pdf.

Lutz, J.D. 2008. *Water Heaters and Hot Water Distribution Systems.* California Energy Commission. http://www.energy.ca.gov/2008publications/CEC-500-2008-082/CEC-500-2008-082-APA.PDF .

Nones M.; Gutierrez, E. 2015. "Evaluation of Residential Recirculation Pumps." Emerging Technology Coordinating Council, ETCC. http://www.etcc-ca.com/reports/evaluation-residential-recirculation-pumps.

Parker, D.; Fairey, P.; and Lutz, J.; . 2015. *Estimating Daily Hot-Water Use in North American Homes.* Journal Article, American Society of Heating, Refrigeration, and Air Conditioning Engineers. http://www.techstreet.com/standards/at-15-021-estimating-daily-domestic-hot-water-use-in-north-american-homes?product_id=1904287.

Stone, Nehemiah, Jerry Nickelsburg, and William Yu. 2015. *Codes and Standards White Paper: Report - New Home Cost v. Price Study.* Pacific Gas and Electric Company. Accessed February 2, 2017. http://docketpublic.energy.ca.gov/PublicDocuments/Migration-12-22-2015/Non-Regulatory/15-BSTD-01/TN%2075594%20April%202015%20Codes%20and%20Standards%20White%20Paper%20-%20Report%20-%20New%20Home%20Cost%20v%20Price%20Study.pdf.

Thornberg, Christopher, Hoyu Chong, and Adam Fowler. 2016. *California Green Innovation Index - 8th Edition.* Next 10.

U.S. Census Bureau, Population Division. 2014. "Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014." http://factfinder2.census.gov/bkmk/table/1.0/en/PEP/2014/PEPANNRES/0400000US06.05000.

U.S. EPA (United States Environmental Protection Agency). 2011. "Emission Factors for Greenhouse Gas Inventories." Accessed December 2, 2013. http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

Wei, Max, Shana Patadia, and Daniel M. Kammen. 2010. "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy* 38: 919-931.

Weitzel, E.; Hoeschele, M. 2014. *Evaluating Domestic Water Distribution System Options With Validated Analysis Models.* U.S. DOE Building America Program. http://www.nrel.gov/docs/fy14osti/62848.pdf.

Zabin, Carol, and Karen Chapple. 2011. *California Workforce Education & Training Needs Assessment: For Energy Efficiency, Distributed Generation, and Demand Reponse.* University of California, Berkeley Donald Vial Center on Employment in the Green Economomy. Accessed February 3, 2017. http://laborcenter.berkeley.edu/pdf/2011/WET_Appendices_ALL.pdf.

Zilllow. 2017. "Zillow Home Value Index: Single-Family Homes Time Series ($)." Accessed February 20, 2017. https://www.zillow.com/research/data/#median-home-value.

Personal Communications:

Payam Bozorgchami, California Energy Commission
Amanda Johnson, Villara Building Systems
Jim Kemper, LADWP
Gary Klein, Gary Klein and Associates
Adam Lorton, Villara Building Systems
Jim Lutz, Hot Water Research
Shawn Mayer, Harris & Sloan
Ken Nittler, Enercomp
Ed Osann, National Resources Defense Council
Bob Radcliff, Villara Building Systems
Danny Tam, California Energy Commission
Jim Vacarro, Rinnai
Yanda Zhang, ZYD Energy

Appendix A: STATEWIDE SAVINGS METHODOLOGY

The projected new residential construction forecast that will be impacted by the proposed code change in 2020 is presented in Table 12.

The Statewide CASE Team estimated statewide impacts for the first year that new single family and multifamily buildings comply with the 2019 Title 24, Part 6 Standards by multiplying per-unit savings estimates by statewide construction forecasts that the California Energy Commission Demand Analysis Office provided. The construction forecast from the Energy Commission presented annual new construction estimates for single family and multifamily dwelling units by forecast climate zones (FCZ). The Statewide CASE Team converted estimates from FCZ, which are not used for Title 24, Part 6, to building standards climate zones (BSCZ) using a conversion factors that the Energy Commission provided. The conversion factors, which are presented in Table 13, represent the percentage of dwelling units in a FCZ that are also in a BSCZ. For example, looking at the first column of conversion factors in see Table 13, 22.5 percent of the homes in FCZ 1 are also in BSCZ 1 and 0.1 percent of homes in FCZ 4 are in BSCZ 1. To convert from FCZ to BSCZ, the total forecasted construction in each FCZ was multiplied by the conversion factors for BSCZ 1, then all homes from all FCZs that are found to be in BSCZ 1 are summed to arrive at the total construction in BSCZ 1. This process was repeated for every climate zone. See Table 14 for an example calculation to convert from FCZ to BSCZ. In this example, BSCZ 1 is made up of homes from FCZs 1, 4, and 14.

After converting the statewide construction forecast to BSCZs, the Statewide CASE Team made assumptions about the percentage of buildings in each climate zone that will be impacted by the proposed code change. Assumptions are presented in Table 12.

Table 12: Projected New Residential Construction Completed in 2020 by Climate Zone[a]

Building Climate Zone	Single Family Buildings					Multifamily Dwelling Units[b]				
	Total Buildings Completed in 2020	Percent of Total Construction in Climate Zone	Percent of New Buildings Impacted by Proposal	Buildings Impacted by Proposal	Percent of Total Impacted by Proposal in Climate Zone	Total Dwelling Units Completed in 2020	Percent of Total Construction in Climate Zone	Percent of New Dwelling Units Impacted by Proposal	Dwelling Units Impacted by Proposal	Percent of Total Impacted by Proposal in Climate Zone
1	465	0.4%	10%	46	0.06%	111	0.2%	10%	11	0.02%
2	3,090	2.6%	10%	309	0.24%	1,582	3.0%	10%	158	0.30%
3	11,496	9.8%	10%	1,150	0.57%	8,432	16.1%	10%	843	1.61%
4	7,435	6.4%	10%	743	0.54%	3,848	7.3%	10%	385	0.73%
5	1,444	1.2%	10%	144	0.11%	747	1.4%	10%	75	0.14%
6	6,450	5.5%	10%	645	0.41%	3,379	6.4%	10%	338	0.64%
7	5,779	4.9%	10%	578	0.55%	3,939	7.5%	10%	394	0.75%
8	9,948	8.5%	10%	995	0.6%	5,153	9.8%	10%	515	0.98%
9	12,293	10.5%	10%	1,229	0.54%	10,350	19.7%	10%	1,035	1.97%
10	18,399	15.7%	10%	1,840	1.72%	4,191	8.0%	10%	419	0.80%
11	3,947	3.4%	10%	395	0.59%	747	1.4%	10%	75	0.14%
12	19,414	16.6%	10%	1,941	1.93%	6,023	11.5%	10%	602	1.15%
13	7,034	6.0%	10%	703	1.20%	1,375	2.6%	10%	138	0.26%
14	3,484	3.0%	10%	348	0.31%	756	1.4%	10%	76	0.14%
15	3,203	2.7%	10%	320	0.35%	454	0.9%	10%	45	0.09%
16	3,188	2.7%	10%	319	0.29%	1,441	2.7%	10%	144	0.27%
Total	**117,069**	**100.0%**		**11,707**	**10.0%**	**52,528**	**100%**		**5,253**	**10.0%**

Source: Energy Commission Demand Analysis Office

a. Statewide savings estimates do not include savings from mobile homes.

b. Includes high-rise and low-rise multifamily construction.

