Title
Heating Hot Water Policy Recommendations

Authors
Singla, Rupam
LaPalme, Glen
Chappell, Cathy

Publication Date
2024-03-28

California Energy Commission

CONSULTANT REPORT

Heating Hot Water Policy Recommendations

Prepared for: **California Energy Commission**
Prepared by: **Center for the Built Environment, UC Berkeley**

Gavin Newsom, Governor
December 2023 | CEC-XXX-XXXX-XXX

California Energy Commission

Primary Author(s):

Rupam Singla, TRC
Glen LaPalme, TRC
Cathy Chappell, TRC

TRC
436 14th St. Suite 1020, Oakland, CA 94612

Contract Number: PIR-19-013

Prepared for:

California Energy Commission

Bradley Meister
Contract Manager

Virginia Lew
Office Manager
BUILDING EFFICIENCY RESEARCH PROGRAM

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Drew Bohan
Executive Director

ABSTRACT

This project, *Getting out of Hot Water: Reducing gas consumption in existing large commercial buildings,* demonstrates, evaluates, and provide a path to scale for an innovative set of non-proprietary cost-effective methods to reduce natural gas consumption in large commercial buildings. This document, *Heating Hot Water Policy Recommendations,* examines current building energy code requirements to identify feasibility, impediments, and opportunities for code enhancement involving hot water control solutions based on project findings. The document also identifies opportunities within California utility program offerings to improve performance of heating hot water systems.

Keywords: Natural Gas, large commercial, energy efficiency, heating, codes and standards, utility programs, measures

Please use the following citation for this report:

Singla, Rupam, Glen LaPalme, Cathy Chappell. 2023. *Heating Hot Water Policy Recommendations*. California Energy Commission. Publication Number: CEC-XXX-201X-XXX.

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EXECUTIVE SUMMARY

Two of the primary pathways to meet the project goals are to drive adoption of measures through codes and standards enhancements and utility programs offerings. The team's objective with respect to codes and standards is to examine current building energy code requirements to identify feasibility, impediments, and opportunities for code enhancement involving hot water control solutions based on project findings. The team focused on code change opportunities in the California Building Energy Efficiency Standards (Title 24) and ASHRAE Guideline 36. The team's objective with respect to utility programs is to identify opportunities within California utility program offerings to improve performance of heating hot water systems. The team identified opportunities for program delivery platforms and measure offerings.

Opportunities for Codes and Standards Changes

The main codes and standards with heating hot water control scope in California are California Title 24 and ASHRAE Guideline 36. The team identified new change opportunities and discussed the steps needed to provide more effective enforcement of the control requirements for both new construction and alterations. The following are the proposed measures:

- Title 24: Reduce Design Maximum Hot Water Supply Temperature. This measure limits the design space heating hot water supply temperatures to 130 °F for new construction, additions, and alterations.
- Title 24: Hot Water Supply Temperature (HWST) Reset: Require chilled water and hot water systems that use variable flow to have temperature reset controls.
- Title 24: HHW Plant Capacity Turndown: Require that the boiler plant minimum operating load be ≤ 5% of the boiler plant full capacity (calculated without accounting for capacity of standby equipment).
- Title 24: ACM Boiler Performance Curve: Revise the ACM boiler performance curves to better reflect actual in-field boiler performance.
- ASHRAE Guideline 36: Improve Setpoint Reset Effectiveness: Revise the trim and respond resets to direct the designer on how to set the default number of ignored requests for each application, rather than provide a fixed value that will not be appropriate for many applications.

Opportunities for Utility Programs

The team provides recommendations on how California's utility program offerings can support improved performance of natural gas fired boiler fed hot water reheat systems. CPUC program policies and platform guidelines dictate what and how programs and measures are implemented. We identified the following measure offerings: Lower VAV box minimums, preventing excess boiler operation, reducing piping distribution losses, HWST reset, and HHW plant boiler rightsizing. The recommended measures can be taken to market through one or more of the following Resource Acquisition program platforms: Deemed, Custom, NMEC, On-Bill Financing and Hybrid.

Additional Measure Opportunities

There are other potential measures that came out of the research that the research team is not currently recommending for implementation in codes, standards, or programs, but that could be incorporated in the future. These measures require more research, have lower or uncertain energy savings potential, require additional data, are not mature enough yet, or do not have a clear path for implementation.

CHAPTER 1: Background

The goals of this project are to substantially reduce natural gas consumption in large commercial buildings through improved performance of natural-gas fired boiler fed hot water reheat systems, and provide a path to scale cost-tiered packages of measures across large commercial building portfolios. Two of the primary pathways to meet these goals and to drive adoption of measures through codes and standards enhancements and utility programs offerings.

The team's objective with respect to codes and standards is to examine current building energy code requirements to identify feasibility, impediments, and opportunities for code enhancement involving hot water control solutions based on project findings. The team focused on code change opportunities in the California Building Energy Efficiency Standards (Title 24) and in ASHRAE Guideline 36 and summarized those in CHAPTER 2: Opportunities for Codes and Standards Changes.

The team's objective with respect to utility programs is to identify opportunities within California utility program offerings to improve performance of heating hot water systems. The team identified opportunities for program delivery platforms and measure offerings.

This document describes recommendations for changes to codes, standards, and utility incentive programs to drive adoption of measures.

CHAPTER 2: Opportunities for Codes and Standards Changes

Introduction

This section provides a background of existing hydronic heating system hot water control requirements in Title 24 and ASHRAE Guideline 36, identifies new change opportunities, and discusses the steps needed to provide more effective enforcement of the control requirements for both new construction and alterations.

