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Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Drain Water Heat Recovery – Final Report

Measure Number**:** 2019-RES-DHW2-F

Residential Plumbing

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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 drain water heat recovery (DWHR) measure is completely new in the California Building Energy Efficiency Standards, and saves water heating energy expended during showering. The proposed code change introduces a new measure to the performance approach. If adopted, builders will be able to receive compliance credit if they install DWHR units in newly constructed low-rise residential buildings, including single family and low-rise multifamily buildings. The proposed code change also modifies the existing prescriptive requirements for domestic hot water systems in low-rise residential buildings. The measure does not change any primary prescriptive pathways, but instead revises alternative prescriptive pathways.

All DWHR systems would need to be verified by a HERS Rater using a newly introduced verification procedure. The proposed code changes would impact Section 150.1(c)8 to revise the alternative prescriptive pathways, add a new HERS test procedure to the Reference Appendix, and add new calculation explanations to the Residential ACM Reference Manual. The proposed change also requires modifications to several compliance documents. The proposed change does not impact additions and alterations.

DWHR is likely cost-effective in some high-rise residential and some nonresidential applications (e.g., hotel laundry rooms), but these applications are not addressed here. In addition, only savings from showering will be modeled in the residential energy software. DWHR comes in horizontal and vertical configurations, and both are included in this measure.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Title 24, Part 6 Standards, Reference Appendices, and compliance documents that will be modified as a result of the proposed change.

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)
DWHR	Compliance options and alternative prescriptive pathways; low-rise residential; new construction	150.1(c)8B	RA3.6.9; RA4.4.21	Yes	• CEC-CF2R-PLB-21-H • CEC-CF2R-PLB-22-H • CEC-CF3R-PLB-21-H • CEC-CF3R-PLB-22-H

Market Analysis and Regulatory Impact Assessment

DWHR is gaining popularity in Canada and the northern United States (U.S.), because lower cold water inlet temperatures in those climates increase the ability of the DWHR device to economically reclaim waste heat.

This proposal is cost-effective over the period of analysis. Overall, this proposal increases the wealth of the State of California. California consumers and businesses save more money on energy than they do for financing the efficiency measure.

The DWHR market is driven by four primary manufacturers, all located in Canada. These manufacturers have the capacity already in place to meet the expected demand created by this code change. Available DWHR research shows that the products tend to last more than 30 years, and are relatively maintenance free since they have no moving parts and are composed primarily of long-lasting copper (Beauchimin, Caruso, Cayer and Velan interviews, 2016). If the current performance standards outlined in this CASE Report remain in place, energy savings persistence is likely to mirror product lifetimes.

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 code change proposal, the Statewide CASE Team interviewed DWHR manufacturers, building officials, plumbing industry representatives, Canadian Standards Association (CSA) representatives, IAPMO, utility program managers, home builders associations, provincial code development officials from Canada, DWHR product testing and certification organizations, Title 24 energy analysts, and others involved in the Title 24, Part 6 code compliance process to simplify and streamline the compliance and enforcement of this proposal.

Cost-Effectiveness

Cost-effectiveness is calculated even though it is not required for compliance options or alternative prescriptive pathways. The benefit-to-cost (B/C) ratio compares the lifecycle benefits (cost savings) to the lifecycle costs. Measures that have a B/C ratio of 1.0 or greater are cost-effective. The larger the B/C ratio, the faster the measure pays for itself from energy savings. The B/C ratio for this measure for the primary configuration in the single family prototype ranged between 0.65 and 1.16 depending on the climate zone. The B/C ratio for this measure for the primary configuration in the multifamily prototype ranged between 1.05 and 1.8 depending on the climate zone.

Note that wall access panels are not included in the first costs. For DWHR installations in enclosed walls, some local jurisdictions may require an access panel. Using a “medicine cabinet” installation from the 2017 RSMeans Residential Cost Book (RSMeans 2017) as a guideline, and using access panel pricing from an online plumbing warehouse pricing (Hallmann Sales 2017), the installed cost for an access panel is approximately $95.

Water meters are also not included in the first costs. Senate Bill (SB) 7 (Wolk 2016), signed by Governor Brown in September 2016, requires multifamily buildings constructed after January 1, 2018 to have water sub-meters at each residential unit for water billing (California Water News Daily California Water News Daily). The bill requires California Department of Housing and Community Development (HCD) to write regulations in the building standards, but this process could take more than three years. Multifamily building DWHR systems that are shared by multiple residential units, such as the multifamily prototype scenario studied here, will likely require one additional water meter per served residential unit to meter the preheated water. Four residential units are served in the multifamily prototype, so four additional water meters may be required compared to the baseline scenario. At approximately $150 each (News Deeply 2016), the multifamily prototype is not cost-effective in virtually all climate zones.

See Section 5 for a detailed description of the cost-effectiveness analysis.

Statewide Energy Impacts

The Statewide CASE Team did not calculate statewide savings since this measure is an alternative prescriptive pathway, not a primary prescriptive pathway or mandatory requirement.

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 A. The key issues related to compliance and enforcement are summarized below:

- In the 2016 California Plumbing Code (CPC) Appendix L, there is a passage about drain water heat exchangers concerning accessibility and a standard written by IAPMO. CPC Appendix L, 606.1 states "Drain water heat exchangers shall comply with IAPMO PS 92. The heat exchanger shall be accessible." Per CPC 1.1.4, CPC appendices are optional unless adopted by a state agency or local enforcing agency. Per the "Matrix Adoption Table" for Appendix L, no state agencies have adopted the chapter. However, local enforcing agencies may do so. If adopted and enforced by a local jurisdiction, it would require DWHR to be compliant with IAPMO PS 92 and accessible.
- SB 7 requires submetering of water usage per dwelling unit in multifamily buildings, and goes into effect on January 1, 2018. As it stands, this bill would prevent DWHR from being cost-effective in multifamily buildings if the DWHR unit serves multiple dwelling units and the preheated domestic cold water is delivered to the associated shower mixing valves. That configuration results in an extra water supply pipe per residential unit, and SB 7 then requires an extra water meter that adds significant cost to the DWHR system. The Statewide CASE Team has discussed this with HCD since SB 7 requires HCD to propose building code language that can include exceptions. If the DWHR unit serves multiple dwelling units but the preheated domestic cold water is delivered to the water heater, then SB 7 does not require additional water meters. Note also that the Statewide CASE Team is not proposing any mandatory or primary prescriptive pathway requirements for this measure.
- During the Statewide CASE Team's research, plumbing industry representatives noted that multifamily homes are sometimes later turned into condominiums, and therefore access to the DWHR unit may be important when the property changes from its original use, since the

DWHR unit may be located in someone else's condominium and still shared as originally designed. Due to questions related to the ultimate ownership of, and access to, the DWHR unit in this scenario, this issue may be worthy of additional research.

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 Title 24, Part 6 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 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/.

The overall goal of this CASE Report is to propose a code change proposal for drain water heat recovery (DWHR). 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, plumbing industry representatives, 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 workshop that the Statewide CASE Team held on October 26, 2016 and March 23, 2017.

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, 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 presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of additional materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs. That is, equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.

Section 6 presents estimates 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 underlined (additions) language for the Standards, Reference Appendices, Alternate Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.

2. Measure Description

2.1 Measure Overview

DWHR is a technology that captures waste heat in the drain line during a shower event, using the reclaimed heat to preheat cold water that is then delivered either to the shower or the water heater. The device can be installed in either an equal flow configuration (with preheated water being routed to both the water heater and the shower as shown in Figure 1) or an unequal flow configuration (preheated water directed to either the water heater or shower). The energy harvested from a DWHR device is maximized in an equal flow configuration.

The proposed code change introduces a new measure to the performance approach. If adopted, builders will be able to receive compliance credit if they install DWHR units in newly constructed low-rise residential buildings, including single family and low-rise multifamily buildings. The proposed code change also modifies the existing prescriptive requirements for domestic hot water systems in low-rise residential buildings. The measure does not change any primary prescriptive pathways, but instead revises alternative prescriptive pathways. For the alternative path of storage type water heaters serving individual dwelling units:

- The water heater rated volume distinction is removed since quality insulation installation (QII) is proposed to be a prescriptive requirement in a separate 2019 Title 24, Part 6 measure.
- DWHR replaces the domestic hot water piping insulation option. Domestic hot water piping insulation is required by 2016 California Plumbing Code (CPC).

For central water heating systems serving multiple dwelling units:

- If DWHR is installed, the solar water-heating system can have a lower minimum solar savings fraction.

All DWHR systems would need to be verified by a HERS Rater using a newly introduced verification procedure. The proposed code changes would impact Section 150.1(c)8 to revise the alternative prescriptive pathways, add a new HERS test procedure to the Reference Appendix, and add new calculation explanations to the Residential ACM Reference Manual. The proposed change also requires modifications to several compliance documents. The proposed change does not impact additions and alterations.

DWHR is likely cost-effective in some high-rise residential and some nonresidential applications (e.g. hotel laundry rooms), but these applications are not addressed here. In addition, only savings from showering will be modeled in the residential energy software. DWHR comes in horizontal and vertical configurations, and both are included in this measure.

Cost effectiveness is calculated even though it is not required for compliance options or alternative prescriptive pathways.

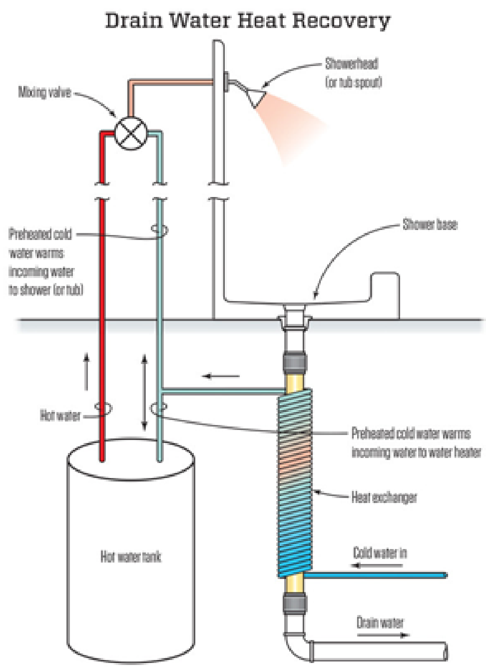

Figure 1: DWHR in equal flow configuration

Source: Journal of Light Construction, September 2016

2.2 Measure History

DWHR has not been addressed by Title 24, Part 6 in the past and is now being considered as compliance options and alternative prescriptive pathways. The measure is now proposed due to the documented energy savings associated with the DWHR technology in other parts of North America, specifically Canada. DWHR captured the attention of policy makers interested in finding additional energy saving technologies. This measure addresses both vertical and horizontal DWHR.

For vertical, two applicable standards have been published by the Canadian Standards Association (CSA) to address DWHR testing, performance, labeling, and safety: CSA B55.1 (CSA 2015a) and CSA B55.2 (CSA 2015b). These CSA standards are referenced in the International Code Council's International Energy Conservation Code (IECC) 2015 and the residential building energy codes for the Provinces of Manitoba and Ontario, Canada, both of which require DWHR for prescriptive compliance. The technology has been available since 1986; Canadian manufacturers and others have assembled new performance data over the past decade potentially relevant to California.