Table 13: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ)

		Building Standards Climate Zone (BSCZ)																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Forecast Climate Zone (FCZ)	**1**	22.5%	20.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	33.1%	0.2%	0.0%	0.0%	13.8%	100.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	75.7%	0.0%	0.0%	0.0%	2.3%	100.0%
	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.9%	22.8%	54.5%	0.0%	0.0%	1.8%	100.0%
	4	0.1%	13.7%	8.4%	46.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%	0.0%	0.0%	0.0%	100.0%
	5	0.0%	4.2%	89.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%	0.0%	0.0%	100.0%
	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.8%	7.1%	0.0%	17.1%	100.0%
	8	0.0%	0.0%	0.0%	0.0%	0.0%	40.1%	0.0%	50.8%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	100.0%
	9	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	26.9%	54.8%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%	5.8%	100.0%
	10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	74.9%	0.0%	0.0%	0.0%	12.3%	7.9%	4.9%	100.0%
	11	0.0%	0.0%	0.0%	0.0%	0.0%	27.0%	0.0%	30.6%	42.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	12	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	4.2%	95.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	100.0%
	13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.6%	0.0%	0.0%	28.8%	0.0%	0.0%	0.0%	1.6%	0.1%	0.0%	100.0%
	14	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.1%	100.0%
	15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	99.9%	0.0%	100.0%
	16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

Table 14: Converting from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ) – Example Calculation

Climate Zone	Total Statewide Single Family Homes by FCZ [A]	Conversion Factor FCZ to BSCZ 1 [B]	Single Family Homes in BSCZ 1 [C] = A x B
1	1,898	22.5%	427
2	8,148	0.0%	0
3	9,396	0.0%	0
4	16,153	0.1%	23
5	11,385	0.0%	0
6	6,040	0.0%	0
7	2,520	0.0%	0
8	12,132	0.0%	0
9	9,045	0.0%	0
10	21,372	0.0%	0
11	3,741	0.0%	0
12	4,746	0.0%	0
13	8,309	0.0%	0
14	518	2.9%	15
15	1,509	0.0%	0
16	159	0.0%	0
Total	117,069		**465**

Appendix B: EMBEDDED ELECTRICITY IN WATER METHODOLOGY

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

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

The CPUC embedded electricity values used in the CASE analysis are show in Table 15. These values represent the average energy intensity by hydrologic region, which are based on the historical supply mix for each region regardless of who supplied the electricity (IOU supplied and non-IOU supplied). The CPUC calculated the energy intensity of marginal supply, but recommended using the average IOU and non-IOU energy intensity to estimate total statewide average embedded electricity of water use in California.

Table 15: Embedded Electricity in Water by California Department of Water Resources Hydrologic Region (kWh Per Acre Foot)

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

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

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

Source: (California Public Utilities Commission 2015b)

The Statewide CASE Team used the CPUC's indoor and outdoor embedded electricity estimates by hydrologic region (presented in Table 15) and population data by hydrologic region from the U.S. Census Bureau to calculate the statewide population-weighted average indoor and outdoor embedded electricity values that were used in the CASE analysis (see Table 16). The energy intensity values presented in Table 15 were converted from kWh per acre foot to kWh per million gallons to harmonize with the units used in the CASE analysis. There are 3.07 acre feet per million gallons.

Table 16: Statewide Population-Weighted Average Embedded Electricity in Water

Hydrologic Region	Indoor Water Use (kWh/ million gallon)	Outdoor Water Use (kWh/ million gallon)	Percent of California Population
North Coast	2,504	1,221	2.1%
San Francisco	3,410	2,127	18.2%
Central Coast	3,360	2,078	3.8%
South Coast	7,227	5,944	44.8%
Sacramento River	2,068	783	8.1%
San Joaquin River	2,194	911	4.7%
Tulare Lake	2,507	1,224	6.3%
North Lahontan	2,213	930	0.1%
South Lahontan	4,352	3,069	5.5%
Colorado River	2,191	908	6.5%
Statewide Population-Weighted Average	**4,848**	**3,565**	

Sources: (U.S. Census Bureau, Population Division 2014, CA DWR (California Department of Water Resources) 2016)

Appendix C: DISCUSSION OF IMPACTS OF COMPLIANCE PROCESS ON MARKET ACTORS

This section discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. The Statewide CASE Team asked stakeholders for feedback on how the measure would impact various market actors during public stakeholder meetings that were held on October 26th, 2016 and March 23rd, 2017. (Statewide CASE Team 2016). The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Table 17 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they will be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated.

The proposed measure does not present any significant challenges to compliance and enforcement. The compliance process generally fits within the current work flow of market actors, although some new tasks will be required (see Table 17). Market actors will continue to coordinate and collaborate with the same actors with whom they currently engage. There will not be any new documentation practices required, such as new compliance documents.

Table 17: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) in Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Title 24 Consultant	• Convey compact eligibility criteria to builder. • Perform required calculations to confirm compliance. • Verify design meets compact criteria.	• Clearly communicate eligibility criteria to builder and construction team. • Demonstrate compliance and energy performance goals are met.	• For "basic" compliance option credit, only work flow impact is plan view calculation. • For "enhanced" credit, need to clearly convey eligibility criteria and need for HERs verification.	• Ensure that any compact eligibility criteria and HERS inspection requirements are clearly articulated in specifications/plans and that design team and builder are aware (enhanced only).
Builder / General Contractor	• Convey desire for compact hot water distribution layout • Work with architect on design elements to ensure compact criteria are met.	• Work is completed according to specifications and within budget and on schedule • Favorable homeowner feedback.	• For "basic" compliance credit, no impact on work flow. • For "enhanced" compliance credit, additional coordination with plumber to coordinate on requirements. • Will need to verify that contractors are aware of HERS inspections and associated requirements. • For "enhanced" compliance credit, will require builders to make sure compact criteria are being met in the field.	• Ensure contracts with subs are explicit with compact requirements (enhanced only). • Work with plumber to optimally locate water heater and identify any installation issues related to water heater relocation (e.g. venting, condensate, and/or gas line). • Clearly articulate goals and expectations to contractors and HERS Rater (enhanced only).
Architect	• Implement compact design strategy through location of hot water use points/fixtures. • Clearly communicate to builder and Title 24 consultant.	• Comply with standards using the compact design credit with minimal paperwork and cost.	• Will require architect to coordinate with plumber on any design implications related to water heater location. • Water heater proximity issues could influence architectural.	• Ensure that any code issues are addressed related to water heater relocation.

			design. As a compliance option, this would not be a required measure, so not clear if this is a significant issue.	
Plumber	• Install plumbing system meeting compact design criteria.	• Meet builder's schedule. • Complete installs without budget overruns. • If "enhanced" design, verify that eligibility criteria are met.	• Need to familiarize designers and installation crews with eligibility criteria (enhanced only).	• Ensure that installation crews are aware of eligibility requirements (enhanced only).
Building Inspector	• Verify that all paperwork is in order and CF-2R and CF-3Rs are signed off and certified. • Complete any inspections. • Sign off permit.	• Minimize time in field and amount of paperwork needed to complete process.	• No impact anticipated.	• No negative impact anticipated.
HERS Rater	• For "basic" design, there is no HERS involvement. • For "enhanced" design, verify that eligibility criteria are met.	• Complete CF3R documentation (enhanced only).	• Simplified HERS process would streamline "enhanced" verification relative to current 2016 requirements. Timing of verification could work well with other HERS visits (enhanced only).	• Combine HERS inspection with other on-site HERS visit (enhanced only).
Plans Examiner	• Verify that CF-1R is consistent with building plans and meets compliance criteria for local jurisdiction.	• Minimize amount of paperwork needed and time to complete review.	• Plan view verification (simple plan takeoff and calculation).	• None.

