CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Residential Instantaneous Water Heaters

Addendum to CASE Report submitted on September 19, 2014

Measure Number: 2016-RES-DHW1-F

Residential Water Heating

2016 CALIFORNIA BUILDING ENERGY EFFICIENCY STANDARDS

California Utilities Statewide Codes and Standards Team January 2015

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

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

1.1 Introduction

This is an addendum to the Title 24 Residential Instantaneous Water Heaters (IWH) CASE Report that was submitted to the California Energy Commission (CEC) by the Statewide Utilities Codes and Standards Enhancement (CASE) Team on September 19, 2014. The addendum contains additional information on the proposed standards for residential water heating in new construction and additions, as requested by CEC staff in October and November 2014. The addendum also includes revisions to the proposed code language originally submitted to CEC in September 2014 and a description of the revised additional prescriptive option.

1.2 Useful Life

The estimated useful life (EUL) of water heaters is variable and depends largely on usage patterns, water quality, and maintenance. Table 1, which is the same as in Table 11 in Section 3.3.1 in the CASE Report, lists the EUL of water heaters as reported by numerous reputable sources. As can be seen in Table 1, IWHs are commonly cited as having a useful life of 20 years and storage water heaters range between 5 and 13 years.

Manufacturer warranties can also be used as a data point for estimating the EUL of a product. Table 1 lists the warranties of various water heaters. Generally, a manufacturer will warranty a product for a portion of its useful life and not for the full life since that would not be cost-effective for the manufacturer. As such, it can be assumed that if a company warranties a product for 15 years, as do a number of IWH manufacturers, then the product will last longer than 15 years if properly installed and maintained.

Based on the range of EULs for IWHs and storage water heaters, it is evident that IWHs are expected to have a longer useful life than their storage counterparts. However, the useful life of will depend greatly on how the water heater is maintained. See Section 3.3.2 of the CASE Report and Section 1.3 below for more information about proper water heater maintenance.

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

Table 1: Product Life Ranges

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

Note: This table is labeled as Table 11 in the CASE Report submitted to CEC on September 19, 2014

Table 2: Water Heater Warranties

Source	Warranty (years)		Reference
	Storage	IWH	
A.O. Smith	6 (tank) 6 (parts)	15 (heat exchanger) 5 (parts)	http://www.americanwaterheater.com/products/resGas.aspx http://www.americanwaterheater.com/products/onDemand.aspx
Bradford White	10 (tank) 6 (parts)	12 (heat exchanger) 5 (parts)	http://www.bradfordwhite.com/sites/default/files/product_literature/39699ZAD.pdf https://www.plumbersstock.com/product/67453/bradford-white-tg-150e-n-nat-gas-tankless-water-heater/?gclid=CIKx6cD6wMACFSsSMwod8hEAIg
Noritz	--	12 (heat exchanger) 5 (parts)	http://www.noritz.com/residential-products/nr71-sv/ http://www.noritz.com/residential-products/nr66/ http://www.noritz.com/residential-products/nr50/
Rheem	9 - 12 (tank and parts)	12 (heat exchanger) 5 (parts)	http://cdn.globalimageserver.com/fetchdocument-rh.aspx?name=performance-platinum-atmospheric-performance-platinum-atmospheric
Lochinvar	6 - 10 (tank) 2 - 6 (parts)	--	http://www.lochinvar.com/products/default.aspx?type=productline&lineid=45

State	6 (tank) 6 (parts)	15 (heat exchanger) 5 (parts)	http://www.statewaterheaters.com/lit/warranty/res-gas.html http://www.statewaterheaters.com/lit/warranty/tankless.html
Rinnai	--	12 (heat exchanger) 5 (parts)	http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCAQFjAA&url=http%3A%2F%2Fwww.rinnai.us%2Fdocumentation%2Fdownloads%2FRinnai_Value_Series_Tankless_Water_Heater_Warranty.pdf&ei=i_2BVJ6SM4XToATi-YLQAQ&usg=AFQjCNFdXU7FHePug2JqI7-_0-a1n2Y1Rg&bvm=bv.81177339,d.cGU
American Water Heaters	6 – 12 (tank) 6 - 12 (parts)	5 – 15 (heat exchanger) 5 (parts)	http://www.americanwaterheater.com/products/resGas.aspx http://www.americanwaterheater.com/products/onDemand.aspx