For horizontal, the International Association of Plumbing and Mechanical Officials' (IAPMO) IGC 346 addresses DWHR testing, performance, and labeling (IAPMO 2017). For horizontal and vertical, IAPMO PS 92 addresses DWHR safety (IAPMO 2013).

DWHR is not currently included in any Title 24, Part 6 energy modeling software. The Statewide CASE Team tested multiple DWHR products in the lab to develop algorithms to estimate energy savings for residential buildings. The CBECC-Res team will incorporate these algorithms into the residential energy modeling software.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each Title 24, Part 6 documents 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

This proposal will modify the following sections of the Building Energy Efficiency Standards as shown below. See Section 7.1 of this report for the detailed proposed revisions to the code language.

SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR LOW-RISE RESIDENTIAL BUILDINGS

Subsection 150.1(c)8: The proposed regulations would add DWHR as compliance options and alternative prescriptive pathways.

2.3.2 Reference Appendices Change Summary

RA3.6.9: The proposed code change will describe the residential field verification protocol.

RA4.4.21: The proposed code change will describe the eligibility criteria for the measure.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal will modify the following sections of the Residential ACM Reference Manual as shown below. See Section 7.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

APPENDIX B – WATER HEATING CALCULATION METHOD

B3. Hot Water Consumption: The proposed regulations briefly summarize the DWHR savings calculations. The Standard Design is not modified, because this measure is only comprised of compliance options.

B4.2. Cold Water Inlet Temperature: The proposed regulations explain that, if DWHR is installed, the cold water traveling through the device is preheated and thus warmer temperatures are used for the water heater inlet and/or shower cold water inlet depending on device configuration (e.g. equal flow, unequal flow to the water heater, or unequal flow to the showers). The associated algorithm can calculate the appropriate temperatures for any of those configurations in both applicable building types: new construction single family buildings and new construction low-rise multifamily buildings.

2.3.4 Compliance Manual Change Summary

The proposed code change will modify the following section of the Title 24, Part 6 Residential Compliance Manual:

- 2.5.1 “Measures Requiring HERS Field Verification and Diagnostic Testing”
- 5.1.1.2 “Prescriptive Requirements”
- 5.4.1 “Single Dwelling Units”
- 5.11.3.1 “Single Family”
- 5.11.3.2 “Multifamily”
- 5.9.2.1 “Multifamily, Motel/Hotels, and High-Rise Nonresidential”[1]

2.3.5 Compliance Documents Change Summary

The proposed code change will modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.5.

- CEC-CF2R-PLB-21-H, Certificate of Installation, “HERS Verified Multifamily Central Hot Water System Distribution”

[1] Please note that the proposed modification to this section is applicable to multifamily buildings only.

- CEC-CF2R-PLB-22-H, Certificate of Installation, “HERS Verified Single Dwelling Unit Hot Water System Distribution”
- CEC-CF3R-PLB-21-H, Certificate of Verification, “HERS Verified Multifamily Central Hot Water System Distribution”
- CEC-CF3R-PLB-22-H, Certificate of Verification, “HERS Verified Single Dwelling Unit Hot Water System Distribution”

The proposed regulations add a table for DWHR specifications and configuration onto these documents. This will help ensure that the installation matches the energy model and that the system saves the expected amount of energy.

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

As referenced earlier, CSA has a performance standard (CSA 2015a) and a safety standard (CSA 2015b) for vertical DWHR units. Similarly, IAPMO has a performance standard for horizontal units (IAPMO 2017) and a safety standard for horizontal and vertical units (IAPMO 2013).

The CSA standards are adopted by reference in the International Code Council’s (ICC) International Energy Conservation Code (Chapter Four), International Residential Code (Chapter 11), and the 2015 International Green Construction Code (Chapter Six). There are DWHR model code requirements in place in the Province of Ontario’s Energy Efficiency for Housing Code (2013) and the Province of Manitoba’s Building Code (2015).

Vertical and horizontal drain water heat exchangers are addressed by Appendix L Section 606 of the California Plumbing Code (CPC), which has not been adopted by any state agencies. If adopted and enforced by a local jurisdiction, it requires DWHR to be compliant with IAPMO PS 92 and be accessible. The proposed language does not mention DHWR accessibility, because that is already covered by CPC to the extent described above.

2.4.2 Relationship to Other Title 24 Requirements

Greywater is wastewater generated in households or office buildings from water streams that do not contain fecal contamination. Sources of greywater include sinks, showers, bath tubs, and clothes washing machines. The California Plumbing Code via Title 24, Part 5 sets the regulatory standards for plumbing and installations of greywater systems. The California Water Code (Section 14877) defines a greywater system as, “…a system and devices, attached to the plumbing system for the sanitary distribution or use of greywater.” Due to the increasing importance of greywater systems as a tool within the state’s portfolio of water conservation programs, and the potential for DWHR units to be complementary or a part of greywater systems, California policymakers need to ensure that future Title 24, Part 5 plumbing standards are coordinated closely with any new DWHR requirements in the 2019 Title 24, Part 6 Standards. It is important to note that the DWHR technology recovers waste heat from higher temperature water to preheat incoming cold water and does not save water.

2.4.3 Relationship to State or Federal Laws

Senate Bill 7 was signed by the Governor on September 25, 2016 creating requirements for submetering of water usage per dwelling unit in multifamily buildings and goes into effect on January 1, 2018. The legislation requires California Department of Housing and Community Development (HCD) to propose building standards code language, but that is not yet publicly available. For the viability of DWHR, it will be advantageous for the HCD to adopt exceptions for central hot water systems and DWHR installations.

There are no federal laws related to DWHR units now. The DWHR technology is promoted and encouraged only as a voluntary energy-saving measure by the United States (U.S.) Environmental Protection Agency (EPA) ENERGY STAR® program in Canada and is promoted by the U.S. Department of Energy (DOE). Therefore, there are no mandatory federal regulatory requirements that California policymakers need to consider, nor are any new requirements likely in the near future at the federal level.

2.4.4 Relationship to Industry Standards

CSA has both a performance standard (CSA 2015a) and a safety standard (CSA 2015b) for DWHR units and together serve as the current industry standard. All DWHR manufacturers adhere to these CSA industry standards as referenced in national and international building codes. The proposed code language espoused in this CASE Report incorporates the CSA standards by reference and proposes no changes to existing standards.

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 these measures. This section summarizes how the proposed code change will modify the code compliance process. Appendix A 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 any negative impacts on market actors who are involved in the process could be mitigated or reduced.

Compliance and enforcement will be the responsibility of builders, architects, energy modelers, HERS Raters, and local building officials. The key changes to the compliance process for new construction are summarized below:

- **Design Phase**: The DWHR unit is incorporated into a shower drain line and requires consideration during piping layout design. It is a plumbing installation requiring no electricity for the unit (i.e., drain water is gravity-fed, and cold water relies on water-utility pressure), and there are no moving parts. However, configuration and layout affect energy savings and could affect the layout of the walls and other utilities within them. At a minimum, designers should list the DWHR unit manufacturer, model, and configuration in the design plans, and the energy modeler should match that.
- **Permit Application Phase**: Aside from plans and the energy model, no other DWHR documentation is needed in the permit phase.
- **Construction Phase**: This work, performed by a licensed plumber, takes approximately two hours or less to perform (Beauchimin, Velan, Caruso, and Cayer interviews 2016) and requires coordination with the framing and insulation contractors. The contractor must complete the appropriate Certificate of Installation.
- **Inspection Phase**: Inspection of DWHR units and review of the Certificate of Installation will be performed by HERS Raters. The HERS Rater will complete the appropriate Certificate of Verification.

The major compliance and enforcement issues discovered in the Statewide CASE Team research include:

- SB 7 requires submetering of water usage per dwelling unit in multifamily buildings, and goes into effect on January 1, 2018. As it stands, this bill would prevent DWHR from being cost-effective in multifamily buildings if the DWHR unit serves multiple dwelling units and the preheated domestic cold water is delivered to the associated shower mixing valves. That configuration results in an extra water supply pipe per residential unit, and SB 7 then requires an extra water meter that adds significant cost to the DWHR system. If the DWHR unit serves multiple dwelling units but the preheated domestic cold water is delivered to the water heater, then SB 7 does not require additional water meters. Note also that the Statewide CASE Team is not proposing any mandatory or prescriptive requirements for this measure.

- Some local jurisdictions may require that DWHR be accessible by their adoption of the CPC Appendix L, which again, no jurisdictions have adopted to date.
- If design and construction teams do not coordinate the drain piping layout, DWHR configuration, and DWHR make and model, there could be re-work during construction that increases cost and/or reduces energy savings.
- The added time for inspection and certification, although minor overall, may be burdensome for those local building departments with limited staff and resources.

If this code change proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 3 and Appendix A 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. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach 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 DWHR market consists of four primary manufacturers, all located in Canada. Two of the four manufacturers are considering new U.S. manufacturing facilities directly related to this code proposal, because a U.S. base may lower the cost of DWHR units. Based on interviews with members of the Statewide CASE Team and all manufacturers in the summer of 2016, approximately 20,000 DWHR units were manufactured and sold in 2015, and installed almost exclusively in Canada (Beauchimin, Caruso, Cayer and Velan interviews, 2016). One manufacturer reported that there were 100,000 DWHR units in operation in North America (Van Decker, October 2016). Most DWHR manufacturers have less than five full-time equivalent (FTE) employees. The industry is relatively small in 2017, and while quite competitive between manufacturers, it is also characterized by open collaboration and communication, and some shared data between manufacturers as they strive for increased market share.

The DWHR units resulting from this code change are readily available from these four manufacturers. Based on annual expected new home starts in California in the coming years[2] all DWHR manufacturers told the Statewide CASE Team that this extra demand can be met with existing manufacturing plants.

The useful life of the typical DWHR unit is advertised at between 30 and 50 years, and manufacturers offer warranties of between four and ten years to the owner. There are no moving parts in DWHR units,

[2] The California Building Industry Association expects 121, 640 new home permits to be issued in 2017, compared to roughly 116,000 permits issued in 2016. Source: New-home Construction, Sales Soar as Building Permits Forecast to be Highest Since '02, September 25, 2016, http://www.ocregister.com/articles/new-730076-permits-year.html.

and no maintenance is required for vertical units, which comprise 95 percent of the market currently. Horizontal units also have no moving parts and comprise the remainder of the market, although the horizontal manufacturer claims to have a higher market share in California. There is only one manufacturer of horizontal DWHR units, and they are also testing and licensing a vertical DWHR unit. This manufacturer believes that horizontal can play an important role in helping save energy in homes and buildings in California (Velan interview, 2016).

DWHR units are sold directly to builders and contractors from the manufacturer and secondarily through wholesale plumbing distributors and Internet sales. Since new residential construction is the primary market, manufacturer sales directly to owners of existing homes is a very small portion of total sales, less than ten percent. One manufacturer sells their units online through Home Depot, and another began selling to select markets in Canada through Costco in 2016.