Appendix D: Documentation for ACM Development

Background

The 2016 Title 24, Part 6 Residential Alternative Calculation Method (ACM) provides for a compliance option credit for CHWDS (California Energy Commission 2015). The fundamental goal of the CHWDS credit is to reward building designs that bring the water heater close to the hot water use points. To qualify for the credit, the builder must have a HERS inspector verify that the total length of plumbing between the water heater and furthest hot water use point is shorter than a threshold value as shown in Table 18. If compliance is demonstrated, the DSM used in residential compliance software calculations is set at 0.7.[14]

Table 18: 2016 Maximum Allowed CHWDS Pipe Lengths

Floor Area Served (ft^2)	Maximum Measured Water Heater to Use Point Distance (ft)
< 1000	28’
1001-1600	43’
1601-2200	53’
2201-2800	62’
> 2800	68’

Under the 2016 Title 24 code, the Statewide CASE Team expects to see a high saturation of gas instantaneous water heaters in new single family homes with typical locations on exterior garage walls, resulting in greater plumbing distances between the water heater and hot water use points. The exterior garage wall location, combined with the associated “cold start” delays, exacerbate hot water delivery, water waste, and increased homeowner wait times.

To address concerns with the current compact criteria and to bolster industry uptake of the measure, the Statewide CASE Team has developed a simplified 2019 CHWDS draft proposal. The credit aims to motivate builders to locate the water heater in a central location, thereby reducing occupant wait time for hot water, and associated energy use and water waste. The credit could be achieved through locating the water heater on the exterior wall of the house adjacent to conditioned space (close to key use points, such as a kitchen or master bath), centrally in the attic, or in a garage location in closer proximity to the fixtures. While these alternative locations are available, builders have expressed a strong preference to locate the water heater in the garage in single family homes. The following narrative description uses the term “centrally located in the garage” to describe the basic concept of bringing the water heater in close proximity to use points.

The proposal is based on two levels of credit: Basic and Expanded. The Basic Credit would consist of a plan view check without any HERS verification, significantly reducing the effort required to demonstrate compliance. Alternatively, builders could pursue an Expanded Credit by meeting more rigorous criteria, including meeting eligibility criteria through several simple HERS verification inspections. The Expanded Credit would increase savings, depending upon the level of compactness of

[14] The DSM compares the proposed distribution system to a “standard” trunk and branch distribution system which has a nominal DSM of 1.0. Better performing distribution systems have DSMs below 1.0 and worse performing would have a DSM greater than 1.0.

the plumbing design. The following sections describe the method of determining compliance for the Basic and Expanded Credit, as well as background information used to develop the approach.

Basic Compact Credit

To apply for the Basic Compact credit, calculations must be completed in the design process that demonstrate that the plumbing design (water heater to fixture proximity) is more compact than a threshold criteria that is defined based on the dwelling unit conditioned floor area and number of stories. Compactness is characterized by calculating the "Weighted Distance" from the water heater to the fixtures, and the threshold is identified by the "Qualification Distance"[15]. Details on the calculations are presented in the following sections.

Weighted Distance

The proposal is based on two different Weighted Distance calculations depending on whether it is a standard non-recirculating distribution system or a dwelling unit with a recirculation distribution system.

Determination of the Weighted Distance for a particular floor plan is also dependent on whether it is a non-recirculating or a recirculating distribution system (the latter, for single family homes only). The calculation is based on a generic equation with modifications based on the distribution system type. In each case the basis of the calculation is the plan-view, straight line distance from the water heater to the center of the furthest use point fixture in three rooms of the house, two of which are the master bathroom and the kitchen. It is calculated using the following equation:

Weighted_Distance = x * d_MasterBath + y * d_Kitchen + z * d_FurthestThird

where,

- x, y, and z = Weighted Distance coefficients (unitless), see Table 17.
- d_MasterBath = The plan view, straight line distance from the water heater to the furthest fixture in the master bathroom (feet).
- d_Kitchen = The plan view, straight line distance from the water heater to the furthest fixture in the kitchen (feet).
- d_FurthestThird = The plan view, straight line distance from the water heater to the furthest fixture in the furthest room[16] in the house (feet), excluding the laundry room.

Table 19: Weighted Distance Coefficients

Distribution System	x	y	z
Non-Recirculating	0.4	0.4	0.2
Recirculating	0.0	0.0	1.0

The rationale behind the weighting factors is as follows. For non-recirculating systems, the master bath and kitchen represent the two use points found in all dwellings which include high hot water usage and

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[15] The Qualification Distance will be automatically calculated by the ACM.

[16] Because the master bath and kitchen represent unique defined use points, the d_FurthestThird fixture must not be located in either of these rooms. The laundry room is excluded, and should not be used as the furthest third room. In some multifamily cases, there may not be another qualifying use point, in which case the d_FurthestThird term equals zero.

are also most prone to customer satisfaction concerns related to long wait times for hot water delivery. For this reason, a higher weighting factor of 0.4 was applied to these two locations. At the same time, the furthest remaining fixture also should be factored in to the compactness assessment, and is therefore assigned a factor of 0.2. For recirculating systems in single family homes, the size of the recirculation loop is dictated by how far the loop has to be extended to serve that fixture (with prompt hot water delivery), hence full weighting is applied to the furthest fixture to represent the loop in close proximity to the most remote use point.

Note that the calculations are only based on horizontal plan view distance measurements from the center of the water heater to the center of the use point in the designated location.[17] Vertical length (For example, the vertical distance from the first to second floor) is neglected in the calculations. Use points that are located on floors different than the water heater would have their location translated to the appropriate floor.

In dwellings with multiple water heaters, the Weighted Distance “z term” calculation is performed for each water heater to arrive at a FurthestThird term averaged over each of the “n” water heaters installed. For a non-recirculating distribution system, the resulting Weighted Distance calculation would include the Master Bath, the Kitchen and an average of the FurthestThird term for each of the installed water heaters. (For recirculating systems, similarly the FurthestThird term would represent an average across the “n” water heaters.)

Figure 3 shows an example weighted distance calculation for an 1,814 square feet two-story house with a standard non-recirculating distribution system. The design locates the water heater on the exterior wall, as shown by the red oval. The dotted blue lines and ovals represent translating the fixtures on the second floor to the first floor, neglecting the vertical distance. The red lines and listed distances represent the distance from the water heater to each fixture used in the calculation. The Weighted Distance calculation for this example is shown below Figure 3.