Paths in Current Codes and Standards

There are a number of different ways to impact codes and standards for heating hot water controls, including modifications to the codes and standards themselves, compliance processes, test methods, and code-readiness studies.

The main codes and standards with heating hot water control scope in California are California Title 24 and ASHRAE Guideline 36. Additional pathways include ASHRAE Standard 90.1, ASHRAE Standard 155P (in development), ASHRAE Standard 100, Reach Codes, and building performance standards.

The following subsections describe existing hot water control requirements, where the code or standard is currently adopted and the process for modifying each of these codes and standards.

California Title 24

The California Building Energy Efficiency Standards (Part 6 of the California Building Standards Code), colloquially and hereinafter referred to as Title 24, are designed to ensure that new and existing buildings meet minimum energy efficiency and indoor environmental quality requirements. The standards are updated on a triennial basis by the California Energy Commission (CEC) to allow consideration and possible incorporation of new energy efficiency technologies and methods. Title 24 contains building energy efficiency requirements applicable to most residential and nonresidential buildings throughout California.

Where Currently Adopted

Title 24 is adopted in all of California.

Existing Hot Water Control Requirements

There are two methods for demonstrating compliance with Title 24:

- **Prescriptive Method**: This approach allows projects to comply by using measures known to be energy efficient and cost effective. To show compliance, each individual component of the proposed building must meet specific prescribed requirements. The prescriptive approach is inflexible but provides a simple path for compliance.

- **Performance Method**: This approach provides more flexibility in building design by allowing projects to trade off different factors so long as the overall simulated performance meets or exceeds that of a standard reference building, which represents the equivalent code-minimum building. This standard building is referred to as Standard Design. Prescriptive requirements are the basis of developing the Standard Design. If a Proposed Design includes a measure that provides better performance than the prescriptive requirement, a credit is given to the proposed model. In addition, the Alternative Calculation Method (ACM) establishes the modeling rules and assumptions for the Standard Design. Refinement of ACM rules can effectively impact the energy use of the Standard Design, and thus lower or raise the bar for a proposed design to show compliance through the performance method.

In addition to the two compliance paths above, there are mandatory measures that apply to all projects. The mandatory measures specify minimum requirements for the envelope, heating, ventilation, and air conditioning (HVAC) and water heating equipment efficiency, and other components in buildings.

Table 1 summarizes the mandatory heating hot water system requirements in Title 24.

Table 1. Title 24 Mandatory heating hot water system requirements

Section	Component	Applicability	Requirement
120.2(j)	Direct digital controls (j)	Hot water system serving > 3 zones and with design heating capacity of ≥ 300 kBtu/h	Provide DDC to the zone
120.3	Pipe insulation	All heating hot water systems	Install pipe insulation of a certain thickness; protect pipe insulation
120.9	Boilers	Boilers with input capacity ≥2.5 MMBtu/h One stack serves two or more boilers with combined input capacity ≥2.5 MMBtu/h	Provide combustion air positive shut-off
		Boiler combustion air fans with motors > 10 horsepower	Fan motor driven by variable speed drive or controls to limit fan motor demand to ≤ 30% of total design wattage at 50% of design air volume

Table 2 summarizes the prescriptive heating hot water system requirements in Title 24.

Table 2. Title 24 Prescriptive heating hot water system requirements

Section	Component	Applicability	Requirement
140.4(a)	Equipment sizing and selection	Mechanical heating equipment	Size equipment to the smallest size necessary to meet the design heating load as calculated based on ASHRAE Handbook, Fundamentals
140.4(g)	Electric resistance heating	Space heating systems	With some exceptions, electric resistance heating not allowed for space heating
140.4(k)	Hydronic systems: flow	Hot water systems with ≤ 3 control valves or hot water systems with total pump system power ≤ 1.5 hp.	Design for variable fluid flow and be capable of reducing pump flow rates to no more than the larger of: a) ≤50% of the design flow rate, or b) the minimum flow rate required by the equipment manufacturer for proper operation
	Hydronic systems: Boiler	Hot water plant with > 1 boiler	Provisions so that flow through any boiler is automatically shut off when the boiler is shut off while still maintaining flow through other operating boiler(s)
	Hydronic systems: temperature controls	Hot water systems >500 kBtu/h	Include controls that automatically reset supply water temperatures as a function of representative building loads or outside air temperature. Exception for systems with variable flow.
	Hydronic systems: flow controls	System with pumps > 5 hp	Controls or devices that result in pump motor demand of ≤ 30% of design wattage at 50% of design water flow. Control pumps as a function of required differential pressure

		Systems with DDC	Static pressure setpoint reset based on the valve requiring the most pressure and the setpoint shall be no less than 80% open
	Hydronic systems: high-capacity gas boiler systems	CZs 1-6, 9-14, and 16; total system input of ≥ 1 MMBtu/h and ≤ 10 MMBtu/h	Gas hot water boilers have thermal efficiency of ≥ 90%. Coils and other heat exchangers selected so that design conditions of the hot water return temperature entering the boilers is ≤ 120F. Under all operating conditions, water temperature entering the boiler is ≤ 120F or hot water supply directly recirculates into the return system.

The Nonresidential ACM Reference Manual details requirements for the Standard Design. Table 3 summarizes the heating hot water system requirements of the Standard Design. The heating hot water system requirements for the proposed design should be modeled as they are.