1.3 Maintenance

Water heaters should be maintained according to manufacturer recommendations to ensure proper water heater performance, prolonged useful life, and warranty coverage. If water heaters are not maintained, the useful life can be shortened and failures may not be covered under the manufacturer’s warranty. Table 3 lists the primary maintenance activities for storage water heaters and IWHs based on manufacturer and plumber recommendations. Some manufacturers recommend additional maintenance activities than those listed in Table 3. For example, a leading water heater manufacturer recommends draining one gallon of water from the bottom of storage water heaters on a monthly basis to remove sediment in the tank. As noted in Table 3, both storage water heaters and IWHs have recommended regular maintenance procedures.

In this addendum the Statewide CASE Team revised Table 12 in the CASE Report (Table 3 in this addendum), as requested by CEC, to include maintenance activities that were not originally included Table 12. Table 3 below supersedes Table 12 in Section 3.3.2 of the CASE Report.

Table 3: Key Maintenance Activities for Water Heaters

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

Note: This table updates and supersedes Table 12 in the CASE Report submitted to CEC on September 19, 2014.

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

Maintenance of Gas Storage Water Heaters

The following paragraphs supersede the discussion on the maintenance of gas storage water heaters presented in Section 3.3.2 of the CASE Report. The discussion provided below has been updated to reflect more detailed information about the recommended maintenance of gas storage water heaters, as requested by CEC.

For a storage water heater, maintenance largely consists of draining the tank, inspecting the anode rod, and replacing the anode rod if necessary. The recommended frequency of regular maintenance varies by manufacturer. Like IWHs, the frequency of maintenance depends on water quality. Most manufacturers recommend draining the tank every six months to once per year in order to remove sediment that has accumulated in the bottom of the tank. As previously noted, one manufacturer recommends draining a gallon of water from the tank every month to remove the sediment that builds up during operation. Some manufacturers also recommend that yearly inspections of the burners, venting system, and temperature and pressure relief valves be conducted by a qualified service technician (see Figure 1).[1] Others recommend visual inspections as frequently as every three to six months.

IMPORTANT

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

Figure 1: Storage Water Heater Maintenance Recommendation

Source: Bradford White 2012

Note: This figure is labeled as Figure 5 in the CASE Report submitted to CEC on September 19, 2014

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

1.4 Water Heater Efficiency Degradation

The Statewide CASE Team was asked by CEC to investigate how efficiency degrades over time for both storage water heaters and IWHs. Paul et al. (2010) evaluated the impact of scale formation on equipment efficiency for electric storage, gas storage, and gas IWHs using an accelerating testing approach. During the test period, the water heaters were not maintained according to manufacturer recommendations.[2] The researchers evaluated 10 of each type of water heater: five water heaters were connected to water that had been treated with a water softener and contained 0.55 grains per gallon (gpg) of water hardness and five were connected

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

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

to un-softened well water that contained 26.2 gpg. It should be noted that water hardness of 26 gpg is very hard. For reference, San Diego has a water hardness of about 15 gpg and Anaheim has a water hardness of about 18 gpg. Both cities have some of the hardest water in the state. As described in Section 3.3.2 of the CASE Report, hard water can cause scale buildup which can reduce the efficiency and useful life of IWHs. As reported by Paul et al., hard water also reduces the efficiency of storage water heaters. Soft water (e.g., 0.55 gpg) may also have detrimental effects on storage water heaters, such as increasing risk of corrosion to the storage tank.

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

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

In addition, Paul et al. extrapolated the test data out a period of years in order to model efficiency degradation over time as a function of water hardness and hot water usage. Table 4 and Table 5 present the results of the extrapolation for gas IWHs and gas storage water heaters, respectively. As can be seen, the efficiencies of gas IWHs and storage water heaters degrade with time due to scale buildup and increased hot water usage. As can be seen in Table 4, at a daily hot water use of 50 gallons, IWHs are projected to require a flushing (i.e. deliming) at roughly two years in areas with *very* hard water (20 gpg) and at four years in areas with hard water (10 gpg). These results are similar to the recommended maintenance schedules provided by the professional plumbers that were interviewed as part of the CASE analysis with one exception: the study projects that IWHs will need to be flushed at approximately eight years in areas with soft water, rather than at four years as estimated by plumbing professionals.