The Canadian market is driven by code requirements. Until any U.S. manufacturing plants are built, all DWHR products installed in California would be shipped from Canada. The Statewide CASE Team was told by all manufacturers during the interviews that existing import/export taxes in 2016 were minimal and not a major barrier (Beauchimin, Caruso, Cayer and Velan interviews, 2016) to sales to consumers in the U.S. However, this could change with a new trade-focused Federal Administration in 2017 and beyond.

3.2 Technical Feasibility, Market Availability, and Current Practices

The technical feasibility of DWHR technology is demonstrated by its inclusion in the residential building energy codes for the Provinces of Manitoba and Ontario. The Province of Manitoba mandated the installation of the DWHR units in all residential new construction effective April 1, 2016.[3] The Province of Ontario introduced DWHR as a trade-off for energy efficiency requirements in other building components in 2013 and mandates the installation of DWHR units for prescriptive compliance beginning January 1, 2017.[4] Both Provincial building energy codes establish a minimum DWHR unit efficiency of 42 percent and require DWHR units for each shower, but not more than two per residence.

The Statewide CASE Team queried manufacturers about their ability to meet the upcoming increase in demand arising from the code change in Manitoba and Ontario. Manufacturers stated that they will be prepared to increase the production of DWHR units with no major changes required and anticipate minimal barriers to their use by builders as the market has become familiar with the technology.

DWHR units are currently available from four manufacturers in the Canadian provinces of Manitoba, Ontario, and Quebec. There is one DWHR supplier located in the U.S., which co-owns manufacturing equipment with a Canadian manufacturer that is also currently planning to begin manufacturing DWHR in Colorado Springs, Colorado. One other manufacturer indicated that they are also considering expanded manufacturing to a facility in Hazelton, Pennsylvania. However, these facilities must be considered speculative until they are operational.

A variety of DWHR models are currently available to builders in California through online purchases directly from manufacturers or participating distributors. Home Depot's website features a variety of one manufacturer's DWHR units for purchase as well. The purchases and installations of DWHR in California have been minimal however, since the technology is new to many builders and plumbing

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[3] Province of Manitoba, Manitoba Regulation 52/2015, Registered April 27, 2015. http://web2.gov.mb.ca/laws/regs/annual/2015/052.pdf.

[4] Province of Ontario, Ontario Ministry of Municipal Affairs, Supplementary Standard SB-12, Energy Efficiency in Housing, Revised July 7, 2016. http://www.mah.gov.on.ca/AssetFactory.aspx?did=15116.

contractors. The Statewide CASE Team learned from personal interviews that there are less than 20 DWHR units installed in California, between all four manufacturers. Again, if this DWHR measure were to be incorporated into the code, it is anticipated that all manufacturers will be able to increase production prior to the measure becoming effective.

While the sale and installation of three-inch DWHR units dominates the market now, there is strong interest in two-inch diameter units in California since they could be installed in thinner walls and because California homes typically do not have basements. One manufacturer currently sells two-inch units and other manufacturers are considering adding them to their product lines.

If DWHR units are incorporated in the design phase of the construction process, there are expected to be minimal delays to new residential construction. Early consideration of DWHR could also help improve energy savings since designers can choose optimal DWHR placement, configuration, make, and model. Retrofit installations, on the other hand, would be disruptive and likely not cost effective since dry wall would need to be removed and replaced in multiple locations.

A minimum level of training for builders and contractors is strongly recommended as the DWHR technology involves only a few minor changes to the typical plumbing installation for a new home. It is also strongly recommended that energy raters and building inspectors receive a minimal amount of training for inspecting the DWHR units during the early plumbing inspection stage and before chases or walls are enclosed or otherwise made inaccessible.

DWHR units are made almost entirely of copper and have expected lifetimes much longer than hot water heaters, furnaces, and household appliances. The product lifetimes quoted by DWHR manufacturers range from 30 to 50 years. Because they reduce the demand for hot water from hot water heaters, they can possibly prolong the lifetime of installed hot water heaters.

The Statewide CASE Team identified the following potential challenges to a successful DWHR project, as noted previously in Section 2.5:

- Some local jurisdictions may require that accessibility be provided.
- There could be modifications during construction that reduce energy savings if design and construction teams do not coordinate the drain piping layout, DWHR configuration, make, and model.
- The added time for permitting and inspection, although minor overall, may be burdensome for some local building departments with limited staff and resources.
- Submetering of water use in multifamily buildings is required by SB 7 effective January 1, 2018.

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 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 2, 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 2015a). 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.

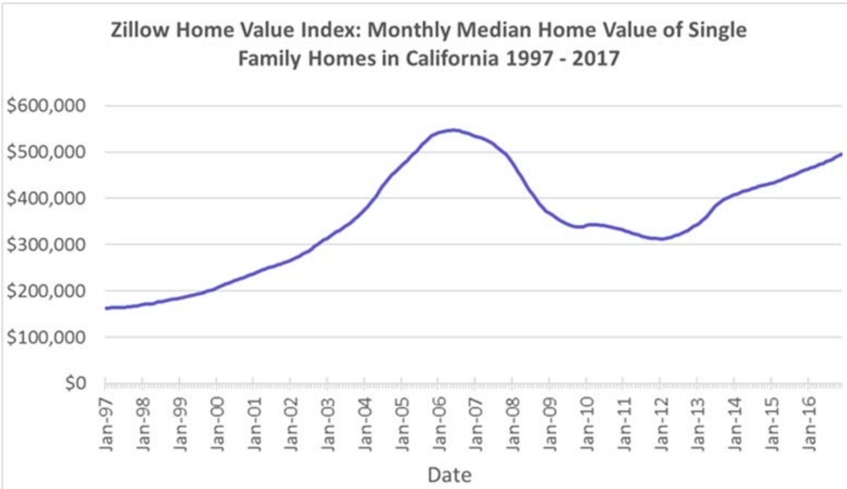

Figure 2: California median home values 1997 to 2017

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 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.

This proposed measure will have a minor impact on builders. DWHR product cost can be reduced for builders who purchase the units in bulk and DWHR installation is like waste pipe and cold water pipe installation.

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 Standards Code and model national building codes published by the International Code Council, IAPMO and ASHRAE 90) are typically updated on a three-year revision cycle. As discussed in Section 3.3.1, all market actors should (and do) plan for training and education that may be required to adjusting 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 so requirements can be met. For this proposed measure, it will be important for building designers to effectively communicate and coordinate with plumbing contractors about DWHR efficiency and installation requirements.

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 (Cal/OSHA). 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.

Stakeholders raised a concern regarding possible increased Legionella risk when the temperatures in cold water pipes are preheated by the DWHR system and due to the assumed hot water supply temperature at the shower mixing valve of 115°F. However, the temperature of 115°F matches the existing assumption in the Residential Alternative Calculation Method (ACM) Reference Manual, and this proposed measure does not modify that assumption. Furthermore, the Statewide CASE Team does not see the DWHR cold water pipes as an increased risk using similar reasoning as in a prior residential plumbing fixtures and fittings Title 20 measure (California Energy Commission 2015b) (California Energy Commission 2015c). For reference, the Statewide CASE Team has provided further discussion on the lack of increased Legionella risk associated with DWHR on cold water pipes in Appendix C.

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 2015a). 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 proposed measure will have minimal to no impact on building owners or occupants. Vertical DWHR is a passive technology that requires no maintenance and the Statewide CASE Team findings indicate they can possibly prolong the life of hot water heaters. The technology makes no noise and will not be seen when enclosed in an interior wall and if exposed, it will typically be in a garage. When offered as an option to homebuyers, manufacturers report that many homebuyers often have a greater interest in investing in other non-energy efficiency measures. When competing with these non-energy efficiency measures, such as granite counter tops, DWHR can be a very low priority for homebuyers. If accessibility were required through any local regulations, the impacts (cost of installation and aesthetics) on building owners and occupants may be significant enough to be a barrier to acceptance.

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

If adopted, the proposed measure will impact manufacturers, distributors, and retailers. While manufacturers are capable of meeting new demand brought by California code, currently there is little to no supply chain to plumbing distributors or retailers in California. Product availability is expected to grow at a steady rate as the manufacturers and builders work together to meet demand in advance of the measure's effective date. Internet sales of the product from building component retailers are expected to be minimal, since most of these sales go to individual consumers.

3.3.6 Impact on Building Inspectors

As DWHR units are installed during the early phase of new home construction, inspection of the unit and its connections to other components of the plumbing system will be relatively easy for building inspectors. Training for energy raters and inspectors is recommended, but due to the simplicity of the technology and its installation, the required time is expected to be minimal.

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.

The proposed measure may have some minimal impacts on employment in the state, which is likely to be limited to plumbing retailers and contractors. The technology requires minimal training due to the simple product design and installation procedures. Furthermore, were a DWHR manufacturer to locate in California, the number of manufacturing jobs created expected would be minimal. Again, each of the four DWHR manufacturers interviewed by the Statewide CASE Team stated they had no more than five FTEs on staff.

3.4 Economic Impacts

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 titled *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., non-industry 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 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.

The proposed measure requires a plumbing contractor to spend one to two hours to incorporate the DWHR measure into the shower the drain line. As DWHR units will be inspected prior to being enclosed in a wall, no more than ten-minutes of additional inspection time is expected to be required.

[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."

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

3.4.2 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 2 lists industries that will likely benefit from the proposed code change classified by their North American Industry Classification System (NAICS) Code. The manufacture of DWHR units occurs exclusively in Canada. The Statewide CASE Team interviewed each manufacturer and determined that they are equipped to meet any increased demand from California for their products and no manufacturers have plans to manufacture their DWHR product in California. The manufacturing process involves wrapping copper coil around a copper pipe (sized to fit current drain pipe diameters), and each manufacturer reported that they employed no more than five FTEs.

The Statewide CASE Team did not yet examine the cost of establishing a DWHR manufacturing facility in California. It is possible for a group of investors to acquire the equipment and materials (principally copper) necessary to manufacture the units. The price for cooper fluctuates and is currently at a ten-year low. In addition, all four Canadian manufacturers purchase their copper from the same supplier and there is some price uncertainty currently due to proposed U.S. international trade policies.[7]

Table 2: 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
Industrial Machinery Manufacturing	3332
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equip. Manf.	3334
Engineering Services	541330
Building Inspection Services	541350
Other Scientific and Technical Consulting Services	541690
Corporate, Subsidiary, and Regional Managing Offices	551114
Office Administrative Services	5611

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 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. The proposed measure does not target business energy use in commercial businesses; it only targets single family and multifamily buildings.

[7] Wall Street Journal article, Copper Rises on a Weaker Dollar, July 26, 2016.

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 to produce goods in California is not expected to change because of this code change proposal.

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 relatively small when compared to the overall costs savings and policy benefits associated with the code change proposals. There are no impacts to state buildings from the proposed measure as it targets single family and multifamily residential buildings only.

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 2, 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 most 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 IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix A, 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. If additional training is required, it will most likely be provided at the expense of either utilities or DWHR manufacturers.