Table 3. Title 24 Standard Design hot water control requirements

Section	Component	Applicability	Standard Design Requirement
5.8.1	Boilers	All non-healthcare facilities	Fuel source: Gas Boiler type: Hot water Boiler draft type: Condensing Number of identical boiler units: >15,000 sqft conditioned floor area: two equally sized boilers Boiler design capacity: 25% larger than the peak loads Boiler efficiency type: <300 kBtu/h capacity: AFUE; >300 and <2,500 kBtu/h: thermal efficiency; >2500 kBtu/h combustion efficiency Boiler efficiency: < 1 MMBtu based on California Appliance Efficiency Regulations; > 1 MMBtu: 90%

			Boiler part load performance curves: Based on Appendix 5.7 Boiler forced draft fan power: 0.2984 W per kBtu/h heat input Boiler minimum unloading ratio: 1% Boiler minimum flow: 0 gpm Hot water supply temperature: 180F Hot water temperature difference: 40F Hot water supply temperature reset: 160F
5.8.5	Pumps	All non-healthcare facilities	Number of pumps: 1 for each boiler Water loop design: primary Pump motor modeling method: power-per-unit-flow Pump motor power-per-unit flow: 19 W/gpm Pump motor horsepower: Reference Table 10 in the ACM Impeller efficiency: 70% Motor efficiency: Reference Table 10 in the ACM Pump minimum speed: 0.10 Pump design flow: Flow rate in gpm shall correspond to a loop temperature drop of 40F Pump control type: variable-speed Pump operation: on-demand mode, tied to the boiler operation Pump part-load curve: pump power is assumed to be constant even though pump is riding the curve

Ways to Impact

The primary ways to impact the effectiveness of Title 24 requirements are through changes to the standard, improving the compliance processes, and code readiness activities. The standard can be impacted by introducing new efficiency measures and by increasing the stringency of existing measures during the update process.

Process for Impacting

The standards are updated on a triennial basis by the California Energy Commission (CEC) to provide consideration and possible incorporation of new cost-effective energy efficiency technologies and methods. Most new potential energy efficiency measures are evaluated through the California utilities' Codes and Standards Enhancement (CASE) process. The CASE process requires extensive research and evaluation of first cost impacts and life cycle cost effectiveness, as well as extensive stakeholder input and public comment. The CEC and other stakeholders may propose additional code change proposals and typically follow the same CASE process.

To accommodate code compliance for new technologies, changes may be required to both the prescriptive and performance paths. Proposed changes to prescriptive requirements must be demonstrated to be life cycle cost effective. Updates to the performance path requires revisions to both the ACM Manual and the compliance software. In the following sections, we review current requirements and changes that could be made to prescriptive and performance requirements (both to the ACM Manual and the compliance software tools).

ASHRAE Guideline 36

ASHRAE Guideline 36 High Performance Sequences of Operation for HVAC System provides standardized sequence logic for the control of select HVAC systems and equipment. The ASHRAE Guideline 36 Committee established high-performance sequences based on a survey of existing logic that has been vetted and improved over decades through a consensus process. Guideline 36 is a set of standardized sequences that prioritizes energy efficiency, ease of operation, indoor air quality, thermal comfort, and code compliance.

Where Currently Adopted

In June 2021, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) gave authorization to reference Guideline 36 in Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings and any other ASHRAE standard. ASHRAE acknowledged that despite Guideline 36 being only a guideline, it went through the same public review process and it is written in mandatory, enforceable language. This opens the possibility for Guideline 36 to be referenced directly by Title 24 and other codes and standards.

The Statewide CASE Team as part of the Nonresidential HVAC Controls CASE report developed a proposal for Title 24-2025 to add requirements for the use of control sequences from ASHRAE Guideline 36 and also requires that controls programming for DDC systems use control logic from an CEC-certified Guideline 36 programming library, based on certification requirements in a new joint appendix (Singla, et al., 2023).

Existing Hot Water Control Requirements

Guideline 36 provides sequences of operation for hot water plants, which include sequences for plant enable/disable, boiler staging, hot water supply temperature reset, non-condensing boiler condensation control, primary and secondary hot water pumps, and minimum flow bypass valve.

Ways to Impact

The guideline can primarily be impacted by expanding the scope or by improving existing sequences of operation within the guideline.

Process for Impacting

Guideline 36 is under continuous maintenance, through a process overseen by a committee of volunteers. The guideline is republished every three years, incorporating any approved addenda since the last publication.

Measure Opportunities

Opportunity – Reduce Design Maximum Hot Water Supply Temperature

Scope of change: Title 24-2022, Section 120.2 (l)

Background and Justification

Heating hot water systems are generally designed to a hot water supply temperature of 180 °F. However, there are several key reasons why the design hot water supply temperature should be reduced, including: to prepare buildings for future all-electric configurations since most air-to-water heat pumps can only provide up to around 130 °F water; to enable more efficient equipment operation of both condensing boilers and heat pumps; to reduce piping distribution losses. The Statewide CASE Team, as part of the Nonresidential HVAC Space Heating CASE Report, gives more detail on how lower design temperatures can support electrification (Boyce, Wang, Stein, & Cheng, 2023).

The research team conducted a test to measure piping distribution losses in real buildings. For the test, we commanded the valves closed on heating hot water end-use components and shut down the air handlers. We operated the heating hot water system to maintain a constant flow and a constant hot water supply temperature setpoint typical for each building. We then measured the steady-state heating power required to maintain that setpoint. In a study by the research team reported results from 7 large commercial buildings at 5 different organizations, all located in California (climate zones 3B and 3C) (Raftery P. V., 2023). Figure 1 shows the results from the testing; the median loss rate was 1.2 W/m^2 (0.37 BTU/hr.ft^2) with a min/max range of 0.8 - 2 W/m^2 (0.25 – 0.63 BTU/hr.ft^2) at each building's typical operating hot water supply temperature setpoint. For context, this is about a third of the average office plug loads of 3 W/m^2 (1 BTU/hr.ft^2) measured by the GSA in 2013 (US General Services Administration 2014), and ranges from 6% to 60% of the annual HW energy consumption for the five buildings for which we had long term data.