[17] For example, a shower/tub combination would take the measurement from the center of the shower/tub, while a two sink lavatory in the master bath would take the measurement from the center of the lavatory furthest from the water heater.

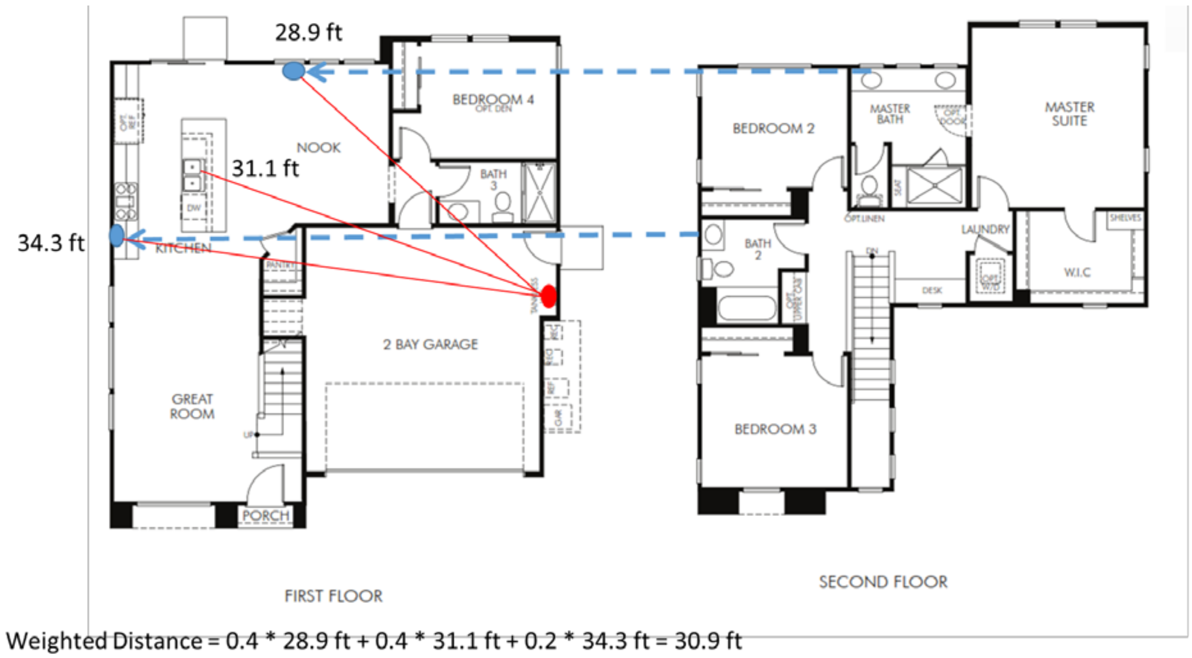

Figure 3: Example weighted distance calculation

Qualification Distance

To qualify for the Basic Credit, the Weighted Distance must be less than the Qualification Distance. The Qualification Distance is a function of conditioned floor area (CFA), number of stories, and number of installed water heaters. It was developed based on a review of 60 production builder single family floor plans from sixteen different builders and from 34 multifamily floor plans from current projects being built throughout California. The Qualification Distance is the identified threshold defining compact from non-compact distribution systems. The proposed criterion was developed based on allowing ~25 percent of the 60 single family floor plans with water heaters located on the external wall of the garage to meet the criteria based solely on the relative compactness of the architectural design. Similarly ~25 percent of multifamily plans with water heaters in exterior closets would also comply based on the proximity of the use points to that location. In both cases, the remaining ~ 75 percent of plans would need to relocate the water heater to achieve the criteria. Similarly, ~75 percent of floor plans with a centrally (optimally) located water heater in the garage achieving the credit.

The Qualification Distance calculation changes based on the type of distribution system (recirculation, non-recirculation, and the number of installed water heaters). The following sections document the Qualification Distance equations for each distribution system type with more detailed information on the plan evaluation results located in the Additional Information on Qualification Distance Calculations section at the end of this document.

The Qualification Distance for single family systems with multiple water heaters is identified by using the equation for the appropriate distribution system (recirculation or non-recirculation), and dividing by the number of water heaters installed.

The generic form of the Qualification Distance formula is shown below, and the coefficients are included in Table 20.

Qualification Distance = (a + b * CFA) / n

where

a, b = Qualification distance coefficients (unitless), see Table 20,

CFA = Conditioned floor area of the dwelling unit (ft^2), and

n = Number of water heaters in the dwelling unit (unitless).

Table 20 presents the values of the coefficients depending on the building type, number of stories, and type of distribution system.

Table 20: Coefficients for the Qualification Distance Calculation

	Coefficient a		Coefficient b	
Building Type	Non-Recirculating	Recirculating	Non-Recirculating	Recirculating
Single Family				
One story	10	22.7	0.0095	0.0099
Two story	15	11.5	0.0048	0.0095
Three story	10	0.5	0.0030	0.0014
Multi-Family				
One story	7.5	n/a	0.0080	n/a
Two or more story	7.5	n/a	0.0050	n/a

The Qualification Distance calculation for the example 1,814 square feet, two-story house in Figure 3 is shown below.

Qualification Distance = 15 + 0.0048 * 1814 ft^2 = 23.2 ft.

Application of Credit in the ACM

2016 Title 24, Part 6 ACM Appendix B uses an equation based on the size of the building and type of distribution system to estimate the energy lost in the pipes. It is currently calculated using the following equation.

$$DLM_k = 1 + (SDLM_k - 1) * DSM_k$$

where

DLM_k = Distribution loss multiplier (unitless),

$SDLM_k$ = Standard distribution loss multiplier (unitless), and

DSM_k = Distribution system multiplier (unitless).

$SDLM_k$ is a function of the size of the dwelling unit, and DSM_k is determined by the type of distribution system. The Title 24 ACM Manual contains a table specifying the DSM_k for each type of distribution system. The 2019 code change proposal would add a term, the Compactness Factor (CF), to that equation. The proposed form is shown below.

$$DLM_k = 1 + (SDLM_k - 1) * DSM_k * \text{CF}$$

The CF is a multiplier that reduces the distribution loss multiplier in compact distribution systems. Plans that are not compliant with the Basic Credit calculation will use a CF of 1. Plans that earn the Basic Credit would receive a CF of 0.7, and plans meeting the Expanded Credit eligibility criteria would achieve a CF less than 0.7, depending upon the level of distribution system compactness.

The 1,814 square foot floor plan has a 30.9 feet Weighted Distance and a 23.2 feet Qualification Distance (as shown in Figure 3). As currently designed, it does not qualify for the Basic Credit and would receive a CF of 1.0. However, relocating the water heater as shown in Figure 4 below results in a significantly reduced Weighted Distance.