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 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.[8]

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 key assumptions used in the energy savings are the effectiveness of the DWHR device, the use of the hot water draw schedule in the 2019 CBECC-Res software, that all showers in the respective residential unit(s) are connected, and the flow configurations (equal flow, water heater preheat, and heating cold water inlet to shower) for each prototype. The Statewide CASE Team assumes the most likely configuration for the single family prototype building is equal flow, and for the multifamily prototype building unequal flow to the shower heads as the showers may be relatively remotely located from the water heater. The equal flow configuration is feasible for the single family building and common practice in Canada per at least one manufacturer. It is much less feasible in multifamily buildings with a central water heater given the potentially long cumulative pipe length to the shower heads and the water heater. Per the same manufacturer, unequal flow to the shower heads is most common.

A three-inch diameter by 48-inch long device with a 46.6 percent effectiveness was assumed for both the single family and multifamily prototype buildings. This size was chosen since it has good effectiveness (i.e., greater than 42 percent, which is the minimum effectiveness allowed in some Canadian energy codes), is a commonly sold size, and can handle the drain water flow.

Lab tests were also performed on a few other devices including a two-inch diameter by 60-inch long device with a 46.1 percent effectiveness. The California Plumbing Code (Title 24, Part 5) allows a maximum of 16 fixture units for a vertical two-inch drain line, which can accommodate five showers and five sinks. Energy savings for this unit are essentially identical to the three-inch diameter by 48-inch long device given the similar effectiveness, so it is not reported separately.

The CBECC-Res hot water draw schedule (Wilcox 2017) was used since it is already part of the software. Many of the shower events have total shower head flow rates that are lower than 1.5 gallons per minute (gpm) and there are a few shower heads with a flow rate above two gpm. If the CBECC-Res software team later modifies the draw schedule, those changes will automatically be reflected in the DWHR savings calculations since the draw schedule is input data.

[8] 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.

DWHR preheating is assumed to begin when the shower mixing valve reaches its assumed set point of 105□F, which is per the Residential ACM Reference Manual. The manual also defines the distribution loss multiplier which is used to calculate the warm-up period duration. For simplicity's sake, the heat in the preheated cold water pipes when the showering event ends is not deducted. In addition, the DWHR unit is assumed to have the same fixed drain inlet temperature of 100.4□F regardless of distance to the shower drain(s).

For the two story prototype single family building, the drain water heat from all shower fixtures is assumed to be recovered by one DWHR device. For the multifamily building, the drain water heat from all shower fixtures in four residential units is assumed to be recovered by one drain water heat recovery device. For those cases where not all showers are connected in the respective residential units, there will be an input in the software that will de-rate the savings.

Energy savings from bathroom sinks are not calculated for simplicity's sake, even though they are included in the draw schedules. To potentially add that in the future, the algorithm would need to be modified and the software would need a user input for the percentage of sinks that are connected.

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared current design practices to design practices that will comply with the proposed requirements. There are existing Title 24, Part 6 Standards that cover water heating systems, so the existing conditions assume a building minimally complies with the 2016 Title 24, Part 6 Standards. A gas-fired water heater meeting the federal energy conservation standard is assumed since that is the prescriptively required equipment. An instantaneous water heater is assumed for single family and a central storage water heater is assumed for multifamily.

The proposed conditions are defined as the design conditions that will comply with the proposed code change. For the single family prototype building, the primary configuration is that heat will be recovered from all shower fixtures and that the DWHR device is installed in the equal flow configuration (i.e. preheated water routed to the water heater and the cold-side of the shower mixing valves). For the multifamily prototype building, the primary configuration assumes that all showers in four residential units are connected to one DWHR device and that it is installed in an unequal flow to shower heads configuration. The savings will vary by climate zone since the building cold water supply temperature differs. The time dependent valuation (TDV) value of gas is relatively constant across climate zones with average cost of gas varying by two percent between the climate zone with highest TDV values and the climate zone with lowest TDV values.

The Energy Commission provided guidance on the type of prototype buildings that must be modeled. Single family building energy savings were calculated solely using the two-story 2,700 square foot prototype from CBECC-Res since the savings are larger for homes with more assumed occupants and showering. The 2,700 square foot prototype has four bedrooms and the shower fixture quantity is not specified in the draw schedule.

For alterative scenarios where only some shower fixtures within a single family home or multifamily dwelling unit are part of a DWHR system, savings are assumed to be directly proportional to the percentage of included shower fixtures. The draw schedule does not assign showering events to shower fixtures, so the Statewide CASE Team cannot prorate the savings in a more sophisticated manner.

Multifamily building savings were calculated based on the one prototype in CBECC-Res which is two stories, 6,960 square feet, and has two one-bedroom and two two-bedroom residential units on each floor. The one-bedroom units are 780 square feet each and the two-bedroom units are 960 square feet each. The water heating system is assumed to consist of a central water heater and a prescriptively required solar hot water heating system.

Table 3 presents the details of the prototype buildings used in the analysis. The two-story 2,700 square foot prototype building is labeled as Prototype 2,700 and the multifamily prototype is labeled as Prototype 6,960.

Table 3: Prototype Buildings Used for Energy, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, Other)	Area (square feet)	Number of Stories
Prototype 2,700	Residential, Single Family	2,700	2
Prototype 6,960	Residential, Multifamily	6,960	2

The energy savings from this measure varies by climate zone. As a result, the energy impacts and cost-effectiveness were evaluated by climate zone. Energy savings and energy cost savings were calculated using a TDV methodology.

Given the proposed edits to the standards, single family measure savings must be compared to compact hot water distribution and multifamily savings must be compared to solar water heating. Per the 2019 Title 24, Part 6 Standards for compact hot water piping distribution, single family savings per building is approximately 5.3 therms per year. For multifamily buildings with a central water heater, solar water heating is required. The minimum solar savings fraction is 0.20 (unit-less) in Climate Zones 1 through 9 and 0.35 in 10 through 16. Solar fraction is directly proportional to water heating savings.

4.3 Per-Unit Energy Impacts Results

Energy savings per prototype building for new construction are presented in Table 4 and Table 5. The per-unit energy savings estimates do not take naturally occurring market adoption or compliance rates into account. For Prototype 2,700, per-unit savings for the first year are expected to range from a high of 26.1 therms/year to a low of 14.0 therms/year depending upon climate zone. Except for Climate Zone 15, savings in all other climate zones are 19.9 therms/yr or greater. For Prototype 6,960, per-unit savings for the first year, whereby unit means such a building with half the shower fixtures connected, are expected to range from a high of 40.5 therms/year to a low of 22.8 therms/year depending upon the climate zone. Outside of Climate Zone 15, savings are 31.0 therms/yr or greater. Climate Zone 15 is a low lying hot desert where city water entering temperature have a minimum of approximately 63^{o}F, a maximum of 89^{o}F, and an average of 75^{o}F.

To put the natural gas savings in context, take Prototype 2,700 in Climate Zone 12 as an example, where the savings are 21.6 therms/year. The latest 2016 CBECC-Res software states that total water heating energy for this building is 120.3 therms/year, so DWHR saves 18 percent of that. Three factors account for the difference between that percentage and the assumed DWHR effectiveness of 46.6 percent. First, the draw schedules indicate that showering accounts for 53 percent of hot water at the water heater. Second, the distribution loss multiplier for this building, which accounts for the average time for hot water to reach the fixtures, is 1.34. Third, the assumed DWHR drain inlet temperature is 100.4□F instead of the assumed shower mixing valve setpoint of 105□F to account for heat loss between the showerhead and the DWHR drain inlet. Combining these factors, and assuming a water heater setpoint of 120□F, yields the following, which is in the range of the 18 percent savings that was calculated:

$$0.466 \times 0.53 \times 1/1.34 \times 100.4/120 = 0.154$$

Table 4: First-Year Energy Impacts Per Prototype 2,700

Climate Zone	No DWHR	Equal Flow		Unequal to Water Heater		Unequal to Shower	
	Standard Annual Water Heating (therms/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	144.3	26.1	5,158	24.3	4,812	17.0	3,364
2	129.4	23.4	4,652	21.7	4,308	15.7	3,116
3	130.0	23.5	4,666	21.8	4,321	15.8	3,128
4	123.8	22.3	4,444	20.6	4,101	15.1	3,006
5	133.1	24.1	4,775	22.4	4,430	16.1	3,184
6	118.1	21.3	4,248	19.5	3,905	14.6	2,908
7	116.2	20.9	4,105	19.2	3,767	14.4	2,823
8	113.2	20.3	4,055	18.6	3,714	14.0	2,799
9	112.9	20.2	4,051	18.5	3,711	14.0	2,794
10	112.1	20.0	4,020	18.3	3,681	13.9	2,774
11	114.4	20.4	4,094	18.7	3,759	13.9	2,791
12	120.3	21.6	4,319	19.9	3,978	14.7	2,930
13	112.2	19.9	4,009	18.3	3,675	13.7	2,745
14	115.7	20.6	4,168	18.9	3,831	14.1	2,832
15	83.6	14.0	2,869	12.5	2,563	10.1	2,057
16	143.2	25.6	5,141	23.9	4,797	16.6	3,323

Table 5: First-Year Energy Impacts per Prototype 6,960

Climate Zone	No DWHR	Equal Flow		Unequal to Water Heater		Unequal to Shower	
	Standard Annual Water Heating (therms/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	771.1	60.8	12,047	57.3	11,365	40.5	8,021
2	692.3	54.5	10,861	51.1	10,175	37.3	7,416
3	695.5	54.8	10,897	51.4	10,210	37.5	7,445
4	662.4	52.0	10,375	48.6	9,691	35.9	7,152
5	712.0	56.2	11,152	52.7	10,465	38.2	7,583
6	632.8	49.6	9,918	46.1	9,230	34.6	6,915
7	622.9	48.7	9,583	45.3	8,905	34.1	6,709
8	606.6	47.3	9,469	43.8	8,783	33.3	6,654
9	605.4	47.1	9,458	43.7	8,773	33.1	6,642
10	600.7	44.6	8,974	41.3	8,320	31.4	6,303
11	612.2	45.3	9,126	42.1	8,482	31.6	6,339
12	643.8	48.1	9,637	44.8	8,985	33.3	6,662
13	600.6	44.4	8,943	41.1	8,300	31.0	6,237
14	619.4	45.9	9,302	42.6	8,655	31.9	6,441
15	449.8	31.2	6,398	28.2	5,796	22.8	4,664
16	764.1	57.1	11,469	53.8	10,819	37.8	7,577

The per-unit TDV energy cost savings over the 30-year period of analysis are presented in Table 6 and Table 7. These are presented as the discounted present value (PV) of the energy cost savings over the analysis period.

5. Lifecycle Cost and Cost-Effectiveness

5.1 Energy Cost Savings Methodology

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 PV dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDV kBtu." Peak demand reductions are presented in peak power reductions (kW). The Energy Commission derived the 2020 TDV values that were used in the analyses for this report (Energy + Environmental Economics 2016).