As expected, higher water temperature does not clearly correlate with higher losses between buildings because other building characteristics have a far larger influence on building energy losses. However, physics dictates that distribution losses within a given building will increase in an approximately linear relationship based on the temperature difference between the ambient air around the piping and the water it contains. Figure 1 also shows that this was the case for the two buildings in which we repeated the test at a lower water temperature. We also normalized the results using the temperature difference between the supply water temperature and an assumed ambient temperature of 21 °C (70 °F) approximating the low end of room and return plenum temperatures where most piping is located; the median was 0.024 W/°C.m^2 (0.0041 BTU/hr.°F.ft^2). See publication for more details (Raftery P. V., 2023).

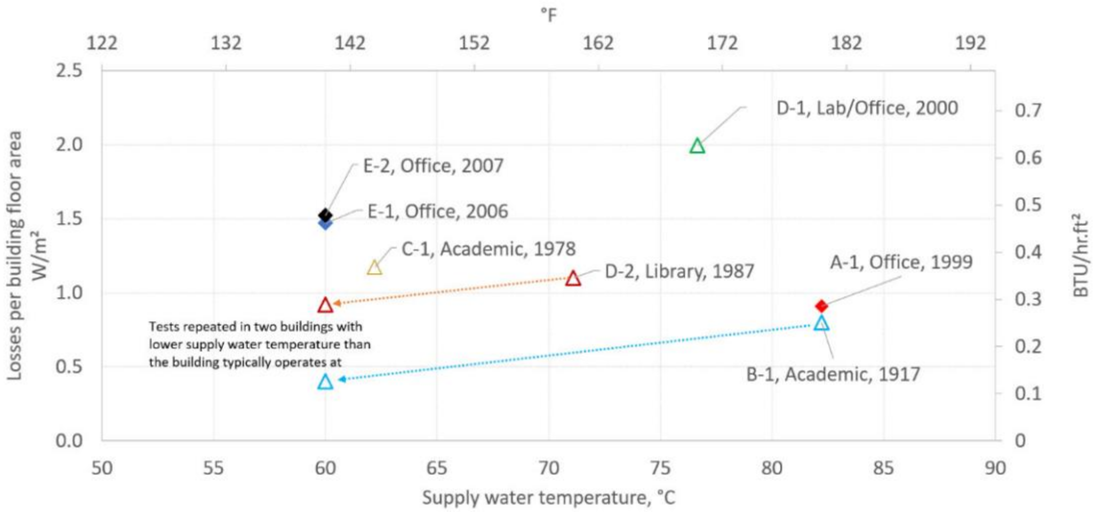

Figure 1. Measured hot water distribution losses in 7 buildings (indicated by color). Filled, diamond shapes indicate relatively new, high-quality instrumentation; unfilled triangular shapes indicate existing instrumentation (Raftery P. V., 2023)

Recommendation

This measure is a mandatory requirement that limits the design space heating hot water supply temperatures to 130 °F for new construction, additions, and alterations. Correspondingly, the ACM would limit the Standard design to a hot water supply temperature of ≤ 130 °F, a hot water temperature difference of 25 °F, and a hot water supply temperature reset of 130 °F.

The requirement also applies to newly installed space-conditioning systems in additions and altered components of space-conditioning systems in alterations.

Implementation Progress

The research team supported the Statewide CASE Team in developing a proposal and providing data to help justify the proposal.

Opportunity – Hot Water Supply Temperature (HWST) Reset

Scope of change: Title 24-2022 Section 140.4(k)4

Background and Justification

Similar to reducing the maximum HWST, HWST reset saves energy through more efficient equipment operation for both condensing boilers and heat pumps, and through reducing piping distribution losses.

Interviews with mechanical design professionals on current industry practice showed that most (11 out of 14) designers use outdoor air-based and demand-based hot water temperature reset strategies, and would pick one or the other based on specific project conditions (Lamon, 2022). While this is already common in the industry, it does not yet have full market adoption. Including this in code would ensure full market adoption.

Recommendation

Title 24-2022 Section 140.4(k)4 prescriptively requires chilled and hot water systems with design capacity above 500,000 Btu/h to have temperature reset controls that automatically reset supply water temperatures as a function of representative building loads or outside air temperature. However, there is an exception for systems that use variable flow.

This measure would remove that exception and require chilled water and hot water systems that use variable flow to have temperature reset controls. This measure would also require that the temperature be reset based on representative building loads, and not allow reset based on outside air temperature unless the zones are not DDC. The temperature reset based on representative building loads would be per Guideline 36, which requires trim and respond logic. Additionally, this measure would require that the HWST reset operate over the range spanned from the design HWST down to the larger of 90 °F and the design HWST minus 60 °F. Correspondingly, the ACM would limit the hot water supply temperature reset in the Standard Design to ≤ 90 °F.

Implementation Progress

The team has not proposed this measure in any code or standard.