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

Table 4: Predicted Efficiencies[1] of Instantaneous Water Heaters as a Function of Water Hardness and Hot Water Usage

Source: Paul et al. 2010

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

1. Water heater energy efficiencies are listed below each water hardness column and are expressed as a percent.

Table 5: Predicted Efficiencies[1] of Gas Storage Water Heaters as a Function of Water Hardness and Hot Water Usage

Source: Paul et al. 2010

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

1. Water heater energy efficiencies are listed below each water hardness column and are expressed as a percent.

1.5 Impact of Isolation Valves on Maintenance Costs of IWHs

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

1.6 Venting

Gas-fired water heaters must be properly vented so the products of combustion that are created when fuel is combusted are directed outdoors and away from people. The Statewide CASE Team has received several questions about the assumptions for venting IWHs. During the 2013 Title 24 rulemaking, the Statewide CASE Team recommended that the water heater venting requirements be updated to ensure that high-efficiency water heaters can be installed in new buildings. The “High-Efficiency Water Heater Ready” CASE Report submitted to CEC by the Statewide CASE Team in 2011 includes detailed information about venting requirements and the cost associated with vents for high-efficiency water heaters, including gas IWH and condensing gas storage water heaters. The Statewide CASE Team’s recommendations on venting have not changed since developing the CASE Report for the 2013 rulemaking.

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

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

The type of vent (e.g., plastic, steel, concentric) is typically specified by the manufacturer of the water heater. While many manufacturers allow plastic vents, several manufacturers of gas IWHs require a stainless steel vent because it can withstand the condensation that is created by the water heater.[3] The installer of the water heater should follow manufacturer specifications to determine the type of vent required for each IWH model.

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

> The National Fuel Gas Code (NFGC), ANSI Z223.1[4], divides gas appliances into four categories based on vent operating pressure and the likelihood of condensation occurring in the vent. The four categories, which are used to determine which type of vent is appropriate for a given appliance, are shown in Figure 2. Negative pressure systems, also known as non-positive pressure systems, operate at static pressures that are less than the surrounding room pressure. The joints of negative pressure systems do not need to be gas tight. If vent leakage occurs, room air will be sucked into the lower pressure flue stream. On the other hand, positive pressure systems require gas tight seals. If a leak occurs in a positive pressure system, flue gases will escape into the equipment room or, even worse, into the living space causing a potentially fatal buildup of carbon monoxide.
>
> The appliance category does not directly indicate the type of venting material needed. Nearly all residential natural draft water heaters are Category I appliance and use a 3 or 4 inch diameter double wall metal type-B vent. There are no Category II gas-fired water heaters. Most residential water heaters with power vent fall into Category III or IV, and they require different venting materials than a standard natural draft water heater. Manufacturers usually provide certified vent materials and installation specifications for their products. Plastic vent pipes, such as PVC, CPVC or ABS pipes, are typically used, although aluminum and stainless steel vents are also used for some models. Size of the vent pipe depends on heat input rating, length of the entire horizontal and vertical pipe sections, and the number of installed elbows. For residential applications, 2-inch diameter pipes are usually used. Some manufacturers require the use of proprietary concentric vent pipes, instead of generic plastic pipes.
>
> There is not a vent product that can be used for all types of water heaters. Some stainless steel vent products, e.g. Z-Flex vents, are certified for Category I through IV applications. When they are used for a Category I natural draft water heater, 3-inch or 4-inch pipes are used. If the water heater is to be upgraded to a power vent water heater, the venting system still might have to be replaced even though it is certified for Category III and IV appliances because the new power vent water heater may only certify the use of a 2-inch diameter pipe vent.