The analytic tool used to quantify energy savings and energy cost savings using the lab test data was the computer scripting language Python, but savings will ultimately be calculated within CBECC-Res. Aside from the DWHR algorithms developed by Davis Energy Group and PG&E, most inputs to the script are data already included in CBECC-Res (e.g. TDV gas schedule, weather data, draw schedule, distribution loss multipliers) or DWHR-specific user inputs that will be added to CBECC-Res. The shower data in the draw schedule may require improvement and is an on-going topic amongst the Statewide CASE Team. The user inputs will include rated DWHR effectiveness, number of included residential units (if multifamily), percentage of showers per residential unit that are connected to the DWHR device, and the configuration of the DWHR device (e.g. equal flow, unequal flow to the water heater, or unequal flow to the shower).

5.2 Energy Cost Savings Results

Per prototype building energy cost savings for newly constructed buildings over the 30-year period of analysis are presented in Table 6 and Table 7. For Prototype 2,700 in Table 6, it is estimated that the TDV energy savings over the 30-year period of analysis will range from a high of 5,158 TDV kBtu ($893) to a low of 2,869 TDV kBtu ($497) depending upon the climate zone. Except for Climate Zone 15, savings are around $700 or greater. For Prototype 6,960 in Table 7, it is assumed that drain water heat is recovered from half of the shower fixtures in the building. It is estimated that the TDV energy savings over the 30-year period of analysis will range from a high of 8,021 TDV kBtu ($1,389) to a low of 4,664 TDV kBtu ($808) depending upon the climate zone. Except for Climate Zone 15, savings are over $1,000. The TDV methodology allows peak monthly gas savings to be valued more than gas savings during non-peak months.

Table 6: TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Two Story Single Family Prototype 2,700

Climate Zone	Equal Flow 30-Year TDV Energy Cost Savings (2020PV $)	Unequal Flow to Water Heater 30-Year TDV Energy Cost Savings (2020PV $)	Unequal Flow to Shower 30-Year TDV Energy Cost Savings (2020PV $)
1	$893	$833	$583
2	$806	$746	$540
3	$808	$748	$542
4	$770	$710	$521
5	$827	$767	$552
6	$736	$676	$504
7	$711	$653	$489
8	$702	$643	$485
9	$702	$643	$484
10	$696	$638	$480
11	$709	$651	$483
12	$748	$689	$508
13	$694	$637	$475
14	$722	$664	$491
15	$497	$444	$356
16	$890	$831	$576

Table 7: TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Multiple Family Prototype 6,960

Climate Zone	Equal Flow 30-Year TDV Energy Cost Savings (2020PV $)	Unequal Flow to Water Heater 30-Year TDV Energy Cost Savings (2020PV $)	Unequal Flow to Shower 30-Year TDV Energy Cost Savings (2020PV $)
1	$2,087	$1,968	$1,389
2	$1,881	$1,762	$1,285
3	$1,887	$1,768	$1,290
4	$1,797	$1,678	$1,239
5	$1,932	$1,813	$1,313
6	$1,718	$1,599	$1,198
7	$1,660	$1,542	$1,162
8	$1,640	$1,521	$1,152
9	$1,638	$1,520	$1,150
10	$1,554	$1,441	$1,092
11	$1,581	$1,469	$1,098
12	$1,669	$1,556	$1,154
13	$1,549	$1,438	$1,080
14	$1,611	$1,499	$1,116
15	$1,108	$1,004	$808
16	$1,986	$1,874	$1,312

5.3 Incremental First Cost

The incremental cost of the proposed code change was determined from four manufacturer interviews, RSMeans 2017 Residential Costs Book (RSMeans 2017), and estimated pipe length takeoffs for assumed baseline plumbing layouts for the prototype buildings. The manufacturers were asked for approximate parts and labor costs for single family and multifamily new construction projects. The gathered information and the assumptions used in the calculations are in Table 8. For Prototype 6,960, it is assumed that drain water heat is recovered from half of the shower fixtures in the building using one DWHR unit. Note also that the cost of any installation will vary greatly from site to site, and the following potential incremental costs are not included: HERS Rater, insulation, access panels, or water meters. In addition, one manufacturer claims that the DWHR unit prices below are approximately $100 too high and that installation cost can also be reduced after successful installation training.

Table 8: Incremental First Cost Data and Assumptions

Item	Prototype 2,700 – 3” ø	Prototype 2,700 – 2” ø	Prototype 6,960 - 3” ø
DWHR Size	3"x48"	2"x60"	3"x48"
DWHR Unit Price (Approximate Average of Manufacturer Quotes)	$400.00	$325.00	$400.00
(60’) of ¾” PEX	$55.20	$55.20	$55.20
(8) PEX Couplings	$5.76	$5.76	$5.76
ABS Couplings	$3.46	$3.46	$3.46
Labor	$108.37	$108.37	$108.37
Plumbing Overhead and Profit	$118.13	$118.13	$118.13
Sales Tax @ 8% of Materials	$37.15	$31.15	$37.15
Location Adjustment Factor Markup	$43.21	$43.21	$43.21
Total Cost	**$771.28**	**$690.28**	**$771.28**

Per the Energy Commission’s guidance, design costs are not included in the incremental first cost.

5.4 Lifetime Incremental Maintenance Costs

This measure covers horizontal and vertical DWHR, but this calculation focuses on vertical. Product life is 30 to 50 years, which exceeds the lifecycle period. With no moving parts, no maintenance is required on this copper product during the lifecycle period, so lifetime incremental maintenance cost is $0.

5.5 Lifecycle Cost-Effectiveness

Cost-effectiveness is calculated even though it is not required for compliance options or alternative prescriptive pathways.

The Energy Commission establishes the procedures for calculating lifecycle cost-effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. In this case, incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV gas cost savings from were also included in the evaluation.

As is the case with all CASE Reports, design and code compliance costs were not included in the incremental cost.

This measure does not propose mandatory or prescriptive requirements. A lifecycle cost analysis is not necessary because the measure is not proposed to be part of the baseline level of stringency. The Statewide CASE Team has provided information about the cost-effectiveness of the measure even though the Energy Commission does not require a cost-effectiveness analysis for the measure to be adopted.

According to the Energy Commission’s definitions, a measure is cost-effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the total present lifecycle cost benefits by the PV of the total incremental costs.

Results of the per-unit lifecycle cost-effectiveness analyses are presented in Table 9, Table 10, and Table 11. Table 9 is for Prototype 2,700 with a three-inch diameter unit, Table 10 is for Prototype 2,700 with a two-inch diameter unit, and Table 11 is for Prototype 6,960 with a three-inch diameter unit. For Prototype 6,960, it is assumed that drain water heat is recovered from half of the shower fixtures in the building using one DWHR unit.

Both Prototype 2,700 scenarios save energy over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost-effective in some climate zones for the three-inch diameter unit and on the cusp of all climate zones for the two-inch diameter unit. The Prototype 6,960 scenario in Table 11 saves money over the 30-year period of analysis relative to the existing conditions and is cost-effective in every climate zone.

Table 9: Lifecycle Cost-Effectiveness Summary Per Single Family Prototype 2,700 – Three-Inch DWHR

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020 PV $)	Benefit-to-Cost Ratio
1	$893	$771.28	1.16
2	$806	$771.28	1.05
3	$808	$771.28	1.05
4	$770	$771.28	1.00
5	$827	$771.28	1.07
6	$736	$771.28	0.96
7	$711	$771.28	0.92
8	$702	$771.28	0.91
9	$702	$771.28	0.91
10	$696	$771.28	0.90
11	$709	$771.28	0.92
12	$748	$771.28	0.97
13	$694	$771.28	0.90
14	$722	$771.28	0.94
15	$497	$771.28	0.65
16	$890	$771.28	1.16

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental present valued costs, the B/C ratio is infinite.

Table 10: Lifecycle Cost-Effectiveness Summary Per Single Family Prototype 2,700 – Two-Inch DWHR

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020 PV $)	Benefit-to-Cost Ratio
1	$893	$696.28	1.28
2	$806	$696.28	1.16
3	$808	$696.28	1.16
4	$770	$696.28	1.11
5	$827	$696.28	1.19
6	$736	$696.28	1.06
7	$711	$696.28	1.02
8	$702	$696.28	1.01
9	$702	$696.28	1.01
10	$696	$696.28	1.00
11	$709	$696.28	1.02
12	$748	$696.28	1.07
13	$694	$696.28	1.00
14	$722	$696.28	1.04
15	$497	$696.28	0.71
16	$890	$696.28	1.28

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental present valued costs, the B/C ratio is infinite.

Table 11: Lifecycle Cost-Effectiveness Summary Per Multiple Family Prototype 6,960

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020 PV $)	Benefit-to-Cost Ratio
1	$1,389	$771.28	1.80
2	$1,285	$771.28	1.67
3	$1,290	$771.28	1.67
4	$1,239	$771.28	1.61
5	$1,313	$771.28	1.70
6	$1,198	$771.28	1.55
7	$1,162	$771.28	1.51
8	$1,152	$771.28	1.49
9	$1,150	$771.28	1.49
10	$1,092	$771.28	1.42
11	$1,098	$771.28	1.42
12	$1,154	$771.28	1.50
13	$1,080	$771.28	1.40
14	$1,116	$771.28	1.45
15	$808	$771.28	1.05
16	$1,312	$771.28	1.70

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite. Incremental cost assumes that HCD will promulgate an exception for projects that use DWHR and central hot water systems.

6. First-year Statewide Impacts

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

The Statewide CASE Team did not calculate statewide savings since this measure is an alternative prescriptive pathway, not a primary prescriptive pathway or mandatory requirement.

6.2 Statewide Water Use Impacts

The proposed code change is not expected to result in water savings. At least one manufacturer thinks there are some water savings, because of shorter shower warm up times, but does not have research to support the claim.

6.3 Statewide Material Impacts

The proposed code change will not result in significant impact to statewide material use.

6.4 Other Non-Energy Impacts

The proposed code change will reduce on-site emissions by the reduced gas usage for water heating.

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 <u>underlining</u> (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

ARTICLE 1 – ENERGY BUILDING REGULATIONS

10-102 – DEFINITIONS

<u>**DRAIN WATER HEAT RECOVERY** (DWHR) consists of a double wall heat exchanger that recovers heat from the effluent in waste piping and uses it to preheat water in a domestic or service water-heating system in order to reduce water heating energy usage.</u>

SUBCHAPTER 8 LOW-RISE RESIDENTIAL BUILDINGS – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR LOW-RISE RESIDENTIAL BUILDINGS

(c) Prescriptive Standards/Component Package.

8. Domestic Water-Heating Systems. Water-heating systems shall meet the requirements of either A~~,~~ <u>or</u> B~~, or C~~. For recirculation distribution systems serving individual dwelling unit, only Demand Recirculation Systems with manual control pumps as specified in the Reference Appendix RA4.4 shall be used:

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

i. A single gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no storage tank, and that meets the requirements of Sections 110.1 and 110.3 shall be installed.