Opportunity – HHW Plant Capacity Turndown

Scope of change: Title 24-2022 Section 140.4(k)

Background and Justification

The research team conducted a study on the HHW load data of 145 buildings and analyzed the load distribution of all of the systems normalized to their maximum load (Raftery, Singla, Cheng, & Paliaga, 2023). The team found that the median building spends 94% of the time operating at loads at or below 50% of the maximum load experienced by that building and 30% of the time operating at loads below 10% of the maximum load. Figure 2(a) shows the hot water load distribution for a typical building within the data set, where the vast majority of operating hours are at very low part loads. Figure 2(b) shows the cumulative fraction of operating hours for each plant, normalized to each plant's maximum load (not the installed maximum capacity), with the blue line representing the average distribution.

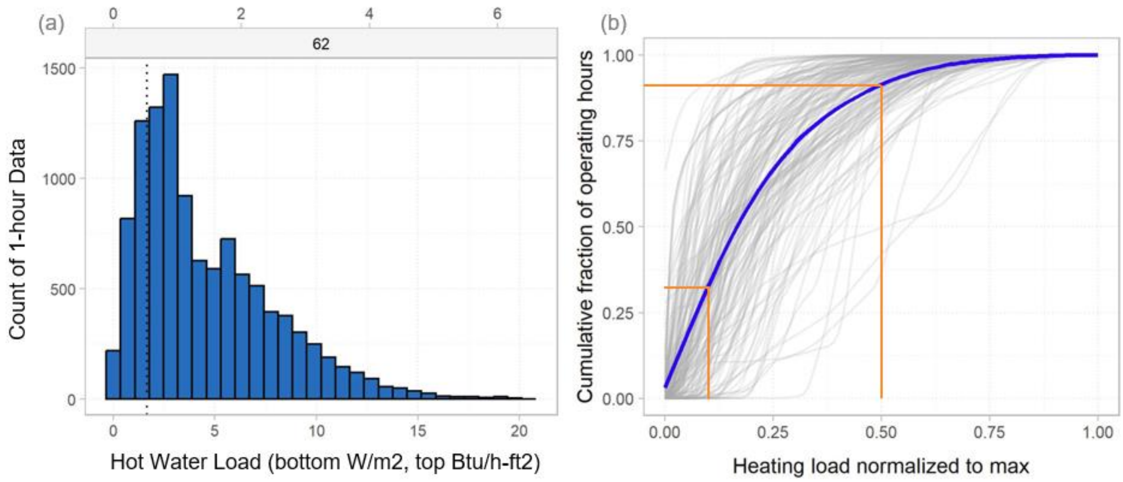

Figure 2. Hot Water Plant Load Distribution

Boiler efficiency is generally only rated at full load, and efficiency falls dramatically at loads below the boiler minimum output, or below the boiler minimum turndown limit. A boiler's turndown limit is the ratio between a boiler's maximum and minimum outputs. Field measures taken as part of this project show a single forced draft boiler with 2:1 turndown capability rated at 84% thermal efficiency had a field efficiency of 50%, due in large part to cycling losses. A boiler plant minimum turndown requirement could significantly reduce cycling losses. The requirement could be met by selecting boilers with high turndown capability and/or having multiple boilers to meet the load.

Recommendation

This measure adds a prescriptive requirement that the boiler plant minimum operating load be ≤ 5% of the boiler plant full capacity (calculated without accounting for capacity of standby equipment).

Implementation Progress

The team has not proposed this measure in any code or standard.

Opportunity – ACM Boiler Performance Curve

Scope of change: Title 24-2022 ACM Performance Curve

Background and Justification

As described in the HHW Plant Capacity Turndown Opportunity, boiler efficiency is generally only rated at full load, and efficiency falls dramatically at loads below the boiler minimum turndown limit. On the other hand, the ACM boiler performance curves reflect idealized boiler performance, not accounting for cycling losses, standby losses, or other contributors to poor field efficiency. The Standard Design non-condensing boiler performance curve assumes that at the lowest load, the boiler efficiency is 75% of the full load efficiency. The Standard Design condensing boiler performance curve varies based on entering water temperature and assumes that at the highest load and highest entering water temperature, the boiler efficiency is around 92% of full load efficiency.

Inaccurate representations of boiler performance in energy modeling software lead to underestimates of energy savings due to heating hot water related efficiency measures.

Recommendation

This measure would revise the ACM boiler performance curves to better reflect actual in-field boiler performance. Further research is needed to determine typical cycling and standby losses in boiler performance.

Implementation Progress

The team has not proposed this measure in any code or standard.

Opportunity – Improve Setpoint Reset Effectiveness

Scope of change: ASHRAE Guideline 36-2021, Sections 5.1.14.3 and 5.21.4

Background and Justification

Trim and respond setpoint reset logic is an energy efficiency strategy that aims to reduce energy use during periods of low demand while still ensuring responsiveness to meet loads during periods of higher demand. The responsiveness of the reset logic can be adjusted by changing the number of ignored requests. Guideline 36 provides a default number of ignored requests. The reset will be more responsive to demand when the number of ignores is set to a low value, and will provide more energy savings when the number of ignores is set to a higher value. In general, the number of ignores should be considered based on the size of the system and the total number of associated zones and systems that can generate requests. The original Guideline 36 language set a default value of 2 for most resets, which is seldom changed in practice. For many larger systems, having only 2 ignores may make the system overly responsive to demand and outlier or problematic zones, which may sacrifice energy efficiency opportunities with resetting setpoints.