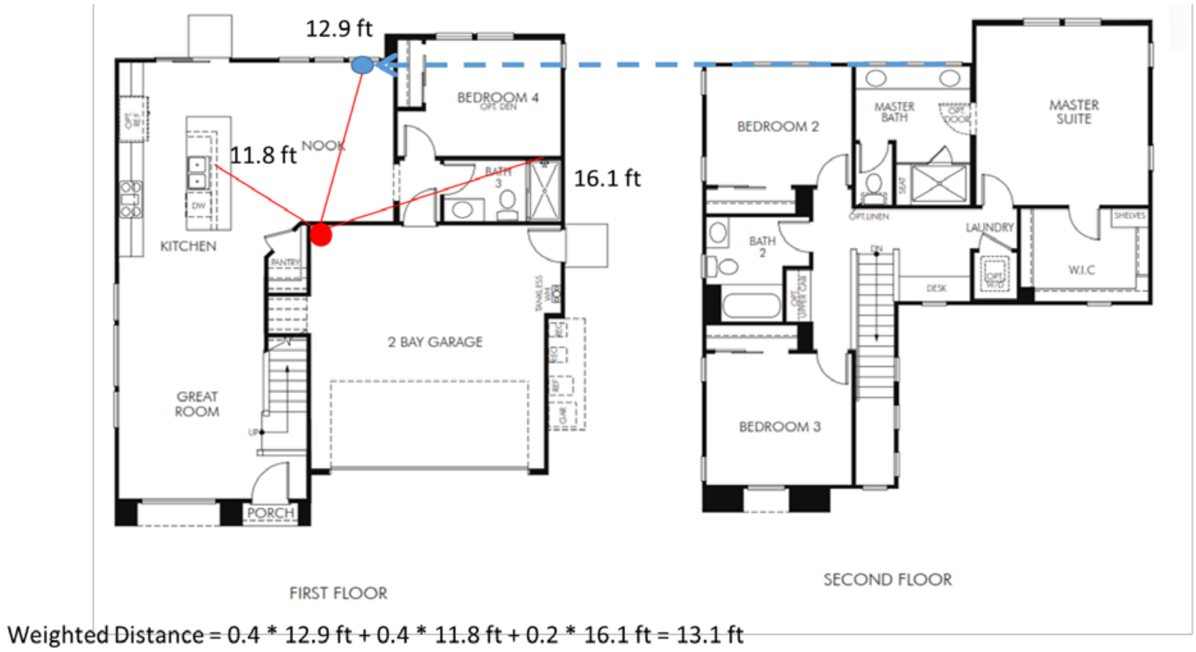

Figure 4: Example weighted distance calculation with a central water heater

With a centrally located water heater, the 13.1 feet Weighted Distance is less than the 23.2 feet Qualification Distance, and the home would receive the Basic Credit. The CF-1R would report that the plan meets the Compact Basic Credit.

Expanded Credit

The Expanded Credit is more difficult to achieve, but rewards the builder with a larger compliance credit, and allows the magnitude of the credit to scale with increasing level of plumbing compactness. In order to earn the Expanded Credit, the plan must first meet the Basic Credit criteria. In addition, there is a HERS verification requirement demonstrating that the following eligibility criteria have been met.

- No hot water piping greater than one-inch diameter is allowed,
- Length of one-inch diameter piping limited to eight feet or less,
- Two and three story dwelling units cannot have hot water distribution piping in the attic, unless the water heater is also located in the attic, and
- Eligible recirculating systems must be HERS-Verified Demand Recirculation: Manual Control conforming to RA4.4.17.

By meeting these eligibility criteria, the builder will earn a credit larger than the Basic Credit that scales with the level of compactness. The scaling factor is based on the ratio of the Weighted Distance to the Qualification Distance. The credit will scale from a minimum of 0.3 (the existing 2016 ACM distribution system credit for point of use systems) to a maximum value equal to the Basic Credit (0.7), as shown below:

CF = 0.3 + 0.4 * (Weighted_Distance) / (Qualification_Distance)

Since a Weighted Distance of zero feet in length cannot physically be met, a CF of 0.3 is not physically possible, but only defines the lower bounds of the equation.

Returning to the 1,814 square feet example shown in Figure 4, the centrally located water heater had a Weighted Distance of 13.1 feet and a Qualification Distance of 23.2 feet. The following equation shows the CF this house would receive under the Expanded Credit.

$CF = 0.3 + 0.4 * (13.1/23.2) = 0.52$

The CF-1R would report that the plan meets the Compact Expanded Credit. The CF-2R Form CF2R-PLB-22-H would specify the required eligibility criteria for the installer and the CF-3R Form CF3R-PLB-22-H would represent the HERS verification component.

Additional Information on Qualification Distance Calculations

The Qualification Distance equations were created based on a review of 60 single family production builder floor plans and 34 multifamily plans currently available in California. To create the Qualification Distance, the following steps were taken:

1. Calculate the Weighted Distance for each floor plan using the water heater location as listed on the plans.
2. Repeat the calculations, assuming a water heater optimally (i.e. central to the use points for that plan) located in the garage (for single family) or in an interior location (multifamily).
3. Create a Qualification Distance formula which passes ~25 percent of floor plans with the non-centrally located water heater,[18] and ~75 percent of floor plans with the relocated, central water heater.

The following series of plots show the data used to create the Qualification Distance equations for single family one-, two-, and three-story buildings for both standard distribution systems and recirculation loops, and for multifamily one and multiple story apartments. In each case the yellow data points represent the Weighted Distance results for the externally located water heater, the blue points for the centrally located water heater, and the red line represents the proposed Qualification Distance line. The tables after each plot show the percentage of floor plans that were reviewed which qualify in both the external location and central water heater locations.

[18] These 25 percent of plans would be considered to have plan designs with use points located closer to the water heater.