~~ii. A single gas or propane storage type water heater with an input of 105,000 Btu per hour or less, rated volume less than or equal to 55 gallons and that meets the requirements of Sections 110.1 and 110.3. The dwelling unit shall meet all of the requirements for Quality Insulation Installation (QII) as specified in the Reference Appendix RA3.5, and in addition one of the following shall be installed:~~

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

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

~~iii.~~ <u>ii.</u> A single gas or propane storage type water heater with an input of 105,000 Btu per hour or less~~, rated volume of more than 55 gallons, and~~ that meets the requirements of Sections 110.1 and 110.3, and in addition one of the following shall be installed:

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

b. ~~All domestic hot water piping shall be insulated and field verified as specified in the Reference Appendix RA4.4.1, RA4.4.3 and RA4.4. 14~~ A drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9 and that is compliant with the eligibility criteria in RA4.4.21. It shall have a minimum rated effectiveness of 42 percent and shall recover heat from at least the master bathroom shower and must at least transfer that heat either back to all the respective showers or the water heater.

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

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

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

a. **EXCEPTION 1 to Section 150.1(c)8~~C~~Bii**: Buildings with eight or fewer dwelling units are exempt from the requirement for two recirculation loops.

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

a. **EXCEPTION 1 to Section 150.1(c)8Biii**: A solar water-heating system and a drain water heat recovery system. The solar water-heating system shall meet the installation criteria specified in Reference Residential Appendix RA4 and with a minimum solar savings fraction of 0.15 in Climate Zones 1 through 9 or a minimum solar savings fraction of 0.30 in Climate Zones 10 through 16. The solar savings fraction shall be determined using a calculation method approved by the Commission. The drain water heat recovery system shall be field verified as specified in the Reference Appendix RA3.6.9 and shall be compliant with the eligibility criteria in RA4.4.21. It shall have a minimum rated effectiveness of 42 percent. The drain water heat recovery system shall recover heat from at least half the showers and must at least transfer that heat either back to all the respective showers or the water heater.

7.2 Reference Appendices

The proposed changes consist of two new identical Subsections: RA3.6.9 within "Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols" and RA4.4.21 within "Appendix RA4 – Eligibility Criteria for Energy Efficiency Measures".

RA3.6.9: HERS-Verified Drain Water Heat Recovery System (DWHR-H)

A HERS inspection is required to obtain this credit. Vertical DWHR unit(s) shall be compliant with CSA B55.2, tested and labeled in accordance with CSA B55.1, and be a make and model listed in the Energy Commission's database. Horizontal DWHR unit(s) shall be compliant with IAPMO PS 92, tested and labeled in accordance with IAPMO IGC 346, and be a make and model listed in the Energy Commission's database. The make, model, and rated effectiveness of the DWHR unit(s) shall match the construction documents. The installation configuration (e.g. equal flow, unequal flow to the water heater, or unequal flow to the showers) and the percent of served shower fixtures shall match the construction documents. The DWHR unit(s) shall be installed +/- 2□ of the rated slope while also complying with any applicable California Plumbing Code requirements.

RA4.4.21 HERS-Verified Drain Water Heat Recovery System (DWHR-H)

A HERS inspection is required to obtain this credit. Vertical DWHR unit(s) shall be compliant with CSA B55.2, tested and labeled in accordance with CSA B55.1, and be a make and model listed in the Energy Commission’s database. Horizontal DWHR unit(s) shall be compliant with IAPMO PS 92, tested and labeled in accordance with IAPMO IGC 346, and be a make and model listed in the Energy Commission’s database. The make, model, and rated effectiveness of the DWHR unit(s) shall match the construction documents. The installation configuration (e.g. equal flow, unequal flow to the water heater, or unequal flow to the showers) and the percent of served shower fixtures shall match the construction documents. The DWHR unit(s) shall be installed +/- 2□ of the rated slope while also complying with any applicable California Plumbing Code requirements.

7.3 Residential ACM Reference Manual

APPENDIX B – WATER HEATING CALCULATION METHOD

B3. Hot Water Consumption: …In cases where a drain water heat recovery system is installed, T_{inlet} at the cold-side of the shower mixing valve and/or T_{inlet} at the water heater makeup water connection is recalculated during every showering event instead of equaling the result of Equation 9 from Section B4.2. Which temperature(s) are affected depends on where the recovered heat is delivered. Regardless, the heat transfer of the drain water heat recovery system is calculated first using Equation 15 in Section B4.2, then the preheated water temperature is calculated using Equation 16.

If only some shower fixtures within a single family home or multifamily dwelling unit are part of a DWHR system, savings are assumed to be directly proportional to the percentage of included shower fixtures.

B4.2. Cold Water Inlet Temperature: In cases where a drain water heat recovery system is installed, T_{inlet} is calculated differently during showering events. First, DWHR heat exchange effectiveness must be calculated (Equation 11). Manufacturers report rated effectiveness at one set of conditions per the DWHR test procedures, and that value must be corrected for potable water inlet temperature (Equation 12), potable water flow rate, and drain water flow rate. If the DWHR configuration is equal flow, then Equation 13 is used to correct for the water flow rates. If the configuration is unequal flow, then Equation 14 is used. Those three later equations are based on experimental data. Second, heat transfer of the drain water heat recovery system is calculated using Equation 15, then the preheated water temperature is calculated using Equation 16. If the recovered heat is only delivered to the shower mixing valves, then iteration is required since the heat transfer is dependent on potable flow rate and that flow rate is dependent on the preheated water temperature.

$$\varepsilon_{Draw} = \varepsilon_{rated} * f_{T_{P,I}} * f_{\dot{V}}$$ *Equation 11*

$$f_{T_{P,I}} = (-3.06 * 10^{-5} * T_{P,I}^2 + 4.96 * 10^{-3} * T_{P,I} + 0.281)/0.466$$ *Equation 12*

$$f_{\dot{V}_{eq}} = -6.98384455 * 10^{-4} * \dot{V}^4 + 1.28561447 * 10^{-2} * \dot{V}^3 + -7.02399803 * 10^{-2} * \dot{V}^2 + 1.33657748 * 10^{-2} * \dot{V} + 1.23339312$$ *Equation 13*

$$f_{\dot{V}_{uneq}} = (1.50240798) + (-1.54775844 * \dot{V}_P) + (7.71878873 * 10^{-1} * \dot{V}_P^2) + (-1.21373939 * 10^{-1} * \dot{V}_P^3) + (1.01401103 * \dot{V}_D) + (-1.98860634 * 10^{-1} * \dot{V}_P * \dot{V}_D) + (-1.29877294 * 10^{-1} * \dot{V}_P^2 * \dot{V}_D) + (3.56076077 * 10^{-2} * \dot{V}_P^3 * \dot{V}_D) + (-2.21066737 * 10^{-1} * \dot{V}_D^2) + (9.21985918 * 10^{-2} * \dot{V}_P * \dot{V}_D^2) + (1.06956686 * 10^{-3} * \dot{V}_P^2 * \dot{V}_D^2) + (-3.51465197 * 10^{-3} * \dot{V}_P^3 * \dot{V}_D^2) + (1.38862333 * 10^{-2} * \dot{V}_D^3) + (-6.82229011 * 10^{-3} * \dot{V}_P * \dot{V}_D^3) + (5.86661087 * 10^{-4} * \dot{V}_P^2 * \dot{V}_D^3) + (1.09840430 * 10^{-4} * \dot{V}_P^3 * \dot{V}_D^3)$$ *Equation 14*

$\dot{Q}_{Avg} = \varepsilon_{Draw} * \min(\dot{V}_P, \dot{V}_D) * \rho * c_p * (T_{D,I} - T_{P,I}) * 60$ *Equation 15*

$T_{P,O} = [\dot{Q}_{Avg} / (\dot{V}_P * \rho * c_p * 60)] + T_{P,I}$ *Equation 16*

where

ε_{rated} = Rated effectiveness of the DWHR unit (unit-less)

$f_{T_{P,I}}$ = Correction factor for potable water inlet temperature (unit-less)

$f_{\dot{V}_{eq}}$ = Correction factor for flow rate for equal flow configuration (unit-less)

$f_{\dot{V}_{uneq}}$ = Correction factor for flow rate for unequal flow configuration (unit-less)

$\dot{Q}_{Avg}$ = Average heat transfer rate (Btu/hr)

ε_{Draw} = Calculated effectiveness of the DWHR unit (unit-less)

$\dot{V}_P$ = Flow rate through potable side of the unit (gallons/minute)

$\dot{V}_D$ = Flow rate through drain side of the unit (gallons/minute)

ρ = Water density (lb/gallon)

c_p = Specific heat capacity at constant pressure for water (Btu/(lb·□F))

$T_{D,I}$ = Drain inlet temperature (□F)

$T_{P,I}$ = Potable inlet temperature (□F)

$T_{P,O}$ = Potable outlet temperature (□F)

60 = Unit conversion from minutes to hours (minutes/hour)

7.4 Residential Compliance Manual

Sections 2.5.1, 5.1.1.2, 5.4.1, 5.11.3.1, 5.1., 3.2, and 5.9.2.1 of the Residential Compliance Manual will need to be revised.

2.5.1 Measures Requiring HERS Field Verification and Diagnostic Testing

… w. ~~Verified pipe insulation credit~~ Verified drain water heat recovery system

5.1.1.2 Prescriptive Requirements

The 201~~6~~9 prescriptive requirements for single-family buildings and multifamily buildings with a dedicated water heater in each dwelling unit are as follows:

Option 1: Install a natural gas or propane instantaneous water heater that meets the minimum requirements in California's Title 20 Appliance Efficiency Regulations, Section 1605.1(f) for federally regulated appliances.

Option 2: Install a natural gas or propane storage water heater with an input rating of 105,000 Btu/hr or less ~~a rated storage volume of 55 gallons or less~~ that meets the minimum requirements in California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f) for federally regulated appliances. In addition, the building must comply with ~~the HERS-verified Quality Insulation Installation (QII) requirements (see Chapter 3 of this compliance manual), as well as~~ one of the following requirements:

1. HERS-verified ~~pipe insulation~~ drain water heat recovery system (see Reference Appendix[1] RA3.6.9 ~~3.6, RA4.4.1, RA4.4.3,~~ and RA4.4.~~14~~21 for the requirements ~~of proper installation of pipe insulation~~ and Section ~~5.6.2.5~~ 5.4.1 of this chapter)

2. HERS-verified compact hot water distribution design (see Reference Appendix RA 3.6 and RA4.4.16 for requirements and Section 5.6.2.4 of this chapter)

~~Option 3: Install a natural gas or propane storage water heater with a rated storage volume more than 55 gallons and an input rating of 105,000 Btu/hr or less. The water heater must meet the requirements in California's *Title 20 Appliance Efficiency Regulations* Section 1605.1(f) for federally regulated appliances. In addition, the building must comply with one of the following:~~

1. ~~HERS-verified pipe insulation.~~
2. ~~HERS-verified compact hot water distribution design.~~

There is no longer a prescriptive option that allows electric water heating. Users that wish to use electric water heating can comply with the Energy Standards using the performance approach.