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

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

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

Figure 2. National Fuel Gas Code Gas Appliance Category

1.7 Additional Prescriptive Options

The Statewide CASE Team wanted to provide an additional prescriptive compliance option to residential gas IWHs that would allow an applicant to install a minimally compliant gas storage water heater in combination with other efficiency measures to achieve a similar overall energy performance as the IWH prescriptive option. When developing the CASE Report it was the Statewide CASE Team's understanding that CEC was only interested in accepting prescriptive options that 1) impacted domestic water heating systems, 2) the additional options had to result in equivalent energy performance in every climate zone, and 3) the additional prescriptive options do not need to be cost effective. The proposal presented in the CASE Report (submitted on September 19, 2014) adheres to those guidelines. However, those guidelines limited the options for potential additional prescriptive options, and eliminated the possibility of proposing a cost-effective alternative.

After submitting the CASE Report, the Statewide CASE Team learned that CEC was amenable to including a prescriptive option that impacted building systems other than water heating. It also came to our attention that the prescriptive option did not need to result in equivalent energy performance in every climate zone, so long as the prescriptive option(s) resulted in equivalent energy performance when evaluated on a statewide basis. These guidelines provided more flexibility in what could be included as an additional prescriptive option, and opened up the possibility of proposing a cost-effective prescriptive option as well.

Prior to CEC's November 3, 2014 pre-rulemaking workshop, CEC released draft language that recommended a prescriptive option that would allow an applicant to install a minimally compliant gas storage water heater in combination with HERS Quality Insulation Inspection (QII) along with either 1) HERS pipe insulation requirements, or 2) compact hot water distribution (HWDS) design. The Statewide CASE Team prefers this additional prescriptive option to the options presented in the CASE Report. The option to include QII to improve envelope efficiency is more practical and cost-effective than the option that calls for the use of a solar thermal system to provide a fraction of the water heating demand. The proposed prescriptive options in the code language released prior to the November 3, 2014 pre-rulemaking workshop read as follows:

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

This section of the report provides additional information about the revised additional prescriptive option, including the energy impacts and cost-effectiveness. While the proposed prescriptive option is cost effective in most climate zones (and is cost-effective on a statewide level), it is still the Statewide CASE Team's understanding that the additional prescriptive option does not need to be cost effective. The components of the additional prescriptive option are described in greater detail below.

1.7.1 Quality Insulation Inspection (QII) (Option 2)

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

1.7.2 Compact Hot Water Distribution System (HWDS) Design (Option 2a)

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

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

Table 4.4.5 in Section RA4.4.16 of the Residential Appendix, outlined in Table 6 below, specifies the maximum pipe length as a function of floor area served, where floor area served is defined as the conditioned floor area divided by the number of installed water heaters. The Residential Appendix states that a HERS inspection is required in order to obtain the credit.

Table 6: HERS-Verified Compact Hot Water Distribution System Requirements

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

1.7.3 Pipe Insulation (Option 2b)

Pipe insulation reduces heat loss (energy loss) between hot water draws and as hot water travels from the water heater to use points, thereby increasing the efficiency of the domestic hot water system. The 2013 Title 24 Standards include mandatory pipe insulation requirements for domestic hot water system in residential buildings (Section 150.0 (j)2). The following piping must be insulated:

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

In addition to the pipe insulation requirements in Title 24, the Residential Appendix includes specifications for the Proper Installation of Pipe Insulation (RA4.4.1) and requirements if an applicant wishes to claim the Pipe Insulation Credit (RA4.4.3) or the HERS-Verified Pipe Insulation Credit (RA4.4.14). The Proper Installation of Pipe Insulation credit does not include requirements beyond those specified in the Standards. Specifically, the pipe insulation credit requires that, “[a]ll piping in the hot water distribution system must be insulated from the water heater to each fixture or appliance.” The current standards do not require insulation on pipe less than ¾ inch in diameter. The Pipe Insulation Credit would require insulation on all pipe including ½ pipe. The HERS-Verified Pipe Insulation Credit states that a HERS inspection is required to verify pipes are insulated correctly.