Single Family Qualification Distance for Non-Recirculating Distribution Systems

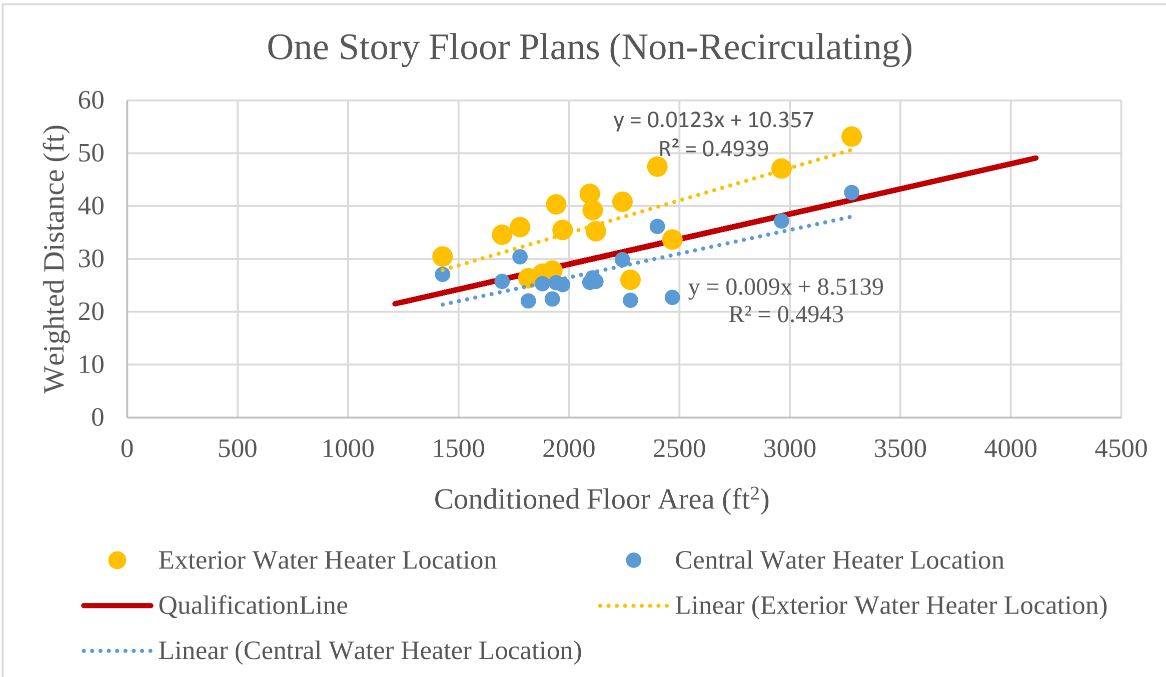

Figure 5: Weighted distance calculations and qualification distance for one-story single family homes (non-recirculating)

Table 21: Single Family One-Story Floor Plans that Meet the Criterion (Non-Recirculating)

Water Heater Location	Passing Floor Plans (%)
External Wall in Garage	24
Central in Garage	76

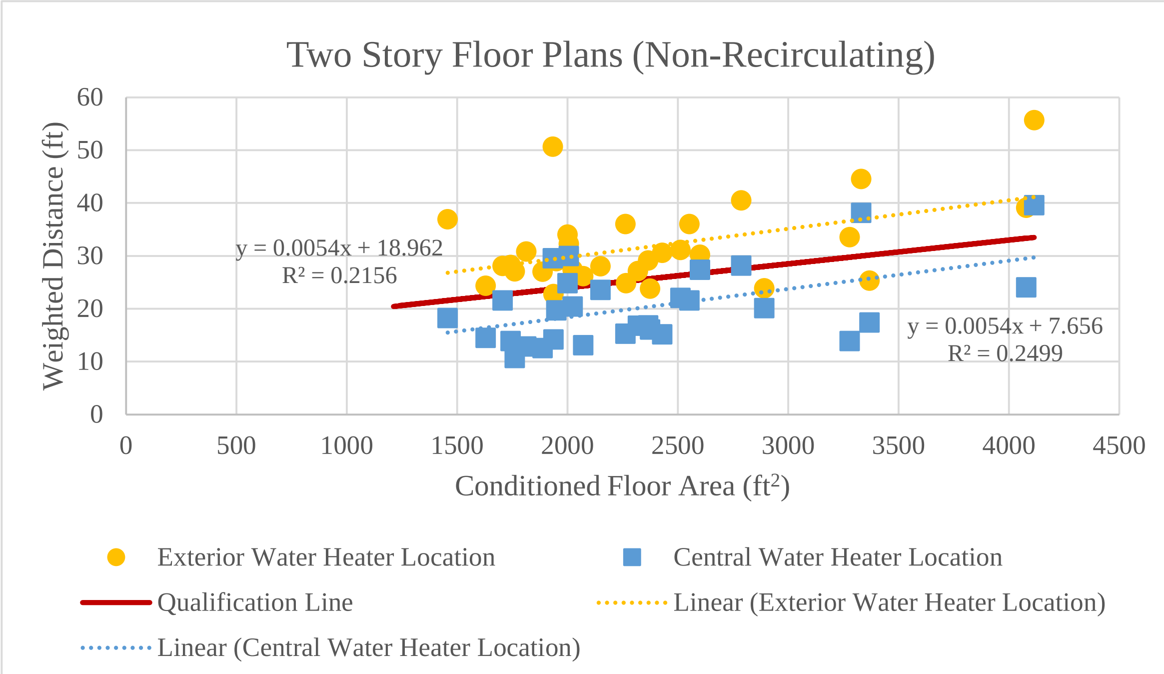

Figure 6: Weighted distance calculations and qualification distance for two-story single family homes (non-recirculating)

Table 22: Single Family Two-Story Floor Plans that Meet the Criterion (Non-Recirculating)

Water Heater Location	Passing Floor Plans (%)
External Wall in Garage	16
Central in Garage	77

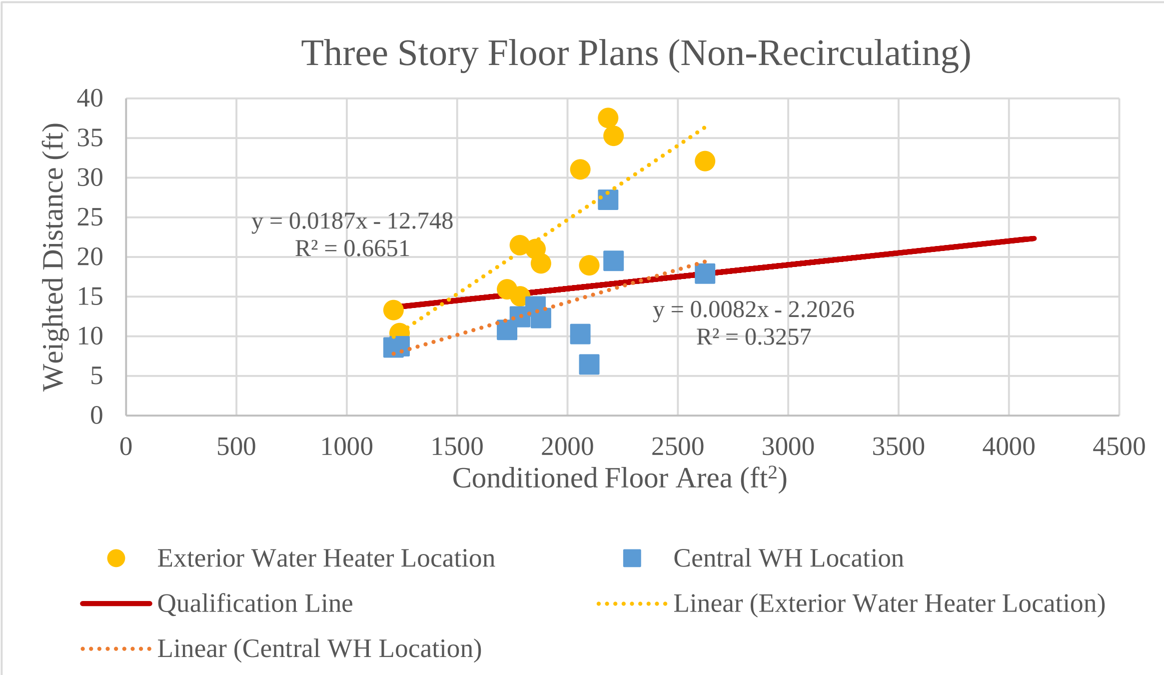

Figure 7: Weighted distance calculations and qualification distance for three-story single family homes (non-recirculating)

Table 23: Single Family Three-Story Floor Plans that Meet the Criterion (Non-Recirculating)