For multifamily buildings with a central water heating system, drain water heat recovery can be used to reduce the required solar saving fraction of the solar thermal system.

5.4.1 Single Dwelling Units §150.1(c)8

There are three options to comply with the prescriptive water heating requirements for newly constructed single dwelling units. For all three options, the water heater must comply with the mandatory requirements for water heaters (See Section 5.3). If a recirculation distribution system is installed, only demand recirculation systems with manual control pumps are allowed. The three options are described below.

Option 1: Install a natural gas or propane instantaneous water heater with an input rating of 200,000 Btu per hour or less.

Option 2: Install a natural gas or propane storage water heater with ~~a rated storage volume 55 gallons or less and~~ an input rating of 105,000 Btu per hour or less. ~~The dwelling unit must meet all of the requirements for Quality Insulation Installation (QII), which requires that a HERS Rater verify QII has been designed and installed in accordance with Energy Standards.~~ The user must also do one of the following:

1. Use a compact hot water distribution design, which requires a HERS Rater to verify that the system has been designed and installed in accordance with the Energy Standards (See Reference Appendix RA4.4.16.)

2. ~~Insulate all domestic hot water pipes which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.~~ A drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9 and that is compliant with the eligibility criteria in RA4.4.21. It shall have a minimum rated effectiveness of 42 percent and shall recover heat from at least the master bathroom shower and must at least transfer that heat either back to all the respective showers or the water heater.

~~Option 3: Install a natural gas or propane storage water heater with a rated storage volume greater than 55 gallons and an input rating of 105,000 Btu per hour or less. The user must also do one of the following:~~

~~1. Insulate all domestic hot water pipes which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.~~

~~If Option 2 is pursued, in which a gas storage water heater that is 55 gallons or less is installed instead of a gas instantaneous water heater, then QII will need to be considered at the start of the design process, and it must be coordinated with several players including the designer, the general and/or insulation contractor, and the HERS Rater. QII will be included as part of the first building inspection, typically well in advance of the actual water heater being installed.~~

~~For more information on QII compliance requirements see Chapter 3 (Building Envelope) of this compliance manual and RA3.5 of the Reference Appendix. QII is required for Option 2 but not for Option 3. That is, if a natural gas or propane water heater less than 55 gallons is installed, the building must also comply with the QII requirements.~~

~~The minimum federal efficiency requirement for storage water heaters greater than 55 gallons is more stringent than storage water heaters that are 55 gallons or less.~~

~~For more information on HERS-verified domestic hot water pipe insulation requirements, see Section 5.6.2.5 of this chapter. The Reference Appendix contains the requirements for the proper installation of pipe insulation (see RA4.4.1, RA4.4.3 and RA4.4.14). The compliance requirements in Reference Appendix RA4.4.3 state that all the piping in a hot water distribution system must be insulated from the water heater to each fixture or appliance following the proper installation provisions in Reference Appendix RA4.4.1. RA 4.4.14 states that HERS inspection is needed to verify that all hot water piping in non-recirculating systems is insulated correctly. A summary of the mandatory pipe insulation requirements is described in Section 5.3.5.1. HERS-verified pipe insulation is included in Options 2 and 3 described above. If a user does not want to insulate pipes, he or she can choose to use a compact hot water distribution design instead.~~

For more information on HERS-verified compact hot water distribution design, see Section 5.6.2.4. HERS-verified compact hot water distribution designs are included in Options 2 and 3 described above. If a user does not use a compact design, he or she can comply with ~~HERS-verified pipe insulation~~ the drain water heat recovery requirements instead.

Any other water heating system that differs from the three options described in this section does not meet the prescriptive requirements. Other systems can be installed if using the performance approach as described in Section 5.5.

For additions, the prescriptive requirements described above apply only if a water heater is being installed as part of the addition. The prescriptive requirements apply only to the space that is added, not the entire building.

For alterations where an existing water heater is being replaced, the water heater must meet the mandatory equipment efficiency requirements. Pipe insulation requirements do not apply to alteration for portion of the pipes that are inaccessible. See Chapter 9 for more detailed explanation for the water heating alteration requirements.

§150.1(c)8

As mentioned, there are ~~three~~two options for users to comply prescriptively with the water heating requirements for newly constructed single dwelling units, including additions. All options must also comply with the applicable mandatory requirements in §110.3 and §150.0 (j and n).

1. A system with a single natural gas or propane instantaneous water heater:

    a. A gas input rating less than or equal to 200,000 Btu/h.

    b. No supplemental storage tank is installed.

    c. If using a recirculation distribution system, only demand recirculation systems with manual control pumps are allowed.

2. A system with a single gas or propane storage water heater ~~with a rated storage volume of 55 gallons or less~~ must have:

    a. A gas input rating of 105,000 Btu/h or less~~.~~, and either

    ~~b. The dwelling unit must meet all of the requirements for QII as specified in the Reference Appendix RA3.5, and either~~

i. ~~Have HERS-verified insulation on all domestic hot water piping (see RA4.4.1, RA4.4.3 and RA4.4.14)~~

~~ii.~~ Have a HERS-verified compact distribution system design (see RA4.4.16).

ii. Use a drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9 and that is compliant with the eligibility criteria in RA4.4.21. It shall have a minimum rated effectiveness of 42 percent and shall recover heat from at least the master bathroom shower and must at least transfer that heat either back to all the respective showers or to the water heater.

~~c~~b. If using a recirculation distribution system, only demand recirculation systems with manual control pumps are allowed.

~~3. A system with a single gas or propane storage type water heater with a rated storage volume of greater than 55 gallons must have:~~

~~a. A gas input rating 105,000 Btu/h or less, and either~~

~~i. Have HERS-verified insulation on all domestic hot water piping (see RA4.4.1, RA4.4.3 and RA4.4.14)~~

~~ii. Have a HERS-verified compact distribution system design (see RA4.4.16).~~

~~b. If using a recirculation distribution system, only demand recirculation systems with manual control pumps are allowed.~~

5.11.3.1 Single Family

HERS verification is required for all hot water distribution types that include options for field verification. The first type is alternative designs to conventional distribution systems that include parallel piping, demand recirculation, and automatic and manual on-demand recirculation. The second type is for compact distribution systems, which can be used only when verified by field verification. ~~In addition, HERS-verified QII is also required for users that comply prescriptively by installing a minimally compliant gas storage water heater that is 55 gallons or less; QII is not required if prescriptive compliance is pursued by installing a minimally compliant gas instantaneous water heater or gas storage water heater larger than 55 gallons.~~ For all of the cases where HERS verification is required, the HERS Rater must verify that the eligibility requirements for the specific system are met.

In addition, HERS-verified ~~pipe insulation~~ drain water heat recovery is an option for prescriptive compliance and as a compliance credit for the performance approach. ~~This credit applies if all pipes in a nonrecirculating distribution system are insulated. HERS verification is required if this credit is taken in combination with the installation credit. Uninsulated hot water pipes in insulated walls or buried in the attic insulation would comply with the requirements. In this case a HERS Rater must verify that the eligibility requirements for pipe insulation have been met.~~

As previously described in this chapter, if a user wishes to comply prescriptively with the Energy Standards and installs a minimally compliant gas storage water heater ~~(55 gallons or less) plus HERS-verified QII or a minimally compliant gas storage water heater with a storage volume greater than 55 gallons~~, then either the compact distribution design or a compliant drain water heat recovery system ~~insulation on all domestic hot water piping~~ must be installed, both of which require HERS verification.

5.11.3.2 Multifamily

The ~~only~~ HERS verification for water heating that applies to central domestic hot water recirculation systems in multifamily buildings is the verification of multiple distribution lines for central recirculation systems, and the verification of drain water heat recovery systems.

5.9.2.1 Multifamily, Motel/Hotels, and High-Rise Nonresidential §150.1(c)8Ciii

Solar water heating is prescriptively required for water heating systems serving multiple dwelling units, whether they are multifamily, motel/hotels, or high-rise nonresidential buildings. The minimum solar fraction depends on the climate zone (CZ). For multifamily buildings only, it also depends on whether compliant DWHR is installed~~: 0.20 for CZ 1 through 9 and 0.35 for CZ 10 through 16~~. See Tables 5-11 and 5-12 below. The drain water heat recovery system shall be field verified as specified in the Reference Appendix RA3.6.9 and shall be compliant with the eligibility criteria in RA4.4.21. It shall have a minimum rated effectiveness of 42 percent. The drain water heat recovery system shall recover heat from at least half the showers in the building and must at least transfer that heat either back to all the respective showers or the water heater.

Table 5-11: Required Performance of Solar Systems Installed in Motel/Hotels and High-Rise Nonresidential ~~Multifamily~~ Buildings with Central Distribution Systems

Climate Zone	Minimum Solar Fraction
1-9	0.20
10-16	0.35

Table 5-12: Required Performance of Solar Systems Installed in Multifamily Buildings With Central Distribution Systems

Climate Zone	Minimum Solar Fraction if no DWHR	Minimum Solar Fraction if Compliant DWHR Installed
1-9	0.20	0.15
10-16	0.35	0.30

7.5 Compliance Documents

The Statewide CASE Team proposes that the following documents are modified:

- CEC-CF2R-PLB-21-H, Certificate of Installation, “HERS Verified Multifamily Central Hot Water System Distribution”
- CEC-CF2R-PLB-22-H, Certificate of Installation, “HERS Verified Single Dwelling Unit Hot Water System Distribution”
- CEC-CF3R-PLB-21-H, Certificate of Verification, “HERS Verified Multifamily Central Hot Water System Distribution”
- CEC-CF3R-PLB-22-H, Certificate of Verification, “HERS Verified Single Dwelling Unit Hot Water System Distribution”

The proposed regulations add a table with content as shown in Table 12 to the multifamily documents and content as shown in Table 13 to the single family documents. This will help ensure that installations match the plans (or shop drawings) and energy model (where applicable) and that the system saves the expected amount of energy.

Table 12: DWHR Table for CEC-CF(2,3)R-PLB-21-H (Multifamily Central Hot Water Systems)

Unit ID	DWHR-1	DWHR-2
Make & model		
Diameter & length		
Rated effectiveness		
Configuration (Equal, Unequal-Shower, or Unequal-Water Heater)		
Quantity of residential units with DWHR		
Total quantity of shower fixtures receiving recovered heat		
Total quantity of shower fixtures amongst all served residential unit(s) (i.e., fully ignore residential units without any DWHR)		

Table 13: DWHR Table for CEC-CF(2,3)R-PLB-22-H (Single Dwelling Unit Hot Water Systems)

Unit ID	DWHR-1	DWHR-2
Make & model		
Diameter & length		
Rated effectiveness		
Configuration (Equal, Unequal-Shower, or Unequal-Water Heater)		
Quantity of shower fixtures receiving recovered heat		
Total quantity of shower fixtures		

The following instructions will also be added: "The make, model, and rated effectiveness of the DWHR unit(s) shall match the construction documents. The installation configuration (e.g. equal flow, unequal flow to the water heater, or unequal flow to the showers) and the percent of served shower fixtures shall match the construction documents. The DWHR unit(s) shall be installed +/- 2□ of the rated slope while also complying with any applicable California Plumbing Code requirements."