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

Pipe Insulation Requirements in the Uniform Plumbing Code

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

The pipe insulation requirements in the UPC will be changing in 2015 so that insulation will now be required on all domestic hot water piping regardless of pipe diameter. The full IAPMO technical assembly voted to approve the draft language (see Figure 3) during their September 2014 meeting. The language presented below is almost certainly going to appear in the 2015 UPC, which will be published in early 2015. Since California typically adopts the UPC, there are questions around how the new pipe insulation requirements, if adopted by HCD and BSC, will impact the proposed pipe insulation prescriptive requirement in Part 6 of Title 24. The pipe insulation requirements in Part 6 of Title 24 conflict with the requirements that will be included in the UPC. CEC is aware of the issue but they prefer to continue pursuing the adoption of the proposed pipe insulation prescriptive option into the Title 24 Standards since there is no guarantee that HCD and BSC will adopt the 2015 UPC pipe insulation requirements. CEC is planning to coordinate with HCD and BSC in advance of their rulemaking process to update the California Plumbing Code next year.

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

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

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

Exceptions:

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

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

Figure 3: 2015 UPC Pipe Insulation Requirement (to be published by IAPMO in 2015)

1.7.4 Additional Prescriptive Option: Cost Assumptions

Table 7 presents the cost assumptions used when evaluating the cost-effectiveness of the additional prescriptive option. All three components of the additional option (QII, compact HWDS, and pipe insulation) were evaluated in other CASE Reports that the Statewide CASE Team developed for either the 2016 or 2013 Title 24 code change cycles. These costs are assumed to be a one-time, first-year cost during construction since the life of these options was estimated in the CASE Reports to be 30 years. The cost estimates in Table 7 have been adjusted to reflect 2014 dollars. Additionally, the "Heating Distribution" CASE Report (2011) presented insulation costs for ¾ inch and larger pipes. For purposes of this addendum, this cost was used as a proxy for the cost of all pipe sizes, including ½ inch pipes. See the relevant CASE Reports for additional information about cost assumptions for each component of the additional prescriptive option.

Table 7: Key Assumptions for per unit Incremental Construction Cost for Additional Prescriptive Option (Option 2, 2a, 2b)

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

1.7.5 Energy Impacts of Prescriptive Options

Table 8 presents the first year energy savings per prototype building for the prescriptive options. The methodology for the energy savings impacts analysis is described in Section 4 of the CASE Report. The analysis was completed using version 3 of the CBECC-Res compliance modeling software. The assumptions for existing conditions (i.e. baseline building) are the same for all prescriptive options. It is also assumed that the QII, compact distribution, and pipe insulation requirements specified in the Residential Appendix will be implemented for the prescriptive storage water heater option.

Table 8: First Year Energy Impacts per Building for All Prescriptive Options

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

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

The first year statewide energy impacts of the proposed prescriptive options are presented in Table 9. The methodology used to calculate the statewide savings are presented in Section 4 of the CASE Report. The results in Table 9 assume that all newly constructed residential buildings will comply with Title 24 using the identified approach. For example, the statewide savings estimate of 838 million TDV kBTU for the IWH prescriptive option assumes that all residential buildings built in 2017 will comply by installing a gas IWH that meets the federal minimum efficiency level. If all buildings complied using the QII + Compact Design option, the statewide savings would be 1,133 million TDV kBTU. Though users can comply with Title 24 by implementing any of the prescriptive options, based on historical trends, the majority of users will likely comply using the performance approach. The IWH prescriptive option establishes the baseline energy budget for the performance approach.

Table 9: First Year[1] Statewide Energy Impacts and for Prescriptive Options

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

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

1.7.6 Cost-effectiveness Results

The incremental cost of the additional prescriptive storage water heater option is presented in Table 10. (The incremental cost of the IWH option (option 1) can be found in Section 5.2.1 of the CASE Report.) The incremental cost of options 2a and 2b only include the cost of materials and installation based on the initial construction cost. Since the type of water heater does not change (baseline storage), there are no equipment or replacement costs included in the incremental cost. There is also no maintenance cost assumed for prescriptive options 2a or 2b over the 30-year period of analysis.