Water Heater Location	Passing Floor Plans (%)
External Wall in Garage	25
Central in Garage	75

Single Family Qualification Distance for Recirculation Loops

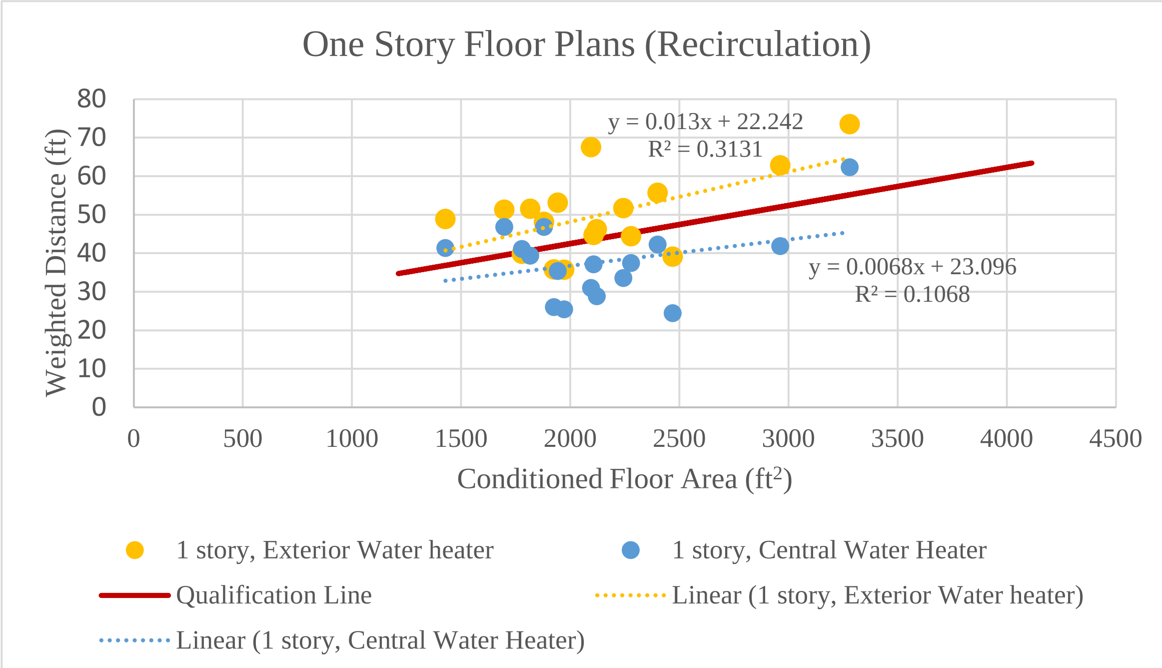

Figure 8: Weighted distance calculations and qualification distance for one-story single family homes (recirculation)

Table 24: Single Family One-Story Floor Plans that Meet the Criterion (Recirculation)

Water Heater Location	Passing Floor Plans (%)
External Wall in Garage	29
Central in Garage	71

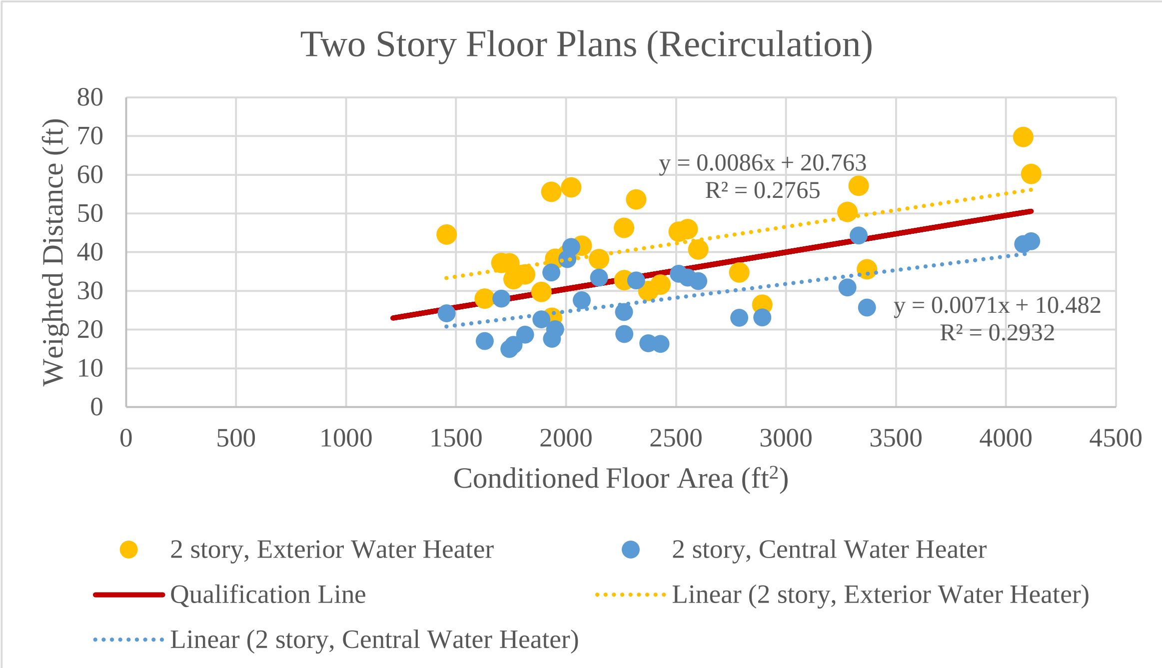

Figure 9: Weighted distance calculations and qualification distance for two-story single family homes (recirculation)

Table 25: Single Family Two-Story Floor Plans that Meet the Criterion (Recirculation)

Water Heater Location	Passing Floor Plans (%)
External Wall in Garage	24
Central in Garage	79