Guideline 36 Section 5.1.14 addresses trim and respond setpoint reset logic, with requests defined in Section 5.1.14.2. Requests are a way for zones and other dependent equipment to indicate a need from source systems or plants. For example, when used with duct static pressure setpoint reset logic, requests are a way for zones to indicate demand for an increase in pressure. However, requests are also used within the guideline to enable equipment. For example, the hot water plant requests generated by hot water valves are prerequisites for a hot water plant to be enabled. Defining requests independently from the setpoint reset logic ensures that associated parameters including importance multipliers and cumulative request hours are applied to all forms of requests.

Recommendation

Revise the trim and respond resets to direct the designer on how to set the default number of ignored requests for each application, rather than provide a fixed value that will not be appropriate for many applications.

Revise the location of where requests are defined to recognize that they are used more broadly than indicated by their current definition as a subsection of Trim and Respond Set-point resets.

Implementation Progress

The research team developed and submitted two proposed addenda to the ASHRAE Guideline 36 project committee detailing this proposal. The first addendum revises the trim and respond resets to direct the designer on how to set the default number of ignored requests for each application. The second addendum revises the location of where requests are defined. The committee voted to approve both addenda on October 18, 2023. The addenda both passed public review and will be incorporated into the next publication Guideline 36, which is due to be in 2024.

CHAPTER 3: Opportunities for Utility Programs

Introduction

In this chapter the team provides recommendations on how California's utility program offerings can support improved performance of natural gas fired boiler fed hot water reheat systems. CPUC program policies and platform guidelines dictate what and how programs and measures are implemented. This chapter describes program delivery platforms and recommended measure offerings.

Measure Offerings

Recommendations are limited to the following HHW system measures:

Offering - Lower VAV Box Minimums

The VAV box minimums measure reduces VAV box minimum airflow setpoints to ventilation minimum flow rates to reduce heating, cooling, and fan energy required in current codes and standards for new construction. Note that this does not reduce the minimum ventilation air requirement for the building, it reduces the amount of air recirculating unnecessarily in the building.

The team recommends the lower VAV box minimums measure as a Behavioral, Retro-commissioning and Operational RCx (BRO-RCx) offering using a Deemed and Hybrid approach, starting with pursuing a Deemed approach through Cal Technical Forum (CalTF). The Deemed approach is the most streamlined and cost-effective path. It requires little review and inspection work, and has the fastest customer or contractor rebate payment process. If a proposed Deemed offering does not pass the CalTF screening process (proposal step 1) or is not later approved by the CPUC (proposal step 2), we suggest getting approval from the CPUC for a Hybrid approach. The Hybrid approach is a simplified estimation approach with limited verification requirements, which reduces the Custom development and review time. The program delivery approaches are described in more detail below.

The recommended measure development process is as follows:

- Submit a Measure Submission Form to Cal TF for review by their Measure Screening Committee.[1]
  - If approved, submit a Measure Development / Update Plan & Receive Cal TF Early Feedback. Continue process for final approval by CPUC.
- If not approved, work with Cal TF and their Custom Initiative team to get an early opinion from the CPUC for a Hybrid offering.

[1] Cal TF, Measure Submission Form, https://www.caltf.org/submit-a-measure

- Request an RCx Lite approach (similar to Custom Lite Direct Install Lighting) as a Hybrid platform. This approach does not require a pre-installation technical review by the PA or CPUC. Removing the pre-installation technical review will expedite implementation, increase customer satisfaction and possibly lead to a deeper RCx engagement. Based on the CPUC influence and M&V rigor guidelines, pre- and post-verification and documentation would still be required. The final claimed savings and project incentive would be determined by a post-installation review. Precedence for this approach is a Direct Install program for small commercial lighting in PG&E territory.
- If Hybrid platform is accepted by the CPUC, develop or use a statewide CPUC-approved calculation tool for collecting inputs and estimating site specific energy savings.

The appropriate savings approach will depend on the scope and size of the project. In 2023, Cal TF endorsed the "PG&E HVAC Tool.xlsm" for estimating RCx savings for AHU, HHWS and CHWS measures. This tool is an Excel based bin simulation. Guidelines and appropriate use of the tool are also available.

Offering - Preventing Excess Boiler Operation

The prevent excess boiler operation measure ensures boiler plant doesn't operate when not needed, such as when AHUs and fan coils are off.

The team recommends this as a BRO-RCx measure, similar to the VAV box minimums measures. If lowering VAV minimums and preventing excess boiler operation were both approved as Hybrid measures, they could be processed as a single program submittal using the same calculation tool.

Offering - Reducing Piping Distribution Losses

The piping distribution losses measure requires insulating hot water systems as required by Title 24, including insulating the valve trains serving terminal units.

The team recommends that the piping distribution losses measure uses the Add-on (AOE) Measure Application Type (MAT) using the existing Deemed measure package for service and domestic hot water "SWWH017-04: Hot Water Pipe Insulation, Nonresidential and Multifamily". Program eligibility requirements for hot water pipe insulation include:

- The pipe must transfer hot water, low-pressure steam, or medium-pressure steam directly from gas-fired equipment, and the fluid type must be indicated. If the fluid is steam, the pressure of the steam must also be indicated.
- The minimum qualifying pipe diameter is ½-inch.
- A minimum of one inch of pipe insulation must be added to existing bare commercial or industrial steel or copper pipe.

- Acceptable types of insulation for hot water pipes include elastomeric foam rubber, polyethylene foam, UV-resistant polyethylene foam, and rigid polyurethane foam.
- Acceptable types of insulation for steam pipes include silicone foam rubber, melamine foam, rigid urethane-based foam, cellular glass, rigid fiberglass, and rigid mineral wool.

For addressing piping distribution losses, savings should be based on the existing measure package (SWWH017-04).