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Appendix A: 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 will impact various market actors during public stakeholder meetings that were held on October 26, 2016 (Statewide CASE Team 2016a) (Statewide CASE Team 2016b). The Statewide CASE Team also did phone interviews, conducted surveys, and coordinated by email with multiple DWHR manufacturers, builder/developers, and codes and standards personnel. The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Table 14 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 compliance process for this measure will benefit from specialized training to increase knowledge and skills, however, training is not necessary. The measure also fits neatly within the current work flow of market actors, and requires minimal modifications to existing documents.

Table 14: 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
Design Team (Including Energy Modeler)	• Specify the DWHR device. • Layout the system. • If using the performance method, model the DWHR system in the energy model. • Coordinate design amongst the team (i.e. architect, plumbing designer, and energy modeler). • Prepare the plans which shall specify the required DWHR system. • Review submittals during construction. • Coordinate with HERS Rater.	• Demonstrate functional and compliant system design on the construction documents. • Properly ascertain energy savings in the energy model and provide output documents in the construction documents. • Streamlined coordination within the team; clearly communicate system requirements to builders. • Easily identify non-compliant substitutions during submittal review. • Effectively coordinate during construction to maintain DWHR return on investment	• Will need additional information on the plumbing plans to specify the DWHR system. • Will need to include new information in the energy model to comply via performance path.	• Refer to Title 24, Part 6 when specifying DWHR to ensure all required information is provided. • Modeling software will include all data fields that must be populated and will have default values. • Attend utility-sponsored training.
Plans Examiner	• For performance path, confirm plans match energy modeling output documents. • If using prescriptive option, ensure that the DWHR requirements in the standards are met and sufficiently documented. • Provide correction comments if necessary.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if data on plans and energy modeling documents (if applicable) meets requirements. • Quickly and easily provide correction comments that will resolve issues.	• Will have additional items on the plans and possibly energy modeling documents to review against the standards.	• Modeling software will show DWHR in the output documents in a way easily compared to plans. • Attend utility-sponsored training.

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
Builders	• If possible, collaborate with the design team during the design phase. • Provide submittals that match the requirements documented on the plans. • Install the system as documented on the plans.	• Procure the correct DWHR device. • Effectively collaborate with the design team to improve DWHR system functionality and/or ROI. • Install a functional system in a cost-effective manner.	• Will have an additional plumbing device to install and may need to install additional piping. • Additional coordination with the general contractor may be required to layout the piping.	• If substituting different equipment, match or exceed the specified effectiveness rating, and choose a CSA compliant device. • Discuss any possible piping layout modifications with the design team to maintain functionality and ROI. • Issue potential DWHR-related RFIs early. • Attend utility-sponsored training.
HERS Rater	• Inspect the system on-site and compare it to the plans and energy model output documents.	• Verify that the system is properly installed.	• Will have an additional item to review on-site while walls are still open.	• Refer to the Standards, Residential ACM Manual, and Energy Code Ace when reviewing DWHR. • Attend utility-sponsored training.

Appendix B: CALCULATION PROCEDURE DEVELOPMENT AND VALIDATION

The Statewide CASE Team documented the lab work completed in support of this project in two phases. The phases of this work are described in the two documents referenced below.

Statewide Utility Codes and Standards Team. 2016. "Development of a Title 24 Compliance Model for Residential Drain Water Heat Recovery Devices." Accessed April 17, 2017. http://title24stakeholders.com/wp-content/uploads/2017/04/Development-of-a-Title-24-Compliance-Model-for-Residential-Drain-Water-Heat-Recovery-Devices.pdf.

Statewide Utility Codes and Standards Team. 2017. "Results of Vertical Drain Water Heat Recovery Phase Two Lab Testing." http://title24stakeholders.com/wp-content/uploads/2017/04/Memo_Results_DWHRPhase2_4Jan2017.pdf.

Appendix C: DWHR AND THE LACK OF INCREASED LEGIONELLA RISK

As stated in Section 3.3.3,

> Stakeholders raised a concern regarding possible increased Legionella risk when the temperatures in cold water pipes are preheated by the DWHR system and due to the assumed hot water supply temperature at the shower mixing valve of 115°F. However, the temperature of 115°F matches the existing assumption in the Residential Alternative Calculation Method (ACM) Reference Manual, and this proposed measure does not modify that assumption. Furthermore, the Statewide CASE Team does not see the DWHR cold water pipes as an increased risk using similar reasoning as in a prior residential plumbing fixtures and fittings Title 20 measure (California Energy Commission 2015b) (California Energy Commission 2015c). For reference, the Statewide CASE Team has provided further discussion on the lack of increased Legionella risk associated with DWHR on cold water pipes in Appendix C.

The United States Department of Labor: Occupational Safety and Health Administration (OSHA) explains the risk factors for Legionella as follows (United States Department of Labor: Occupational Safety and Health Administration n.d.).

Water conditions that tend to promote the growth of Legionella include:

- stagnation;
- temperatures between 20°C and 50°C (68°F - 122°F). The optimal growth range is 35°C - 46°C (95°F - 115°F);
- pH between 5.0 and 8.5;
- sediment that tends to promote growth of commensal microflora; and
- micro-organisms including algae, Flavobacteria, and Pseudomonas, which supply essential nutrients for growth of Legionella or harbor the organism (amoebae, protozoa).

During showering events, the DWHR system preheats the cold water pipes between the DWHR unit and the shower(s) and/or water heater. These pipes will not be insulated and the pipes will gradually cool to match the temperature of all other cold water pipes in the building until the next showering event. Furthermore, these sections of pipe are used daily, so there is no risk of stagnation or dead legs. For most of the day (every day), the pipe temperature will match all other cold water pipes in the building.

Building cold water supply temperatures vary by climate zone. The Residential ACM Reference Manual defines assumed inlet (cold water supply) temperatures for each climate zone. Figure 3 and Figure 4 present, for the hottest (Climate Zone 15) and coldest (Climate Zone 1) climate zones, the annual building cold water supply temperature ("T_p_in_CZx"), and the preheated pipe temperature during showering events for the three possible DWHR configurations ("T_p_out_..."). Note that the building cold water supply temperature in Climate Zone 15 exceeds two of the Climate Zone 1 preheated data series in the summer.

Note that some European manufacturers have addressed Legionella directly, also stating that the elevated temperatures are temporary and the pipes in question are not dead legs (Joulia n.d.) (Zypho n.d.).

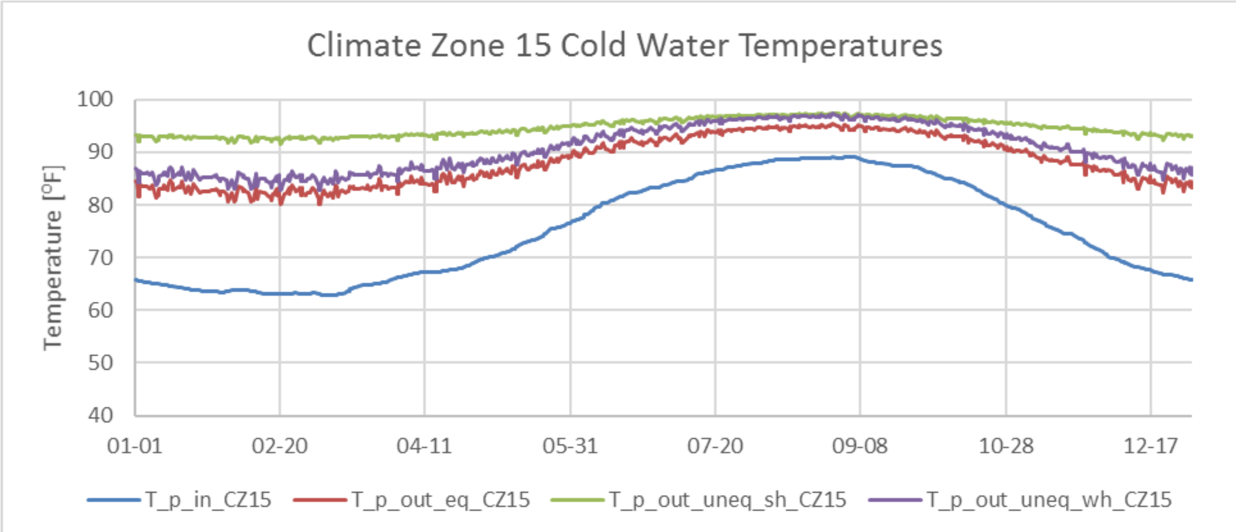

Figure 3: Annual cold water supply temperatures and temperatures after preheated with three DWHR configurations for Climate Zone 15 (hottest climate zone)

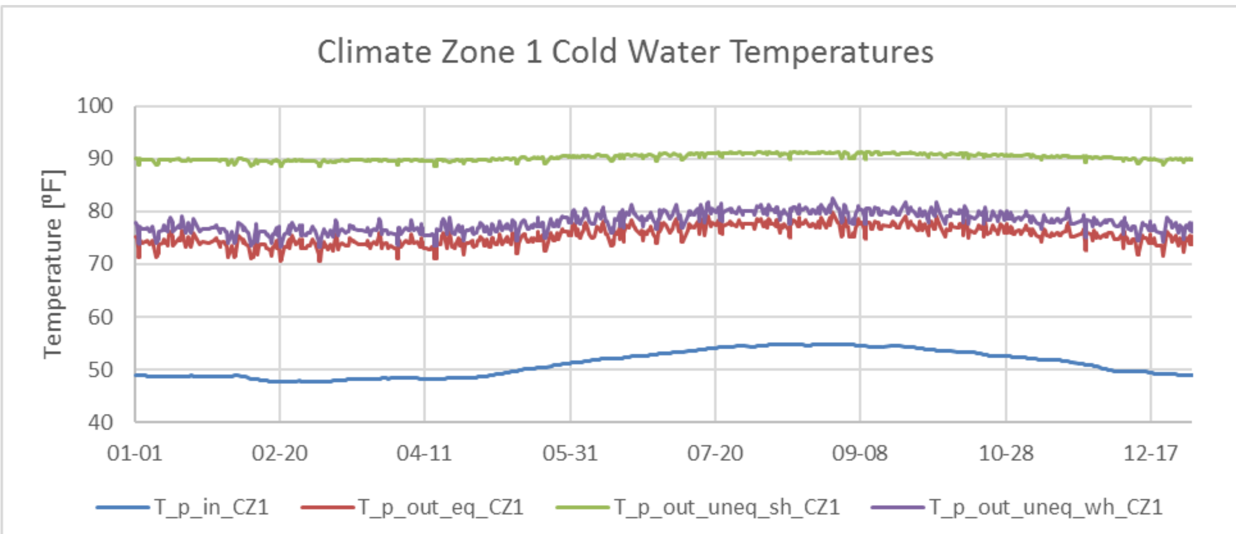

Figure 4: Annual cold water supply temperatures and temperatures after preheated with three DWHR configurations for Climate Zone 1 (coldest climate zone)