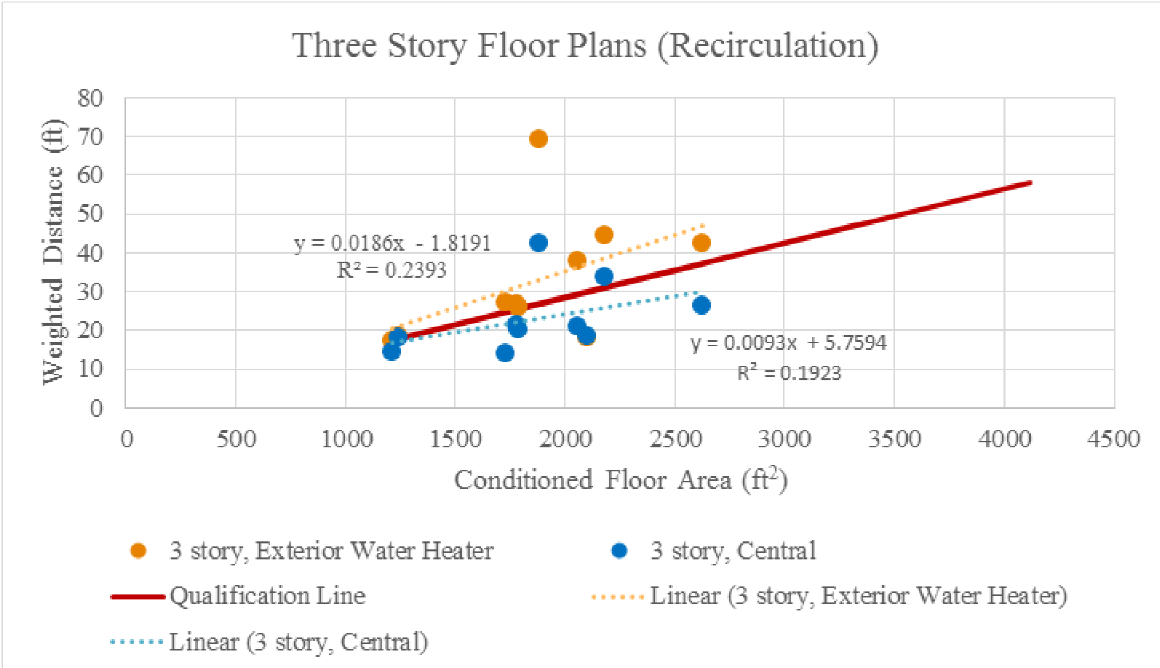

Figure 10: Weighted distance calculations and qualification distance for three-story single family homes (recirculation)

Table 26: Single Family Three-Story Floor Plans that Meet the Criterion (Recirculation)

Water Heater Location	Passing Floor Plans (%)
External Wall in Garage	20
Central in Garage	70

Multifamily Qualification Distance for Non-Recirculating Distribution Systems

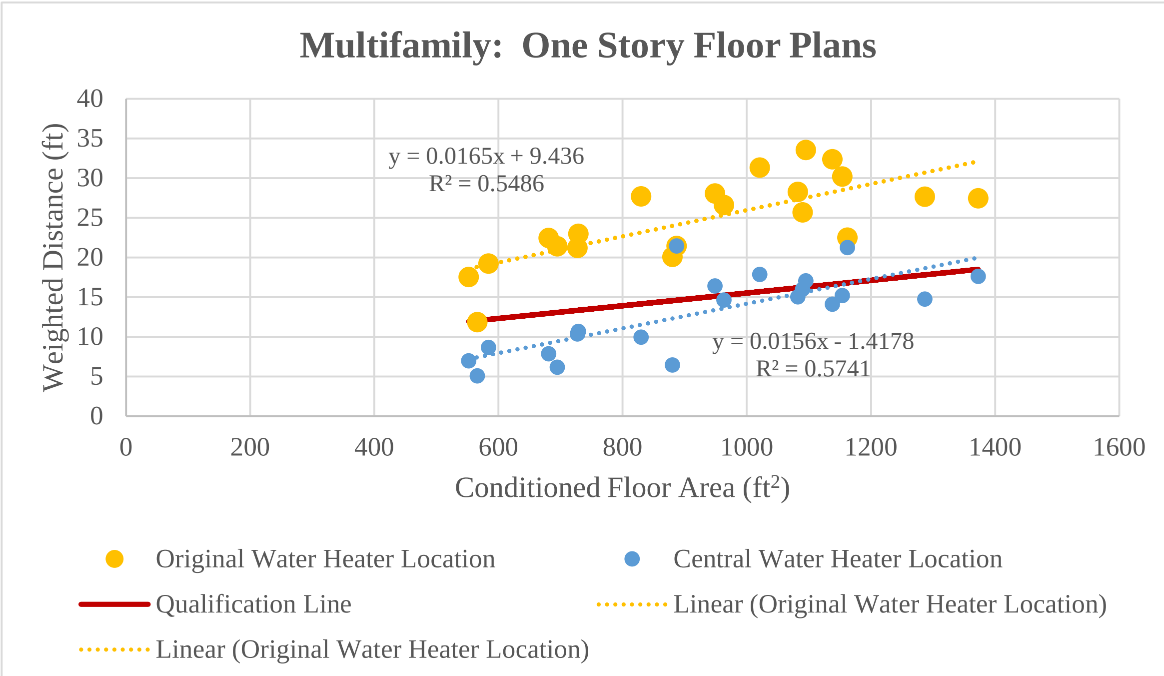

Figure 11: Weighted distance calculations and qualification distance for one story multifamily homes (non-recirculating)

Table 27: Multifamily One-Story Floor Plans that Meet the Criterion (Non-Recirculating)

Water Heater Location	Passing Floor Plans (%)
Original Location	5
Central in Apartment	76

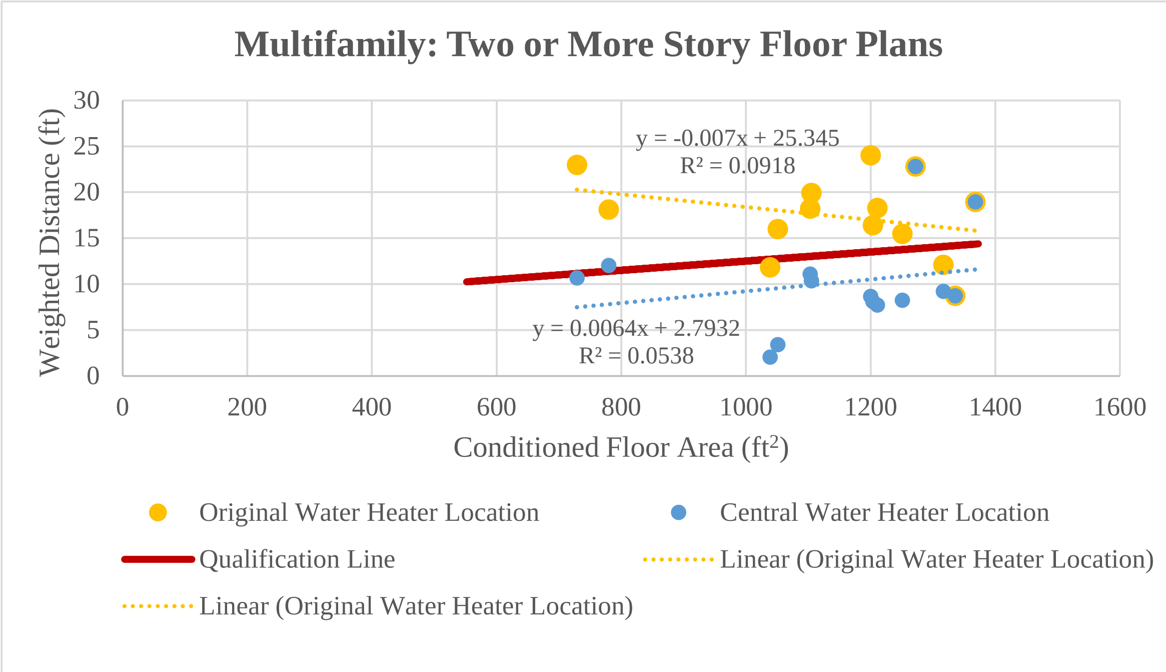

Figure 12: Weighted distance calculations and qualification distance for two or more story multifamily homes (non-recirculating)

Table 28: Multifamily Two or More Story Floor Plans that Meet the Criterion (Non-Recirculating)

Water Heater Location	Passing Floor Plans (%)
Original Location	23
Central in Apartment	77