Table 10: Incremental Cost of Additional Prescriptive (Option 2)[1]

Option 2	Equipment Cost[2]	Present Value of Maintenance Cost[4]	Total Cost[5]
	Current = Post Adoption[3]		
2a. Incremental Cost of Baseline Storage Water Heater with QII & Compact HWDS	$1,182	$ -	$1,182
2b. Incremental Cost of Baseline Storage Water Heater with QII & Pipe Insulation	$1,131	$ -	$1,131

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

Energy cost savings for the prescriptive options are presented in Table 11. These energy cost savings are based on a prototype building (See Section 4.3 of the CASE Report for additional information on the prototype building). As can be seen, in most California climate zones prescriptive options 2a and 2b result in fewer energy cost savings than option 1 (IWH) over the 30-year period of analysis.

Table 11: TDV Energy Cost Savings Over 30-Year Period of Analysis - Per Building[1]

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

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

The results of the cost-effectiveness analysis for the storage water heater prescriptive option (option 2a and 2b) is presented in Table 12 and Table 13. As can be seen, the additional prescriptive option 2a and 2b are cost effective in all climate zones except climate zones 6, 7, and 8. As previously stated, the additional prescriptive option does not need to be cost-effective in every climate zone as long as it is cost-effective on a statewide level.

Table 12: Cost-effectiveness Summary per Building, Option 2a (Storage Water Heater with QII & Compact Design) [1]

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

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

Table 13: Cost-effectiveness Summary per Building, Option 2b (Storage Water Heater with QII & Pipe Insulation)[1]

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

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

1.8 Proposed Code Language

The following proposed code language supersedes what was proposed in the CASE Report submitted to CEC on September 19, 2014.

The proposed changes for the 2016 Title 24 Standards and Residential ACM Reference Manual are provided below in red text. Changes to the existing (2013) standards are marked with underlining new language and ~~strikethroughs~~ deletions.

1.8.1 Standards

SECTION 110.3 – MANDATORY REQUIREMENTS FOR SERVICE WATERHEATING SYSTEMS AND EQUIPMENT

(c) Installation.

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

SECTION 150.0 – MANDATORY FEATURES AND DEVICES

{Content that does not pertain to proposed standard omitted}

(n) **Water Heating System**.

1. Systems using gas or propane water heaters to serve individual dwelling units shall include the following components:
   - A. A 120V electrical receptacle that is within 3 feet from the water heater and accessible to the water heater with no obstructions; and
   - B. A Category III or IV vent, or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed; and
   - C. A condensate drain that is no more than 2 inches higher than the base of the installed water heater, and allows natural draining without pump assistance, and
   - D. A gas supply line with a capacity of at least 200,000 Btu/hr.
2. Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 110.3(c)5.
3. Solar water-heating systems and collectors shall be certified and rated by the Solar Rating and Certification Corporation (SRCC) or by a testing agency approved by the Executive Director.
4. Instantaneous water heaters with an input rating greater than 6.8 kBTU/hr (2 kW) shall comply with Section 110.3(c) 7.

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

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

{Content that does not pertain to proposed standard omitted}

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

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

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

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

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

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

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

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

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

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

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

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

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

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

{Content that does not pertain to proposed standard omitted}

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

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

{Content that does not pertain to proposed standard omitted}

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

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

i. If natural gas is connected to the building, a natural gas water heater that meets the requirements of the Appliance Efficiency Regulations. For storage type water heaters the capacity shall not exceed 60 gallons. ~~A natural gas or propane water-heating system that meets the requirements of 150.1(c)8.~~ No recirculation system shall be installed; or

ii. If no natural gas is connected to the building, an electric water heater that ~~has an energy factor equal to or greater than required under~~ <u>meets</u>

the requirements of the Appliance Efficiency Regulations. For storage type water heaters the capacity shall not exceed 60 gallons. No recirculation system shall be installed; or

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

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

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

1.8.2 Reference Appendices

There are no proposed changes to the Reference Appendices.

1.9 References

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

___. 2011b. "Codes and Standards Enhancement (CASE) Report for the 2013 California Building Efficiency Standards: Single Family Water Heating Distribution System Improvements" http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_R_SEMPRA_Single_Family_DHW_%20Sept_2011.pdf.

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

[CEC] 2013. California Energy Commission. "Residential Appendices."

http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/final_rulemaking_documents/44_Final_Express_Terms/2013_RA_FINAL.pdf

[PNNL] Pacific Northwest National Laboratory. 2013. "Impacts of Water Quality on Residential Water Heating Equipment."

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