Offering - Hot Water Supply Temperature (HWST) Reset

The HWST reset measure saves heating system energy consumption by more accurately matching the heating source supply temperature with the building demand.

The potential program MAT for this measure could be BRO-RCx or AOE. The BRO-RCx measure could be applied to all boilers with existing reset controls that are non-operational or not meeting current or recommended setpoints. For both pathways, the appropriate baseline is existing conditions. The applicable program offering is Custom or, if available, Hybrid. Like the prior measures "PG&E HVAC Tool.xlsm" is an appropriate program calculation methodology.

Offering - HHW Plant Boiler Rightsizing

The HHW plant boiler rightsizing measure lowers part-load boiler heat loss from oversized boilers.

The results of this study show that the median building spends 94% of the time operating at loads at or below 50% of the maximum load experienced by that building and 30% of the time operating at loads below 10% of the maximum load (Raftery, Singla, Cheng, & Paliaga, 2023). However, the actual system capacity is typically oversized and much larger than the maximum load experienced by that system, which exacerbates this problem, and causing even more short-cycling and poor efficiency. Oversizing and short-cycling tends to be particularly problematic in systems with a single boiler, or systems with limited turndown capability. Buildings could be initially screened for participation based on these criteria. The CA IOU programs offer two different pathways for incentivizing this measure. First, for Normal Replacement (NR) and New Construction (NC) measures, a Deemed offering is available. The appropriate eTRM measure package is SWHC004-06. It covers high-efficiency space heating boilers that meet the following Measure Case ID specifications:

- The boiler must be used for space heating to induce human comfort, as defined by the California Appliance Efficiency Regulations (Title 20) and Building Energy Efficiency Standards (Title 24).
- The boiler must meet efficiency and reset requirements based on input ratings and types shown in eTRM measure package SWHC004-06.
- The installation address must have a commercial natural gas account with a California IOU.
- This measure is applicable for the following nonresidential and multifamily building types, of all vintages: Multi-family, Commercial, Education - Community College,

Education - Secondary School, Education – University, Health/Medical – Hospital, Health/Medical - Nursing Home, Lodging – Hotel, Office – Large, Office – Small, Retail - Multistory Large, and Manufacturing Biotech.

Deemed measure offerings are designated based on boiler efficiency and in some cases OA reset controls. Therefore, there could be overlap that impacts the baseline assumed for the HHW reset recommendations.

The other program offering is Accelerated Replacement (AR). In this case, existing conditions are the baseline. However, a preponderance of evidence (PoE) is required to demonstrate viability of equipment remaining useful life (RUL) and program influence. The eligible baseline energy consumption can be based on the verified load profile and rated or measured part-load efficiency curve. Per AR policy, the smaller post-installation boiler savings consumption would be based on the same load profile used in the baseline, with the new and code compliant part-load efficiency and controls requirements.

Successful Program Outcomes

As described above, these five measures can be targeted as individual high performing gas savings measures, incentivized by utility program Deemed rebates or Hybrid/Custom projects. However, marketing and deploying these measures collectively as a targeted program offering can have a number of benefits. First, program marketing and outreach efforts, especially with utility and trade-ally support, can be very effective at getting cost-effective and high-impact measures to market. For programs, reaching customers is typically not the issue. Having cost-effective measure offerings, readily available incentives and timely project review is more often the challenge. Our research shows that there are more losses in heating hot water systems (at the boiler plant and through the distribution) than are usually assumed. Therefore, savings for these and other HHW measures may be under-estimated. More accurate accounting of actual boiler efficiencies will improve cost-effectiveness for these and other HHW measures. Second, these improvements could provide predictable and noticeable energy savings that can be quickly incentivized, if the suggested Deemed or Hybrid incentive platforms are available. This type of direct influence and positive customer experience has been lacking in larger and more comprehensive program efforts in large commercial incentive programs. A positive customer experience could improve customer engagement that leads to additional energy efficiency and RCx opportunities, such as implementing G36 on existing building controls.

Program Delivery Platforms

The recommended measures can be taken to market through one or more of the following Resource Acquisition program platforms: Deemed, Custom, NMEC, On-Bill Financing and Hybrid.

Deemed

The Deemed Platform, use pre-determined estimates of energy or demand savings, costs, and other ex-ante values reported in measure packages (formerly "workpapers"). Measure packages must show savings by climate zone to reflect values statewide and usually are processed as single measures. Qualifying measures are typically homogenous, high volume, and repeatable interventions. They have historically been developed by Program Administrators (PAs) with CPUC input and approval, but are now primarily the responsibility of the 3rd Party program implementors (3PPI's). The CPUC-sponsored Electronic Technical Reference Manual (eTRM) is an online application that serves as the repository for all statewide deemed measures for California.[2]

Custom

In the Custom Platform, savings are quantified through a site-specific analysis of the customer's facility. The measurement and verification (M&V) process must comply with policy requirements and typically follows International Performance Measurement and Verification Protocol (IPMVP), Options B, C and D. Custom projects are submitted to and approved by the PA before being sent to the CPUC for possible parallel review. This process can take from 3 – 6 months, the longer duration is often due to the parallel review process. The customer cannot purchase or install any equipment until they receive a pre-approval from the PA and CPUC in a notice to install to implement the project.[3] The financial incentive is paid upon the completion and verification of the installation. An implementer designing a program with custom, unique, large-scale interventions should follow the CPUC Statewide Custom Project Guidance documents.[4]

NMEC

In the Normalized Metered Energy Consumption (NMEC) Platform, savings are determined at the whole-building or system-level, based on a comparative analysis of pre- and post-installation metered energy consumption data from participating sites. Engineering analyses of forecasted savings are still required for ex ante approval, using Custom or Deemed values. The level of rigor required for ex ante savings estimates has been a frequent topic in the development and implementation of NMEC projects. Guidelines for meter-based projects, guidance will likely continue to evolve.

On-Bill Financing

The On-Bill Financing Platform (OBF), which provides 0% financing, was designed for customer and measure application types that can be verified using Population-level NMEC. OBF gives Implementers a low interest financing mechanism for energy efficiency projects with

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2 https://www.caltf.org/etrm-overview

3 California Public Utilities Commission, July 14, 2011, Decision 11-07-030: Third Decision Addressing Petition for Modification of Decision 09-09-047.

4 CPUC Statewide Custom Project Guidance, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/custom-projects-review-guidance-documents.

cost recovery through a customer's utility bill, in order to achieve cost neutrality for the customer This financing can be used with Custom incentives (OBF) or without (OBF-NI). However, financing is not allowed with Deemed rebates. The Custom review process has recently been incorporated into the program to evaluate savings claims for loans that are not eligible for Population-level NMEC.

Hybrid

Since 2020, CalTF has working to define and operationalize the idea of a Custom "Hybrid" approach for incentivizing measures, which is a cross between Deemed and Custom.[5] However, policy advancements in this area have been slow to develop beyond residential and small commercial Direct Install (DI) programs. The Hybrid approach may be the best fit for the HHW measures presented.

5 April 23, 2020, Hybrid Measure Update, https://www.caltf.org/tf-meeting-materials

CHAPTER 4: Additional Measure Opportunities

The measures discussed in Chapter 2 and Chapter 3 are high priority measures that are ready to be implemented into codes, standards, and programs. Research from this project show high energy savings potential and measure feasibility for each measure.

There are other potential measures that came out of the research that the research team is not currently recommending for implementation in codes, standards, or programs. These measures require more research, have lower or uncertain energy savings potential, require additional data, are not mature enough yet, or do not have a clear path for implementation. Table 4 summarizes these measures and recommended next steps for the measure.

Table 4. Additional Measure Opportunities

Measure	Background & Justification	Future Research
Remove or reduce limitations on electric resistance heating in Title 24.	Research from a limited set of buildings shows heating hot water systems shows significant losses at the boiler plant and throughout the hot water distribution. Heating with electric resistance coils could eliminate the need for heating hot water systems and the associated losses.	Further research is needed on in which scenarios (climate zones, building types, etc.) it may make sense to allow electric resistance heating and the impact of allowing electric resistance.
Include realistic piping system distribution losses in compliance energy modeling software.	Title 24 compliance software currently does not take into account piping system distribution losses. Properly accounting for these will more accurately estimate energy use and the impact of efficiency measures.	Further research on typical piping system distribution losses for central boiler systems and how those could be implemented in the modeling software.
Further improve setpoint reset effectiveness, including: • Require resets be based on demand and outside air temperature • Require resets to not respond to highly transient behavior	Most HHW systems operate most efficiently when they supply water at the lowest temperature that will meet the requirements of all end-uses in the building. This	Further research on specific measures that are effective in getting the HWST to reset and that persist over time.

• Change how requests are generated. For example, rather than generating a zone heating request when a hot water valve is 100% open, require the valve to be 100% open and the zone temperature to be below setpoint before generating a request. • Require graphics at the BAS front end to help building engineers better manage the resets	both minimizes distribution heat losses and improves equipment efficiency for most heating equipment. Our research shows that HWST often do not reset as much as they could.	
Reduce the peak heating load and improve the overall efficiency of morning warmup by: • Have a long ramp up period where not all of the zones ramp up at once so that the system stays in a more efficient operating mode • Set default boiler staging with delays such that the second boiler does not stage on unnecessarily for a brief period during morning warmup	Limited field testing showed that peak heating demand during morning warmup could be significantly reduced, with a potential for improving heating system efficiency as well.	The ASHRAE Journal approved an article written by the research team, which will be published later in 2024. ASHRAE approved a work statement by the research team proposing further research.
Improve boiler efficiency ratings by defining an efficiency metric that captures part-load and transient conditions and that would more accurately represent annual field efficiency.	Field measures taken as part of this project show an existing non-condensing boiler rated at 84% thermal efficiency had a field efficiency of 50%. An ASHRAE working group has been developing a new boiler efficiency test method.	Additional research on field performance of boilers. Work with ASHRAE working group to publish test method. Consider federal preemption constraints around this measure.
Consider realistic heating hot water system efficiency when estimating energy savings and cost-effectiveness of heating hot water system measures.	This research project shows significant losses in heating hot water systems. Energy modeling done to inform codes, standards, and programs typically uses software that does not	Further research on industry standard practice and heating hot water system efficiency.

	sufficiently capture these losses.	
In existing buildings, require implementing heating hot water system measures upon various triggers. Triggers could be based on the scale or the scope of an already-occurring retrofit.	Our findings show that most heating hot water systems are not performing optimally, with many operating almost continuously, and without substantial HWST reset.	Further research is needed to develop implementation pathways that are not overly burdensome.
Revise ACM for Boiler Cycling and Standby Losses	Default boiler performance curves in the Title 24 energy modeling software do not properly account for cycling and standby losses. Field measures taken as part of this project show a boiler rated at 84% thermal efficiency had a field efficiency of 50%, in part due to cycling and standby losses.	Further research is needed to determine typical cycling and standby losses.

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